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ABSTRACT

The aesthetic beauty of a landscape is a very subjective issue: every person has their own opinions and their own idea of what beauty is. However, all people have a common evolutionary history, and, according to the Biophilia hypothesis, a genetic predisposition to liking certain types of landscapes. It is possible that this common inheritance allows us to attempt to model scenic preference for natural landscapes.

The ideal type of model for such predictions is the psychophysical preference model, integrating psychological responses to landscapes with objective measurements of quantitative and qualitative landscape variables. Such models commonly predict two thirds of the variance in the predications of the general public for natural landscapes.

In order to create such a model three sets of data were required: landscape photographs (surrogates of the actual landscape), landscape preference data and landscape component variable measurements. The Internet was used to run a questionnaire survey; a novel, yet flexible, environmentally friendly and simple method of data gathering, resulting in one hundred and eighty responses. A geographic information system was used to digitise ninety landscape photographs and measure their landforms (based on elevation) in terms of areas and perimeters, their colours and proxies for their complexity and coherence.

Landscape preference models were created by running multiple linear regressions using normalised preference data and the landscape component variables, including mathematical transformations of these variables. The eight models created predicted over sixty percent of variance in the responses and had moderate to high correlations with a second set of landscape preference data. A common base to the models were the variables of complexity, water and mountain landform, in particular the presence or absence of water and mountains was noted as being significant in determining landscape scenic preference.

In order to fully establish the utility of these models, they were further tested against: changes in weather and season; the addition of cultural structures; different photographers; alternate film types; different focal lengths; and composition. Results showed that weather and season were not significant in determining landscape preference; cultural structures increased preferences for landscapes; and photographs taken by different people did not produce consistent results from the predictive models. It was also found that film type was not significant and that changes in focal length altered preferences for landscapes.

Natural Landscape Scenic Preference:

Techniques for Evaluation and Simulation

A thesis submitted to the Robert Gordon University
in partial fulfilment of the requirements for the degree of Ph.D.

By

JoAnna Ruth Wherrett

M.A. in Mathematics (University of Cambridge)
M.Sc. in Rural Resource Management (University of Wales)

Robert Gordon University
Aberdeen

and

Macaulay Land Use Research Institute
Craigiebuckler
Aberdeen

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Techniques for producing digital images of and simulating landscapes were then examined. Four alternatives to the classical camera were used: a digital camera; and three methods based on the use of digital elevation models. Preferences for digital camera images were comparable to those for photographs, while the landscape simulation images did not produce similar preference scores to photographs of the same landscapes. However, the model predictions from one of the landscape simulation methods fitted the photographic preference data well.

An example using photomontage techniques showed the utility of the preference models for determining which of a number of management options would alter the landscape in the most positive manner, in terms of scenic quality. By drawing together both the preference modelling aspect and the landscape simulation elements, this thesis presents a coherent system for landscape evaluation and visualisation.

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Wherrett, J.R. (1996) Visualisation Techniques for Landscape Evaluation. Extended Abstract, *GISRUK 96*, Canterbury, Kent April 1996.

Wherrett, J.R. (1997) SyLViE: a system for landscape visualisation and evaluation. *Proceedings of the . Sixth Annual IALE(UK) Conference*, University of Ulster, Coleraine, September 1997.

Wherrett, J.R. (1997) Natural Landscape Scenic Preference: Predictive Modelling and the World Wide Web. *Conference on Urban, Regional, Environmental Planning and Informatics in Planning in an Era of Transition*, Athens, October 1997.

Wherrett, J.R. (1997) Truth, Honour, Freedom and Courtesy: Issues in using the Internet as a medium for landscape preference surveys. *Data Visualisation 97: Previewing the Future*, St Louis, Missouri, USA, October 1997.

Wherrett, J.R. (1998) Scenic Landscape Evaluation: Combining Visualisation and Predictive Preference Modelling. Extended Abstract, *GISRUK 98*, Edinburgh, April 1998.

Wherrett, J.R. (1998) Managing Scenic Resources: Modelling Natural Landscape Preferences. *Resource Technology 98 Nordic, International Symposium on Advanced Technology in Environmental and Natural Resources*, Rovaniemi, Finland, June 1998.

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ACRONYMS

The following acronyms and abbreviations are used in the text:

CAD	Computer-aided Design
GIS	Geographical Information System
HTML	Hyper-text Markup Language
MLURI	Macaulay Land Use Research Institute
NNR	National Nature Reserve
PERL	Practical Export and Reporting Language
RGU	Robert Gordon University
SGI	Silicon Graphics Incorporated
VRML	Virtual Reality Modelling Language
WWW	World Wide Web

A glossary of computer-related terms is included in Appendix I.

CHAPTER ONE

NATURAL LANDSCAPE SCENIC PREFERENCE: TECHNIQUES FOR EVALUATION AND SIMULATION

"ου τοι εγω γε ης γαιης δυναμαι γλυκερωτερον αλλο ιδεσθαι."

("One cannot see another land sweeter than his own". Homer, 9th Century. B.C.)

1.1 Introduction

In the United Kingdom natural heritage protection is of increasing importance to the general public. People are no longer content to watch as the landscape they live in, work in or relax in is adversely changed by the actions of mankind. The visual landscape itself is important in many communities for reasons of cultural identification, environmental integrity and economic well-being.

This cultural imprint of our scenery is reflected in many nationally important songs. For example, 'Flower of Scotland' (Williamson, 1969), pretender to the Scottish national anthem includes phrases such as "wee bit hill and glen" and "the hills are bare now, the autumn leaves lie thick and still"; both being very evocative of Scotland's scenery. The well know hymn, 'Jerusalem' talks of "England's mountains green", its "pleasant pastures" and "England's green and pleasant land"; again evocative of the English countryside.

As far back as the times of the ancient Greeks, the importance of the visual landscape to a person's sense of identity was recognised; in many cultures there is a notion that exposure to nature, including scenery, enhances psychological well-being (Ulrich, 1981). There is an integral tie between the physical aspects of landscape and the human response to it, yet landscape is a resource which is often taken for granted and looked upon with indifference (Marr, 1909).

This societal importance defines the visual landscape as a valuable resource which must be considered in land use and land management decisions. Local governments in rural areas are often motivated by pressure groups and individuals to impose stringent planning conditions which ensure that both the developers and the community are aware of the effects of the development and the alternatives available.

It can be argued that the visual attractiveness of a landscape is not a parameter that can be judged solely by an expert but that it is a product of the opinions of all the individuals concerned with that landscape. It is, therefore, important to consider proposed changes to the landscape as an integral part of land use management, and to consider the visual implications of human intervention on the landscape.

In examining the rationale behind this thesis, it is necessary to ask why the research was undertaken and what it is about.

Why has this research been undertaken ?

The current concern for the natural environment has already been noted. As natural resources world-wide are depleted ways must be found to protect, manage and enhance those areas which remain. If a landscape is to be altered, through the actions of human-kind or natural processes, it is important to be able to visualise that change and model how a negative effect can be minimised to alleviate a decline in the scenic quality of the landscape, or help in its enhancement.

The aim of this research is to produce a planning aid to assist those wishing to alter the landscape to do so in a manner sensitive to the perceived scenic qualities. Such an aid would help in monitoring the scenic and cultural qualities of the landscape in both the present and the future. The system created will aid landscape evaluation for visual impact assessment in terms of positive and negative impact of a policy or management change and the relative level of such an impact on the landscape preference of the general public.

1.2 Research Description

The research description examines how the research was undertaken, where it was done, and who the research was done for.

What was the research about ?

It is not the aim of this thesis to examine *how* or *why* we react to certain aspects of the visual landscape, rather the aim is to examine *which* aspects of the visual landscape we react to, and *whether* those features may be measured in an objective manner to assist in the landscape planning process.

This type of measurement was approached using a landscape preference modelling methodology. Psychological data on landscape preferences can be related to physical landscape component data which can be objectively measured, to create a psychophysical predictive landscape scenic preference model.

If such models are to be used for landscape planning, they must be able to predict preferences not for *today's* landscapes, but for *tomorrow's*. We cannot yet see these landscapes but we are able to predict what they might look like; therefore, it is necessary to examine different methodologies of landscape simulation, *i.e.* the visual prediction of future landscapes. It is also important to examine how people respond to such simulations and whether such simulations can be used for preference prediction.

To determine which features and aspects of the visual landscape are the most suitable for predicting landscape preference, it is necessary to investigate all possible feature types in terms of their utility for predicting landscape preference.

How was the research undertaken ?

The research undertaken can be broadly divided into three topics: the use of the Internet to gather preference data; the creation and modification of landscape preference models; and the use of landscape simulation techniques to visualise potential landscapes.

The World Wide Web (WWW) was used to gather landscape preference data through the use of a survey, written in HTML (hyper-text markup language) and PERL (practical export and reporting language).

This approach to the gathering of data enabled different versions of a questionnaire to be used simultaneously, and allowed a wide range of people access to the survey. A further advantage of the use of the Internet was the ease of altering questionnaires to examine different aspects of landscape preference.

A methodology similar to that of Shafer *et al.* (1969) was employed to create a number of landscape scenic preference models. All landscapes used in the Internet survey were digitised, using a GIS (Geographic Information System), into landcover and landform types. The colours within each photograph were also measured using the GIS.

Landcover variables included vegetation and non-vegetation in three distance zones, following the work of Shafer *et al.*; landform types were based on levels of elevation - flat land, low hill, steep hill and mountain. To these variables were added sky, water (divided into still water, moving water and sea) and obscuring vegetation. Both the landcover and landform variables are quantitative in nature. Further qualitative variables were also used, representing complexity and coherence within a scene; quantitative proxies for these variables were measured, relative image file size representing complexity and polygon count representing coherence.

The landscape preference models were created using multiple linear regression on the landscape variable data and the preference score data. This process created six models which could be further tested on a variety of alternate datasets.

The initial phase of model creation left many questions unanswered; these questions were then investigated using further Internet surveys.

- *Does the weather and the season in which the photograph is taken affect the score it is given?*
- *How do cultural structures affect landscape preference?*
- *Does it matter what type of film is used for the photographs, who takes them and what focal length they are taken at?*
- *Is photograph composition a significant factor in preference scoring?*

The final section of research looked at the simulation of landscapes. Landscapes can be simulated in many ways, the photograph is perhaps the most common method for recording a landscape. The use of computer simulation, including computer-aided photomontage, was examined in order to look at methods for visualising the landscapes of tomorrow. A further landscape preference questionnaire was undertaken to examine how people reacted to the simulations of landscape and whether those images could be used to predict preferences for real landscapes.

Where was this research undertaken ?

The landscapes used for this research cover a wide range of the natural landscapes of Scotland. There are a diverse range of landscape types within Scotland, from flat agricultural land to mountain scenery. The landscape shows the effects of volcanic activity, ice ages, the sea and mankind. Appendix II describes Scotland's landscapes, both in modern and prehistoric times. The landscapes of Scotland play a major role in both the identity of the Scottish people and in identifying Scotland to the rest of the World.

Who was the research for ?

The research has been undertaken for two different groups. Firstly, the respondents to the Internet surveys, to enable the inclusion of non-expert views into the landscape planning process. The research goes beyond this group: they are representative of the general public, of all those who visit the countryside, those who live there and those who look upon the landscapes of Scotland. Secondly, the research is for the landscape planners and managers, to assist them in the decision making process by providing a tool which allows them to compare relative preference scores for a number of alternative landscape scenarios.

1.3 Summary of Chapters

1.3.1 Chapter One: Introduction

This chapter gives a brief introduction to the research within this thesis. The Project Objectives and Plan of Work, as set out in the original project proposal, are included in Appendix III. The publications from this work, as detailed in the contents, are included as an addition to the main text. This text is also accompanied by a CD-ROM containing all data used in this work, and copies of the text of the thesis and publications in HTML format. The structure of the CD-ROM is detailed in Appendix IV. A list of equipment, including software, used during the research is also available in Appendix V.

The thesis is split into three sections: techniques for evaluation, consisting of Chapters Two through Seven; techniques for simulation, comprising Chapters Eight through Ten; and finally, the concluding chapters.

NATURAL LANDSCAPE SCENIC PREFERENCE: TECHNIQUES FOR EVALUATION

1.3.2 Chapter Two: Review of Landscape Evaluation, Preference and Perception

This review sets the scene for the work that is to follow within this thesis. Landscape is defined and its protection discussed. The review then examines the need for public input to the evaluation process and notes some of the social and demographic effects which may influence people's evaluations. This chapter finally reviews the main types of landscape assessment and evaluation techniques currently in use.

1.3.3 Chapter Three: Review of Psychophysical Landscape Preference Models

The second section of the literature review concentrates on psychophysical predictive preference models. This technique for landscape evaluation is discussed and the criticisms levelled at it debated, with particular reference to the work of E.L. Shafer and colleagues. Components used in these models are then noted, with regard to both qualitative and quantitative variables.

1.3.4 Chapter Four: Landscape Preference Questionnaire (Part I)

Survey Methodology

Chapter Four sets out the rationale and methodology behind using the Internet to undertake preference surveys for this research. The layout and functionality of the surveys is explained. The validity of using this methodology is examined with reference to previous and current work, and where required, with reference to experiments carried out to examine the validity of a specific point. In particular, Pilot and Paper surveys are described, the results given and the significance of these results discussed.

1.3.5 Chapter Five: Landscape Preference Questionnaire (Part II)

Main Survey and Validation Survey

The second chapter concerned with the Landscape Preference Questionnaire details the respondent results from the Main and Validation surveys are described, with reference to socio-demographic information. This data is discussed where appropriate. The results are then compared to a variety of results from other surveys and the validity of the methodology and respondent sample is further examined.

1.3.6 Chapter Six: Predictive Preference Models

In Chapter Six, six predictive preference models are derived and the results from the two surveys detailed in Chapter Five are analysed. As a prelude to this, the techniques for analysing the landscape images, which were used in the surveys, are discussed in detail, and the utilisation of each landscape component variable described. Following the methodology used for creating predictive preference models, the resulting data is summarised and the most functional models detailed. These models are then examined in depth and the explanatory abilities of the variables discussed. Finally, the landscape components of an ideal landscape are detailed.

1.3.7 Chapter Seven: Landscape Preference Questionnaire (Part III)

Weather, Lighting and other Refinements

Part III of the Landscape Preference Questionnaire chapters covers refinements to the original models. Several novel aspects of landscape preference are examined using several different surveys, conducted as part of this research. Firstly the effects of weather, season and lighting are examined using a collection of fixed point photographs.

Secondly the effects of cultural structures on landscape preference are looked at. The third section describes the use of postcards to examine the accuracy of the models when applied to photographs taken by experts. The fourth section examines the results from a survey designed to investigate the effect of colour on preference directly, by using photographs taken with different print film. The penultimate section notes at the effects of focal length on landscape preference and the last section describes an experiment to examine whether there is any left/right bias in landscape preference.

NATURAL LANDSCAPE SCENIC PREFERENCE: TECHNIQUES FOR SIMULATION

1.3.8 Chapter Eight: Review of Landscape Visualisation Issues

In this chapter concepts of landscape simulation and visualisation are reviewed. The problems of adequate photo-realism and the validity of simulations are discussed at length. The uses of a variety of rendering techniques are noted, and several problems are highlighted. Vegetation modelling is discussed and several methods of sylvan simulation are detailed. Several models and decision support systems using visualisation are commented on and issues of inter-operability discussed.

1.3.9 Chapter Nine: Landscape Visualisation Techniques

This chapter follows on from the review work in Chapter Eight by demonstrating and discussing a variety of methods of landscape simulation. Four different levels of simulation are detailed and examples are given. These include traditional techniques, basic Geographic Information System (GIS) simulations, more advanced GIS simulations and dedicated visualisation software. The ability of these methods to simulate both present and altered landscapes is then examined.

1.3.10 Chapter Ten: Landscape Preference Questionnaire (Part IV)

Real and Simulated Landscapes

The fourth and last part of the landscape preference questionnaire quadrulogy deals with the comparisons between photographs of real landscapes and 'snapshots' of simulated landscapes of the same geographical area. The use of digital cameras as opposed to print film cameras is examined, with a survey which used images taken with both a standard print film camera and a digital camera. The chapter then goes on to examine how respondents react to simulated landscape by using four types of landscape visualisation to represent scenic landscapes.

Finally, the utility of a combined system for visualisation and evaluation is deliberated, and an example of the use of such a tool is given using photomontage techniques to creating and evaluating an alternative landscape management scenario.

NATURAL LANDSCAPE SCENIC PREFERENCE: CONCLUDING CHAPTERS

1.3.11 Chapter Eleven: General Summary and Discussion

The penultimate chapter of this thesis summarises the work undertaken, noting: the methodologies used and their novelty and utility; the predictive preference models; the technologies used for landscape simulation; and the potential for combining visualisation and evaluation of landscape for the greater public good. In addition to this, the chapter looks forward, noting areas where further work would be beneficial and where there are still issues to be investigated.

1.3.12 Chapter Twelve: Conclusions

The final chapter of this thesis draws together the findings from this research, and discusses what has been learnt from the work that has been undertaken, and what might be discovered from further investigations.

The flow chart in Figure 1.3.1 overleaf displays how the chapters within this thesis fit together.

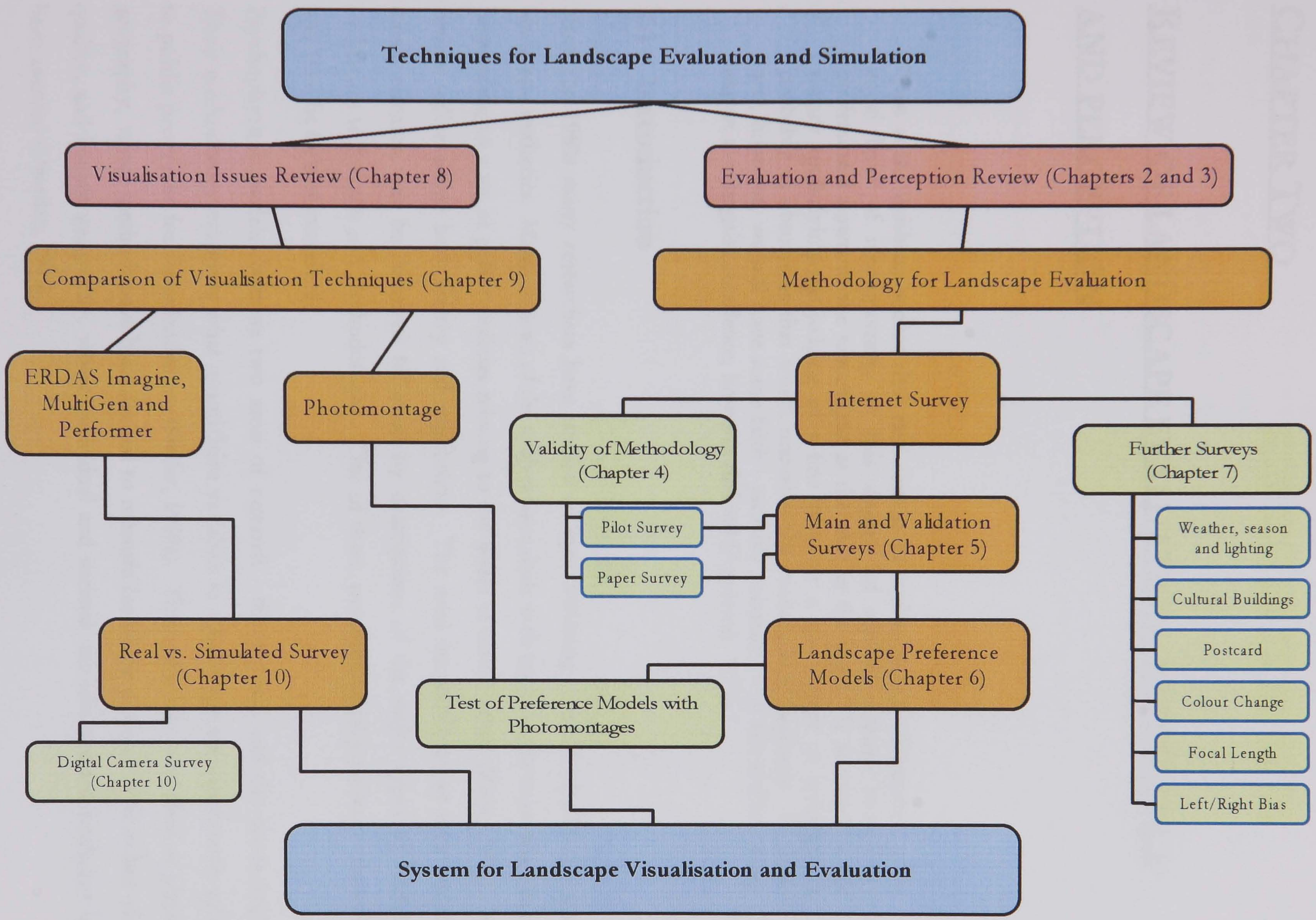


Figure 1.3.1 Thesis flow chart

CHAPTER TWO

REVIEW OF LANDSCAPE EVALUATION, PREFERENCE AND PERCEPTION

> "Just as the Brisbane wicket after rain used to be said to reduce all batsmen to an equal level of incompetence, so this absence of aesthetic theory brings the professional down to the same plane as the man in the street. It is true that the theory underlying the judging of a fine wine or a good piece of sculpture is probably as obscure as that which underlies the *evaluation of landscape*. In those arts, however, we still have some faith - possibly misplaced - in the ability of the expert to recognise excellence, however defined (Appleton, 1975)."

2.1 Introduction

Since the 1960s many researchers have studied an ever widening number of philosophies of landscape aesthetics. Many reviews of the subject have dealt with applications more than theory, responding to a set of public policies relating to the issues of scenic values (Zube, 1976). This review will examine both theory and application. The need for public input into landscape scenic research will be reviewed followed by descriptions of the major types of landscape evaluation techniques and methodologies. One of these, psychophysical preference modelling, will then be further examined.

Psychophysical models combine two areas of research - the physical and the psychological. Their methodology examines what quantitative variables in a landscape are significantly related to public preference for those landscapes (Shafer, 1969a). This unifies the two areas of physical geography, where methods have been devised to measure landscape parameters to reflect visual quality, and human geography, where individual and societal attitudes toward landscape have been assessed (Dearden, 1985).

Abello and Bernaldez (1986) said that landscape appreciation was not only the expression of aesthetical tastes or a style of liking, but also a style of being, while Shuttleworth (1980a) argued that there was a fundamental theoretical divergence of opinion over the question of whether landscapes have an intrinsic beauty which is measurable or comparable, or whether scenic beauty was a value that can only be attributed to an area or specific landscape.

In the last few decades, assessment of landscape beauty has increasingly been recognised as important in decisions regarding land use and management (Arnot and Grant, 1981; Dearden, 1985). By analysing the landscape's visual vulnerabilities it should be easier to design alterations which lie easily upon the landscape (Litton, 1973).

2.1.1 Terminology and Definitions

<u>Landscape</u>

Before the subject of landscape evaluation can be reviewed, it is necessary to define what is meant by 'landscape'. Hull and Revell (1989) define landscape and scenes as:

> "The outdoor environment, natural or built, which can be directly perceived by a person visiting and using that environment. A scene is the subset of a landscape which is viewed from one location (vantage point) looking in one direction ..."

The Hull and Revell definition of landscape clearly focuses upon the visual properties or characteristics of the environment, these include natural and artificial elements and physical and biological resources which could be identified visually; thus non-visual biological functions, cultural/historical values, wildlife and endangered species, wilderness value, opportunities for recreation activities and a large array of tastes, smells and feelings are not included (Amir and Gidalizon, 1990; Daniel and Vining, 1983). Similarly, Appleton (1980) defines landscape as 'the environment perceived', especially visually perceived.

The landscape can also be defined as an ecological-psychological-social construct (Abello and Bernaldez, 1986); a human phenomenon, emergent of the interplay between the observer and landform and land use (Craik, 1986). Zube (1976) notes that landscape refers to the combined physical attributes of the environment while Forman and Godron (1986) simply state that a landscape is a three-dimensional mosaic of environmental compartments or zones. Ironically, the Landscape Research Group of Great Britain has always been at pains to *avoid* defining with any precision what it means by 'landscape' (Appleton, 1986).

In this review 'landscape' will refer to the visual properties of what may be termed 'total landscape', that which includes the less tangible properties of 'scenery'.

Landscape quality

Often landscape quality is defined as including a wide range of environmental / ecological, socio-cultural and psychological factors. According to Jacques (1980) the distinction between 'value' and 'quality' is meaningless, since both terms refer to the comparison of the landscape in front of your eyes to an idealised landscape in one's mind. Visual quality is a phrase synonymous with beauty, with overtones of objectivity, whereas landscape value is a personal and subjective assessment of aesthetic satisfaction derived from a landscape type, a product of an interaction between humanity and the landscape (Jacques, 1980; Zube, 1976); other authors, however, state that scenic beauty and visual quality are equivalent. The judgement of landscape quality is taken to be an evaluation, by design professionals, as distinct from landscape valuation.

2.1.2 Laws and designations of scenic beauty

In some countries there are designations designed to protect scenic areas. Múgica and De Lucio (1996) state that mountain landscapes with abundant vegetation and different manifestations of water have been associated with attractive and beautiful sceneries to the extent that many of these have been assigned legal protection status, such as the Lake District National Park in England and the Yosemite National Park in the USA. Yet land is often viewed through policy and practice as a collection of discrete parcels rather than as a resource continuum (Zube, 1976).

In the Swiss constitution it is stated that the scenery must be protected and, if it is of great interest to the general public, it has to be preserved undiminished (Lange, 1994). In the state of Wisconsin, in the USA, scenic beauty has assumed an importance in the law that currently serves as a major consideration in many of the state's regulatory functions. In 1952, the State Supreme Court ruled that the "right of the citizens of the state to enjoy our navigable streams includes the enjoyment of scenic beauty".

The court held that "the occupancy (by the public) is visual" and that the enjoyment of the beauty of the land constitutes a legitimate public use of land whether or not the public is allowed to set foot on it (Bishop and Hull, 1991).

In Scotland, as in the rest of Britain, political and economic policies are still the major influences on decisions about locations for new industrial developments. Already, much of its lowland landscape has been intruded upon by many sources, such as extractive industry and urbanisation, and its highland landscape by such sources as reservoirs, commercial forestry and energy creation schemes (Aylward and Turnbull, 1977).

Although local government has at its disposal a planning legislation, the community is still concerned that fundamental changes may occur in the physical and visual quality of their environment and often suspects that planning consent may be given to a development without the full disclosure of effects on the community (as discussed in section 2.2). The presentation of the evidence must be in a form that can be clearly understood and assessed by all parties.

European landscape protection

The European Centre for Nature Conservation (ECNC, 1997) notes that most European Union countries have some form of legislation which affects landscape either directly or indirectly, for example through protection of features or restrictions of agricultural practice. The major observed threat to landscapes throughout Europe is summarised by one word "polarisation" - the intensification and marginalisation of agriculture. It is only recently that research institutions have started to respond to the European-wide appreciation for its characteristic landscapes.

The ECNC (1997) state that:

> "The landscape approach has for some time been used at the national and regional level to analyse issues such as aesthetics, cultural heritage, nature conservation and sustainable land use. However, subjective connotations of the concept of landscapes have prevented the full integration of landscape assessment into the 'hard' science and international environmental law."

Despite this handicap, the assessment of landscape diversity is a growing subject among landscape ecologists and environmental economists. The European Environment Agency is currently exploring the methodological and conceptual aspects of landscape classification as a tool for integrated environmental awareness (ECNC, 1997).

Landscape protection in Great Britain

There is no single focus group within Great Britain that concentrates interests on landscape. Rather, such interests are fragmented into countryside, sport, bird life and other separate concerns. Although areas of landscape significance, valued for aesthetic qualities and with clear regional identity, have long been designated, their maintenance has little public visibility (Goodey, 1986). The National Parks of England and Wales have worked to preserve areas for public enjoyment and there are special development controls in place to preserve landscapes of high value which are in private ownership (Arnot and Grant, 1981).

Landscapes are more likely to be designated for nature conservation value than for the landscape itself. There are many possible designations for nature while landscape is only protected under a few designations: National Parks and Areas of Outstanding Natural Beauty in England and Wales and National Scenic Areas in Scotland.

As Marr noted in 1909:

> "America has its National Park set aside for ever, as a thing of beauty, owing to the far-sighted intelligence of its legislators. We too have our exquisite jewels of natural beauty, jewels so exquisite that they are prized not only by hosts of our own countrymen, but by others who come from afar to gaze at them. Devon and Cornwall, Wales, the Highlands of Scotland, and perhaps above all, the Lake District of Cumberland and Westmorland."

Yet we in the United Kingdom have not afforded these areas the protection which the National Parks of the USA have enjoyed for over one hundred years.

Preservation versus conservation

Penning-Rowsell (1986) commented that our attitudes towards landscape are static and preservationist; we hope the present landscapes we love will endure, despite the pressures we put on them; we seek stability rather than change. Lee, K. (1995) examined the case of Yew Tree Tarn in the Lake District, an area protected by the National Trust - one of the National Trust's commitments is 'to preserving the beauty and unique character of the Lake District'. Its unique character includes its geological formations which make the area beautiful. In deciding to restore Yew Tree Tarn, thereby 'to ensure its beauty will be permanent', the landscape (an ecosystem in this matter) would have been 'frozen' against natural changes in order that its beauty be preserved 'permanently'. The National Trust did not accept the long term dynamism of natural geological processes.

In a conflict between the requirement of conserving beauty of the landscape on the one hand and natural processes at work which might undermine that beauty on the other, should aesthetic considerations always have priority? Although both Yosemite and Lake District are protective of both the aesthetic and the geological, why is there, nevertheless, a difference in their respective management policies? (Lee, K., 1995).

2.1.3 Evolutionary aspects of landscape evaluation

> "It has been assumed pretty generally that the Greeks and Romans had little attraction for the beauties of rugged nature. On the contrary, it has been argued that the appreciation of the majesty of the mountains and the grandeur of the sea of wholly of modern origin, a development of northern romanticism. Thus a fundamental difference has been assumed to exist between the ancient and modern attitude toward nature" (Hyde, 1915).

Preferences and prejudices could derive from a hierarchy of elements: biological characteristics, social systems, personal characteristics. Biologists stress the biological bases of behaviour, whereas psychologists stress the role of personality differences. Others see the foundation of preferences as part socially determined by cultural milieu and part biologically influenced. The controversy over biological theories of behaviour exists perhaps because they threaten people's feelings that they have their own independent ideas (Penning-Rowsell, 1986).

Evolutionary bias in landscape preference

Despite the ease with which observers of landscape images are able to make preference judgements, and the highly regular and meaningful pattern of their results, people are generally unable to fully explain their choices (Kaplan, S., 1987). Perhaps this can be attributed to an evolutionary bias in humans favouring certain kinds of environments, certainly an inclination to prefer environments that make survival more likely would not be unique to our species. Good habitats, as measured by the features that contribute to survival and reproductive success, should evoke strong positive responses while poorer habitats should evoke weaker or negative responses (Orians, 1986). There is a considerable body of theory and data upon which to build hypotheses oriented to human behaviour. However, those inclined to emphasise the role of consciousness in human thought and action might find these theories disturbing (Kaplan, S., 1987); aestheticism has long been considered anthropocentrically, assuming that human consciousness is the sole source of all values (Lee, K., 1995).

Human landscape preferences are concerned with information, and more particularly, with the gathering of information on the one hand and the danger of being at an informational disadvantage on the other. Neither being out in the open nor being in the woods is favoured, placing the individual right at the forest edge. Ecologists point out that such an area is the richest in terms of life forms; it is likely to be the safest as well (Kaplan, S., 1987). This suggests that Appleton's habitat and prospect and refuge theories are important steps toward identifying biological bases for aesthetic behaviour (Bourassa, 1988).

Increasingly, preference may be considered to be an expression of an intuitive guide to behaviour, an inclination to make choices that would lead the individual away from inappropriate environments and toward desirable ones (Kaplan, S., 1987).

Bourassa (1988) explains how different parts of the human brain respond differently to sensory information. The brain may be divided into three parts: reptilian, paleo-mammalian and neo-mammalian; in terms of structure and function the reptilian and paleo-mammalian brains (the limbic system) are similar to their counterparts in the brains of more primitive creatures. However, the neo-mammalian brain is more uniquely human and is the base of those capabilities found only in humans. Indications have been found that the reptilian section of the brain programs stereotypical behaviour according to instructions based on ancestral learning and ancestral memories. It is therefore possible that instinctive and rational responses to landscape occur separately, in the different parts of the brain, thus we need not be conscious of visual stimuli for such stimuli to be processed by the brain.

Biological and cultural theories of landscape evaluation

Human aesthetic response to landscape occurs at two levels: the uniquely human cultural level relating to the neo-mammalian brain; and the biological level which is shared with other animals, relating to the limbic system part of the brain (Bourassa, 1988). The cultural level concerns aesthetic pleasure derived from a landscape that contributes to cultural identity and stability; the biological from the dialectic of refuge and prospect in the landscape.

There is often confusion between cultural perception and ecological function. Nassauer (1995) states that to improve the ecological function of landscapes, landscape ecologists need to know that the cultural perception of nature is independent from ecological function. It is still a problem in the study of human biology to determine the extent to which our current behaviour patterns have been moulded by our long-term evolutionary history. Identifying which human behavioural characteristics are highly modifiable as a result of experience, and which are more resistant to changes because they are more constrained by genetically-based properties of the nervous system, is an extremely difficult task (Orians, 1986).

Both the nature of predictor variables and the nature of preference responses have tended to support an evolutionary interpretation. This is in contrast to the position taken by several investigators in this area. The claim is frequently made that the aesthetic reaction to landscape is largely or even completely a learned cultural pattern (Lyons, 1983). Subsequent work, however, has tended to support the hypothesis that evolutionary factors play a nontrivial role in human preference patterns

Environmental preference may constitute an important conceptual link in analysing how evolution could have an impact on behaviour. Much recent discussion of potential evolutionary influences has tended to ignore psychological mechanisms. Here preference could play a useful bridging function. It is a domain in which, based on animal studies, an evolutionary role might be expected. The factors that have been demonstrated empirically to be predictors of preference are consistent with such an evolutionary interpretation (Kaplan, S., 1987).

The Biophilia hypothesis

Ulrich (1993) puts forward a series of arguments for the biophilia/biophobia hypothesis: there is a partly genetic basis for human's positive response to nature, with a corresponding genetic predisposition for phobic responses to natural stimuli which have constituted survival threats throughout human evolution. This theory explains why people in many societies consistently dislike spatially restricted environments but respond favourably to settings with high visual openness.

A functional-evolutionary perspective implies that people should respond positively to natural settings with water and spatial openness, and that certain classes of natural elements (such as water, green vegetation and flowers) should be visually preferred over modern synthetic elements (such as concrete). Preferences should also tend to be higher for scenes with green vegetation in contrast to the vegetation characteristic of arid or desert environments, where water would be difficult to find. All of these theories are supported by research into landscape appreciation. The proposition that humans have a genetic disposition to respond positively to nature now seems plausible. The natural environment was the context of everyday experience throughout human evolution and provided advantages, challenges and risks. It is proposed that evolution has left its mark on mankind, in the form of a disposition to preferring certain types of landscapes (Ulrich, 1993).

Historical changes in landscape perception

Landscape perceptions change in time, even over the last few decades a significant process of "aesthetic maturity" has taken place to such a degree that certain landscapes which were previously rejected are now considered valuable, at least by some sectors of the population (Múgica and De Lucio,1996). Landscapes reflect our culture and society, our values and our traditions. It could be said that grouse moors and farmed landscapes are expressions of today's capitalist society. Different cultures also link their landscapes with different meanings: English landscapes are closely linked to heritage, while American landscapes are more likely to be linked to the environment (Penning-Rowsell, 1986).

One consequence of the Victorian era was the widespread appreciation of the beauties of nature, from which a desire to obtain some insight into the origin of scenery has sprung (Marr, 1909). During the last two centuries, the idea that exposure to nature improves psychological and physical well-being has become part of the appreciation of landscapes (Ulrich, 1993).

The perception of the general public to landscape has changed dramatically over the last two hundred years. In the first half of the eighteenth century and earlier in England, the Lakes and Peak District and other similar parts of the country were perceived to be frightening and threatening, not beautiful (Lee, K., 1995); mountains which are now attractive to so many were generally regarded with repulsion or horror in a relatively recent time period (Marr, 1909). The popular value of wilderness changed in the USA in the 19^{th} century largely because of the portrayal of wilderness in literature and art, and the emergence of tourism (Nassauer, 1995). There is even an element of religiosity in landscape appreciation, which is, to a substantial degree, a result of Western Man's mental inheritance from the Romantic Revival (Arnot and Grant, 1981).

2.2 Public Input to Evaluation

For natural resource managers to plan for a more healthy environment, and to elicit public and political support for such plans, two needs have been identified: (1) to predict the responses of public groups to changes in the environment, for some of which the visual impact may be the dominant indicator, and to plan to minimise any negative impacts; (2) once a proposal is developed, to communicate the effects of proposed changes to other agencies and public review groups to facilitate decision-making (Orland, 1994a).

Two fundamentally different approaches for an evaluation can be distinguished: one, an expert based approach, where the evaluation is carried out by an expert or a group of experts; the other, a publicly based approach, where the evaluation is carried out by a number of lay people representing the public or different social groups (Lange, 1994).

2.2.1 The need for public preference input to landscape evaluations

It can be argued that the best source of data for studies on such a subjective issue as landscape quality is the general public (Arthur *et al.*, 1977). Although planners may claim that it is their duty to guide public taste in these matters, the level of scenic beauty of the landscape is ultimately a product of the aggregated opinions of all the individuals concerned with that landscape (Briggs and France, 1980).

The sampling of both landscapes and people in equal measure is vital to research in landscape perception; it would be misleading to sample one systematically while ignoring the sampling of the other. A large number of studies explain preference responses solely as a function of the physical components of natural and man-made landscapes (Shuttleworth, 1980b). Many ignore in their analysis the fact that preferences are expressed by people and that people with different backgrounds and experiences probably have unique preferences (Lyons, 1983). Participation permits the influence of regional, cultural and other, more local, factors to modulate these broad differences and to contribute a welcome distinctiveness (Kaplan, R., 1985).

A variety of cultural, social and demographic factors have been shown to be influential in the environmental and aesthetic preferences of the general public (Anderson, 1981; Lyons, 1983). It would also appear possible that landscape appreciation is linked more to perceptions of the subtleties of landscape and the interaction between elements than to the presence or absence of single or readily observable landscape attributes (Penning-Rowsell, 1982).

Citizen interest is thought by some to be lacking in landscape evaluations because of the inherently subjective and somewhat intangible nature of the problem. However, researchers who have used the public in landscape assessments have found them to be highly motivated, interested in the topic and willing to donate their time irrespective of social, economic and educational backgrounds (Dearden, 1981).

Buhyoff *et al.* (1978) examined whether landscape architects could determine the rank order of a series of landscapes as they were preferred by another group of subjects, based on knowledge of what this group had said they liked and did not like about the landscapes. The results showed that a group of landscape architects, given general information as to what a sample of people like and do not like about a set of photographs, can come close to reproducing the client group's rank orderings of those photographs.

2.2.2 Socio-demographic effects

There are five factors to consider when designing surveys of landscape preference: the characteristics of the observers; the medium selected for presentation; the response format; the relevant environmental attributes of the settings; the nature of the transaction with the specific setting (Hetherington *et al.*, 1993). The first two of these are also mentioned by Tips and Savasdisara (1986a) as being the two basic factors of influence: the characteristics of the interviewed subjects, such as age, gender, familiarity with landscapes, nationality or occupation; and the characteristics and the origin of the landscape scenes and the dimensions of the medium used for presentations.

Many different social and demographic factors have been shown to influence the perception of landscape. Land Use Consultants (1971) noted the following association and factors as influential to the perception of landscape: an awareness of historical/cultural associations; well known names; home environment, cultural environment; education; experience of other landscapes; knowledge of landscape; familiarity of landscape; role (*e.g.* on holiday); position relative to landscape; and immediate state of mind. However, Tips and Savasdisara (1986b) found no statistically significant disagreement between preferences for groups classified by age, gender, income and religion.

Each socio-demographic factor highlighted by authors in the literature is considered in the following sub-sections.

Gender

Gender is an important social differentiator of people's attitudes toward the natural world (Lyons, 1983). Indeed, Hull and Stewart (1995) showed that men and women look at different objects while walking, with men more likely to be viewing the ground, topography and ephemeral objects than women. Bernaldez *et al.* (1987) found inconclusive differences between preferences due to age and sex of children. They hypothesised that this corresponded to some type of more mature sensibility in older children and - more precociously - in girls.

Education and environmental awareness

General education level combined with environmental awareness can significantly influence landscape preference (Lyons, 1983; Yu, 1995). In a study by Balling and Falk (1982) further-education students had more favourable attitudes towards wilderness than secondary school students. Education can also be linked to the perception of crowding in a recreational landscape. Glyptis (1991) found that higher educated people were less tolerant of crowding than others. However, this was not found in a study based on loch-side and forestry landscapes (Wherrett, 1994) where more highly educated people were more likely to accept a higher level of crowding.

It has been suggested that there is an environmentally aware public and an environmentally unaware public, who possess quite different perceptions (Dearden, 1981). The former are often members of environmental organisations, a factor which has been shown to indicate a variation in attitude towards natural landscapes (Harvey, 1995).

Cross cultural differences

It appears that the similarities across cultures in terms of perception and cognition are much more impressive than the differences (Ulrich, 1977); relatively high agreements have been found when cultures are broadly similar *e.g.* Scots and Americans; Australians and Americans; Danes and Dutch (Buhyoff *et al.*, 1983; Yang and Brown, 1993). Landscape photograph preferences support a physiographic tendency, Danes and Dutch prefer flat and open landscapes, whereas Americans and Swedes show a higher appreciation of forested and mountainous scenes (Buhyoff *et al.*, 1983).

Landscape preference is significantly influenced by cultural backgrounds (Yu, 1994), however, Zube and Pitt (1981) found that groups showed preferences for landscapes similar to their home environments, while Yang and Brown (1993) found that people were inclined to prefer the landscape style not matched by their own cultural background.

> "When speaking enthusiastically to a Scotch boatman of the beautiful hill scenery of the north end of the Isle of Arran, I was at first somewhat surprised at his remark that I should see the flatter south end with its cornfields. I was not prepared for the influence of contrast with the normal surroundings, in determining a man's ideas of what is beautiful" (Marr, 1909).

One conclusion which may be reached is that it may not be prudent policy to suggest landscape management strategies for the public based on only the responses of young western adult samples. We must be cautious in generalising landscape assessment principles to non-European cultures (Zube *et al.*, 1983).

Familiarity and landscape experience

Knowledge and familiarity of a landscape are noted as factors affecting perceptions of landscapes (Land Use Consultants, 1971). If familiarity with landscape influences perception, and if there are distinct regional differences, then generic landscape models may not be viable (Wellman and Buhyoff, 1980). Several authors have looked at this factor with differing results.

Previous experience of landscapes has a "profound influence" on human perception and preference, according to Balling and Falk (1982), who state that landscape preference is undoubtedly not simply a function of some innate preference. Purcell (1992) comments that humans experience each new or previously encountered landscape within the context of mental models of previous landscape experience. Lyons (1983) found that preferences were highest for the most familiar biome, supporting the hypothesis that a person's landscape preference is strongly influenced by their residential experience in different biomes. Penning-Rowsell (1986) notes that perception and cognition are inseparable from experience but asks how familiarity creates affection for or indifference to landscapes?

The study of Wellman and Buhyoff (1980) showed that their subjects did not demonstrate greater visual preference for a particular region and that subjects from widely different geographic regions evaluated the landscapes, in terms of preference, in essentially the same manner, suggesting that regional familiarity may not be a serious problem for landscape preference researchers. This result is backed by the work of Tips and Savasdisara (1986c) who found that travel experience has virtually no influence on landscape preference, therefore suggesting that exposure to a wide variety of landscapes, hitherto unknown, has no influence on preference. Ulrich (1993) states that the findings of the last two decades has led to the conclusion that the similarities in response to the natural scenes usually far outweighs differences across individuals and groups with differing experiences or from diverse cultures.

Both familiar and unfamiliar environments are capable of generating strong involvements, there being an evident trade-off between the excitement of new environments and the comfort generated by familiarity (Orians, 1986). Connotations of the risk and uncertainty associated with some natural settings are important ingredients of natural landscape preferences. Moreover the 'alarming, deterring' or 'stimulating, exciting' character of certain landscape features depends on the personal capacity for accepting risk or challenge (Bernaldez *et al.*, 1987).

Age

Age-related differences in landscape preference can be seen in many studies. Balling and Falk (1982) found significant age-related changes in the preference for landscapes that differ and that underlying preference can be modified by experiences across the life span. Abello and Bernaldez (1986) noted that complexity, unpredictability and incongruence of natural or artificial scenes is related to age (maturity implies greater tolerance of complexity, uncertainty and surprise).

Lyons (1983) found that preference scores for vegetational biomes started low for young children, then stabilised or rose for college-aged and adult subjects, dropping again for elderly subjects; these differences may be in part due to the way that different ages used the rating scale. Zube *et al.* (1983) suggest that some hierarchy of functional importance exists wherein young children are maximally sensitive to the most basic, elementary functional aspects of landscape. With cognitive development, other more complex, information-based principles of coherence, complexity and mystery emerge.

Zube *et al.* (1983) further suggest that there may be cohort effects attributable to the elderly adults' scenic assessments relating to having been socialised prior to the environmental movement of the 1960s and 1970s. Such a hypothesis ties in closely with theories of historical changes in landscape perceptions, as discussed in Section 2.1.

Consensus

Most landscape evaluation techniques proceed on the assumption that there is a broad consensus within our society upon what is considered to be of high landscape value. This assumption is linked to another: that "visual quality" is an intrinsic property of landscape and can be stated objectively (Jacques, 1980).

Landscape preference studies should not rely exclusively on general rankings of preference, but should also consider other trends of variation and eventually compare individual patterns of selection. If only aspects of consensus are examined (*e.g.* group preference rank), idiosyncratic features remain ignored.

The partition of the total variation between consensus scales and other trends of variation will probably depend on the degree of socio-cultural homogeneity of the group of respondents (Abello *et al.*, 1986).

Reasons for the real variation in consensus levels remain elusive. Evidence suggests little overall correlation between perceived attractiveness and consensus levels, although the more 'extreme' evaluations rarely attract majority support.

2.2.3 Summary

The previous section has examined the role of public input to the landscape evaluation process. There are two basic approaches to evaluation: an expert-based one and a general public-based one: it can be argued that the latter is the most accurate, as the public are likely to be the best source of data for issues regarding their own aesthetic preferences.

It is accepted that a wide range of both people and landscapes need to be sampled in order to fully represent the range of perceptions that exist. Many factors influence the perceptions of the public, several of them have been noted by a variety of researchers.

Gender is important in terms of what people look at and what they are looking for in a landscape view. Education may affect landscape preference, as may environmental awareness. In both these cases the additional knowledge gained is likely to influence how people react to a landscape. Age has been shown to be significant in several studies, with attitudes altering throughout the lifespan.

People from different cultures are often found to prefer physiographically different landscapes; research has found groups preferring both their own culture's landscapes (*e.g.* Zube and Pitt, 1981) and the landscapes of other cultures (*e.g.* Yang and Brown, 1993). This is perhaps explained by the findings of Orians (1986) who notes that there may be a balance between the excitement of the new and the safety of the familiar. Familiarity and experience of landscapes may affect perception; while this phenomenon has been studied it is not clear how familiarity affects preference, and many researcher's findings are contradictory (*e.g.* Wellman and Buhyoff, 1980 and Lyons, 1983).

It is assumed that there is some broad consensus within a western society regarding 'scenic landscapes'. However, it should be remembered that this consensus takes in many differing views, and in a sense 'averages' over them. Those landscape which are more likely to instil extreme reactions, are also those which are least likely to have high levels of consensus.

2.3 Landscape Evaluation Options

Numerous techniques of landscape evaluation have been devised in recent years (Crofts and Cooke, 1974). They form a spectrum in which the extremes are represented on the one hand by techniques based unequivocally on the subjective assessments of landscape quality by individuals or groups (*e.g.* Shafer *et al.*, 1969) and on the other by techniques using physical attributes of landscape as surrogates for personal perception (*e.g.* Land Use Consultants, 1971; Linton, 1968).

2.3.1 Types of landscape evaluation and landscape perception paradigms

The academic discussion of landscape perception paradigms and disciplines demonstrates a difference between journals with theoretical and applications orientations. Geographic journals tend to emphasise the experiential approach to landscape perception, while the behavioural and recreation journals concentrate on cognitive and psychophysical approaches; the management and applications journals, particularly within forestry and landscape, place heavy emphasis first on expert and subsequently on psychophysical approaches. This might suggest that landscape managers, planners and designers have little interest in theoretical literature, especially in the experiential and cognitive paradigms, and particularly if it is lacking in suggestions of practical use (Zube *et al.*, 1982).

Landscape evaluation models can be subdivided in several ways. Arthur *et al.* (1977) splits them into descriptive inventories and public preference models, both categories being further split into non-quantitative and quantitative methods. Briggs and France (1980) use direct and indirect methods to subdivide the models, but state that the former has not been used to any great extent, while indirect methods are further classed into classificatory and non-classificatory methods. Crofts (1975) describes two sorts of technique - preference and surrogate component techniques. Daniel and Vining (1983) split the methods into ecological, formal aesthetic, psychophysical, psychological and phenomenological models. Zube *et al.* (1982) use four landscape perception paradigms: the expert, psychophysical, cognitive and experiential. For this review the methods will be split into *descriptive inventories*, *public preference methods* (after Arthur *et al.*, 1977) and a third category of *quantitative holistic techniques*.

It is important to examine the reliability and validity of landscape evaluation models and to identify any assumptions central to the models. Internal and external validity are of concern in the development of any landscape visual assessment system. External validity reflects, in part, how well the system-generated assessments correspond to other, known measures of visual quality. Internal validity reflects how well the system's internal logic withstands testing and violation of assumptions (Buhyoff *et al.*, 1995).

The cognitive paradigm differs from both the expert and psychophysical paradigms in providing a theoretical foundation for landscape perception, by attempting to explain why people prefer different landscapes. It attempts to bridge the gap between subjectivity and objectivity by using a theoretical model from which assumptions can be made and tested using empirical techniques (Kroh and Gimblett, 1992). Applying traditional criteria of reliability, sensitivity, validity and utility, Daniel and Vining (1983) concluded that a merger of the psychophysical and cognitive approaches currently provides the best avenue to an adequate landscape assessment system (Herzog, 1985). A description of each of the three types of models now follows.

2.3.2 Descriptive inventories

Descriptive inventories embodying the expert paradigm include ecological and formal aesthetic models, methods which are mostly applied by experts in an objective manner. They comprise the largest category of techniques for assessing scenic resources; they include both quantitative and qualitative methods of evaluating landscapes by analysing and describing their components (Arthur *et al.*, 1977).

Scenic elements (such as landform and visual effects), vegetative patterns and so forth, are first identified then described or rated (Arthur *et al.*, 1977). The ratings are primarily based on traditional values within the landscape architecture profession (Palmer, 1983). Although these surrogate methods of landscape evaluation can provide general assessments of landscape quality and a landscape inventory based on subjectively-selected but objectively-applied criteria, the objectivity of their application, and their precise, often quantitative, results disguise their underlying subjectivity (Crofts and Cooke, 1974).

The descriptive inventory approach contains several assumptions. One is that the value of a landscape can be explained in terms of the values of its components. Another is that scenic beauty is embedded in the landscape components, that it is a physical attribute of the landscape. However, scenic beauty depends on the observer as well as that which is being observed (Arthur *et al.*, 1977).

Formal aesthetic models

The basic theory of the formal aesthetic model is that aesthetic values are inherent in the abstract features of the landscape. These properties are defined as basic forms, lines, colours and textures and their interrelationships (Daniel and Vining, 1983). In this model landscapes are first analysed regarding their formal abstract properties. The relationships between these elements are then inspected to classify each area in terms of variety, unity, integrity or other complex formal characteristics. The method is almost always applied by an expert, usually a landscape architect. These models have been found to be seriously deficient with regard to the fundamental criteria of sensitivity and reliability (Daniel and Vining, 1983).

An example of a formal aesthetic model is the Visual Management System (VMS) developed by the USDA Forest Service. It has the purpose of evaluating scenic resources within a land-management framework and assumes that scenic quality is directly related to landscape diversity or variety (Daniel and Vining, 1983). VMS uses character classification (such as gorges, mountains, foothills and plateaux), variety classification (form, line, colour and texture) and sensitivity level (referring to the relative importance of the landscape as a visual or recreational resource).

Ecological models

Within the ecological model, the environmental features that are relevant to landscape quality are primarily biological or ecological. The landscape is characterised in terms of species of plants and animals present, ecological zones, successional stage or other indicators of ecological processes. Modern humans are characterised as users of the landscape, their contribution is habitually in the form of negative aesthetic impacts (Daniel and Vining, 1983).

Ecological landscape planning models tend to be designed for specific areas and are therefore difficult to apply generically; they are also more sensitive in distinguishing between natural and human-influenced environments than in making distinctions within either of those classes. If the alternatives for land management are to manipulate or not manipulate the environment, ecological models will almost invariably indicate against any manipulation (Daniel and Vining, 1983).

A major underlying assumption of ecological models is that landscape quality is directly related to naturalness, or ecosystem integrity. The validity of this model depends upon the assumption that "natural" areas undisturbed by humans are highest in landscape quality (Daniel and Vining, 1983).

An example of such a model is that of Cooper and Murray (1992), who used local patterns of land class distribution and land class clusters to divide a region into geographically distinct landscape units. High-elevation and upland areas were differentiated from lowlands, and boundaries were then drawn in relation to selected physiographic and landform features such as watersheds and specified juxtapositions of land classes.

2.3.3 Public preference models

Public preference models (the experiential paradigm), such as psychological and phenomenological models, are often undertaken using questionnaires, and are unavoidably linked to the problems of consensus among the public. The visual quality of a landscape is rated on the basis of an observer's individual preference of the whole landscape. The essence of the public preference approach is the judgement of the landscape in totality, as opposed to the measurement techniques, which rely on the definition of factors to explain variation in landscape quality (Dunn, 1976). Ideally, these techniques encompass a wide and diverse sample of individuals.

Questionnaires or verbal surveys are the most commonly used non-quantitative method for sampling scenic preference of various groups. They are useful for determining preferences for extremely divergent categories of landscape (Arthur *et al.*, 1977). One can provide visual stimuli for evaluation, such as photographs (*e.g.* Shuttleworth, 1980b; Wade, 1982) or one can use other stimuli, such as sound (Anderson *et al.*, 1983) or verbal descriptions.

Psychological models

The psychological approach has been used in many studies where dimensional analyses of people's preferences for different landscapes are performed. These studies have demonstrated that various psychological constructs such as complexity, mystery, legibility and coherence are important predictors of human landscape preferences (Buhyoff *et al.*, 1994). The psychological model refers to the feelings and perceptions of people who inhabit, visit, or view the landscape. A high-quality landscape evokes positive feelings, such as security, relaxation, warmth, cheerfulness or happiness; a low-quality landscape is associated with stress, fear, insecurity, constraint, gloom, or other negative feelings (Daniel and Vining, 1983).

Because psychological methods use multiple observers and yield one or more quantitative scale values for each assessed landscape, their reliability and sensitivity can be determined. These methods base landscape assessments on the reactions and judgements of the people who experience and/or use the landscapes. In this regard there is an important element of validity inherent in the method (Daniel and Vining, 1983).

Phenomenological models

The phenomenological model places even greater emphasis on individual subjective feelings, expectations, and interpretations. Landscape perception is conceptualised as an intimate encounter between a person and the environment (Daniel and Vining, 1983). The principal method of assessment is the detailed personal interview or verbal questionnaire. Phenomenological models tend not to be used to rank landscapes in terms of scenic beauty.

Phenomenological approaches have largely sacrificed reliability in favour of achieving high levels of sensitivity; by emphasising very particular personal, experiential and emotional factors, the visual properties of the landscape become only very tenuously associated with landscape experience. However, by emphasising the unique role of individual experiences, intentions, and expectations, the phenomenological model serves to point out the importance of the human context in which landscapes are encountered (Daniel and Vining, 1983).

2.3.4 Quantitative holistic methods

Quantitative holistic techniques use a mixture of subjective and objective methods and include psychophysical and surrogate component models; these use both the psychophysical and cognitive paradigms. Unwin (1975) describes three phases of landscape evaluation. Firstly, there must be landscape measurement, an inventory of what actually exists in the landscape. Secondly, the landscape value should be measured, this will be an investigation and measurement of value judgements or preferences in the visual landscape. Finally, there is the landscape evaluation, an assessment of the quality of the objective visual landscape in terms of individual or societal preferences for different landscape types.

Quantitative holistic methodologies combine two approaches: quantitative public preference surveys and inventories of landscape features. Measures of landscape quality are systematically related to physical / biological and social features of the environment so that accurate predictions of the implications of environmental change can be made (Arthur *et al.*, 1977).

These models represent a compromise between techniques which assess the effects of landscape elements on overall preference by summing evaluations of individual dimensions (descriptive methods) and techniques which emphasise the interactions of landscape elements by evaluating the scenic quality of the entire image (preference models) (Arthur *et al.*, 1977; Buhyoff and Riesenman, 1979). They have tended to be a tool for research rather than for impact assessment. Their orientation is to predict scenic quality based on the presence of quantifiable landscape attributes (Palmer, 1983).

Psychophysical models

The relationships of interest are those between physical features of the environment (*e.g.* topography, vegetation, water) and psychological responses (typically judgements of preference, aesthetic value or scenic beauty). Researchers have measured areas, perimeters, and tones of the differentiated landscape zones of photographs and related them to preference rankings (*e.g.* Shafer *et al.*, 1969; Shafer and Tooby, 1973; Brush and Shafer, 1975). These studies illustrate a systematic approach to relating components to preferences (Arthur *et al.*, 1977).

To develop such models, a number of different landscapes must be assessed and their physical characteristics evaluated (Daniel and Vining, 1983). This can be done using colour photographs or slides (Arthur, 1977) or on-site assessments at the landscapes (Schroeder and Daniel, 1981). These models are discussed in further detail in Chapter Three.

Surrogate component models

The basis of component techniques is the identification and measurement of those physical components of the landscape which are regarded as surrogates of scenic quality. The individual components are isolated, their identification and measurement discussed and their combined utility within existing techniques evaluated. Because component ratings are compared to overall preference ratings in these models, the contribution of particular components to scenic beauty can be measured in terms of explained variance (Arthur *et al.*, 1977).

These components can be assigned to three groups in relation to their assumed importance in determining scenic quality. The major components comprise the landscape skeleton as expressed by macro relief, relative relief and water presence. The minor but permanent components are variations of the macro forms at micro scales including the overall variations such as surface texture and ruggedness, and particular features such as the irregularity of two-dimensional outlines and three-dimensional forms, and the singularities such as isolated features.

Finally, there are the transitory, changing, components of the characteristics of water bodies and surface textures, such as changes in vegetation during the seasons (Crofts, 1975).

2.3.5 Economic methods of landscape evaluation

How do preference values determined from models relate to economic values of the same landscapes? Results of an exploratory study (Brush and Shafer, 1975) suggest that a consumer's evaluation of real estate that overlooks a given natural scene correlates highly with the scene's predicted preference scores. It should be possible to develop a relationship that ties scenic preference values to economic land values; the results of such research would be useful in benefit-cost and environmental impact analyses of the effect of proposed man-made changes in natural environments.

Traditional economic analyses have generally failed to account for unmarketed (non-pecuniary) resources, such as aesthetics. The effect of excluding non-pecuniaries from trade-off (economic) decisions is that they have entered the system as if they were free. Recognition of this problem has, in part, motivated attempts to evaluate scenic resources. If applied to aesthetic resources, redefinition would require putting a price on scenic beauty or charging for its "use". However, putting a price on aesthetic resources is probably not feasible for several reasons (Arthur *et al.*, 1977). Scenic views are often valuable to those who do not own them. Scenery is a non-exclusive good because it is difficult to keep non-owners from enjoying a view. It is non-rival in consumption because the value of scenic viewing for any one person is not diminished by the number of persons enjoying it, up to the point of congestion (Johnson *et al.*, 1994).

<u>Methods of economic evaluation</u>

Attempts to estimate the economic value of scenic quality have taken three forms: contingent valuation studies of landscape beauty or quality which have generally focused on benefits to a larger society; contingent value or travel cost studies focusing on the contribution of scenery to recreation experiences; and hedonic approaches seeking to determine the contribution of scenery attributes to market price or consumer surplus.

All of these studies have found that measures of scenic quality were strongly and positively associated with measures of economic value (Johnson *et al.*, 1994). Other methods include opinion tallies and revealed demand. Opinion tallies often result in undervaluation; revealed demand is complicated by the necessity of identifying all of the variables acting on the situation (Arthur *et al.*, 1977).

The hedonic price method (HPM) is a less subjective way of scoring landscape components; components of landscape are valued against people's willingness to pay to live in particular types of landscape, defined as consisting of different bundles of components (Willis and Garod, 1993). HPM is a process of constrained maximisation in which systems of equations involving both prices and quantities for the composite commodity and its attributes are constructed and then solved (Price, 1994).

The travel cost method (TCM) uses a sample of visitors to a site which embodies desired environmental attributes and asks them factual questions about the origin of their journey to the site, their mode of transport and perhaps about other costs incurred and their own socio-demographic characteristics (Bergin and Price, 1994).

Contingent valuation techniques (CVT) in landscape evaluation are seen as a natural evolution from landscape evaluation methods based on the scoring of landscape components and other public preference techniques such as landscape ranking. By valuing landscape as an entity, CVT avoids many of the problems, such as those of separability and collinearity, often associated with travel cost and hedonic price methods of landscape valuation (Willis and Garod, 1993).

Willingness-to-pay (WTP) studies can assist in valuing today's landscape, they also attempt to value the benefits which residents and visitors might derive from alternative landscapes which could arise at some time in the future. WTP's linearity means that it is a predetermined function of the quantity of the feature in the landscape. However, evidence suggests that the impact of a landscape feature does not increase in proportion to its size (Willis and Garod, 1993). Unfortunately, WTP values are often too high (Arthur *et al.*, 1977) and willingness to pay to gain a commodity is generally less than willingness to accept compensation for losing it (Price, 1994).

2.3.6 Methodological problems and error in models

All these types of models are complicated by methodological problems that can affect interpretation of results. One such problem is whether numerical ratings of landscape beauty represent people's preferences for the landscapes, their judgements of scenic beauty of the landscapes, or both. There is considerable support for the argument that scenic beauty judgements differ from scenic preferences (Arthur *et al.*, 1977); according to Jacques (1980) public preferences tend to give a measure of 'value', 'quality' is discerned through judgement. When asked to indicate their preference for various landscapes, observers tend to apply criteria for use of those areas (recreation, residence *etc.*) rather than for inherent beauty (Arthur *et al.*, 1977).

There are some persistent errors in the evaluation of landscape, as identified by Hamill (1985). Examples of the following seven types of mathematical error have been found in the literature:

1. incorrect use of numbers derived from position in a classification;
2. incorrect use of numbers to stand for words;
3. use of spurious numbers in simple mathematical operations;
4. use of 'bad data' in complex mathematical and statistical operations;
5. use of data that does not satisfy requirements of the model;
6. use of numbers to support, derive, or demonstrate meaningless, spurious or useless concepts; and
7. use of concepts without adequate operational definitions.

Other errors may stem from the interpretation and measurement of photographic images by those evaluating the scenes, which is currently a subjective process to which objective rules are applied. More errors may occur from sampling too few, or too biased, a sample of either landscapes or people.

CHAPTER THREE

REVIEW OF PSYCHOPHYSICAL LANDSCAPE PREFERENCE MODELS

3.1 Introduction

The literature reviewed in the final section of Chapter Two discussed a number of methods for landscapes evaluation. Of these, psychophysical models appear to offer the best approach and fulfil the criteria of a merger between the psychological, the physical and the cognitive which was set down by Daniel and Vining (1983) as the best route to an adequate landscape assessment system.

Of all landscape assessments, these methods have been subjected to the most rigorous and extensive evaluation. They are adapted from psychophysics, a branch of psychology established in the early 1800s, which provides precise quantitative indices based on people's perceptions of stimuli (Hull *et al.*, 1984). They have been shown to be very sensitive to subtle landscape variations and psychophysical functions have proven very robust to changes in landscapes and in observers (Daniel and Vining, 1983).

3.1.1 Psychophysics

> "Psychophysics is the study of measurement theory and procedure which attempts to relate environmental stimuli to human sensations, perceptions and judgements."
> (Hull *et al.*, 1984)

Classical psychophysics sought to establish precise quantitative relationships between physical features of environmental stimuli and human perceptual responses (Daniel and Vining, 1983). Traditional psychophysical models, while not "classifying" landscapes, are developed to make predictions of scenic preference or visual quality from variables which are often selected for their predictive, rather than explanatory ability (Buhyoff *et al.*, 1994).

3.1.2 Psychophysical landscape preference models

Landscape features, such as land cover, land use, forest stand structure and arrangement, are measured and then statistically related to judgements of scenic quality. Models such as paired comparisons, Likert scales, and sorting and ranking scales are a means to evaluate scenes quantitatively (Arthur *et al.*, 1977); multiple linear regression has recently been the most commonly used technique to determine these relationships (Buhyoff *et al.*, 1994).

Relying on ordinal or interval scales of measurement, psychophysical methods have consistently been able to provide different landscape-quality assessments for landscapes that vary only subtly. However, they require the full range of scenes to be selected to represent all of the physical characteristics used as predictors of scenic beauty (Hull and Revell, 1989). They also provide good assessments of public perceptions of the relative scenic quality differences between landscapes (Buhyoff *et al.*, 1994).

However, the models can be expensive and time consuming to develop and are restricted to a particular landscape type and to a specified viewer population and perspective; in the short term they are not highly efficient (Daniel and Vining, 1983). The very structure of these models is often a limiting factor in their explanatory value and wide generalisation (Buhyoff *et al.*, 1994). There is also a concern that the individual rater, rather than the group average, is the more appropriate unit of analysis for tests of validity of photo-based assessments (Hull and Stewart, 1992).

The psychophysical method of landscape preference modelling relates affective responses to physical data, that is, responses not influenced by emotions or other outside factors, such as environmental awareness. However, respondents tend to give cognitive responses, based on prior knowledge and a level of information processing regarding the image they are viewing, therefore, psychophysical models cannot be used to elicit the cognitive explanations for the responses.

<u>Techniques of preference versus measurement</u>

Measurement approaches to the assessment of visual landscape quality rely on the reduction of the landscape to its constituent components which are allocated points according to the relative contribution of each to landscape quality.

Preference approaches make no attempt to single out landscape components or to allocate them points. Instead, it is the total appearance of the tract of land that is judged.

Aside from philosophic arguments against the reductionist approach implicit in measurement methods, preference methods are likely to prove more valid (Dearden, 1981). Psychophysical techniques can be seen as a compromise between these two approaches.

Aesthetic response

Aesthetic response is defined as preference or like-dislike affect in association with pleasurable feelings and neurophysiological activity elicited by visual encounter with an environment (Ulrich, 1986). Preference is experienced as direct and immediate. There is no hint in consciousness of the complex, inferential process that appears to underlie the judgement of preference (*cf.* Section 2.1). Given the range of variables that are being assessed, the underlying process must be carried out with remarkable speed and efficiency (Kaplan, S., 1987).

Aesthetics is not the reflection of a whim that people exercise when they are not otherwise occupied. Rather, such reactions appear to constitute a guide to human behaviour that has far-reaching consequences. Aesthetics could be seen as a set of inclinations, however intuitive or unconscious, which might influence the direction people choose not only in the physical environment but also in other domains (Kaplan, S., 1987).

Application

Psychophysical models strive to bridge the gap between the landscape emphasis of the ecological and formal approaches and the observer-emphasis of the psychophysical and phenomenological approaches (as discussed in Chapter Two, Section 2.3). They often involve large samples of both landscapes and observers, and try to establish statistical relationships between observer preferences and landscape characteristics (Dearden, 1987).

Psychophysical assessments are useful in many management contexts - features such as quantitative precision, objectivity, and a basis in public perception and judgement are important. The assessments are not based on one expert's opinion, but reflect a measured consensus among observers representative of the public that views landscapes and is affected by management actions (Daniel and Vining, 1983).

There is little danger that one assessment approach will be settled upon to the exclusion of all others. The diversity of assessment methods which continue to emerge will testify to that. If any theory should come to dominate the field it will do so by reflecting and explaining all the various ideas, perceptions, and methods which are possible, rather than by expecting all aesthetic experience to conform to a particular model or rationale (Ribe, 1982).

3.1.3 Scenic beauty assessment techniques

Two scenic beauty assessment techniques in common use are the Scenic Beauty Estimation (SBE) procedure and Thurstone's Law of Comparative Judgement (LCJ). Both procedures are based on psychophysical methods and theories which have been developed in, and adapted to, a variety of disciplines such as environmental psychology and landscape assessment (Hull, 1986).

The SBE method uses ordinal-levels of scenic quality, providing interval-level values corresponding to the degree of perceived quality in the landscape (Anderson and Schroeder, 1983). The LCJ method, on the other hand, requires the comparison of all possible pairs of landscapes (Hull *et al.*, 1984).

These two types of assessment have been compared and contrasted by several authors in regard to their sensitivity and convergence, with the overall result that they are similar with respect to their theoretical foundations and their independently derived scenic beauty metrics (Hull *et al.*, 1984).

Rationales for using the two procedures are that LCJ provides the most sensitive assessment of perceived overall differences between the management options represented, while SBE more closely approximates the typical context in which a forest visitor might encounter the effects of forest management on the landscape (Thorn *et al.*, 1997). Time can also be a major factor: due to observer fatigue, the LCJ procedure is limited to 15 photographs at one sitting; the SBE method is less time consuming as observers need only see each landscape once, this is its greatest advantage over LCJ (Hull *et al.*, 1984).

Pair comparison and rank ordering techniques are generally recognised as allowing finer discriminations among stimuli than categorical scaling techniques. There are two reasons for this:

1. The SBE technique allows observers only one chance to make a scenic beauty assessment for each landscape, without seeing its relationship to all the other landscapes;
2. The SBE rating imposes high and low boundaries above and below which the observer cannot extend his scale and potentially forcing landscapes to be rated as similar even though they may be perceived as different.

The LCJ procedure, in contrast, does not allow landscapes to be rated as similar; judges simply choose which of a pair of landscapes is preferred (Hull *et al.*, 1984; Hull, 1986).

Tahvanainen *et al.* (1996) note that the pairwise-comparison and rating methods are useful assessment methods and produce closely corresponding results; Hull *et al.* (1994) suggest that either scaling method might be used to assess scenic beauty. In research using both methods Buhyoff *et al.* (1980) demonstrated that interval landscape preferences for the same forest scenes with and without insect damage can be measured with a different methodology, fitted to the same model, and produce equivalent results.

In conclusion the SBE procedure is sensitive and can differentiate between similar scenes at least as well as the LCJ pair comparison. Finally, the convergence of the LCJ and SBE metrics provides evidence of the validity of these psychophysical procedures in assessing scenic quality (Hull, 1986).

3.1.4 Photographs as landscape surrogates

The use of pictures as surrogates for real landscape has often raised objections in the sense that photographs are less complex, less multi-dimensional, and offer less interaction than do real scenes (Abello *et al.*, 1986). Hull and Stewart (1995) state their concern regarding the threat to the ecological validity of photo-based assessments caused by differences between on-site and photo-based contexts; Kroh and Gimblett (1992) question whether or not people respond the same to a real landscape as to a simulation. It is even commented, by Buhyoff *et al.* (1983), that such factors as lighting conditions, content and photographic quality could in some cases be more decisive in determining preferences than the landscape type *per se.*

The use of photographs in recent work concerned with environmental aesthetics, perception and preferences has been commonplace, because photographs can be used with greater economy, speed and control than can real-world situations. This approach follows the long tradition in psychological studies and experimental aesthetics of using stimulus substitutes (Shuttleworth, 1980b). However, photographs are useful in landscape management decisions only if respondents rank pictures in approximately the same order as they rank the actual scenes (Shafer and Brush, 1977). A number of researchers have reported high correlations between photo-based judgements and on-site judgements of scenic beauty (Hetherington *et al.*, 1993). Nevertheless, Pocock (1982) states that however good the simulated landscape may be:

> " it does not obscure the fact that a photograph is totally unable to convey the life of the scene: unable to discriminate: it merely records everything at one instant".

Perceptual distortions

When a surrogate environmental display such as a photograph is used, perceptual distortions can and do occur. The most obvious source of variation between photographs of a view and the view as seen on the ground is caused simply by the fact that the two may differ in content. The eye takes in a much larger field of vision than the camera, having a very wide lateral cone of vision. There is a need to provide constancy scaling and perspective resolution aids in photographs if they are to allow the viewer to perceive accurately objects as the same solid visual shapes, with their characteristic properties of colour, shape and distance, as perceived in the original (Shuttleworth, 1980b).

A fundamental source of perceptual distortion lies in the differing physical nature of views and photographs. The view consists of three-dimensional objects, stationary or moving, at various distances in space, whereas the photograph is merely a two-dimensional image of that reality obtained by the projection of the view through a more or less complex optical system. Retinal images, although the result of "seeing" as commonly understood, occur merely as one link in the chain of events which constitutes the process of seeing (Shuttleworth, 1980b).

Validity of photographic simulation

Several authors have tested the validity of using photographs as simulations of real landscapes. Thayer *et al.* (1976) tested the model of Shafer *et al.* (1969) and found it to be a valid predictor of perceived landscape beauty in photographs, this model will be discussed later in this section; Stamps (1990) conducted a meta-analysis of papers discussing preferences obtained *in situ* and preferences obtained through photographs, resulting in a combined correlation of 0.86; the conclusion reached by Dunn (1976) was that photographs may be used to accurately represent landscapes.

Shuttleworth (1980b) looked at eight investigations of the validity of photographic surrogates. All the studies provide evidence that scenic quality evaluations based on photographs are similar to ratings made by different observers in the field, and provide some tentative evidence that not only overall responses but also the details of those responses are similar. It was concluded that photographic simulation proved most reliable in dealing with the overall perception of the landscape, but less reliable when dealing with perception of detail elements and characteristics in the landscape.

However, not all authors agree with this result. Kroh and Gimblett (1992) found that people do not respond similarly to an on-site landscape experience and a simulation and that classifications drawn from field experience differ from laboratory ones because of the impact of multi-sensory stimuli. The utility of the validity research has been limited to the static environment, because the represented landscapes did not contain any prominently dynamic elements (Hetherington *et al.*, 1993) and thus the preference measured is that of the static landscape (Kroh and Gimblett, 1992). It has been concluded by these authors that the static surrogate (colour slides) do not sufficiently preserve dynamic environmental features, while the dynamic surrogate (video) produces flow-related differences in ratings of scenic beauty.

Panoramic verses regular prints: issues of framing

People may frame selected views in field experience just as a photographer does in taking a photograph. That a photographer would select the same frame, or isolate the same landscape elements, as every other viewer of a given landscape seems unlikely (Nassauer, 1983). When a great deal of the landscape is included in the photographic frame, the viewer may scan the photograph much as she/he might scan the landscape, selecting from a range of stimuli those that are important. The elements included in the photograph will be limited by the horizontal range of the view, and by the frame selected by the photographer.

In the study of Nassauer (1983) panoramic slide sets received significantly higher ratings than wide-angle slides for scenic landscapes displaying dominant horizontal landscape form. This framing effect is apparently operational only in scenic landscapes. Special attention should be paid to technical quality of the picture and instead of a 28mm lens camera, a panoramic camera with, for example, a 50mm lens would be preferable (Tahvanainen *et al.*, 1996). However, Coeterier (1983) found that photos taken with a standard lens were more in accordance with the actual scale relationships that are found in the direct perception of the landscape than wide-angle photos.

The use of 360° panorama photographs, observed from a rotating viewpoint on a colour monitor has not yet been researched. This type of photograph may overcome several of the problems associated with framing issues.

Results of experiments into photographic surrogates of landscapes

The results of Shuttleworth (1980b) indicated that there were very few differences of significance between the reactions to and perceptions of the landscapes either when viewed in the field or as photographs. The results also suggest that black and white photographs tended to induce more extreme and more highly differentiated responses than colour photographs, and that the latter related more closely to field responses.

Stamps (1992) tried to find out if people could distinguish alterations from reality in photographs. In the study only 14% of the responses were correct identifications of photographic alteration. It was found that the effects of simulation within photographs on judgements of environmental preference are in the order of five to ten percent of the variance in preference (Stamps, 1993).

Best method of photographic simulation

Factors affecting photographic preference include type of lenses employed, depth of focus in the photo, angle of view, scale of different elements in the landscape, general composition of the photo, time of day, and season in which the photo was taken (Hull and McCarthy, 1988; Kreimer, 1977).

The landscapes must be depicted by colour photographs to maintain a potentially important source of landscape variety in the study (Shuttleworth, 1980b), colour clearly gives the viewer more information about the landscape than a black and white image (Nassauer, 1983). Framing formats using wide-angle formats may be superior for simulating field experience and providing the lateral and foreground context in each of the views without apparent distortion of the actual scale relationships that are found in the direct perception of landscapes (Shuttleworth, 1980b).

3.1.5 Discussion of Shafer model

The Shafer method

The Shafer method (Shafer *et al.*, 1969; Shafer and Brush, 1977) is a landscape-preference model which uses perimeter and area measurements of certain landscape features. The landscape zones used are (Brush and Shafer, 1975):

- the immediate, where individual leaves of trees and shrubs, soil texture, stones and rocks are discernible;
- the intermediate, where only the forms of trees and shrubs are discernible and the outlines of rocks and prominent features of snow covered or bare land are distinguishable; and
- the distant zone, where the forms of individual trees cannot be distinguished and no details of soil, rocks, grasses or snow can be recognised.

The model uses measurements of the area or perimeter of major vegetation, such as trees and shrubs, non-vegetation, such as exposed ground, snowfields and grasses, and water, including streams, lakes and waterfalls.

The details of the ten zones used in the original study by Shafer *et al.* (1969) are:

1. sky zone, sky and clouds only;
2. immediate-vegetation zone;
3. intermediate-vegetation zone;
4. distant-vegetation zone;
5. immediate non-vegetation zone;
6. intermediate non-vegetation zone;
7. distant non-vegetation zone;
8. stream zone, including only water and rocks in a stream;
9. waterfall zone, including only water and rocks in a waterfall; and
10. lake zone, including water and rocks in a lake.

Further information on this model is contained in Chapter Six, Section 6.5.

The model predicts quite accurately how people will rank (or score) natural landscapes although it does not predict landscape appeal directly, as it predicts the appeal of a photograph (Brush and Shafer, 1975; Shafer *et al.*, 1969). The model's terms include those features that are important in a landscape's aesthetic appeal. The three landscape elements measured - vegetation, non-vegetation and water - are also the gross features in natural landscapes that man is capable of altering to an appreciable degree.

Through area and perimeter measurements, the model also uses the relative proportions of landscape features in the landscape. The sense of depth in a view, as established by textural gradients and overlapping land forms, is generally recognised as a major factor in scenic preference (Shafer and Brush, 1977). The use of three zones in the model takes into consideration the textural variation of vegetation and non-vegetation (as distance increases the textural detail will decrease).

The following items had positive effects on the aesthetic appeal of landscape (Shafer *et al.*, 1969):

- perimeter of immediate vegetation;
- perimeter of intermediate non-vegetation;
- perimeter of distant vegetation multiplied by area of water;
- area of intermediate vegetation multiplied by area of distant non-vegetation; and
- area of intermediate vegetation multiplied by area of water.

The negative effects were:

- perimeter of immediate vegetation squared;
- area of water squared;
- perimeter of immediate vegetation multiplied by distant vegetation;
- perimeter of immediate vegetation multiplied by area of intermediate vegetation; and
- perimeter of intermediate vegetation multiplied by area of distant non-vegetation.

Perimeter measurements stress the prominent edges between the forest canopy and open ground or water, edges that separate masses of contrasting texture and tone. Studies have shown that viewer's attention focuses at points along such edges (Brush and Shafer, 1975). Water, when combined in a scene with forest cover, strongly enhances scenic quality, yet if it occupies too much of a scene, water detracts from the scenic quality. This suggests that without the contrast of dark vertical masses of trees in the distance, the presence of water can diminish the scenic quality of a scene (Shafer and Brush, 1977).

Comments on Shafer's work

Factors that may have influenced model results include weather conditions and photographic composition. Third-order terms may have explained more variation, unfortunately the computer used in the original 1969 study did not have the storage space to cope with these additional terms (Shafer *et al.*, 1969). The study was repeated in Scotland in 1972; the landscape preference equation developed from the original study in 1969 accurately predicted the preferences of Scottish people for American landscapes, although it was developed from data collected in the United States (Shafer and Tooby, 1973).

A principal advantage of the regression model is the use of second-order terms that describe interrelated or interlocking elements of the landscape. The model also recognises the importance of framing and of water.

Two of the strongest criticisms of the Shafer model are the lack of any theoretical foundation and the failure to account for individual differences (Propst and Buhyoff, 1980). Several authors have written critiques of E.L. Shafer's work on landscape aesthetics. One of the first was West (1969) in reply to the publication of the model (Shafer *et al.*, 1969). West thought that "the thesis that aesthetics can be quantified is fascinating" but would not accept that the method was of use except in predicting preferences of black and white photographs: "...colour; this element cannot be disregarded". West went on to question "the submission that their method can be used to help evaluate and compare the aesthetic quality of different landscapes".

Shafer replied in person to these comments (Shafer, 1969b). He accepted some criticisms, and requested that "someone who has a larger research budget than ours will attempt to replicate our original experiment, but using coloured photographs". This has since been done, in several pieces of work.

West also commented on the use of professional photographers and their subjectivity, to which Shafer replied that many photographers were used and that the effect of such variations as photographer subjectivity was already included in the study design (West, 1969; Shafer, 1969b).

Kreimer (1977) commented on the assumptions used by Shafer *et al.* (1969). These were noted as a basic assumption that visual characteristics of the environment can be measured and that it is possible to describe the appearance of a landscape in terms of the quantity of specific characteristics. It was assumed that, to a large extent, individual preferences will be determined by the visual characteristics of the environment. The paper assumed and took for granted the existence of a twofold isomorphism, (1) between the real environment and the simulated environment and (2) between the real environment and people's mental images of that environment.

3.2 Quantitative Landscape Components

3.2.1 Landscape descriptor dimensions

The psychophysical and surrogate component techniques of landscape evaluation require the landscape to be segmented. This can be done in many ways, similar to those used in the models previously discussed, from simple methods to more abstract definitions. Examples include landform elements (Gardiner, 1974; Land Use Consultants, 1971), landscape patterns or themes (Hammitt *et al.*, 1994; Linton, 1968), landscape character (Crofts, 1975), landscape qualities (Morisawa, 1971; Palmer, 1983), dimensions (Propst and Buhyoff, 1980) and landscape preference predictors (Brush and Shafer, 1975; Hammitt *et al.*, 1994).

Hull and Buhyoff (1983) and Gobster and Chenoweth (1989) have divided the landscape dimension into 2 or 3 types; the former use cognitive/psychological and physical/biometric measures, while the latter use artistic measures. This review will separate landscape variables into two sections: firstly the physical, measurable components; and secondly, the cognitive, intangible components, which may be measurable through the use of surrogate variables.

3.2.2 The theory and problems behind landscape characteristics

There are questions regarding the selection of components, the relationships between components, and the relationship between the components and scenic quality as perceived by individuals and groups (Crofts, 1975). The assumption that the visual landscape can be reduced to constituent components, that the visual quality of each component can be measured in isolation and that, when added together, these components represent the total landscape, is a major weakness in component based models (Dearden, 1980).

> "Without some theoretical grounds, why should we assume that beauty resides in mountains, in woods, in streams, and not in some unexamined relationship between them" (Appleton, 1975).

In many studies reference is made to 'edge', 'edge tracts' or 'edge categories', all of which seem to refer to boundaries or zones of contact between contrasting landscape features. There are some theoretical grounds for believing that these phenomena of 'edges' and 'skylines' are of importance in the aesthetics of landscape. Outdoor recreationalists commonly prefer to use edge environments *e.g.* the lake edge, the river edge, the cliffs edge, the edge of forests. If edges are of more or equal importance than the landscape elements they contain, are any of the models discussed truly describing landscapes?

However detailed the search for relevant factors, there will inevitably be a proportion of the landscape that cannot be explained by the assembled factors alone. This proportion will consist of the subtleties of landscape, such as interaction between elements, and properties of the landscape such as colour, form, shade and lighting (Dunn, 1976).

Methods based on intrinsic landscape factors are proclaimed objective, to avoid public scrutiny of certain projects and achieve "democratic" legitimacy (Tips, 1984), yet the components, regarded as surrogates of scenic quality, are subjectively selected; this selection must be subjective, but it must also be shown to be more than just the opinion of the professional judge (Crofts, 1975; Dearden,1980). These techniques also fail to take account of both the quality of the scenery at a point and the quality of a view from that point in all directions. Lastly, some measurement methods contravene the theories of levels of measurement by using nominal or ordinal scales of measurement and then employing standard arithmetic procedures, such as multiplication and addition, as mentioned in Chapter Two, sub-section 2.3.6. In these circumstances the methods become invalid (Dearden, 1980).

3.2.3 Terrain and hydrological components

Crofts (1975) identified three of the most important terrain components: macro form, relief and landform types; other important components include minor and ephemeral components and hydrological components. The elements of macro form include the categories of the geomorphologist, such as mountains, uplands, valleys and coast (Linton, 1968; Land Use Consultants, 1971).

Relief is used in some classifications as a single factor alongside biological, hydrological and human components (Crofts, 1975). Other methods use relief as an absolute measurement, or use variants such as available relief, relative relief or relief as a measure of grandeur (Crofts, 1975; Linton, 1968).

Landform types, classified genetically as individual or groups of landforms in geomorphological mapping schemes, represent an amalgamation of virtually all geomorphological components (Crofts, 1975). Landform is the most permanent of all landscape features, as it is the most difficult to alter (Brush, 1981), with exception of volcanoes and the chisel (Mount Rushmore can no longer be classed as natural) and therefore should be a stable basis for landscape classification.

Minor terrain components include visually significant irregularities, such as abruptness of accidentation (Linton, 1968) and contour distinction (*e.g.* rock outcrops and isolated landforms). Micro features of the landscape, such as surface texture are rarely included in classifications. They are more important in smaller areas and are perhaps best suited to site evaluations, along with biological textural components (Crofts, 1975). Singularities in landform include isolated hill masses, waterfalls and other unique forms, such as found in glaciated areas (Linton, 1968); these components have an immediate visual impact by focusing the attention of observers. Ephemeral components add detail to the landscape, and can be measured in terms of presence/absence or in terms of the rates of physical change (Crofts, 1975).

Hydrological components refer to either water bodies or to river valleys and basins. The primary component is the presence/absence of water, where a water body acts as a focal point and can be regarded as a singularity (Crofts, 1975). Water has always been a great geomorphological agent, which models the landscape in both physical and economic aspects (Ramos and Aguilo, 1988). Of visual importance is the contrast in water surface character - such as discharge, flow variability and velocity. The physical parameters of a linear water body - river width and depth, bed slope, bank erosion and deposition are also important factors.

3.2.4 Landscape components used with evaluation models

Landform elements

In viewing any scene, the attributes which strike us specially are size, form, character of surface, colour and movement, and of these attributes there is little doubt that form is by far the most important (Marr, 1909).

Land Use Consultants (1971) developed a technique for use in evaluating Scottish landscapes using two series of physical landscapes: relief classes defined in terms of high, normal and low relief per unit area; and landform types such as valley, lowland, plateau, edge and coast. These are then amalgamated and allotted to previously defined landscape tracts. The method omits major landforms, such as mountains and uplands but includes the negative aspects of landform.

In the Leopold method (Crofts, 1975) components of valley and river character are identified to obtain a comparative assessment of the scenic quality of particular sites along certain rivers. Valley character is derived by comparing the width of the valley floor with the height of adjacent mountains (a measure of grandeur); river character is assessed in terms of the width, depth, size, presence and frequency of rapids.

Linton (1968) divided up the Scottish landscape into six "landform landscapes" - lowland, hill country, bold hills, mountains, plateau uplands and low uplands. Linton never defined the components rigorously but used personal judgement, the defined landscapes vary greatly in scale and hence visual impact is equally variable. Linton also used the highly subjective assumption that attractiveness increases with an increase in steepness of slopes and boldness of landforms (Crofts, 1975).

Kaplan *et al.* (1989) describe a method using physical attributes which are divided into landform and landcover. Landform elements are:

- slope/relief (the prominence of the landform);
- edge contrast (contrast between adjacent landforms); and
- spatial diversity (variety of space created by landform).

Landcover elements include:

- naturalism (absence of direct human influence);
- compatibility (fit between adjacent landcover types);
- height contrast (height variation among adjacent elements); and
- variety (diversity of landcover types or patterns within a type).

Morisawa (1971) classified landscape based on relief and water-appearance components, together with seven landscape qualities. Gardiner (1974) argued that relative relief, the presence of water and slope characteristics are the basic landform elements contributing to scenic quality; by using the drainage basin as the fundamental unit of scenic quality, the method omits a large area of landscape from consideration (Crofts, 1975). The approach of Warsynska attempts to derive mathematical notations of scenic beauty in order to evaluate the scenic attraction of areas for tourism. The method uses coefficients of relief attractiveness, surface water attractiveness and forest cover attractiveness. From these three coefficients an overall coefficient of attractiveness is derived (*ibid.*).

The Norwegian Institute of Land Inventory (NIJOS, 1995) has developed a landscape classification system based on three levels of regionalisation of the landscape. The following landscape components are systematically described and evaluated: terrain type; geological characteristics; vegetation; water structure; cultivated land; and human population distribution. Maps for evaluation of vulnerability and evaluation of perceptual value can be created from this methodology.

Bishop and Hulse (1994) achieved a high level of prediction of scenic beauty values using five variables computed using a GIS database. These were amount of foreground river, amount of high slope in the foreground, amount of orchard land use in the foreground, amount of forest in all distance ranges and range of relief in visible cells without vegetative screening. The coefficients for nearby rivers, high foreground slope and high relief were positive. Although rough ground textures have been negatively correlated with preference, a high slope at the view position generally is indicative of a significant vantage point offering views and a range of positive visual characteristics such as legibility and complexity.

Patsfall *et al.* (1984) used distance zones similar to that of Shafer *et al.* (1969) together with areal measurements of vegetation. In this particular study vegetation was divided into left, centre and right sections, with left and right foreground vegetation found to have significant and opposing regression weight signs.

Nine forest and pastoral landscape patterns or themes were used in the model of Hammitt *et al.* (1994). These were: stream/river; pond/lake; several-ridged; rolling plateau; valley development; farm valley; ridge and valley; one-ridged; and unmaintained. The regression equation is based on six significant predictors: area of sky; area of largest ridge (background or very distant); linear perimeter of ridge line (background/very distant); area of moving water (*e.g.* streams, rivers); obstructing vegetation squared; and area of rolling plateau (background/very distant).

The incorporation of a distance weighting scheme, in order to account for inevitable visual differences of near and far objects, is a common methodology (Meitner and Daniel, 1997). A distance landscape dimension was found to have a nonmonotonic predictive relationship with perceived scenic beauty; the implication of this nonmonotonicity is simply that the minimum or maximum influence of a landscape dimension can occur at some medium level of the dimension's range rather than at its extremes (Hull and Buhyoff, 1983). An equally important conclusion is that distance proved to be a very good predictor of perceived scenic beauty.

Propst and Buhyoff (1980) describe policy capturing. A multi-variate linear model simulating the decision of a number of judges' is computed by calculating the regression of landscape preferences on ten dimensions thought to influence such preference. This method uses ten important dimensions: foreground vegetation; mountains; man-changes area; visible distant landforms; green colours; blue colours; unobstructed expanse of view; clouds; and undisturbed forest.

Landscape qualities

The Bureau of Land Management in the USA simplified aesthetic criteria into a procedure for making professional appraisals of four qualities (form, line, colour and texture) inherent to three landscape components - land/water, vegetation and structures (Palmer, 1983). Morisawa (1971) classified landscape based on relief and water-appearance components, together with vista, colour, vegetation, serenity, naturalness, access and pollution. The method has two major problems: the quantitative assessments assume the components are of equal importance; and that no other factors are relevant to the scenic assessment of the site (Crofts, 1975).

Craik (1972) emphasised components of visual analysis, such as vertical enclosure, texture, and focal view. Abello *et al.* (1986) used four preference-determining characteristics: fertility, plant vigour and healthy biomass verses less plant vigour; wintry or defoliated landscape with increased plant structure legibility verses no defoliation; barren soil verses covered grassy soil; recurrent patterns or rhythm verses no recurrent pattern. The fertility/plant vigour dimension was found to be a key feature in deciding preference between two scenes. Calvin *et al.* (1972) identified three dimensions: natural scenic beauty, natural force and natural starkness, of which the first two were suggested to be the major dimensions which people use in their subjective assessments of scenic beauty.

Buhyoff *et al.* (1994) in their EVA model use a visual composition component which assesses the effects of landscape characteristics such as complexity and the vividness of patterns in the landscape and a spatial organisation component which includes accessibility, mystery, enclosure, scale, image refuge, prospect and contemplation.

The informational variables of Kaplan *et al.* (1989) describe variables that could be used with psychological models.

- Coherence is orderly, with repeated elements and regions;
- complexity has richness, is intricate and has a number of different elements;
- legibility is concerned with finding one's way there and back, as well as with distinctiveness;
- mystery is the promise of new but related information.

The last variable is a key element in the informational model. Mystery emphasises an inferential process and points to the importance of a search for information. It has turned out to be a remarkably reliable and effective predictor, consistently outperforming complexity (Kaplan *et al.*, 1989). Kaplan *et al.* (1989) also describe perception based variables, which are openness, smoothness and locomotion.

Ephemeral features

Ephemeral landscape features are often either ignored or controlled in attempts to assess impacts of more permanent and hence manageable landscape features. Therefore, landscape assessments based on these methods may be biased if the ephemeral landscape features have significant scenic impacts. However, in experiments, landscape type and other permanent and semi-permanent features were the major determinants of scenic quality evaluations, even with the presence of an ephemeral landscape feature such as wildlife (Hull and McCarthy, 1988).

Hull and McCarthy (1988) also mention the importance of the quality of light as a landscape feature, as evidenced by the emphasis given to it by landscape photographers.

Water, vegetation and rock

Water is an important predictor of landscape preference. It has been found to enhance perceived landscape quality (Vining et al., 1984); in combination with mountains, fast moving water or large stretches of water are highly preferred (Hull and McCarthy, 1988; Herzog, 1985; Hammitt *et al.*, 1994). Yang and Brown (1992) also noted the importance of reflection on water.

Vegetation is also an important predictor usually inspiring high consensus (Bernaldez *et al.*, 1987; Kaplan, S., 1987). The highest rated scenes of Yang and Brown (1992) were surrounded by vegetation and showed reflections of the trees on the open and long views. When comparing the three major landscape elements - water, vegetation and rock, water was the most preferred element, vegetation next, and rock, the least preferred element.

The lowest rated scenes lacked vegetation, and had blocked views. In addition, rectangular or linear forms were one of the most common characteristics among the least preferred photos. The scenes showing rock with a background of vegetation are more preferred than scenes of rock without vegetation. This leads to a very interesting conclusion from a design perspective. It brings up the issue of soft landscape elements, which in this study appear to enhance preference versus hard materials which were not highly preferred (Yang and Brown, 1992).

Visual absorption

The visual absorption capacity (VAC) of a landscape is based upon the sound premise that not all landscapes are equally able to absorb or hide landscape change. Several factors influence the VAC of an area. Slope is the most important factor, with steep slopes obviously being able to hide little landscape change compared to flat and gentle slopes. Vegetation pattern diversity is also important, with a highly diverse cover in terms of species, with many openings, having a higher VAC than mono-specific, dense stands with few openings. Finally, soil productivity is suggested as an important factor, due to its influence on revegetation time-lag (Dearden, 1983).

3.3 Qualitative Landscape Components

Landscape perceptual preference involves more than a visual evaluation of a static scene. Researchers in environmental perception have concluded that personal experience of landscape can be classed into four general categories: physiographical characteristics, the presence of specific physical features, cognitive variables and viewer interest (Baldwin *et al.*, 1996; Kliskey and Kearsley, 1993).

Human preference for landscape is directly linked to the nature of people as multi-sensory beings. The verbal descriptions given by respondents in this research indicate that tactile, dynamic features significantly contribute to preference (Kroh and Gimblett, 1992). Although the evaluation may be based primarily on the visual aspects of the setting, other aspects, such as sound and smell also contribute to landscape perception (Balling and Falk, 1982). The effects that are considered here include labelling of the landscapes, sound and motion, looking time (relating to viewing slides or photographs), complexity, mystery and prospect and refuge. Some of these factors cannot be used in a surrogate landscape study, in particular sound and motion require different media of presentation than the standard photograph or slide.

3.3.1 Non-visual parameters

Labels in the landscape

The influence on aesthetic values of the names of land areas has been explored by Anderson (1981). The results demonstrated that scenic quality judgements were affected by the land use designations, as well as by the appearance of the slides. The 'wilderness area' and 'national park' labels consistently elevated evaluations of landscape quality, while the 'leased grazing range' and 'commercial timber stand' labels consistently reduced observers' judgements of attractiveness (Anderson, 1981). Hodgson and Thayer (1980) also looked at labelling, replacing labels of lake, pond, stream bank and forest growth with reservoir, irrigation, road cut and tree farm - all labels implying human influence.

The results of these studies implied that for landscapes of relatively high scenic quality, an enhancing label can improve aesthetic value, while a detracting label will have only a slight effect on an attractive scene but a much stronger negative effect on a relatively ugly landscape.

One explanation for this is that the labels induce expectations of different levels of scenic quality in the landscape. When the appearance of the landscape confirms these expectations, the effect of the names is more pronounced than when the actual scene is not congruent with the expectation (Anderson, 1981). Implied naturalness and economic connotations resulting from the labels also affect scenic quality rankings.

Sound and motion

Acoustic impacts on aesthetic evaluations of different settings have been addressed in only a few studies. This lack of research may reflect a consensus among researchers that visual features of a setting are paramount in determining aesthetic response to it (Anderson *et al.*, 1983). However, sound and the interaction of sound and site were highly significant in explaining variance in a study by Anderson *et al.* (1983). They found that there is an interaction between acoustic and other features of a setting that modifies the effect of different sounds in determining the quality of the setting.

The results of Hetherington *et al.* (1993) indicate that both sound and motion influence judgements of scenic beauty. Motion without sound produces similar results to the static digitised image condition, while the motion with sound and the original video results suggested a consistent polynomial relationship between perceived scenic beauty and flow. The static surrogate (slides or photographs) does not sufficiently preserve dynamic environmental features, while the dynamic surrogate (video) preserves flow related differences in ratings of scenic beauty (Hetherington *et al.*, 1993).

Looking time

Wade (1982) hypothesised that differences would be found in preferences for landscapes in direct proportion to the time spent looking at visual representation of those landscapes. However, the linear relationship between average looking time and the average preference rank showed that as preference for landscapes increases, time spent looking at them tends to decrease. Through talking with some of the subjects, the investigator learned that the subjects looked at some of the slides longer because they were more interested in or curious about the landscape than in actually showing a preference for it as a scenic vista. The main conclusion from the study was that there is no relationship between looking time and preference rank.

Herzog (1985) stated that viewing time interacts with content categories in that preference reactions to the most and least liked categories are heightened with increased viewing time. Orians (1986) notes that very simple environments are immediately comprehended and further viewing is unlikely to yield additional information useful to making an assessment of preference. Wohlwill (1968) found that although highly complex images elicited a greater amount of looking time than low complexity images, if a subject had already seen both images and was then given a choice to looking at one again, they tended to choose the low complexity one.

3.3.2 Cognitive criteria

Cognitive criteria are intangible, physiological characteristics of landscape which often cannot be measured - evolutionary history has left its mark on contemporary humans in the form of strong biases concerning perception and preference (Ulrich, 1977). Mystery and complexity concern information available for further processing and hence fall within the exploration category; coherence and legibility contribute to the ease of comprehending a scene and hence belong in the understanding category (Kaplan, S., 1987).

In some cases surrogates have been found for these components; Baldwin *et al.* (1996) suggest that relief, depth or view, horizon characteristics could be measured using GIS functionality and that criteria such as drama, mystery and coherence may have measurable surrogates by using the modelled view as a basis for their definition. It is well known that these visual characteristics cause psychophysical effects, which have been called the 'Ulrich effect'. In experiments by Bernaldez *et al.* (1987) these characteristics appeared in a component of factor analysis reflecting consensus and in a second component reflecting conflict between preference for exuberant vegetation and scene legibility or structure, itself impeded by tangled vegetation.

The elements of a landscape that would have afforded an early human being survival or prospect and refuge, or legibility, or coherence, or complexity, also could be validly described in terms of a patch-corridor-matrix structure: the same typology of landscape that is relevant for scientific analysis is relevant for human aesthetic analysis (Nassauer, 1995).

<u>Complexity</u>

The complexity of an environment is an important component of its ability to arouse feelings (Orians, 1986). It has been found that individuals tend to prefer complex natural landscapes over less complex ones. Complexity has been shown to be an important predictor in landscape preference evaluation.

Several authors cite results showing a positive relationship between complexity and visual preference (Leckart and Bakan, 1965; Schutte and Malouff, 1986; Ulrich, 1977; 1981; Wohlwill, 1968), in many cases finding curvilinear relationships and in some linear relationships.

Complexity affects not only the amount of information in a landscape scene, but also the time and effort required to process the display. While results have consistently indicated that preference and complexity are related in a hyperbolic manner, research has shown that human perception is characterised by a bias favouring patterned information; under certain conditions, high complexity displays can evoke high preference (Ulrich, 1977).

Orland *et al.* (1995) used a computer model in an attempt to simulate human preference based on complexity and scenic beauty. Computer measures of complexity included colour, edges, fractal dimension, standard deviation, entropy, huffman encoding and run-length encoding. In the preference results old growth forest received the highest ratings for beauty and complexity and the new growth forest received the lowest. This contradicts the computer measures, which showed that the new forest images contained the highest degree of complexity and the old growth forest the least (Orland *et al.*, 1995).

It is possible that in the absence of a commonly used conception of scenic complexity the human respondents are simply doing what they are used to - rating their underlying preference for the scene (Orland *et al.*, 1995).

Mystery

Mystery is defined as the "degree to which you can gain more information by proceeding further into the scene" (Lynch and Gimblett, 1992). It may refer to instances when the new information is not present, but is inferred from what is in the scene (Kaplan, S., 1987).

Mystery has been found to be a consistently perceived attribute of landscapes. Lynch and Gimblett (1992) found the following structural relationships were important:

- perception of mystery decreases with perceived distance;
- the perception of mystery declines as perceived screening declines;
- as perceived spatial definition increases, the perception of mystery increases;
- perceived physical access increases the perception of mystery.

While mystery alone does not have total influence in the overall preference for landscape, it has been shown to be a major contributor (Lynch and Gimblett, 1992). Mystery contributes some ambiguity and uncertainty to visual displays; therefore, certain instances of high mystery should have a negative effect on aesthetic preference (Ulrich, 1977), this has been found in studies by Baldwin (*pers. comm.*). The compositional qualities of landscape relevant to mystery include: distance from forest stands; edge diversity; and absorptive or reflective qualities such as those inherent in water features

The most powerful single variable found by Ulrich (1977) was mystery. The presence of this factor heightened attractiveness irrespective of the ranges of the legibility variables. This model illuminated the importance of informational determinants. In a study by Kaplan, S. (1987) the most preferred scenes were those offering a sense of mystery, trails disappearing round bends or clearings partially obscured from view by vegetation. These types of scenes appeared to promise that more information could be gained by moving deeper into the depicted setting.

Using geographic analysis, examination of horizon characteristics and the masking of visible areas, should make it possible to generate a mystery component in a landscape preference model when combining landsurface and landcover information. (Baldwin *et al.*, 1996).

Coherence and legibility

Man's origins necessitated that he became a highly visual animal, and that an ability to handle large quantities of visual landscape information has been essential for our species' long term survival (Ulrich, 1977). People should prefer landscape scenes having qualities which aid in making sense of the information present.

If a given scene has attributes which facilitate its comprehension, then a creature who likes to acquire large amounts of knowledge should favour the scene. To be preferred, therefore, a scene should not only present information, but it should also be identifiable and easily grasped. A scene that is ambiguous and resists identification, or which places very high processing demands on the observer, should be less preferred (Ulrich, 1977).

The underlying informational theme in coherence is the capacity to predict within the scene. The ease with which the information in the scene can be organised into a relatively small number of areas is the central issue here. One might hypothesise that a scene yielding five ± two areas would be more highly preferred (Kaplan, S., 1987).

Legibility concerns the inference that being able to predict and to maintain orientation will be possible as one wanders more deeply into the scene (Kaplan, S., 1987); the concept of locomotion is associated with this criteria, being able to move in the landscape is crucial to survival (Bourassa, 1988). Yang and Brown's (1992) research suggests that scenes which allow visual access were more preferred than those in which visual access was lacking, blocked or unclear.

Focality, ground texture and depth

Focality refers to the degree to which a scene contains a focal point, or area that attracts the viewer's attention; it is produced when lines, textures, landform contours, and other patterns direct the viewer's attention to a specific part of the scene. Irregular textures present the viewer with unordered high complexity. Such displays should evoke low preference responses because they resist rapid and efficient comprehension. Surfaces that have even textures, or areas of textural homogeneity, should be accorded higher preference since the complexity is ordered (Ulrich, 1977).

Ground textural gradient is important in distance perception. A uniform, even texture preserves the sense of "continuous" ground surface which is necessary if distance is to be accurately perceived. Rough, irregular textures may disrupt a sense of continuous ground surface, thereby resulting in spatial ambiguities, lower legibility, and reduced preference (Ulrich, 1977). If depth could not be perceived, landscape features would stand ambiguously in two dimensions; depth is linked to legibility through its effects on the scale of landscape elements (*ibid.*).

One can extract an estimate for depth of view from the viewing angle function in a GIS. However, the appropriate inclusion and significance of the incorporation of such a measure within landscape value assessment remains unclear. An alternative approach may be to generate an area weighted mean value (from viewer to all points within the viewshed) or a standard deviation component for all such points (Baldwin *et al.*, 1996).

Prospect and refuge

Prospect and refuge is concerned with the openness or enclosure of views and observation points; light and darkness, for example, are associated with prospect and refuge (Bourassa, 1988). A study by Nasar *et al.* (1983) examined this effect in terms of the effects on male and female subjects. Subjects rated the more open views as safer than the enclosed ones, with females assessing the safety lower than males. The preference score for females was higher from the protected location than the unprotected one, while the opposite was true for males.

The observer's context (in this case location and gender) seemed to influence emotional response. The open view was judged as safer than the closed one, and this effect was more pronounced from an open observation point than from a protected one. This effect did not carry over to environmental preference, and males (unlike females) liked the setting with less available refuge (Nasar *et al.*, 1983)

3.4 Summary of Psychophysical Landscape Preference Models

3.4.1 Landscape components and predictive modelling

It is recognised that there are a few permanent landscape characteristics which are prime contributors to scenic quality - terrain, water, ground cover (Crofts, 1975). Where psychophysical models have been derived, public judgements do seem to distinguish landscapes on the basis of features that are intuitively appropriate. For example, rushing water, large trees, grassy meadows and jagged mountains have all been found to be positive aesthetic features by the criterion of public judgements. Downed wood, dense stands of small trees, and recently felled trees have been found to be negative aesthetic features (Daniel and Vining, 1983).

Landscape measurement (component models) is the first stage of the landscape evaluation process, after which follow landscape preference or value measurement and the evaluation of landscape in terms of individual and societal preferences for different landscapes as measured by components (Crofts, 1975).

Predictive modelling requires sensitive and reliable assessments of the predictors and the response which, ideally, are measurements of interval or better quality (Bishop and Hulse, 1994). The computational capabilities of a GIS, together with prediction equations based on assessment of video panoramas of locations affected by landscape change, could enable a more objective and cost-effective visual assessment and prediction procedure to be developed (*ibid.*).

However complicated the technique might be, public preference for natural environments is itself a complex phenomenon. Not to use mathematics (and computer technology) to examine this phenomenon would be "like trying to fell a tree with a chain saw without turning on the power switch" (Brush and Shafer, 1975). However, using complex mathematics leads to a mathematical description of perception involving a complex array of terms which are difficult to interpret in terms that are meaningful to anyone except a mathematician (Shafer, 1969a). While linear models have performed quite well, preliminary experiments suggest that second-degree terms (squares and products) in a polynomial regression may improve the precision of the models. Non-linear transformations of the predictors may also be appropriate (Schroeder and Daniel, 1981); however, it has been shown that more complex non-linear models perform only slightly better than the simple linear ones, and therefore may not be appropriate for predicting landscape preference from field data (Schroeder and Brown, 1983).

3.4.2 Landscape evaluation models

Psychophysical landscape evaluation models have been created, compared and modified many times. Steinitz (1990) compared five existing models against one new one, results showed all five original models to be less accurate than the new model. Abello *et al.* (1986) and Calvin *et al.* (1972) both claim their factors account for 85% of the total variance in preference; Hammitt *et al.* (1994) claim between 71% and 76% of the variation. The early model of Shafer et al. (1969) by comparison claims only a modest 66% of the variance, although this result was not found by Steinitz (1990) using the same model. The admission to Meitner and Daniel (1997) of a preliminary model which produced a non-significant regression of 34% is indeed unusual.

Those models which have been reported to account for high percentages of the variation in the preference of the general public are rarely tested on second datasets (unlike that of Shafer *et al.* (1969) which was tested against a second set of photographs). Perhaps if these models were tested against new images they would be somewhat less impressive? Unfortunately the actual models are rarely printed and therefore difficult to test.

3.4.3 Summary of landscape components used in predictive models

Two distinct patterns are apparent in the predictors used for preference models - the abstract, more subjective properties and the more objective, measurement based properties of landscapes. The former appear to be used to explain measured preference, and are rarely used to create a model to predict preference for a new landscape. The latter are used to create models which can be generically applied, such as the model of Shafer *et al.* (1969) which was developed in the United States and was later applied to Scotland (Shafer and Tooby, 1973).

The model of Abello *et al.* (1986) and Calvin *et al.* (1972) used preference rankings to determine relatively abstract properties of landscapes - the studies would be difficult to apply. EVA (Buhyoff *et al.*, 1994) is an expert-system and is as such objective, however, it still uses semi-tangible concepts (mystery, complexity, vividness of patterns) which have been defined so as to be quantifiable.

Many of the other models use areas and perimeters of landscape zones, in three distance classes: immediate, intermediate and distant (Shafer *et al.*, 1969) or foreground, middleground and background (Patsfall *et al.*, 1984); although using distance classes does not always increase prediction of scenic preference (Hammitt *et al.*, 1994). Some use all three in a very systematic fashion (Shafer *et al.*, 1969; Patsfall *et al.*, 1984) while others use only some in conjunction with other descriptors (Bishop and Hulse, 1994; Hammitt *et al.*, 1994; Propst and Buhyoff, 1980).

Vegetation presence within the zones is used to delineate the landscape - Patsfall *et al.* (1984) used presence in the left, centre and right of the distance classes while Shafer *et al.* (1969) used vegetation, non-vegetation and water in the distance classes. The more complex zonations of Hammitt *et al.* (1994), Bishop and Hulse (1994) and Propst and Buhyoff (1980) use other components of the landscape such as sky or cloud (Hammitt *et al.*, 1994; Propst and Buhyoff, 1980), ridge lines or range of relief (Bishop and Hulse, 1994; Hammitt *et al.*, 1994), green and blue colours (Propst and Buhyoff, 1980), area of obstructing vegetation (Hammitt *et al.*, 1994) and area of unobstructed view (Propst and Buhyoff, 1980).

3.4.4 Summary of explanatory results of the predictive models

Vegetation is important in predicting scenic quality (Abello *et al.*, 1986) but too much in the foreground can obstruct vision and detract from visual quality (Hammitt *et al.*, 1994; Shafer *et al.*, 1969). Fore and mid-ground vegetation has also been shown to be a major predictor of visual quality (Hammitt *et al.*, 1994). It has also been shown to have different effects if it is present on the left and right of a scene (Patsfall *et al.*, 1984). Water is also very important, in the form of rivers (Bishop and Hulse, 1994), moving water (Hammitt *et al.*, 1994) and waterfalls (Brush and Shafer, 1975), these are all aspects of natural force, a predictive factor identified by Calvin *et al.* (1972). Again, too much water can detract from a scene (Brush and Shafer, 1975).

Similarly, a large area of sky or a large ridge is a negative predictor of scenic quality (Hammitt *et al.*, 1994), possibly because it impedes vision of the landscape and decreases the area of potentially interesting or complex landscape. This is also highlighted in the visual composition and spatial organisation components of the EVA system (Buhyoff *et al.*, 1994). The importance of edges of landscape components (Shafer and Brush, 1977) is due to contrast of texture and tone; this can be looked at as the level of complexity or diversity in the landscape.

Such landscape components as mountains, undisturbed forest in the middle and background and length of unobstructed view are all important positive predictors (Propst and Buhyoff, 1980; Patsfall *et al.*, 1984; Hammitt *et al.*, 1994) whereas human development and changes are negative predictors of scenic preference (Propst and Buhyoff, 1980); this relates to the natural beauty predictor in the model of Calvin *et al.* (1972).

In many ways, it is the semi-tangible landscape properties that make sense of the predictive power of a wide range of explicit, measurable landscape components.

CHAPTER FOUR

LANDSCAPE PREFERENCE QUESTIONNAIRE (PART I)

SURVEY METHODOLOGY

4.1 Introduction

A key objective of this research is to produce a predictive model for scenic landscape preference. Following the review of a number of such models in Chapters Two and Three, the work of Shafer and colleagues (Shafer *et al.*, 1969; Shafer and Tooby, 1973; Brush and Shafer, 1975; Brush, 1981) has been selected as a basis from which to create a scenic landscape preference model for natural (more accurately semi-natural) Scottish landscapes. Although this approach does not predict the appeal of natural landscapes directly, it has been proven that people will react in essentially the same way to surrogates of the landscape, *i.e.* photographs, as to the landscape itself (Hetherington, *et al.*, 1993; Shafer and Brush, 1977).

Therefore, a methodology was constructed to gather data on landscape preference, for use in the creating and validation of a psychophysical landscape preference model (see Chapter Six). This chapter describes the methodology and the issues involved in using the Internet to undertake landscape preference research. The steps taken to validate the approach to data gathering used, including the use of a pilot survey and a survey using traditional paper-based images, are then detailed. The validation of the actual data gathered, in terms of the validity of the sample of respondents, is discussed in Chapter Five.

4.1.1 Summary of surveys detailed within this thesis

Survey	Date undertaken	Chapter and Section	Number of images	Number of versions	Number of images per version	Rationale behind survey
Pilot	11/97	4.4	20	9	20	to test the Internet methodology
Paper	1/97 - 5/97	4.5	20	1	20	to validate the use of monitors for viewing landscape images
Main	1/97 - 5/97	5.5	90	9	20	to gather preference data required to create psychophysical landscape preference models
Validation	6/97	5.6	36	9	12	to validate landscape preference models
Weather I	1/98 - 3/98	7.2	120	10	12	to test the effects of weather, season and lighting on landscape preference
Weather II	4/98	7.2	60	6	10	to validate the results of Weather I survey
Cultural	6/97	7.3	43	6	12	to examine the effect of cultural structures on landscape preference
Postcard	6/97	7.4	12	6	12	to examine the effect of different photographers on the utility of the landscape preference models
Colour	4/98	7.5	12	2	6	to examine the use of different film types for landscape preference data gathering
Focal Length	4/98	7.6	16	n/a	8	to test the effect of different camera focal lengths on landscape preference
Left/Right Bias	4/98	7.7	24	4	12	to examine compositional bias effects on landscape preference
Digital Camera	9/98	10.2	20	2	10	to test the use of a digital camera against the use of a standard camera
Simulation	10/98	10.3	40	4	10	to examine how respondents react to simulated landscapes

Table 4.1.1 Summary of surveys

4.2 Methodology

The method adopted for landscape preference data gathering was a computer-based approach using the graphical user interface of the Internet, *i.e.* the World Wide Web (WWW), rather than a traditional paper-based approach. This method of conducting a preference questionnaire is a novel approach to the problem of collecting a large enough sample of responses to photographic stimuli (landscape images) to be able to create a robust predictive preference model.

4.2.1 Why use the Internet?

It has been shown (Bishop, I., 1997) that the Internet can provide a convenient medium for undertaking experiments in perception studies. If the experiment does not require a specific audience profile, then replies may be taken from any source where there is Internet access. It is relatively easy to post any Universal Resource Locator (URL) address, in this case the questionnaire location, to a number of search engines and newsgroups, and there are a number of facilities which will 'broadcast' the URL to a large number of other sites. However, limitations of using this method include: the sample may be extremely diverse; and it is restricted to users of the Internet.

As Shafer (1969a) commented:

> "Often (to paraphrase an old Arab saying) we may have to take the mountain to the recreationist rather than take the recreationist to the mountain to study environmental perception."

The use of the Internet enables us to take the landscape to the observer with greater ease than any previous techniques allowed.

Growth of the Internet

The Internet has growth exponentially in the last 15 years, as shown in Figure 4.2.1. The number of hosts has risen from 213 in August 1981 to almost 20 million in late 1997, representing an increase of over nine million percent in 16 years; in the last two years alone the number of hosts has tripled.

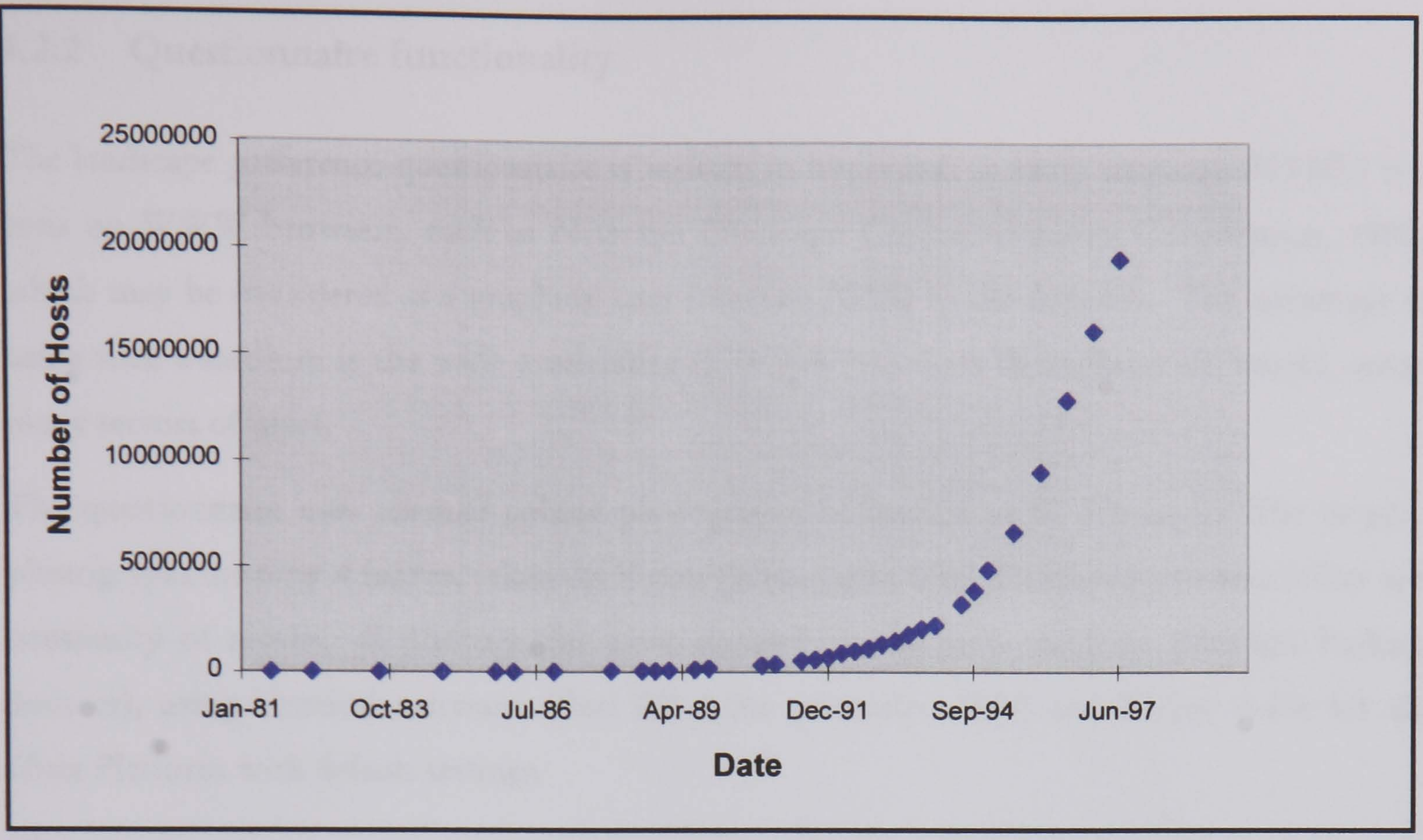


Figure 4.2.1 Internet growth: 1981 to 1997

It is not possible to determine exactly how many people have access to the Internet, nor to discover exactly how many hosts there are. It is only possible to determine the minimum number of domains, hosts and users. With over 20 million hosts, the Internet has become a global phenomenon with massive potential for exploitation in research, marketing and communication.

<u>Benefits of using the Internet</u>

There are indubitable benefits with using the Internet as a questionnaire medium - it requires no paper, does not need postal or face-to-face interviews and a high degree of automation can be achieved for processing the replies. The use of electronic media to undertake a questionnaire means that data from the replies does not have to be manually input into a database, it can be sent automatically. The use of this medium also allows few or several versions to be run simultaneously, and changes to the questionnaire to be made with relative ease. Once set up, it is far less time consuming to run than a traditional postal or personal interview.

4.2.2 Questionnaire functionality

The landscape preference questionnaire is written in hyper-text markup language (HTML) and runs on WWW browsers, such as Netscape (Netscape Communications Corporation, 1998), which may be considered as a graphical user interface (GUI) to the Internet. The advantage of using such a medium is the wide availability of WWW-browsers throughout the world, across many sectors of users.

The questionnaire uses scanned colour photographs of landscapes in Scotland. The original photographs are 6 by 4 inches, taken on 35mm colour print film. To ensure reproducibility and continuity of results, all photographs were scanned on the same machine (Hewlett Packard Scanner), using identical software: Pixel FX 1.06a (Mentalix, 1991) and XView 3.10a for the Unix Platform with default settings.

The questionnaire also uses pages written in PERL (Practical Export and Reporting Language) script. In general terms, the respondent reads an introductory page, is then given instructions and asked to proceed to the questionnaire appropriate for their computer screen size. They are then asked to practice scoring using a single landscape picture. At this point the respondent is assigned a random number corresponding to a particular set of photographs. In the Pilot and Main survey they are then given ten photographs which they may look at before progressing to a scoring page containing the same ten photographs. A second set of ten photographs is then browsed and scored, and finally some socio-demographic information is requested. The respondent is then given a chance to provide some feedback and then leave the questionnaire.

The questionnaire is described in a flow chart (Figure 4.2.4) to aid comprehension.

Introduction and instructions

The first two pages are standard HTML text. The introduction explains why the questionnaire is being run and what the respondent can expect. The second page provides instructions, with the more important information highlighted, both in the text and in a scrolling information bar created using JavaScript· After reading the instructions, the respondent is asked to choose the screen size closest to their own. It has been found that different screens require different size pictures to maximise the size of image possible, as explained in further detail in sub-section 4.3.3. In later versions of the questionnaire a second JavaScript is used to automatically send respondents to the correct version for their screen resolution.

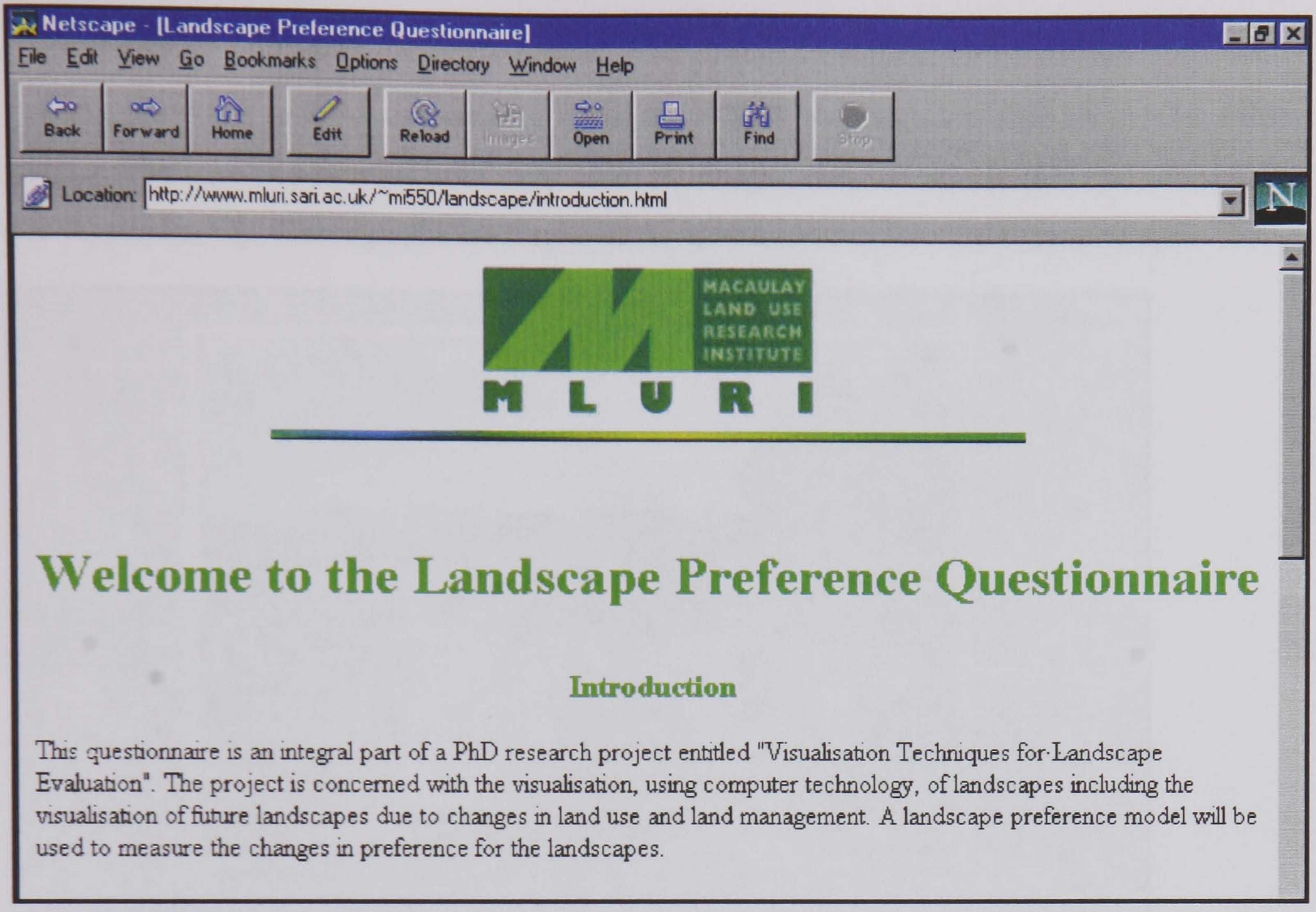


Figure 4.2.2 Questionnaire introduction page

Practice pages

The choice of screen size sends the respondent to a practice page, where they are shown one photograph and asked to score it between one and seven. On submitting this score the first PERL script is run using the CGI (Common Gateway Interface) protocol, which returns the same page, with a additional line describing the score which was input *e.g.* medium-high preference score. It is intended that this will reduce any possible confusion between which end of the scale is 'high' and which is 'low'. The respondent is then asked to start the questionnaire. They are assigned a random number, the calculation of which is based upon the time at which the request is submitted, which sends them to the appropriate questionnaire version.

Browser pages

Before the scoring pages, the respondent is given a chance to review the photographs of the set they are about to score. This allows them to obtain an impression of the range of photographs before proceeding to score them. The layout is serial, with the photographs viewed one at a time. Arrows are provided to allow the user to go up or down the list. When they reach the end of the list, the user is asked if they wish to browse the photographs again or to start the scoring page.

Scoring pages

For the pilot and main questionnaires these are HTML documents embedded within PERL scripts; otherwise (for surveys with only 10 or 12 images) they are standard HTML documents (see Appendix VI). Photographs are displayed in the same order as in the browser pages.

Figure 4.2.3 Example of questionnaire scoring methodology

Once scored, the respondent is helped to move to the next photograph by using a down arrow, hyper-linked to the next photograph. The first scoring page stores the preference scores for the first set of images, keeping them as hidden input type fields in the next page. The second uses a 'form-mail' script to download the scores and socio-demographic information by electronic-mail (e-mail).

Socio-demographic information

The socio-demographic information gathered is to be used for a classification of the respondents. This information includes the age (grouped into bands), gender, occupation and nationality of the respondent, as well as in which city and country they are currently situated. The student groups used in the main survey (see Chapter Five) are asked to complete a different set of questions, again including age, gender and nationality, but also the year of attendance at University, the Faculty and School or Department they belong to, and which subject they are reading.

Feedback page

Respondents are encouraged to give feedback and provide a name and e-mail address, should they wish to take part in any of the further experiments, however, this is not compulsory. To leave the questionnaire, respondents may take their own route out or use the page provided, which has further links to MLURI and RGU homepages, as well pages describing the research.

HTML, PERL and JavaScript examples

Extracts from the initial PERL script and several scripts used to run a variety of the questionnaires can be seen in Appendix VI along with examples of a browser page and a scoring page. Appendix VII details the pages used in the questionnaires, for both questionnaires containing 20 images and those containing 12.

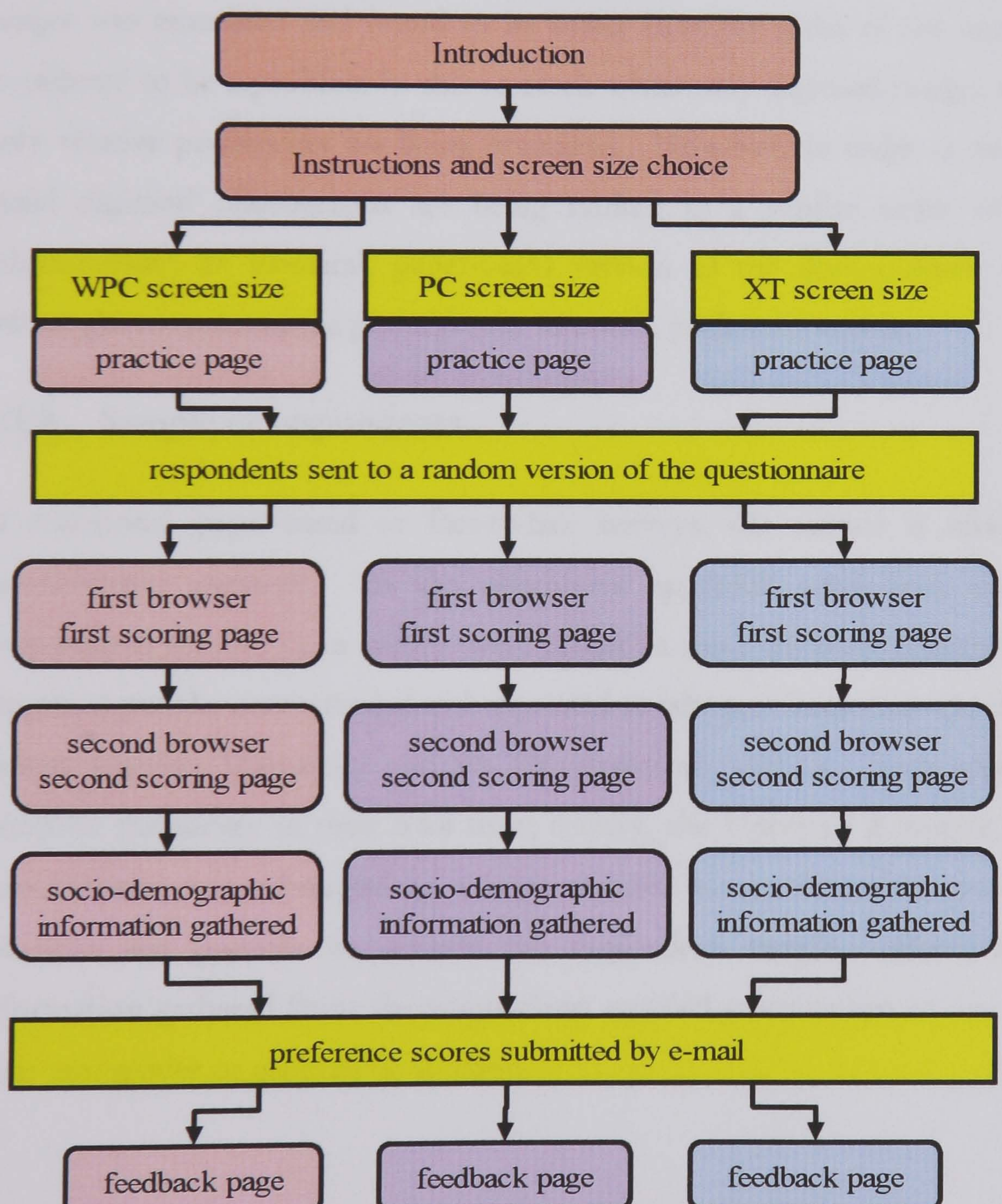


Figure 4.2.4 Flow diagram describing Internet questionnaire

4.3 Issues in using the Internet to undertake Questionnaire Surveys

There are several issues which must be addressed to determine the validity of using the Internet as a medium to undertake a visually-based preference questionnaire, including the medium of display, the sample of respondents, monitor and colour resolution, hardware and software issues and questionnaire design issues. These issues have been examined in several ways as explained in this section.

4.3.1 Medium of display

It has been shown that photographs can be used as surrogates for real landscapes (see Chapter Three, sub-section 3.1.3). In the work of Bishop and Leahy (1989) the average rating of digitised images was examined and found to be lower than for slides of the same scenes. This is not considered to be a problem in this research when only digitised images are being compared, as only relative preferences are being examined. However, in order to verify that the monitor-based digitised photographs are being ranked in a similar order to non-digitised images (photocopies), an identical, paper-based version of the questionnaire was undertaken using colour photocopies of the photographs to obtain preference scores.

4.3.2 Sample of respondents

In traditional paper-based or face-to-face surveys, the sample is often sought out by the questionnaire manager. In the alternative approach used here, this was not possible. Respondents for the main survey were found in three different manners: firstly, a number of interested people were e-mailed and requested to take part in the survey; secondly, students from Robert Gordon University and the University of Aberdeen were approached and asked to complete the survey in their own time; thirdly, the Universal Resource Locator (URL) of the questionnaire was submitted to a large number of search engines on the Internet. It was therefore not possible to control the respondent sample. However, socio-demographic information gathered from the respondents enabled examination of any differences caused by their age, gender or geographic location.

4.3.3 Monitor size effects

The size of images may have some effect on the scores given to a set of landscapes. In order to examine this, three screen sizes were used: 14 and 15 inches (WPC*), assumed to be using 640 by 480 resolution; 17 inch screens (PC) using 800 by 600 resolution; and 1024 by 768 resolution and above for desk-top screens above this and for X-terminal screens (XT). Respondents were asked to identify one of these sizes as appropriate to their monitor and the choice was recorded in the results.

It was assumed that many respondents asked to choose a screen pixel resolution would not be able to do this correctly as they would not have set the screen resolution themselves but used the standard for their computer laboratory. Therefore, they were asked to use a screen size corresponding to their monitor. One problem with this approach is the assumption of a correlation between screen size and resolution, with a high possibility of receiving smaller images than the maximum size for the screen.

Image sizes were then tailored to be seen as large as possible for the screen size. These sizes are given in Table 4.3.1.

Monitor Size	Assumed resolution	Pilot, Main, Validation and Cultural Surveys	Weather and Simulation Surveys
WPC	640 x 480	335 x 228	335 x 228
PC	800 x 600	400 x 272	445 x 303
XT	1024 x 768	470 x 320	580 x 395

Table 4.3.1 Image sizes for each monitor size

The later surveys (Chapters Seven and Ten) used a JavaScript to determine screen resolution exactly and therefore eliminate user error (for Netscape browser users only). Therefore, the image size was able to be increased to further maximise the size of image seen without introducing additional errors.

* WPC:- *wee* personal computer; PC:- personal computer (standard size); and XT:- X-Terminal size

4.3.4 Colour resolution effects

Two graphics formats will function with WWW browsers, namely JPEG (Joint Photographics Experts Group) and GIF (Graphics Interface Format). The major differences between these formats are the number of colours each saves and the compression format: JPEG is a 24 bit format using lossy compression; while the GIF format is 8 bit and uses lossless compression. Lossy compression looks for groups of colours it can describe in one bit and therefore reduces the number of colours in an image; lossless compression shrinks file size with no loss in quality (Bishop, K., 1997).

It was decided to use the CompuServe GIF87 format for the landscape images. This format uses only 256 colours, therefore creating less difference between those who use 8 bit graphics displays and those who use 16 or 24 bit displays. The initial instructions for the questionnaire advise that 4 bit systems will not be able to display the images correctly.

There is evidence to suggest that while 16 bit (high colour) and 24 bit (true colour) visual display units (VDU) more closely simulate true photographic quality (Bishop and Hull, 1991), 8 bit colour (256 colours) can legitimately be used for the simulation of landscapes (Bishop and Leahy, 1989). It is only in recent years that high and true colour displays have become common-place, and it must be assumed that many respondents will be using computer systems capable of only 256 colours; for example it was discovered in February 1997 that neither university in Aberdeen had standard computer laboratories capable of running more than 8 bit colour displays.

In a recent study, Bishop, I. (1997) found very high correlations between the overall mean and the means for those respondents who used 16 or 24 bit systems and 8 bit systems, suggesting that there is no significant difference between responses from those displays that have 256 colours, and those with 16 and 24 bit colour .

4.3.5 Hardware and software issues

The questionnaire should ideally run on 486 or 586 (Intel Pentium) or higher processor computers, with a screen resolution of 800 by 600 pixels and 256 (8 bit) colours. Improved performance is obtained with Netscape 3 and 4 over other browsers. Many features will not function within Netscape 1 and 2 due to the use of HTML 3.0 (which was not implemented in Netscape 1) and JavaScript (only fully functional in version 3.0 of Netscape and above). Problems also exist with all versions of Microsoft Internet Explorer (Microsoft, 1997) and NCSA Mosaic (NCSA, 1997), which do not interpret JavaScript.

It is, therefore, important that those who complete the questionnaire understand that they may have problems if their computer is not of the ideal format (*i.e.* 586 processor, 800 by 600 screen, 256 colours and Netscape 3 plus) and that they will not be able to complete the questionnaire if their computer set-up is below the minimum requirements (386 processor, 256 colours and a graphical WWW browser). It is also important to recognise that many respondents will not have access to higher powered computing facilities, and the questionnaire must be tailored so as not to exclude these people. In the earlier questionnaires (1997) these base-lines were Netscape 2 and a 486 PC; later questionnaires (1998) ideally required a 586 PC running Netscape 3.

It is possible that those using earlier versions of Netscape, Microsoft Internet Explorer or NSCA Mosaic would not be able to complete the questionnaire. However, later versions of Microsoft Internet Explorer have been proven to work, as have several of the less well known browsers, without compromising the integrity of the questionnaire.

In a recent survey by Nua Ltd. (1997) for the Irish Internet Association, 55.4% of users used a version of the Netscape browser, with 44.6% using Microsoft Internet Explorer. In a separate study by Pitkow *et al.* (1997), the Eighth GVU WWW user survey found that 60% of users used a version of Netscape, while only 21.5% used Microsoft Internet Explorer. This finding justifies the use of Netscape as the standard browser for this questionnaire.

4.3.6 Design issues

The time required for the client's computer resource to process each page must also be considered; graphically intense pages may take an extremely long time to load onto a PC with a 386 processor, but may be almost instantaneous on a Sun Workstation. Therefore, the design and content of a WWW page, coupled with the power of both the server and client computers, may test the tolerance of the user to delays during the completion of the questionnaire. A consequence of a poorly designed questionnaire would be a low response rate, particularly from those for whom there was an unacceptable delay in downloading the images.

4.4 Pilot Questionnaire: Methods and Results

Staff at the Macaulay Land Use Research Institute (MLURI) in Aberdeen were asked to complete the pilot questionnaire; a total of 36 replies were received over a two week period in November 1996. The pilot version of the questionnaire was designed to both test the responses regarding the questionnaire of those who completed it and to test the effect of order of presentation of the photographs. This questionnaire used photographs scanned at 100 dots per inch (dpi).

The pilot questionnaire was the first implementation of the design described in section 4.2. The response to the questionnaire was favourable, with few people having negative comments about the medium of presentation. Some need for improved instructions was identified, and these were correspondingly changed.

Nine versions of the questionnaire were used to look at the different orders of photographs. In order to randomise the pilot versions, a methodology using birthdates was adopted. The subject entered the date of birth, and the digits were then added together, and then re-added to form a number between one and nine. Unfortunately, this system did not prove to produce sufficiently random numbers in this small sample, and was subsequently replaced. Table 4.4.1 details this distribution over the nine versions.

Questionnaire Version	Number of Respondents	Ordering Test
1	9	within set
2	6	within set
3	1	within set
4	4	within set
5	2	within set
6	3	within & between set
7	4	within & between set
8	3	between set
9	4	between set

Table 4.4.1 Respondent numbers: Pilot Survey

4.4.1 Ordering effects

The pilot questionnaire tested the effects of order in two ways: seven versions of the questionnaire (numbers one through seven) looked at order within a set of ten photographs. Four versions (numbers six through nine) looked at the effect of order of the set of photographs; the first set in versions six and seven became the second set in versions eight and nine and vice versa. Only twenty photographs were used in the survey, with photographs being randomly placed within the sets. The results from the pilot study were entered into a database and an analysis of variance using repeated measures was run, using 95% confidence intervals and assuming sphericity (see Appendix VIII for details of significances).

Between-Subject Effects	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Intercept	7342	1	7342	990	0.000
Ordering	12.36	6	2.06	0.28	0.941
Error	163.2	22	7.42		

Table 4.4.2 Ordering effects: Pilot Survey

The results in Table 4.4.2 imply that the order in which landscape images are seen is not significant in influencing the preference score given to the image. This result means that the basic methodology behind the questionnaire *i.e.* viewing and then scoring ten photographs, is a functional method for gathering landscape preference data.

Within-Subject Effects	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Photograph	233.2	19	12.27	7.53	0.000***
Ordering by Photograph	215.4	114	1.89	1.16	0.153
Error	681.3	418	1.63		

Table 4.4.3 Interaction between order and photograph effects: Pilot Survey

Table 4.4.3 shows that the interaction between the viewing order and the photograph is negligible while the photograph is a highly significant source of variation. This shows that it is the photographs (*i.e.* the landscapes) which are being scored.

Within-Subject Effect	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Photograph	158.4	19	8.34	6.73	0.000***
Set by Photograph	101.3	57	1.78	1.44	0.038*
Error	235.5	190	1.24		

Table 4.4.4 Within-subject effects: Pilot Survey

The influence of set (the first or second set of the photographs) on the preference scoring is examined in Table 4.4.4. This again shows that the photograph is highly significant in determining preference score. There is a significant interaction between the sets and the photographs. In the light of this result, each photograph in the main survey appears once in the first set of photographs and once in the second set of a different version.

In conclusion, in all cases the photographs are the significant source of variation in the scores given. This implies that the methodology for showing landscape images to a sample of respondents is functional. The interaction between the set and the photographs reflects an experience factor when scoring the second set of images, having already scored the first set.

4.4.2 Utility of Internet questionnaire

There are unresolved problems with the questionnaire. It is not possible to ensure that all data is filled in without creating further problems, and therefore missing values are inevitable. There is also a problem with loss of data from the PERL scripts, which can be recovered if the respondent has read and understood the instructions. It is unclear why this problem occurs, but it may be connected to respondents attempting to view the browser pages before all of the images have been loaded. Respondents are encouraged to wait for the documents to load completely by a flashing warning notice at the top of the browser pages.

A further problem is caused by the presence of 'reset' buttons: should a respondent hit one by accident, all the scores they have previously input will be deleted.

4.5 Paper Questionnaire: Methods and Results

4.5.1 Rationale

In order to confirm that photographic images displayed on a VDU produce the same response as the original photographs, a paper questionnaire was implemented using the same photographs as the pilot questionnaire. Previous work (Hetherington *et al.*, 1993; Shafer and Brush, 1977) has shown that people will respond in essentially the same way to real landscapes and photographs of that landscape: this questionnaire was used to take these findings one step further.

As the approach to undertaking an image-based questionnaire survey was a novel one, there has been little work done on determining if monitor-viewed and paper-viewed landscape images would elicit the same responses. Therefore, a separate survey was undertaken to examine this issue. Figure 4.5.1 demonstrates why this step was required to validate the methodology being used.

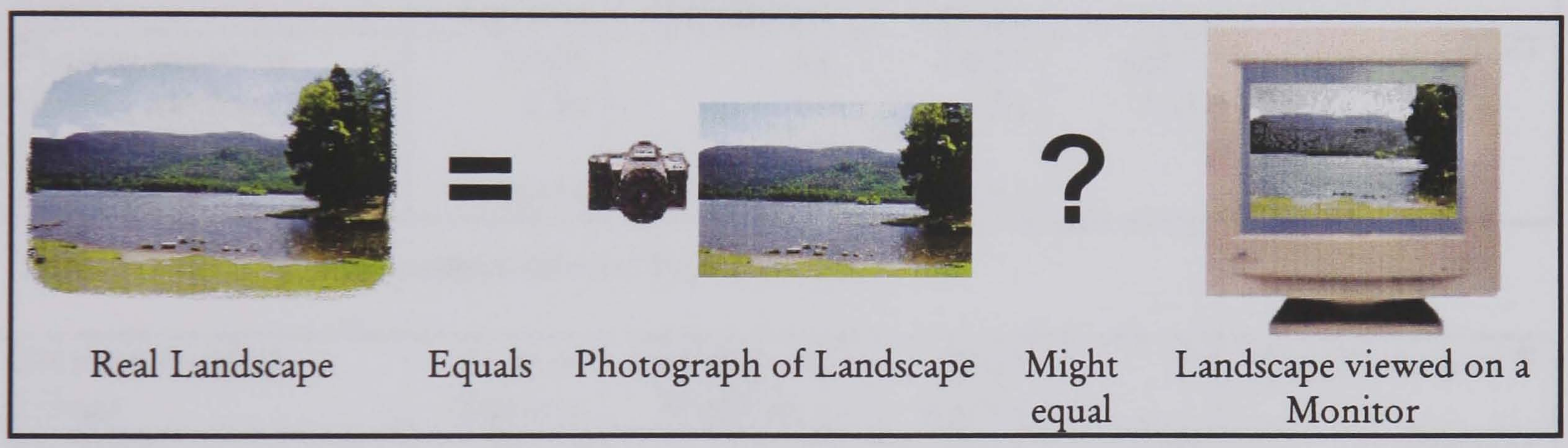


Figure 4.5.1 Connection between real and monitor viewed landscapes

4.5.2 Methodology

A paper questionnaire was designed using the Internet questionnaire as a template. The questionnaire comprised one page of introductions and instructions, four pages of scoring sheets and one page for additional information. Together with the questionnaire, respondents were given a booklet with photocopies of the landscapes which they were able to browse through before scoring the images, in a scoring bar such as that shown in Figure 4.5.2.

Fifteen questionnaires were completed. Students and staff from RGU Faculty of Design and RGU School of Computing and Mathematical Sciences and several members of the general public formed the sample.

Landscape One

Low Scenic Preference	~1~ ❑	~2~ ❑	~3~ ❑	~4~ ❑	~5~ ❑	~6~ ❑	~7~ ❑	High Scenic Preference

Figure 4.5.2 Scoring methodology: Paper Survey

4.5.3 Results

A multivariate general linear model using repeated measures was run on the data. There was no significant over-all effect attributed to the medium of display (Table 4.5.1 and Table 4.5.2); however, some landscapes' scores were affected, those photographs tended to be ranked very high or very low in one of the sets of preference scores.

Within-Subject Effects	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Photograph score	14901	1	14901	928.7	0.000***
Display Medium by Photograph score	6.96	1	6.96	0.43	0.510
Error(score)	16334	1018	16.04		

Table 4.5.1 Within-subject effects: Paper Survey

Between-Subject Effects	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Intercept	96166	1	96166	4857	0.000***
Display Medium	6.96	1	6.96	0.35	0.553
Error	20158	1018	19.80		

Table 4.5.2 Between-subject effects: Paper Survey

In both Table 4.5.1 and Table 4.5.2 the display medium and the interaction of the display medium with the photograph was not significant thus validating the use of the monitor to display landscape images.

Correlations between monitor and paper-based questionnaires

There was a correlation of 0.72 (using both types of normalised scores, as described in Chapter Six, Section 6.4) between the Internet and paper based surveys - this is significant at the 0.01 level. If the Intergroup Reliabilities for the two surveys (0.733 for the paper-based and 0.890 for the monitor-based) are compared to this correlation, it is seen that the correlation within the groups is similar to that between the groups.

In recent work undertaken by Daniel (1997) a correlation of 0.95 was found between 45 slides and scanned images viewed on a 27" monitor. It was not reported what scoring system was used for these images. These two results suggest that it is valid to gather preference scores using a visual display monitor in place of a photograph, and therefore that scores given to monitor viewed landscape images can be substituted for scores given to actual landscapes.

4.6 Summary and Discussion

4.6.1 Questionnaire functionality

The landscape preference questionnaire uses the medium of the Internet to gather data. The exponential growth of the Internet in recent years means that it is now feasible to obtain a sufficiently large sample electronically for the type of preference research described here. This survey used a combination of HTML pages and PERL scripts to run the questionnaire.

The survey is fairly simple, requiring respondents to read the introduction and instructions, practice scoring one landscape, and then browse and score a selection of landscape images. Scores and socio-demographic information are e-mailed directly back, with e-mail addresses and any comments mailed separately for reasons of confidentiality and anonymity.

4.6.2 Issues

The approach to data gathering for a visual subject, such as landscape preference, is a protégé of modern computer technology, and would not have been possible before 1994 and the advent of WWW browsers, such as Netscape. However, there are several issues to be addressed.

The issues concerning the effects of monitor size, colour display, hardware and software have been discussed. The effects of monitor size are further discussed in Chapter Five, sub-section 5.7.6; the use of monitor size specific image sizes maximises the size of image any respondent may see. In order to avoid questions regarding the rendering of 24 bit colour images on an 8 bit colour screen, all images were in the GIF format, which is an 8 bit system.

Hardware and software issues remain problematic. As standards change, new software and faster processors become available, and older machines become obsolete. When conducting surveys over the Internet such as this one, lowest common denominators for hardware and software must be set, and the questionnaire must be designed to that level. Within the lifetime of this research, this baseline level has changed; advances in technology must be carefully watched while running surveys such as this, and steps taken to avoid becoming 'out of date'.

4.6.3 Pilot survey

The questionnaire was piloted within MLURI, with 37 staff and students completing the survey. The pilot served to test the utility of the questionnaire, both in itself and with the respondents. Feedback regarding the utility of the questionnaire was positive. The few problems discovered were minor, and easily altered.

The order in which the landscapes were viewed in is not significant within a set of ten photographs, although there is some difference in scoring for the first and second sets of images. This effect is negated either by using only one set of photographs, or by placing the same photograph equally in the first and second sets of a survey. It is not known whether the second set of images produce scores more or less well correlated to scores which would be obtained in the real environment. To study this effect is outwith the scope of this thesis.

4.6.4 Paper survey

The paper survey was run in order to validate the use of monitor viewed images as opposed to print or slide photographs. Many researchers have validated the use of photographs as surrogates of landscape; this survey was undertaken in order to validate the use of scanned photographs. The results from this survey, and from subsequent work undertaken by others, have proven that this approach to displaying landscape images for evaluation purposes is valid.

4.6.5 Summary

This chapter has examined the methodology implemented in undertaking a landscape scenic preference questionnaire. The questionnaire has proven to be highly functional, a novel yet potentially extremely useful method of data collection. Several issues have been addressed in order to validate the use of this approach, with no negative results. In conclusion, there is substantial merit in using the Internet as a medium for executing visual preference research.

CHAPTER FIVE

LANDSCAPE PREFERENCE QUESTIONNAIRE (PART II)

MAIN SURVEY AND VALIDATION SURVEY

5.1 Introduction

Following the validation of the methodology in Chapter Four, the Main survey was implemented to recreate the research of Shafer *et al.* (1969) by running a survey along a similar basis to their research. There are several major differences in the two research methodologies: Shafer used black and white photographs in the field, scored using a ranking system; this research uses scanned colour images viewed over the Internet, scored using a preference scoring system. However, the approach to the analysis is similar, using landscape component measurements to create a predictive landscape preference model.

The Validation survey used a new set of landscape photographs to test the models which are described in Chapter Six. It is necessary to examine the utility of such models on different data sets to ensure they are not specific to the dataset used to create them.

This chapter details the Main Survey, outlining the choice and geographical distribution of the photographs used. The log-ins to the Main Survey are then examined, in relation to their temporal and geographical characteristics. The socio-demographic breakdowns of the two surveys are then examined and compared to determine the comparability of the two groups of respondents.

5.2 Main Survey

Following the completion of the Pilot study and Paper survey, the methodology for using the Internet to undertake visual preference surveys was validated. The Main survey was placed onto a web-site and the URL of this survey was distributed in several ways:

- The URL was submitted to a number of search engines and broadcast services on the Internet;
- The URL was e-mailed to a number of colleagues, contacts and other interested parties; and
- Students in certain classes at RGU were requested to complete the survey.

The survey used ninety photographs of Scottish landscapes, the choice of which is described in the sub-section 5.2.1. These digital images were then distributed randomly among nine versions of the questionnaire, with each appearing in two versions. The photographs were scanned at 200 dpi (dots per inch); higher resolutions were not possible due to data storage limitations.

Within the questionnaire pages all images are identically sized, with the ratio of height to width kept constant in the three screen size versions. All photographs were therefore cut to an appropriate size after scanning, to ensure the ratio of height to width remained constant and images were not being distorted when viewed on the screen.

5.2.1 Choice of photographs

The ninety photographs used in the main survey were obtained from a large sample taken by the author over a number of years, supplemented by photographs taken for the purpose of the questionnaire. The images used were chosen to represent a wide range of landscape types in Scotland, with a wide variety of topographies, land covers and geographical areas.

All photographs were taken with the same 35mm compact camera (Nikon RF), using Kodak ISO 200 film and developed, with the exception of a very few, by the same company. Although it is acknowledged that photographs taken with a 50mm lens are closer to the actual experience of the landscape (Institute of Environmental Assessment and Landscape Institute, 1995), the availability of previously collected photographs and lack of access to alternative camera equipment meant that using 50 mm landscape photographs was not practicable.

It was not practical to collect a series of photographs with similar weather and seasonal conditions due to the vagaries of the Scottish climate. Those photographs displaying high degrees of seasonality (such as snow and autumnal vegetation) were discarded, as were those displaying severe sky effects (such as storm clouds or sunsets); these effects are examined in Chapter Seven.

Figure 5.2.1 shows the geographical distribution of the photographs used in the Main survey.

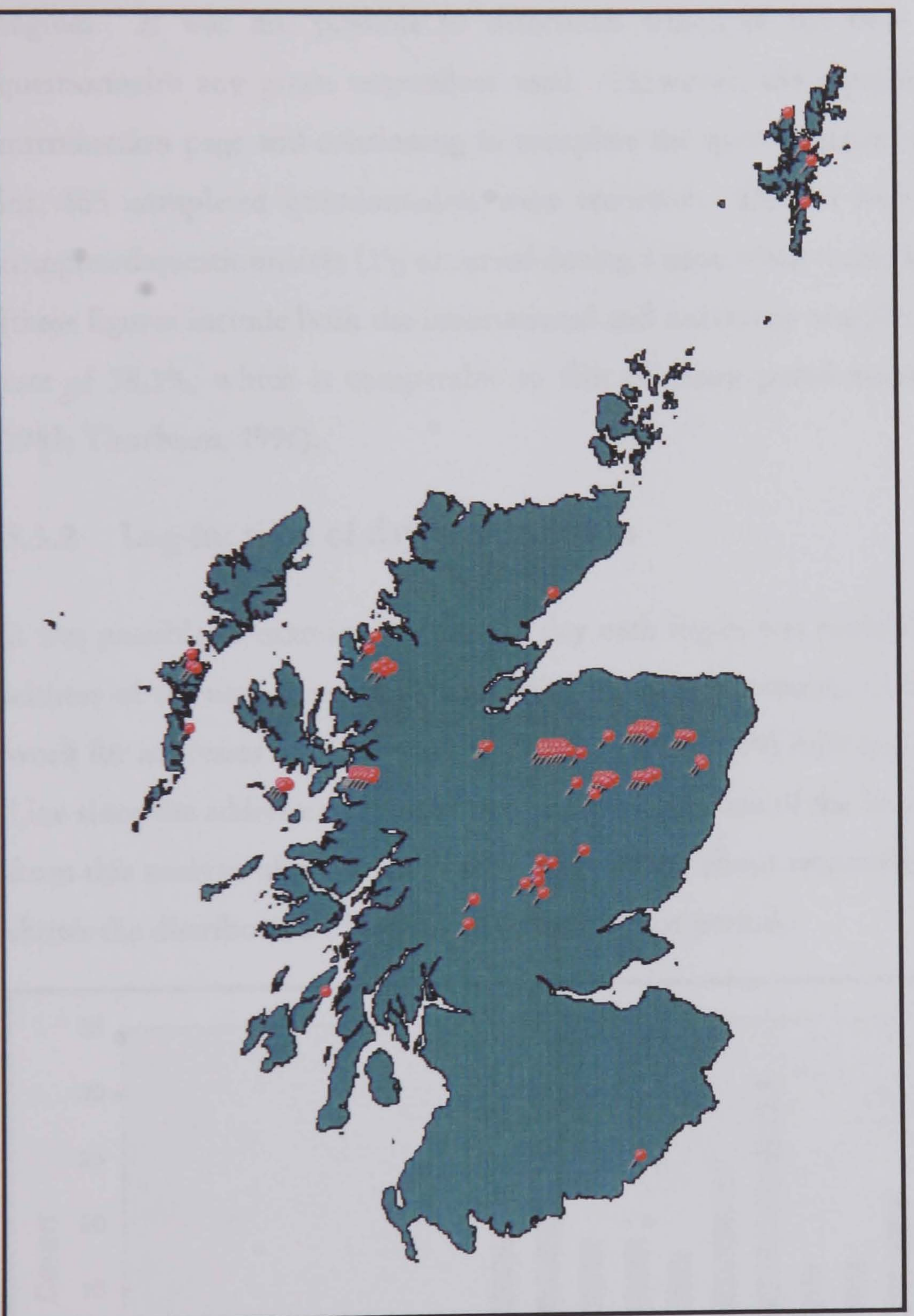


Figure 5.2.1 Geographical distribution of photographs: Main Survey

5.3 Analysis of Responses

5.3.1 Response rate

Unlike postal questionnaires or personal interviews, this survey relied on respondents either being informed of the questionnaire or finding it by searching on one of the Internet search engines. It was not possible to determine which of the two methods of arriving at the questionnaire any given respondent used. However, the percentage of those arriving at the introduction page and continuing to complete the questionnaire can be calculated. Of 431 log-ins, 165 completed questionnaires were recorded. Due to technical failures, the remaining completed questionnaires (15) occurred during a time when recording of log-ins was not possible (these figures include both the international and university samples). This equates to a response rate of 38.3%, which is comparable to that of many postal surveys (Armstrong and Mather, 1983; Thorburn, 1996).

5.3.2 Log-in: time of day and duration

It was possible to examine the time of day each log-in was made, by working out where the IP address of the user is registered and adjusting to take account of time-differences (this does not work for addresses from Internet service providers (ISPs) such as CompuServe and America On-Line since the addresses are based in one city, regardless of the location of the user). The results from this analysis allow some further information about respondents to be gleaned. Figure 5.3.2 shows the distribution of log-ins over the 24 hour period.

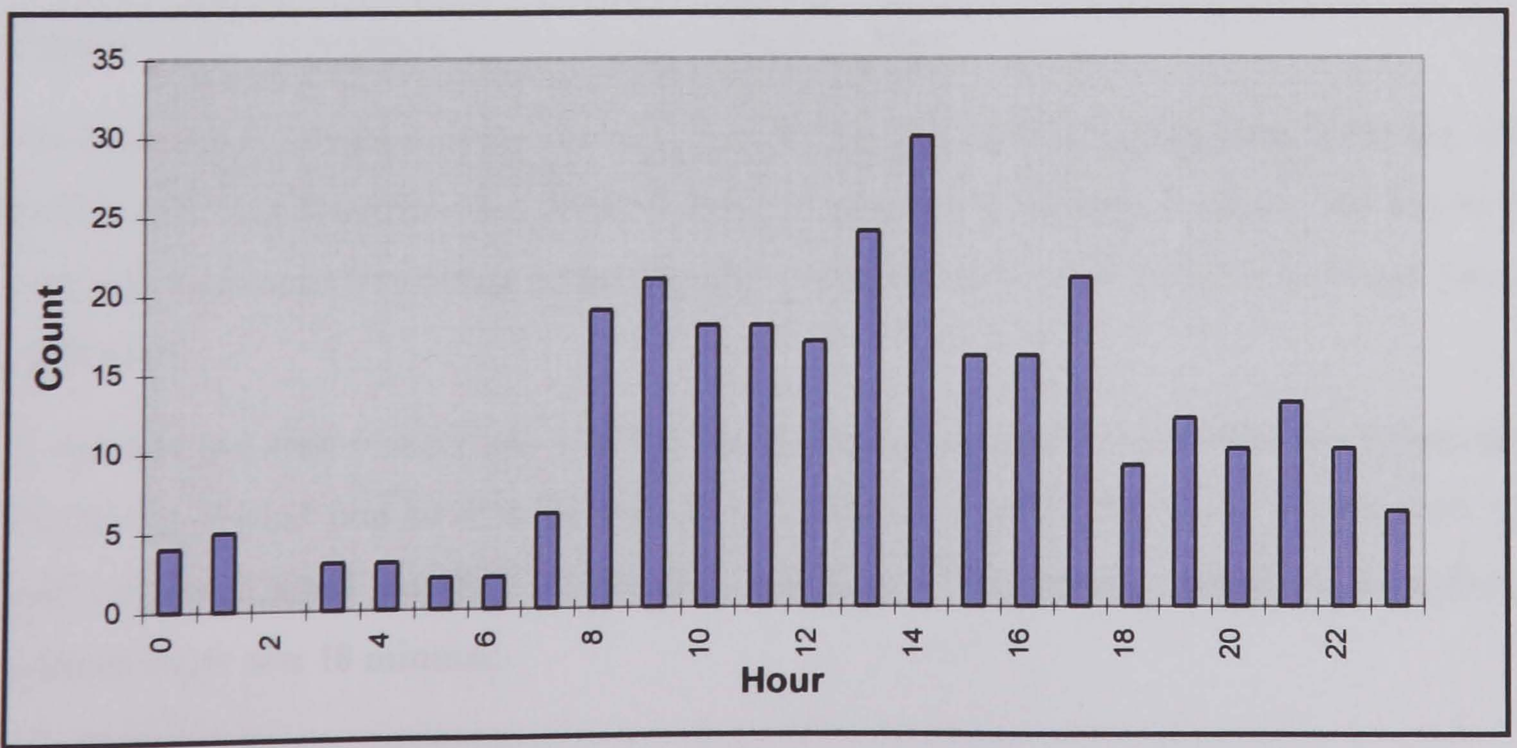


Figure 5.3.2 Distribution of log-ins throughout the day: Main Survey

From this graph it is important to notice the increases in log-ins at eight o'clock in the morning, around the lunch-time hours and at five o'clock in the evening. This suggests the majority of log-ins are coming from people who are still in the work place, and at times when 'surfing' is acceptable *i.e.* before and after the core work hours and during the lunch-time break. This may reflect the possible socio-demographic profiles of respondents - if the majority of people are responding from the work place then they are in a position where Internet access is available at work, thus limiting the numbers of occupations they may have and the socio-demographic sector they belong to.

Figure 5.3.3 shows where log-ins were made from. This map does not show any log-ins made from Great Britain, due to the large number of respondents from the British Isles (179 log-ins).

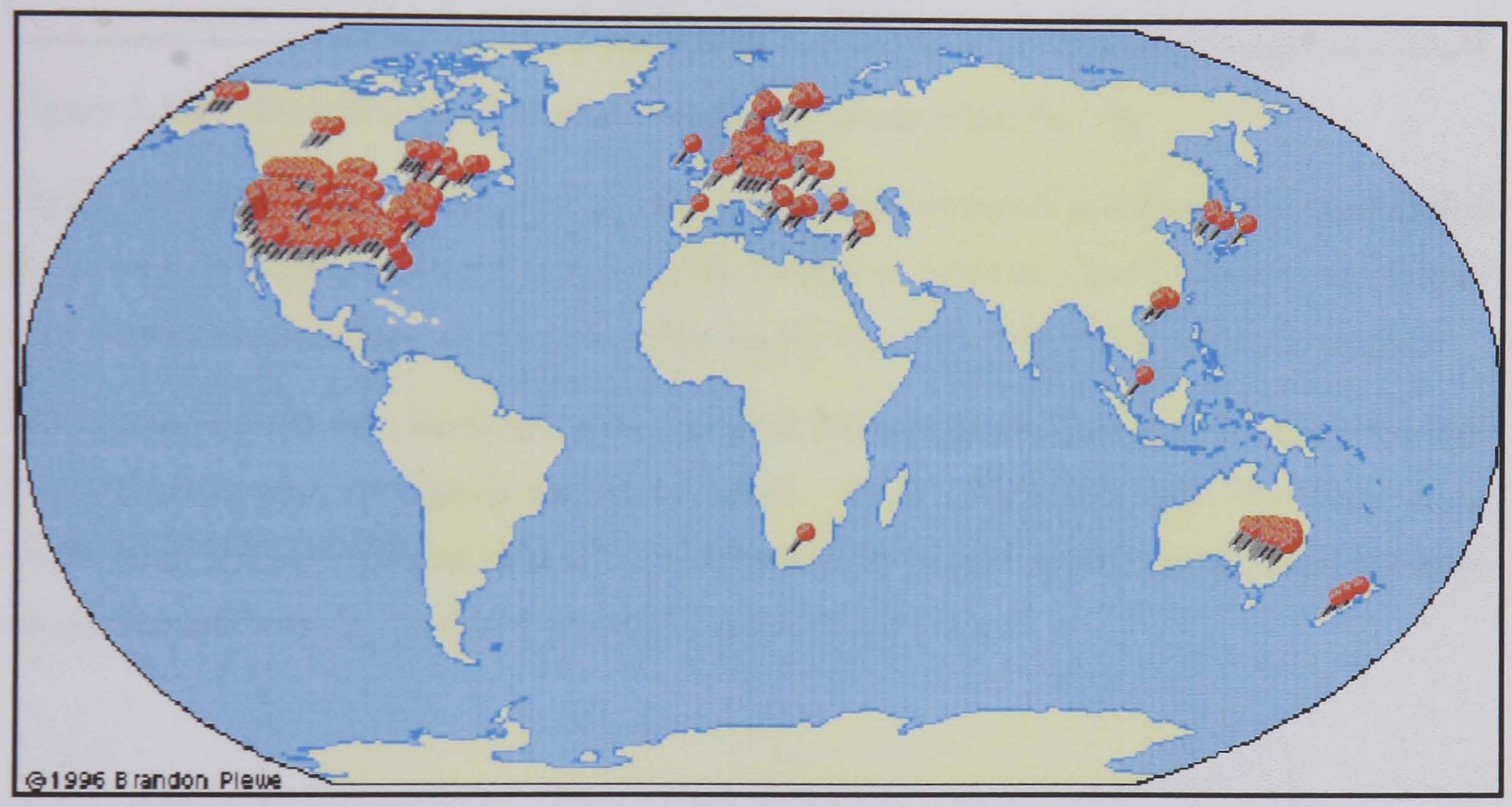


Figure 5.3.3 Geographical locations of log-ins: Main Survey

From this map it can be seen that the majority of non-British log-ins came from the United States, with large numbers also from Canada, Australia and western Europe. No log-ins were received from any developing countries, although the location of some IP addresses remained unknown.

It was also possible to calculate how long each respondent took to complete the questionnaire. Durations of over one hour were discarded, on the assumption they came from servers which had only a limited number of postings per day. The average length to complete the questionnaire was 18 minutes.

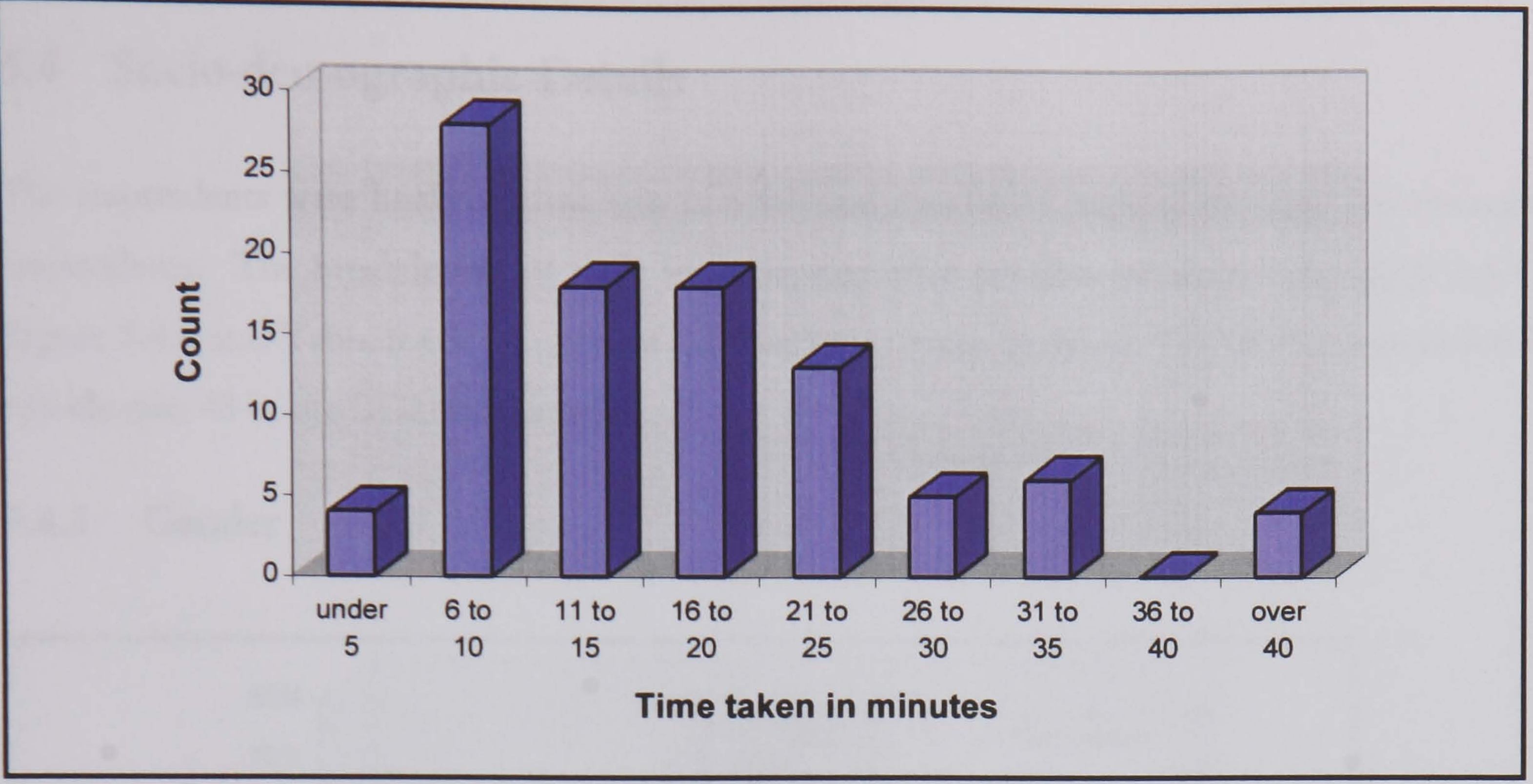


Figure 5.3.4 Distribution of survey completion times: Main Survey

Figure 5.3.4 shows that the majority of respondents took between 6 and 25 minutes to complete the survey. It is hypothesised that many of the longer completion times are caused by poor or slow network connections, therefore lengthening the time required to download the images.

The connection between landscape preference and the time spent looking at a landscape image (be it photographic or digital) has been studied. Wade (1982) concluded that there is no relationship between looking time and preference rank; people merely spend longer on some images because they are interested or curious about that landscape.

5.4 Socio-demographic Details

The respondents were broken down into two sub-samples: RGU respondents and International respondents. The breakdowns of their socio-demographic profiles are shown in Figure 5.4.5, Figure 5.4.6 and Table 5.4.1. A total of 180 responses were analysed: 132 in the International sub-sample; 48 in the RGU sub-sample.

5.4.1 Gender

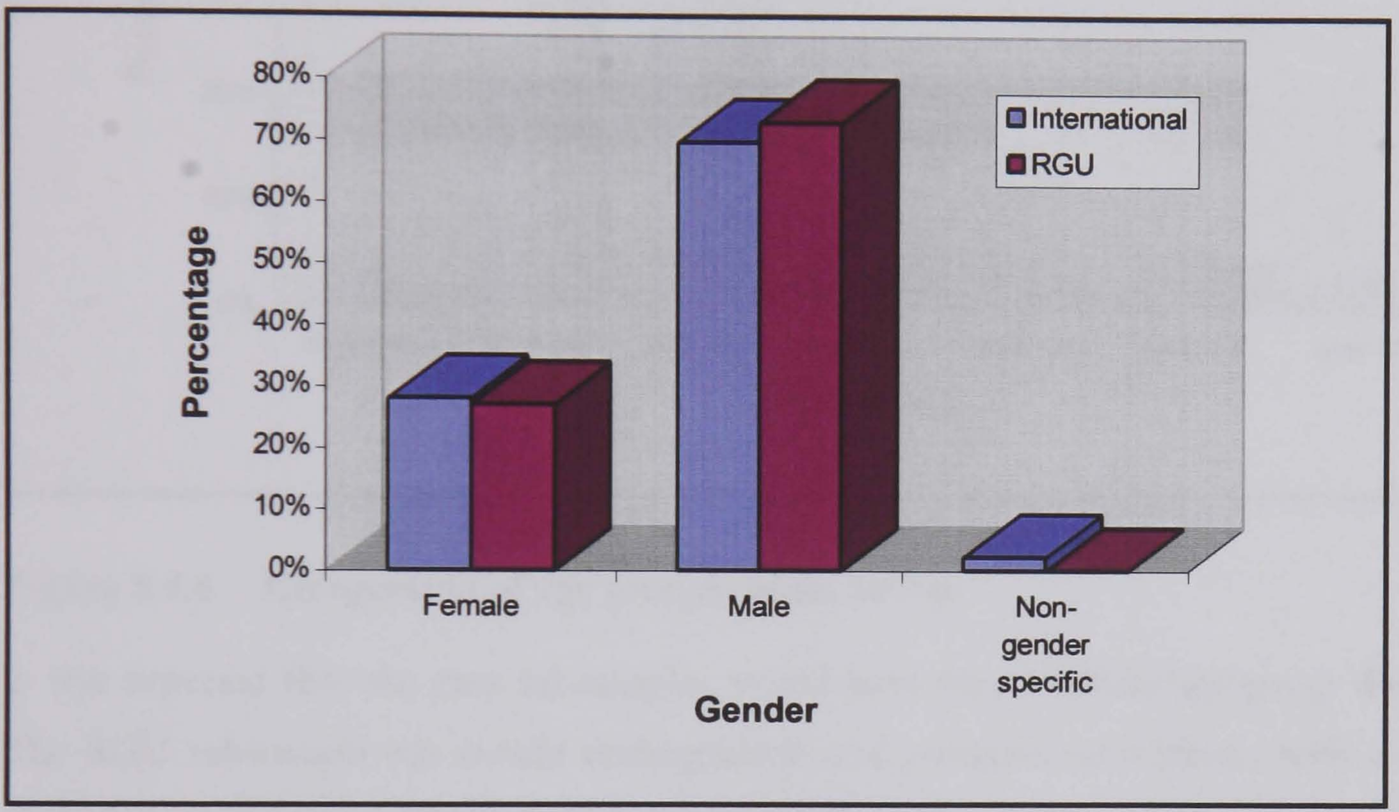


Figure 5.4.5 Comparison of genders: Main Survey

The two sub-samples have very similar female/male ratios, despite the fact that most of the classes at RGU requested to complete the questionnaire were predominately male. There is still, however, a significant difference between numbers of the two genders. Following the Pilot study, the category of non-gender specific was added; all respondents who fail to register their gender are placed into this category.

5.4.2 Age groups

Standard age bands were used to divide the respondents into age groups.

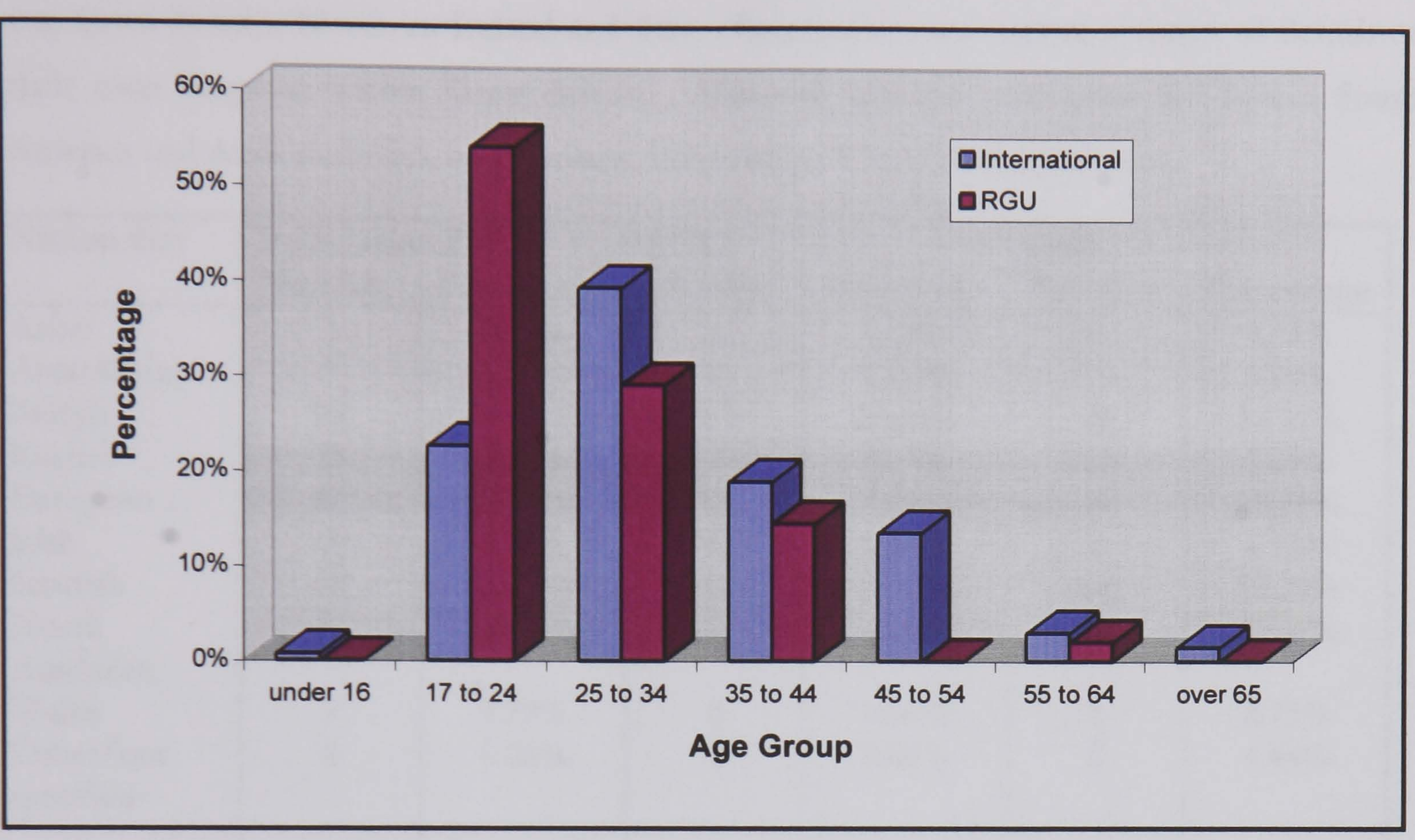


Figure 5.4.6 Comparison of age groups: Main Survey

It was expected that the two sub-samples would have very different age-group distributions. The RGU sub-sample was mostly undergraduate and postgraduate students, with a number of staff also taking part. This graph therefore implies that the International sample was not a predominately student-based population, it is however still a relatively young sample. The lack of under 16s responding to the survey is in many ways expected. Currently, it is not until students reach University level that they are introduced to the Internet on an open-access basis. The one under 16 respondent was supervised by a teacher when completing the survey.

5.4.3 Occupations of respondents

The occupations of the respondents were examined. By far the majority of the International sub-sample were in either the academic field (34.4%) or were students (34.4%). Those in computer related fields made up only 6.1% of the sample, with professionals totalling 19.1% of the sample. The remainder of the occupational groups were management (3.8%) and other (2.3%).

5.4.4 Nationality

Respondents were asked to state their nationality or continent of origin. The exception to this was Great Britain, Northern Ireland and Eire. Respondents were given a choice of British or their own kingdom within Great Britain. Although options were given for Africa, South America and Arab countries, no responses were obtained from these continents.

Nationality	International		RGU		Both	
	Number	Percentage	Number	Percentage	Number	Percentage
Asian	3	2.27%	3	6.25%	6	3.33%
Australasian	7	5.30%	0	0.00%	7	3.89%
British	28	21.21%	10	20.83%	38	21.11%
English	13	9.85%	3	6.25%	16	8.89%
European	17	12.88%	2	4.17%	19	10.56%
Irish	2	1.52%	0	0.00%	2	1.11%
Scottish	28	21.21%	30	62.50%	58	32.22%
North American	21	15.91%	0	0.00%	21	11.67%
Welsh	5	3.79%	0	0.00%	5	2.78%
Other/not specified	8	6.06%	0	0.00%	8	4.44%
Total	132	100%	48	100%	180	100%

Table 5.4.1 Nationalities of respondents: Main Survey

Within the sub-sample from RGU the majority of respondents (90%) were of British origin, with 70% of these stating that they were Scottish. The International sub-sample was far more varied. 59% were from the British Isles and Eire, with the majority of the remaining respondents from Europe and North America. The low response rate from the far-eastern Asian countries was surprising: there is no lack of Internet access in these countries, yet only three people replied from South Korea and Japan. It is perhaps a lack of interest in the subject area or a problem with language which is preventing a higher response rate from these countries.

The lack of responses from Africa, South America and the remainder of Asia is thought to correspond to countries being less technologically able at present. However, although no responses have been received from these areas, log-ins have been recorded from South Africa, Chile and Brazil during this research.

5.5 Analysis of the Socio-demographic Differences

Significance of socio-demographic differences

A general linear model using repeated measures was run using the SPSS statistical software package on each of the nine questionnaire versions to examine the main effects of the influence of the three main socio-demographic categories: age, gender, nationality, as well as monitor size. The results of this analysis are shown in Table 5.5.1.

Questionnaire Version	1	2	3	4	5	6	7	8	9
Source	**Significance of within-subject effects**								
Photograph	**0.001**	0.345	0.022	0.189	**0.000**	**0.000**	**0.002**	0.025	**0.003**
Age	0.055	0.211	0.388	0.518	0.616	**0.000**	0.480	0.532	0.751
Gender	0.106	0.727	0.915	0.395	0.152	**0.002**	0.085	0.453	0.970
Nationality	0.060	0.759	0.433	0.138	**0.003**	**0.000**	0.234	0.752	0.962
Monitor Size	0.020	0.978	0.982	0.454	0.050	0.035	0.525	0.470	0.344
	Significance of between-subject effects								
Photograph	0.041	0.050	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.002**
Age	0.222	0.768	0.299	0.872	0.149	**0.009**	0.187	0.462	0.807
Gender	0.630	0.793	0.440	0.945	0.038	0.190	0.679	0.343	0.923
Nationality	0.250	0.731	0.205	0.519	0.183	**0.008**	0.337	0.387	0.995
Monitor Size	0.198	0.525	0.939	0.875	0.467	0.053	0.556	0.617	0.854

Table 5.5.1 Significance of socio-demographic effects: Main Survey per questionnaire

Two questionnaire versions (numbers five and six) had significant effects contributed by all four socio-demographic sources (all significant and highly significant results are highlighted). It is not understood why these sources are significant in these versions and not in others.

As there was no one socio-demographic source which appeared to be significant in all questionnaire versions, it can be concluded that none of the socio-demographic effects or the size of image seen affects the preference scoring significantly. The photographs were at least slightly significant in all versions, with the exception of the within-subject significances of versions 2 and 4, which raises some concerns.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Intercept	6917	1	6917	1213	0.000
Photograph	1861	89	20.91	11.82	0.000***
Gender	14.30	2	7.15	2.009	0.178
Age	23.56	6	3.93	0.781	0.599
Nationality	73.72	9	8.19	1.796	0.123
Monitor Size	2.507	2	1.25	0.708	0.493
Gender by Age	19.98	4	5.00	2.823	0.024*
Gender by Nationality	21.23	6	3.54	2.000	0.062*
Age by Nationality	138.2	24	5.76	3.255	0.000***

Table 5.5.2 Significance of socio-demographic effects: Main Survey

Table 5.5.2 details the significance of the socio-demographic effects for the all questionnaire versions. Again the photograph is a highly significant source of variation in the preference scoring. Neither gender, age nor nationality have a significant effect on the preference scoring, however, there are significant interactions between gender and age, gender and nationality and a highly significant interaction between age and nationality.

Intergroup reliability

The intergroup reliability can be calculated for the nine questionnaire versions. This figure was calculated by sub-dividing each group into two and calculating the correlation coefficient between the averages of the two sub-groups. This process was repeated four times for each questionnaire version, using random sub-groups. The average correlation coefficient is shown in Table 5.5.3. It can be seen from Table 5.5.3 that there was a high degree of internal reliability within the nine groups of respondents, all are significant at the 0.05 level. This result suggests that the data collected is therefore consistent.

Questionnaire version	Intergroup Reliability	Number of Respondents in Group
One	0.818	17
Two	0.833	18
Three	0.869	27
Four	0.748	15
Five	0.769	24
Six	0.825	21
Seven	0.734	22
Eight	0.713	18
Nine	0.702	18
Average	0.779	20

Table 5.5.3 Intergroup reliability: Main Survey

5.6 Validation Survey

5.6.1 Methodology

The Validation survey was employed to test the accuracy of the predictive preference models created from the Main survey in Chapter Six. A new set of 36 photographs was collected for the survey, during a number of field trips in the Scottish Highlands; these trips were designed to collect photographs from areas which had not been previously visited. Photographic equipment and development was identical to that used previously. The geographical distribution of photographs can be seen in Appendix IX.

Within the survey, nine versions of the questionnaire were used, with each photograph appearing in three versions. Each questionnaire had only 12 images to facilitate faster completion of the survey, and to simplify questionnaire response management.

5.6.2 Sample of respondents

It was decided to use visitors to the MLURI Open Day in June 1997 to collect the required data. An exhibition was set up during the three days of the Open Day and visitors to the Institute were encouraged to complete the questionnaire. The sample of respondents obtained was socio-demographically wider than the Internet and RGU sample, due to a wide range of visitors, broadly stratified into three groups: professionals, academics, and the general public. In total 73 people completed the questionnaire over the three days. Three identical X-terminals were used to show the images, therefore there was no influence from differences in screen size, resolution or colour system.

It should be noted that this survey took place in the middle of summer, during a reasonably hot period, whereas the Main survey took place in winter and spring (for Northern hemisphere respondents). Buhyoff and Wellman (1979) noted that there was a seasonality bias in landscape preference scoring, *i.e.* respondents scored landscapes differently in spring and autumn. It is possible that the differing season in which the two surveys were completed may have some effect on the scores, particularly for those landscapes which display stronger degrees of seasonality.

5.6.3 Socio-demographic details

The details of the respondents' genders, age groups and nationalities are described below. Occupations of respondents were not collected during this survey. The Intergroup Reliabilities are also detailed.

Gender

Gender	Number	Percentage
Female	30	41.10%
Male	43	58.90%
Non-gender specific	0	0.00%

Table 5.6.1 Comparison of genders: Validation Survey

The gender ratio from this survey (Table 5.6.1) reflects the percentages of the visitors to MLURI during the Open Days. It is therefore closer to an even proportion than the ratio of genders obtained from the Internet respondents.

Age groups

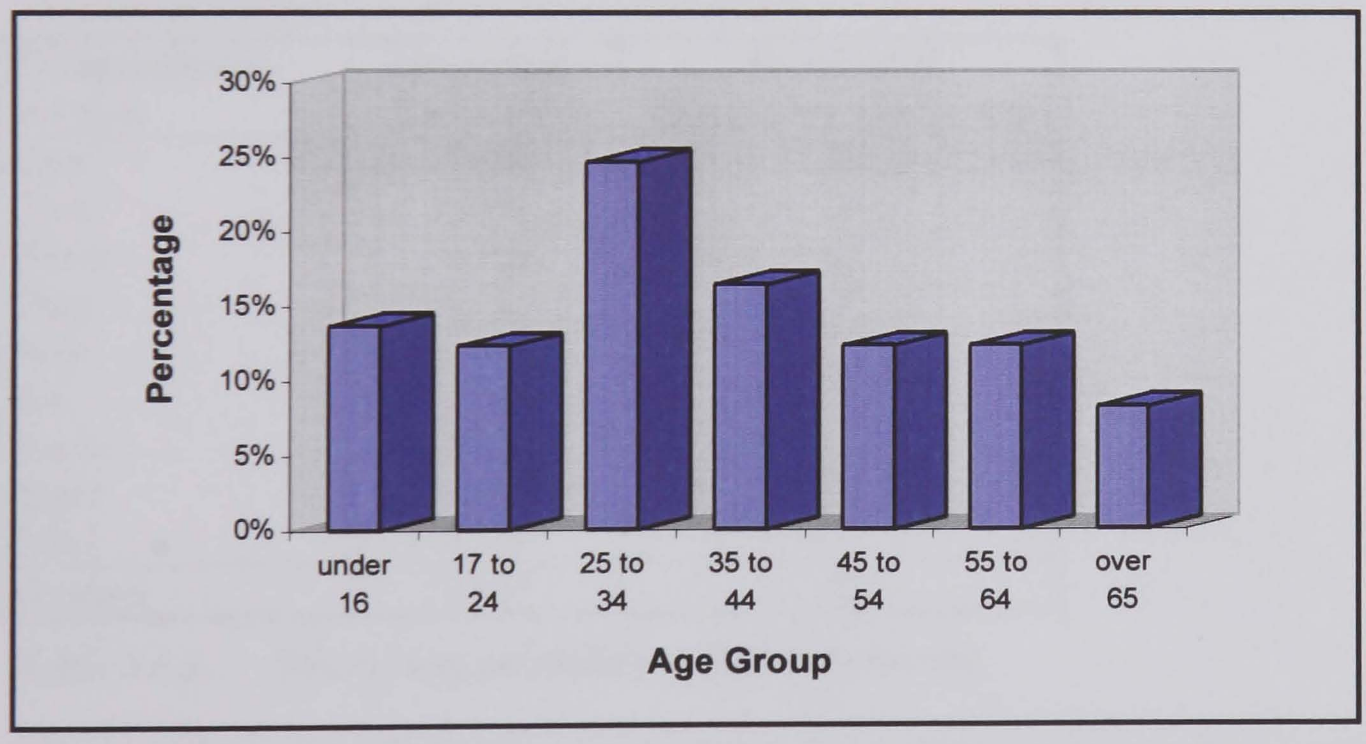


Figure 5.6.7 Comparison of age groups: Validation Survey

Figure 5.6.7 shows a fairly even distribution of age groups among the respondents to the Validation survey, with the lowest and highest age categories well represented.

Nationality

Nationality	Number	Percentage
Asian	1	1.37%
Australasian	1	1.37%
British	31	42.47%
English	4	5.48%
European	3	4.11%
Irish	0	0.00%
Scottish	30	41.10%
North American	0	0.00%
Welsh	0	0.00%
Other/not specified	3	4.11%

Table 5.6.2 Nationality of respondents: Validation Survey

It is not surprising that 89% of respondents are from Great Britain. The majority of visitors to the MLURI Open Day hailed from Aberdeen and its environs. Those respondents who gave their nationality as Asian, Australasian or 'other' were either temporary visitors to MLURI or were now living in Aberdeen.

Intergroup reliability

Questionnaire version	Intergroup Reliability	Number of Respondents in Group
One	0.634	8
Two	0.551	7
Three	0.325	11
Four	0.557	8
Five	0.742	7
Six	0.627	8
Seven	0.516	10
Eight	0.439	7
Nine	0.736	7
Average	0.570	8

Table 5.6.3 Intergroup reliability: Validation Survey

The reliability of the Validation survey data is lower than that for the Main survey, while still falling into the 'moderate correlation' category. This is due to the low numbers of respondents for each questionnaire version. However, as each image appears in three, rather than two, of the versions, each photograph was seen by between 19 and 27 people, with an average of 22.7 people scoring each image. Within this thesis, responses from 20 or more observers per photograph is assumed to be sufficient to achieve consensus. For 20 respondents per image, an internal reliability would be significant at the 0.01 level for $R=0.765$, and at the 0.05 level for $R=0.632$.

5.7 Discussion

Having previously established the validity of the survey methodology with sample groups from MLURI and RGU, the Main questionnaire has been examined for its own utility. As the sample of respondents is created through self-selection it is impossible to determine if the sample is representative of the general population (Pitkow *et al.*, 1997). However, by comparison to wider, commercial Internet surveys, it is possible to determine if the sample is representative of the Internet public *i.e.* that section of society which has access to the Internet.

5.7.1 Utility of Internet questionnaire survey

Several aspects of the survey management were examined, including response rate, time of log-ins and the time taken to complete the questionnaire. The response rate obtained compared well with other, traditional postal questionnaire; no other response rates for Internet questionnaires are known.

The ability to log and trace the IP address of all visitors to the questionnaire web-site allowed the examination of the local time of day when people logged into the Introduction page. This was found to coincide with the work day, with peaks at the beginning and end of the day and at lunchtime. This finding suggests visitors are logging in from their place of work, but outside 'core' working hours. The average and distribution of lengths of time to complete the questionnaire showed that people are neither rushing the survey nor spending overlong considering each image.

Comments regarding the usage of the survey were favourable. Many respondents showed an interest in the subject and requested to be informed of the results; others commented on the image quality, the colours and the content of the photographs.

5.7.2 Comparison of Internet surveys: Gender

Gender	International	RGU	Validation	GVU	Survey.net	IIA	Hermes
Female	28.0%	27.1%	41.1%	38.5%	32.6%	25%	29.3%
Male	69.7%	72.9%	58.9%	61.5%	64.8%	75%	60.7%
Non-gender specific	2.3%	0.00%			2.6%		

Table 5.7.1 Comparison of Internet surveys: Gender

The genders of respondents to recent Internet surveys are compared in Table 5.7.1 to the three samples of respondents used in the Main and Validation surveys. The female/male ratio found in the Main survey samples are highly similar to the ratios in the Survey.net (InterCommerce Corporation, 1997), IIA(Nua Ltd, 1997) and Hermes (Gupta and Pitkow, 1997) surveys.

The Validation data corresponds more closely to the GVU survey (Pitkow *et al.*, 1997). However, the data from the Validation survey was not gained over the Internet, rather it was collected using the Internet from a sample who did not necessarily have Internet access normally. Therefore, the results collected over the Internet would appear to be in close agreement with results collected by other, larger, Internet surveys. This confirms that the Main survey sample is representative of the general Internet public in terms of gender.

5.7.3 Comparison of Internet surveys: Age groups

Age group	International	RGU	Validation	GVU	Survey.net
under 16	0.8%	0.00%	13.7%	2.2%	4.3%
17 to 24	22.7%	54.2%	12.3%	19.8%	31.1%
25 to 34	39.4%	29.2%	24.7%	27.3%	29.8%
35 to 44	18.9%	14.6%	16.4%	21.9%	17.0%
45 to 54	13.6%	0.0%	12.3%	16.6%	9.8%
55 to 64	3.0%	2.1%	12.3%	6.3%	3.0%
over 65	1.5%	0.0%	8.2%	3.1%	1.2%

Table 5.7.2 Comparison of Internet surveys: Age groups

The GVU (Pitkow *et al.*, 1997) and Survey.net (InterCommerce Corporation, 1997) surveys recorded age groups similar to the age groups used in this research (Table 5.7.2). As mentioned previously, the Validation survey data is not representative of an sample Internet population and is therefore not likely to correspond closely to any other sample Internet population. Similarly, the RGU sub-sample is representative of an University Internet population and is therefore unlikely to correspond to other samples. The International sub-sample is not highly dissimilar to the samples from the commercial Internet surveys. This result again suggests that this sample is representative of the general Internet public.

5.7.4 Comparison of Internet surveys: Nationality

The nationalities of Internet respondents to the Main survey and the GVU survey (Pitkow *et al.*, 1997) can be compared (Table 5.7.3). As the surveys were based in different countries, those two countries (USA and Canada, and Great Britain) are not included in the comparison.

Continent/Nationality	Main survey	GVU survey
Africa	0.0%	3.0%
Asia	8.0%	7.4%
South America	0.0%	3.6%
Middle East	0.0%	2.0%
Australasia/Oceania	18.9%	24.0%
Europe	45.9%	59.6%

Table 5.7.3 Comparison of Internet surveys: Nationality

The nationalities of Internet users corresponds closely with the nationalities found in the Main survey (Table 5.7.3). Due to the differences in the sample sizes (132 compared to around 10,000) it is not unsurprising that there are no respondents for several of the nationality categories in the Main survey results.

5.7.5 Occupations of Internet respondents

The occupations of respondents were compared to the findings from the GVU survey (Pitkow *et al.*, 1997) in Table 5.7.4. Only the International sub-sample is included in this table.

Occupation	Main survey	GVU survey
Computer related	6.11%	20.63%
Academic/Student	68.70%	23.14%
Management	3.82%	11.69%
Professional	2.29%	21.40%
Other	19.08%	23.14%

Table 5.7.4 Comparison of Internet surveys: Occupation

There are differences in the types of occupation taken by the two samples above (Table 5.7.4). One reason may be that respondents in the GVU survey chose one of the five categories above, while respondents in the Main survey gave their actual occupation and were then assigned to one of the groups above. There may also be effects due to nature of the survey. The research conducted in this thesis is likely to be of interest to a restricted group, particularly those involved in the landscape field, compared to the broader surveys of Internet users.

5.7.6 Monitor sizes of Internet users

The sizes of monitors were recorded in the Main survey. The results of the general linear model suggest that there were no overall significant effects due to differences in these sizes; however, it was not possible to record the effects of differences in pixel resolution or colour resolution.

In the survey run by Pitkow *et al.* (1997) monitor size, resolution and colour were recorded.

Monitor Size	Percentage	Monitor Resolution	Percentage
laptop	3.76%	640 x 480	12.35%
13" - 15"	39.50%	800 x 600	19.35%
16" - 18"	23.10%	1024 x 768 +	22.55%
19" +	27.02%	don't know	45.75%
other	6.62%		

Source: GVU Internet User Survey (Pitkow *et al.*, 1997)

Table 5.7.5 Monitor details: GVU Internet User Survey

Due to the large numbers of 'other' and 'don't know' in Table 5.7.5 it is not possible to drawn many conclusions about monitor usage in the general Internet public. However, it can be noted that the ratio of the three monitor sizes (44 : 26 : 30) and the ratio of the three resolution types (23 : 35 : 41) are quite different. This has repercussions for the survey, as the size of image shown to a respondent corresponds to their monitor size rather than resolution on the assumption that these were highly correlated. In many cases respondents are therefore not viewing the largest possible image. The use of a JavaScript to determine screen resolution in later surveys will resolve this problem for all respondents using the later versions of Netscape browser.

As noted previously, the breakdown of respondents from the Main survey correspond well with the results from the commercial Internet surveys. The ratio of the three monitor sizes in the survey was 48 : 21 : 30, which is very close to the ratio found by the GVU survey.

5.8 Summary

5.8.1 Summary of Main and Validation surveys

The Main survey was run between January and May of 1997, using 90 photographs of Scottish landscapes and receiving 180 completed questionnaires. Investigation of the response rate revealed that almost 40% of those viewing the site completed the questionnaire; with the majority of responses coming during work hours, at non-core times. Analysis of log-ins to the questionnaire revealed that the majority of interested parties were North American or Western European, with Oceania also figuring highly. South America and Africa accomplished one log-in between them, with Asia, in particular Korea and Japan showing slightly more interest.

The Validation survey sample was closer to representing the general public, drawing from those who attended the MLURI Open Days in June 1997; a total of 73 responses were collected. A new set of 36 photographs of the Scottish Highlands was used for this survey; the areas photographed were different from the original geographic distribution of photographs.

5.8.2 Validity issues

The issues that must be addressed before undertaking an Internet questionnaire were discussed in Chapter Four. In order to validate the methodology of the questionnaire these issues were further investigated, both in Chapter Four and in the current chapter. The use of monitor displayed images has been validated, both by this research and other work, and the successful piloting of the study allowed the Main survey to proceed.

The question of the representativeness of the sample has been addressed in detail and it has been shown that while the sample is not representative of the general public, it is representative of the general Internet public, with the exception of occupation: this survey showed a higher than average percentage of academic/student respondents

One problem has been noted; that monitor size and resolution may not be highly correlated. This is circumvented in later surveys by the use of a JavaScript which is able to determine screen resolution for Netscape 3 and 4 users.

CHAPTER SIX

PREDICTIVE PREFERENCE MODELS

6.1 Introduction

6.1.1 Landscape analysis methodology

In order to create a psychophysical predictive landscape preference model, following the basis of the work by Shafer and colleagues (Shafer *et al.*, 1969; Shafer and Brush, 1975), it is necessary to measure and analyse the landscape components in each of the photographs used in the surveys. These steps were done using ERDAS Imagine 8.2 (ERDAS, 1994). Three sets of variables were chosen, defined and measured as described in the next section. The sets comprise landcover variables, landform variables and colour variables. The methodology used to measure these is discussed in Section 6.2. A summary of the variables used is included, together with a note of the minimum and maximum values each variable may take.

6.1.2 Predictive preference model: methodology of creation

Before any further analysis, the landscape variable and preference data was tested using the original Shafer model to assess if the model could predict preference accurately for the new data set. The original model was created in North America almost 30 years ago. However, there was a possibility that the model would be functional for present day Scotland.

To produce the mathematical psychophysical models, the preference scores were regressed against the component data (Section 6.4), and against several standard mathematical transformations of the data: inverse, natural logarithm and square. Criteria for the models require to be set; selecting the most functional of those models fitting the criteria reduced the number of models to six. These models are detailed in Section 6.6 and the variables used in them are examined in the following section. The examination looks at how the model terms are related to the components, and what they imply in terms of landscape preference.

6.2 Variable Measurement

In previous studies the landscape components have been measured using a grid and designating each square within the grid to a component. Using the guidelines set by Shafer *et al.* in 1969 and other component definitions, the aim is to be as objective as possible in the designation of landscape distance zones and cover types (see Table 6.2.1) and landform types, however, it is recognised that there is an inherent subjectivity in this process.

In order to measure landscape components, a grid system similar to that of Shafer *et al.* was implemented. Landscapes were digitised in ERDAS Imagine (ERDAS, 1994) (example image in Figure 6.2.1) at a known pixel size, and the measurements were then converted into units. Each photograph comprised 1080 units, with a length of 40 units and a height of 27 units. This technique allows reproducibility without the need for digitising equipment to permit the broadest applicability of the method.

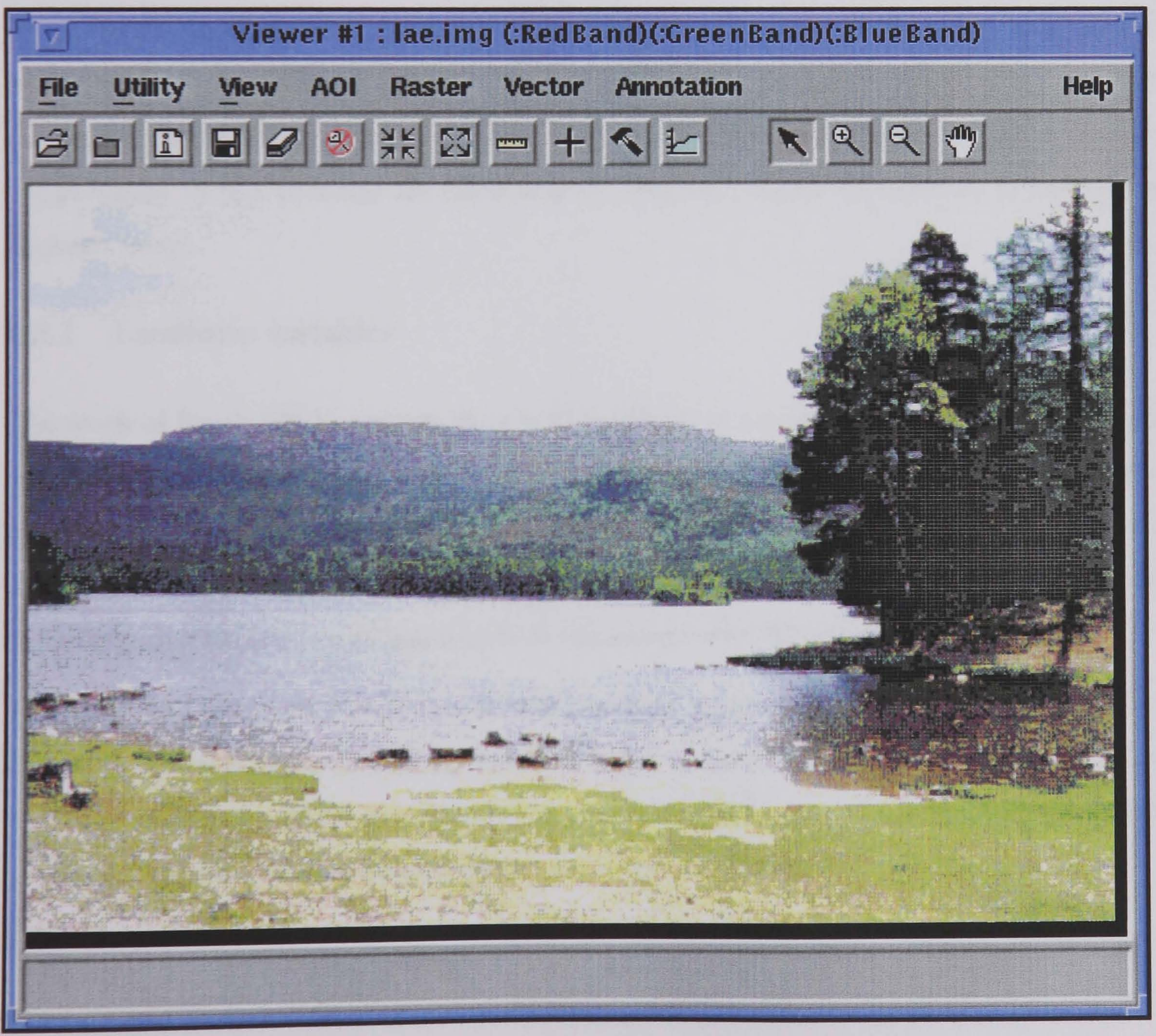


Figure 6.2.1 Example of raster image in ERDAS Imagine

6.2.1 Land cover variables

Distance zones	Vegetation	Non-vegetation
Immediate zone	Where the characteristics of individual leaves, needles, bark, or stems of trees or shrubs are easily distinguishable.	Where soil or snow texture, blades of grass, or detailed characteristics or individual stones, boulders, or rock outcrops are distinguishable.
Intermediate zone	Where the outlines of individual trees or shrubs are recognisable, but not in the fine detail found in the immediate zone.	Where the outlines of individual rocks, large crevices in rocks, prominent features of exposed soil, grass or snow-covered areas are recognisable, but not in the fine detail found in the immediate zone.
Distant zone	Where trees or shrubs occupy the landscape, but the shape of individual crowns is not discernible.	Soil, rocks, grass or snow cover, but no details of these features are recognisable. (After Shafer *et al.*, 1969)

Table 6.2.1 Landscape distance zones and cover types

In order to measure these components, the scanned images were resized to an identical size (580 by 395 pixels) to allow for meaningful comparisons of area and perimeter. The files were then converted into raster files in ERDAS Imagine (an example is shown Figure 6.2.1). A vector coverage is then digitised, using the raster image as a background. The areas and perimeters of the polygons in this coverage are calculated by Imagine. Figure 6.2.2 shows an example of a digitised image.

6.2.2 Landform variables

The work of Brush (1981) suggests the use of landform as a preference predictor. In the study, the photographs used by Shafer *et al.* (1969) were divided into those which displayed only one landform in the whole scene, and those which did not. Using only the scenes where one landform alone could be used to describe the landscape, the predictive capability of the Shafer model was significantly raised (from 66% of variance to over 80% of variance predicted).

The variables used in this analysis used the landform types in an alternative manner to Brush (1981). Landscapes were divided up into five types of landform and the area and perimeter of each was calculated. Water was considered a separate landform and therefore not included in any measurements. The landform types were defined as follows:

- **Flat** - Land which has no undulations or slopes, such as arable fields.
- **Low hill** - Land which has minor undulations or a small slope, not considered to cause any difficulty to a person walking over it.
- **Steep hill** - Land which had either major undulations or a significant slope, might cause some breathlessness in a person walking over it.
- **Mountain** - All land over 2000 feet (in Scotland) and any other land significantly steeper than previous landform types.
- **Obscuring vegetation** - Vegetation which obscures the landform behind it. Does not include vegetation which obviously obscures either sky or water.

These variables can be further defined by examining their degrees of steepness. If the rules of McKerchar (1998) are adapted, the four categories can be roughly defined as:

Landform Variable	Range of degrees of steepness
Flat	under 5°
Low Hill	5° - 25°
Steep Hill	25° - 40°
Mountainous	over 40°

Table 6.2.2 Landform variables: degrees of steepness

Figure 6.2.3 shows an example of a landform coverage, digitised in the same way as for a landcover coverage.

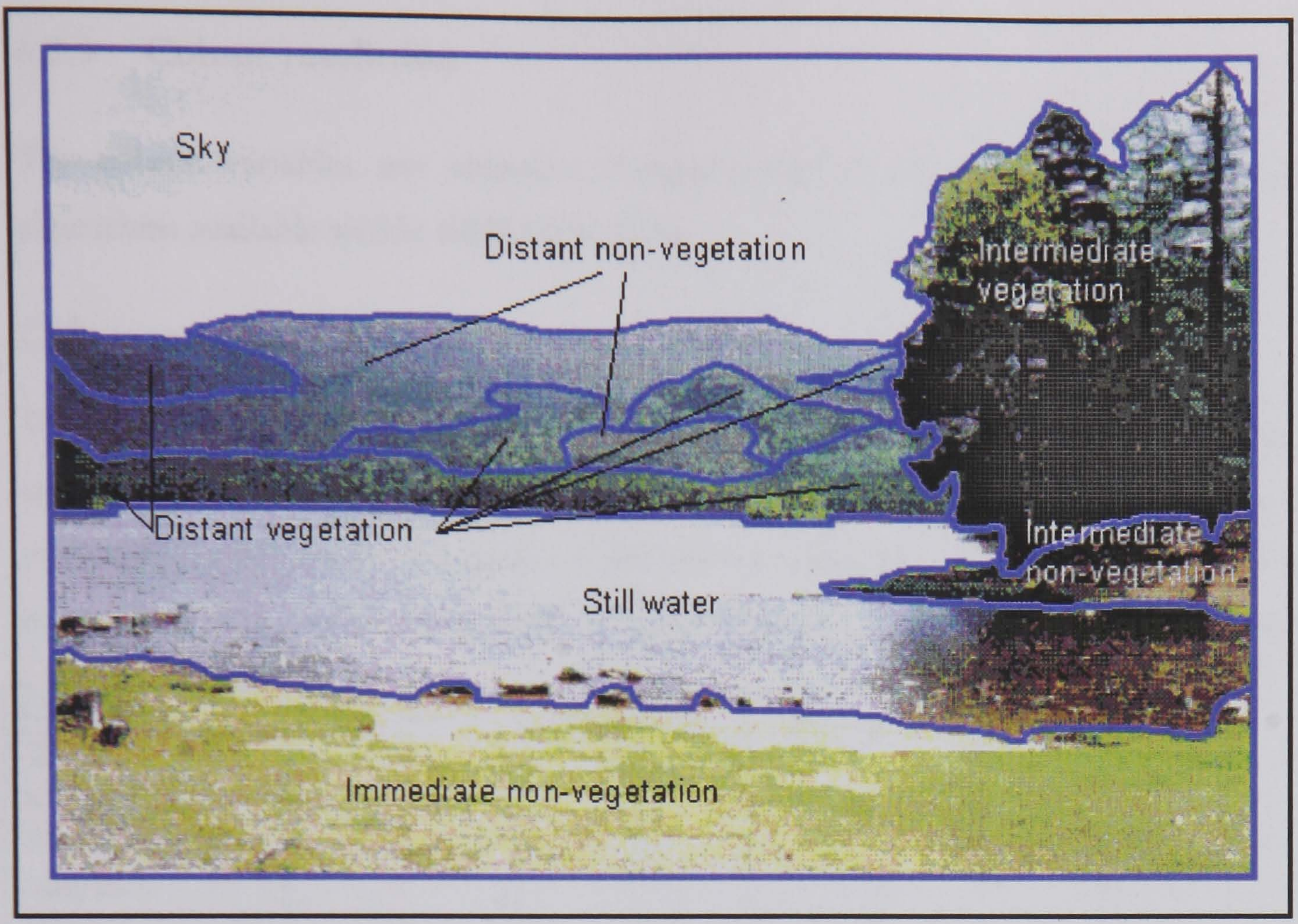


Figure 6.2.2 Landcover vector coverage

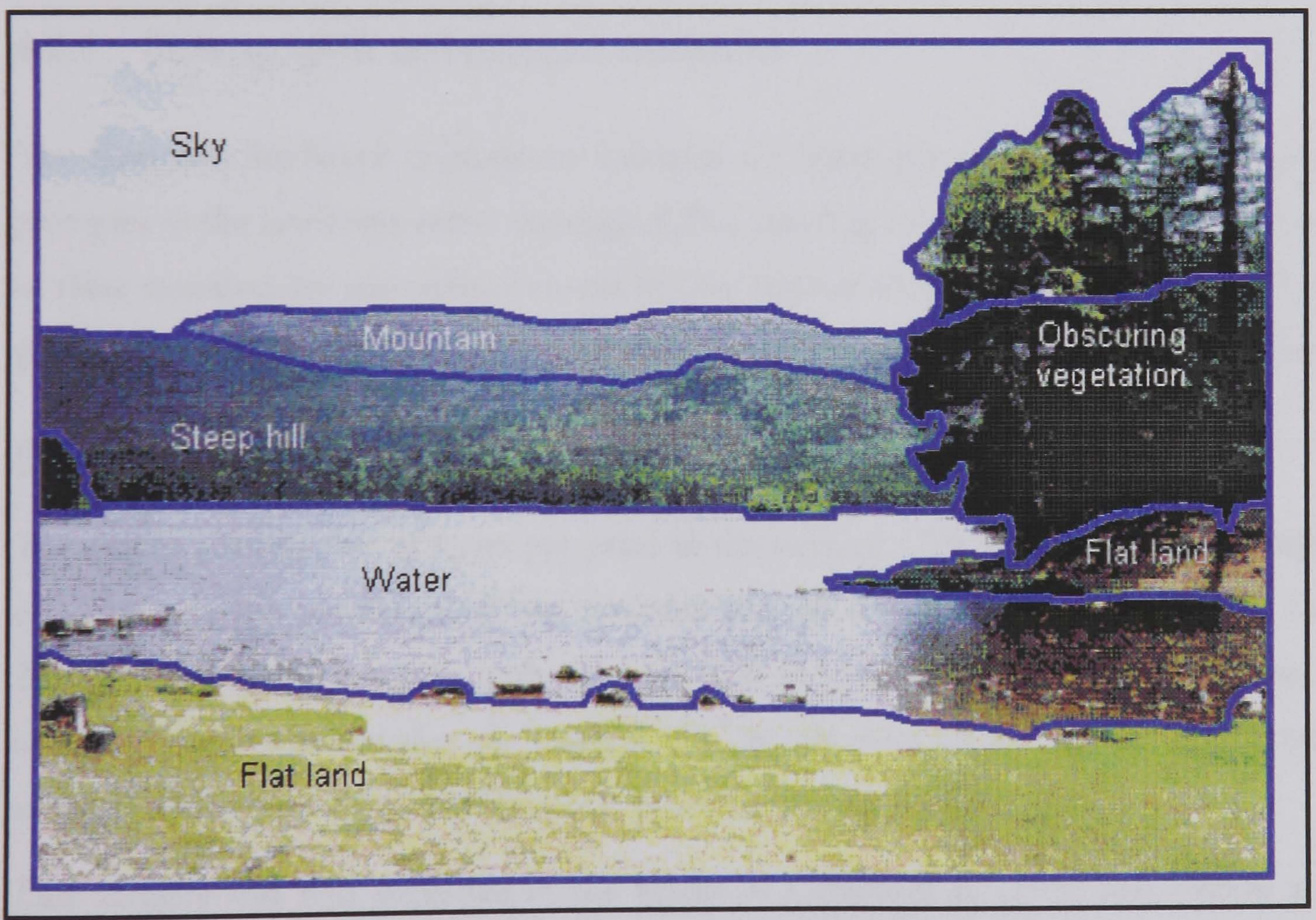


Figure 6.2.3 Landform vector coverage

6.2.3 Colour resolution

The colour variables are objective characteristics of the images and are measured using algorithms available within ERDAS Imagine.

Colour measurement

Within an IMG raster file each pixel is assigned a level for red, green and blue bands between 0 and 255. Table 6.2.3 displays values for a variety of colours. The image information function within ERDAS Imagine was used to calculate the mean and standard deviation for each colour band giving six variables for each photograph. These values were rounded to integers.

Colour	Red Band	Green Band	Blue Band
White	255	255	255
Mid-red	128	0	0
Mid-green	0	128	0
Mid-blue	0	0	128
Black	0	0	0

Table 6.2.3 Colour values

6.2.4 Photographic and polygon resolution

The final two landscape component variables are bytes per pixel (BPP) and the number of polygons in the landform vector coverage (LPC, standing for Landform Polygon Count). Both of these measures are non-subjective and neither require a GIS to be calculated. BPP requires a graphics package for the purposes of measurement, while LPC can be calculated by hand.

Bytes per pixel (BPP)

To identify the number of bytes per pixel in the original GIF image, the size in pixels (before conversion to the standard size) was recorded and the size in bytes was divided by this figure. The resulting figure was then multiplied by 1000 and rounded to zero decimal places for later use. It should be noted that the original GIF images were all within +/- five percent of the standard size, as the increase in file size is proportional to the increase in image size.

This variable was first suggested in the works of Orland *et al.* (1995) and Bishop and Leahy (1989). Their studies used a variety of methods to calculate complexity of the image, one of which was to examine the compressibility of the image. If all the images of this study were to be saved in the IMG format within ERDAS Imagine the file size of the images would be identical (for identically sized images).

If we examine the method of compression used in the GIF format, we discover that the larger the blocks of colour, the greater the length of compressible bits (see Figure 6.2.4). As noted in Chapter 4, GIF format uses lossless compression, reducing file size by recording the length of a horizontal line of the same colour instead of recording the colour of each pixel in that line (Bishop, K., 1997). It is not inconceivable that one definition of complexity would be proximity of colour changes within an image. Therefore, the file size of the GIF image represents the level of compression available for each image thus corresponding to the level of complexity of the image.

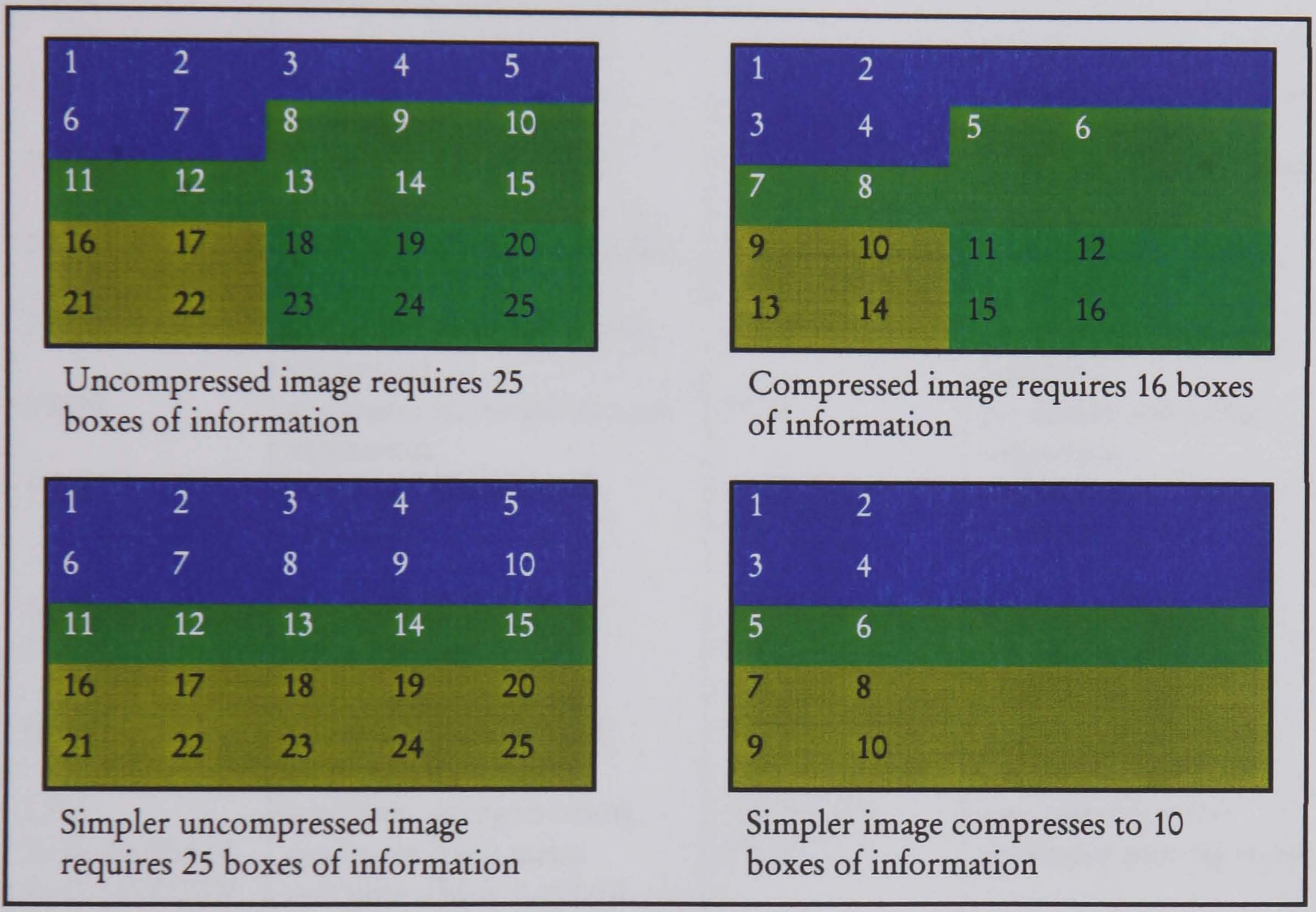


Figure 6.2.4 Demonstration of lossless compression

<u>Landform polygon count (LPC)</u>

It is suggested by S. Kaplan (1987) that coherence within a scene is concerned with the number of areas a scene can be organised into. If it is assumed that the number of polygons which require digitising within a scene is therefore related to a measure of coherence, then LPC is a potentially useful variable. It can be measured simply by counting the number of polygons in a scene. For simplicity, only polygons which take up 1% or more of a scene have been counted in this study.

6.3 Summary of Data

Code	Variable	Code	Variable
ANV	area immediate vegetation	LF	area flat landform
AMV	area intermediate vegetation	LL	area low hill landform
AFV	area distant vegetation	LS	area steep hill landform
ANN	area immediate non-vegetation	LM	area mountain landform
AMN	area intermediate non-vegetation	OBSVEG	area obscuring vegetation
AFN	area distant non-vegetation		
PNV	perimeter immediate vegetation	PLF	perimeter flat landform
PMV	perimeter intermediate vegetation	PLL	perimeter low hill landform
PFV	perimeter distant vegetation	PLS	perimeter steep hill landform
PNN	perimeter immediate non-vegetation	PLM	perimeter mountain landform
PMN	perimeter intermediate non-vegetation	POV	perimeter obscuring vegetation
PFN	perimeter distant non-vegetation	WATER	area water
		PWATER	perimeter water
SKY	area sky	AWSEA	area sea water
PSKY	perimeter sky	PWSEA	perimeter sea water
		AWSTILL	area still water
BPP	bytes per pixel (of GIF image)	PWSTILL	perimeter still water
LPC	landform polygon count	AWMOVE	area moving water
R/G/BMEAN	red/green/blue mean	PWMOVE	perimeter moving water
R/G/BSTDEV	red/green/blue standard deviation		

Table 6.3.1 Variable codes

Four mathematical transformations were made for each variable (Table 6.3.2) (with the exception of colour variables, which are treated separately). The inverse, natural logarithm, ratio of area to perimeter and square of each variable was calculated. These transformations were chosen as they are the most likely relationships to appear in an equation relating to natural phenomenon.

In the cases of the inverse, natural logarithm and ratio divisor, the value of 1 was added to each variable value to prevent errors occurring when the variable value was equal to zero. The exceptions to this were the area and perimeter of sky and bytes per pixel, none of which may ever equal zero. In several cases the ratio of two different variables was calculated, *e.g.* R_PSKYPWATER.

Colour variables were treated slightly differently (Table 6.3.2). The square of the standard deviation (the variance) was calculated for each colour band and the products of means of two or more colour bands were also calculated. Terms combining the standard deviation and mean (in ratios and products) were used in the regressions.

Finally two new variables were added, high landform and total visible land, which are both composites of two or more landform types.

Code	Mathematical transformation
INV_X	inverse 1/(X+1)*
LN_X	natural logarithm LN(X+1)*
R_X	ratio of area to perimeter AREAX/(PERIMX +1)* (or ratio of two variables)
X^2	square X^2
R/G/BVAR	red/green/blue variance (equals standard deviation squared)
RGBMEAN	product of red, green and blue means
RGMEAN	product of red and green means
LHIGH	product of areas of steep and mountain landform
TVL	total visible land (sum of areas of four landform types)
	* With the exception of sky, perimeter sky and bytes per pixel, which do not require the addition of 1

Table 6.3.2 Codes for mathematical transformations of variables

The minimum and maximum value any variable may have in order to be used in a model created from the preference score data is detailed in Table 6.3.3. The score obtained from a model for a landscape which falls outside these boundaries will not be valid. It should be noted that this only applies to the variables used in each model.

Code	Minimum	Maximum		Code	Minimum	Maximum
ANV	0	941		LF	0	647
AMV	0	524		LL	0	760
AFV	0	314		LS	0	431
ANN	0	384		LM	0	518
AMN	0	360		OBSVEG	0	624
AFN	0	666				
PNV	0	455		PLF	0	236
PMV	0	218		PLL	0	193
PFV	0	205		PLS	0	155
PNN	0	167		PLM	0	141
PMN	0	122		POV	0	264
PFN	0	396				
SKY	44	778		LHIGH	0	949
PSKY	72	247		TVL	0	949
WATER	0	482		BPP	177	650
PWATER	0	170		LPC	2	11
AWSEA	0	420		RMEAN	69	184
PWSEA	0	141		GMEAN	71	181
AWSTILL	0	482		BMEAN	49	165
PWSTILL	0	169		RSTDEV	44	99
AWMOVE	0	403		GSTDEV	59	101
PWMOVE	0	170		BSTDEV	73	110

Table 6.3.3 Minimum and maximum allowable values for landscape components

6.4 Statistical Methodology

6.4.1 Manipulation of preference score data

Two separate techniques were used to normalise the scores gained from the preference survey giving similar, but not identical, ranks to the 90 landscape images. These techniques were used to remove any differences in the ranges of scores given by respondents. It has been noted in Chapter Two that respondents of different ages, genders or cultural backgrounds may score on different ranges. By normalising the preference data these differences can be partially removed. It is important to undertake this manipulation, since the models created will be based on the average opinion of the population of respondents, rather than the opinions of individual respondents.

The two techniques will be referred to as normalising per questionnaire and normalising per respondent. Normalising per questionnaire was implemented following statistical advice; normalising per respondent follows methodologies used elsewhere in questionnaire surveys (such as the work of Hull and McCarthy, 1988). Examples of the two techniques can be seen in Appendix X.

Normalising per questionnaire

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

Equation 6-1 Normalising per questionnaire

Due to the necessity of running an ANOVA on the preference scores to create the data required for this normalisation, incomplete data sets could not be used. Therefore, where a respondent had failed to complete a score for one or more image, the respondents scores were deleted from the analysis. Scores from each questionnaire version were then added to create the overall score. While it has been assumed in this research that there is no influence from the remainder of the set of ten photographs in which any one photograph was seen, this methodology takes into account the scores for the other landscapes seen.

The range of scores produced by this type of normalisation will vary according to the number of questionnaire versions each photograph is seen in. It must be remembered that it is relative scores which are important and not absolute scores compared to another survey. This will not affect correlations between results produced by preference surveys and predictive models, as one set of results will merely be on a different scale from the other.

Normalising per respondent

$$\text{Score} = \frac{1}{\text{number of respondents}} \sum_{\text{all respondents}} \frac{(\text{Photograph score} - \text{Respondent mean})}{\text{Respondent Standard Deviation}}$$

Equation 6-2 Normalising per respondent

An advantage of this method of normalising is that because it is done on an individual basis, it makes no difference if the respondent completed two preference scores or all twenty. Scores for all respondents were averaged over the versions of the questionnaire; influence from other photographs was assumed to be null.

Comparison of the two methods of normalisation shows that the scores and ranks obtained both correlate with R=0.988, representing a very high correlation. However, both methods will be used throughout this thesis.

6.4.2 Analysis of variables

Principle components factor analysis

Factor analyses were run on the variables described in Section 6.2, following the work of Shafer *et al.* (1969), as well as on three mathematical transformations of these numbers: square, natural logarithm, and inverse. The analyses were run on different combinations of the variable types (landcover, landform, colour variables) to find the best combination of variables. The variables shown to be the most significant were then cross-multiplied to provide interaction terms. The resulting data was input to a multiple linear regression.

This analysis was undertaken using a variety of combinations of the landcover, landform and colour variables. However, none of the models produced from this analysis fitted the model criteria detailed in sub-section 6.4.3.

Regression analysis: individual varaibles

If the individual variables are examined for their predictive power, the following variables (Table 6.4.1) have R^2 of over 0.1.

Variable	Normalisation per questionnaire		Normalisation per respondent	
	R^2 (R^2 adjusted)	Significance	R^2 (R^2 adjusted)	Significance
INV_WATER	0.357 (0.349)	0.000	0.348 (0.341)	0.000
INV_PWATER	0.355 (0.347)	0.000	0.347 (0.340)	0.000
INV_BPP	0.219 (0.210)	0.000	0.207 (0.198)	0.000
LPC	0.194 (0.185)	0.000	0.198 (0.189)	0.000
INV_PLM	0.162 (0.152)	0.000	0.147 (0.137)	0.000
INV_LM	0.159 (0.149)	0.000	0.129 (0.119)	0.000
LN_AWST	0.132 (0.123)	0.000	0.153 (0.144)	0.000
BLUEVAR	0.131 (0.121)	0.000	0.100 (0.090)	0.002
LN_AMN	0.119 (0.109)	0.001	0.135 (0.126)	0.000
LN_PWST	0.116 (0.106)	0.001	0.133 (0.123)	0.000
PMN	0.111 (0.101)	0.001	0.129 (0.119)	0.001

Table 6.4.1 Variables explaining over 10% of variance in preference scores

From this analysis it can be seen that water, complexity, coherence and mountain landform are all important preference predictors. It is expected that a combination of these would appear in the models created.

The appearance of inverse terms in four of the best landcover/landform predictive variables indicates a presence/absence scenario. These terms become large for zero or very low values of the landscape variables, and tend to zero for large values. The transition from the higher values (*e.g.* variable=0) to the low values (*e.g.* variable=50) is exponential in nature - the dramatic changes in the inverse curve occur only at low values. Therefore, the use of these terms implies that the variables are more important in terms of their presence or absence, rather than their absolute value.

Regression analysis: combinations of variables

In addition to the factor analysis, regression analyses using forward variable input were used. Interaction terms were included in these analyses, as were ratio terms (using the ratio of area to perimeter). Groups of variables were input (*e.g.* landcover and colour, landform alone) and the variables which were the most efficient at predicting the preference scores noted. This analysis was undertaken for both types of normalisation.

The results from these analyses indicated which variables should be used in further regression analyses. These smaller sets of variables were then used in multiple regression analysis using forward and manual variable input. A total of over 200 models were created and then compared against the criteria set out in the following sub-section.

It is not known if people give preference scores to landscapes on a linear basis, therefore it was decided to use the calculated normalised scores, rather than the ranks, to create the models. Actual scores were used, rather than transforming the data into a simpler scale (such as 1 to 100), as it is not known what score the least/most scenic landscape in Scotland would have received. Ranks were used in the analysis as it is important to look at the relative position of landscapes, in terms of their scenic beauty, as well as the actual score given to each landscape.

6.4.3 Model rationale and criteria

Using these methods, over 200 predictive models were created, with R^2 of between 0.5 and 0.9. These were then examined to find those models which best fitted the criteria below. The criteria were chosen on the basis of requiring accurate yet reproducible results.

It was necessary for models to fit the data set well; it was decided that only models with an adjusted R^2 of greater than 0.6 (*i.e.* explaining 60% of the variance in the preference scores) should be further considered. Models must not be overfitted to the data; it is possible to create a model explaining 100% of the variance, but such a model will only fit one dataset. For this reason models with over 20 variables were discarded.

Any model created should be useable by outside parties. This gives rise to several criteria. Models should preferably use either landcover or landform but not both (sky and water are included in both sets of variables), this requirement reduces the time spent analysing the landscapes by half because each landscape requires digitising only once, not twice. In addition to this criteria, it was felt important to create at least one model which did not require the use of computer technology (*i.e.* did not use colour variables or BPP) and could thus be used with only an acetate grid to measure landscape components.

Finally, models were required to predict the scores and ranks from the Validation Survey with correlations of at least 0.6 (all correlations over 0.45 are significant at the 0.01 level). As this set of data differed both temporally and geographically from the original dataset, high correlations would show models with promise. It was also recognised that the models would not be able to predict preferences for any image which had one or more variables with a value outside the range of the original data set. For this reason not all images used in the validation survey were valid to be used in the model testing.

The criteria can be summarised in the following five points.

- Models must have an adjusted R^2 of above 0.6.
- Models must not use over 20 variables.
- Models which use either land cover or landform variables but not both are preferable.
- Models should be useable by outside parties.
- Models must be able to predict scores and ranks from the validation survey with correlations of at least 0.6.

6.5 Comparison with Shafer Model

The accuracy of the Shafer model (Shafer *et al.*, 1969) was tested on the preference score data. The original Shafer model explained 66% of the variance in the preference scores using ten terms and six landscape component variables (see Appendix XI for details of the model). The data for the photographs were entered into the model, and the results compared to the actual scores obtained for both the Main and Validation surveys (Table 6.5.1); the correlations are significant at the 0.05 level. As no variable measurement in the Shafer model is allowed to have a value greater than the largest in the original dataset used to create the model, not all photographs were valid. Of the Main survey photographs, 63 out of 90 were valid; of the Validation Survey photographs, 29 out of 36 were valid.

Correlation with	Score	Rank	Normalisation
Main survey	-0.408	0.418	per questionnaire
	-0.414	0.429	per respondent
Validation survey	-0.450	0.435	per questionnaire
	-0.464	0.431	per respondent

Table 6.5.1 Shafer score compared to actual results

Previously, several authors have compared scores produced using the Shafer model to actual scores. Steinitz (1990) found that the Shafer model predicted only 17% of the variance in the preference data. Tan (1997) found a perfect correlation between the Shafer model and actual results; however this is not a statistically significant result as only five landscapes were used in the study. It should be noted that negative correlations in Table 6.5.1 are due to the Shafer model scoring in the reverse order to scoring used in this thesis.

There are several reasons which may have lowered the correlations. The photographs used by Shafer were of a different width to height ratio (40 by 32) than current photographs (40 by 27). The Shafer model therefore will not fit the current data exactly. The method of measurement is also different. Shafer used a grid technique, counting only components which filled over half a grid square. The current measurement technique uses smaller units of measurement, the pixel, and then transforms to a 40 by 27 unit image. This technique may give measurements which are slightly smaller or larger than would have been obtained using a grid system of measurements. Finally, the Shafer model used black and white photographs, which may give a very different image of a landscape than the colour photographs used for this study. It has been proven (Daniel, 1997) that there is little correlation between preference scores for black and white and colour photographs of the same scene.

6.6 Predictive Preference Models

Following examination of all models, six were chosen for further analysis. No models fitted all five criteria; the six chosen each fitted four of the five set criteria. Only Model F does not use any colour variables and is therefore able to be used without digitising software, however, it does not have a correlation of rank above 0.6. Model D has 21 variables, but will still be analysed. Model E uses both landcover and landform variables, the only model to do so.

6.6.1 Summary of models

All models are summarised below (Table 6.6.1). The correlation of each one with the data obtained from the validation survey is noted; both the scores and the ranks of the photographs are examined. Table 6.6.2 details the minimum, maximum, average and standard deviation of scores for each model.

Model	**R^2 (R^2 adjusted)**	**No. of terms**	**Variables types**	**Normalising**	**Correlation with validation data (score, rank)**
Model A	0.658 (0.638)	5	landform, colour, bpp	per questionnaire	0.604, 0.605
Model B	0.642 (0.625)	4	landform, colour, bpp	per questionnaire	0.651, 0.635
Model C	0.658 (0.637)	5	landform, colour, bpp, lpc	per questionnaire	0.644, 0.618
Model D	0.832 (0.780)	21	landform, colour, bpp	per questionnaire	0.641, 0.711
Model E	0.779 (0.748)	11	landcover, landform, colour, bpp	per respondent	0.684, 0.675
Model F	0.724 (0.681)	12	landform	per respondent	0.630, 0.583

Table 6.6.1 Summary of predictive preference models

Model	**Minimum Score**	**Maximum Score**	**Average**	**Standard Deviation**
Normalisation per questionnaire	-0.745	0.586	-0.000	0.283
Model A	-0.610	0.437	-0.000	0.230
Model B	-0.558	0.448	0.000	0.227
Model C	-0.564	0.445	0.000	0.230
Model D	-0.699	0.652	-0.003	0.258
Normalisation per respondent	-1.181	1.067	-0.008	0.518
Model E	-0.985	1.065	0.127	0.453
Model F	-1.067	0.999	-0.004	0.440

Table 6.6.2 Further details of predictive preference models

Examination of Table 6.6.2 shows that Models A, B, C and F all predict minimum and maximum scores within the range of the actual preference scores; these models also have averages of close to zero. Models D and E, however, show problems; Model D predicts a maximum outside the range of the actual data and Model E has an average well above zero. This suggests that these models may present some problems when applied to new datasets.

6.6.2 Details of Models A to F

The coefficients and significance of each term in the chosen models are detailed in Appendix XII together with the ANOVAs and residual and scatterplots for all five models. The forms of the models are set out below.

Model	Form of mathematical equation
Model A	Constant - INV_BPP + REDVAR - INV_PLM- INV_WATER+ LN_LS
Model B	Constant - INV_BPP + REDVAR - INV_PLM - R_PSKYPWATER
Model C	Constant - INV_BPP + LPC + REDVAR - INV_PLM - R_PSKYPWATER
Model D	Constant - INV_BPP + GSTDEV- BSTDEV- RGBMEA N - LN_LM - INV_PLM + LN_LS- LN_PLS + OBSVEG - POV - $OBSVEG^2$ + OBSVEG.POV + LN_TVL + R_SKY - INV_SKY - SKY + $PWATER^2$ - INV_WATER + $AWSEA^2$ - $PWSEA^2$ - PWMOVE
Model E	Constant - INV_BPP + BMEAN.BSTDEV - RGMEAN + LN_LM - INV_PLL+ PFN.AFV- R_PSKYPWATER + INV_PWATER + $AWSEA^2$ - INV_AWSTILL + INV_PWSTILL
Model F	Constant - INV_PLM + LHIGH - INV_PLL - INV_LF - LF^2 + OBSVEG + LN_SKY - SKY - INV_WATER + PWSTILL + R_WSEA - $PWSEA^2$

Table 6.6.3 Form of predictive preference models

A brief examination of the model variables in Table 6.6.3 shows that there are several variables appearing in almost all of the models. These variables are INV_BPP, INV_PLM and INV_WATER or INV_PWATER (also in the form R_PSKYPWATER). It is no coincidence that these are the same variables which were noted in sub-section 6.4.2 for their high predictive powers. The remaining variables within the smaller models (A, B, and C) can be considered to be 'tweaking' the model, while the larger models (D, E and F) use variables which have lower individual predictive powers to increase the predictive powers of the models from around $R^2=0.65$ for the smaller models to $R^2>0.72$ for the larger models.

6.7 Analysis of Model Variables

Several landscape component variables appear in the same transformations or combinations in two or more of the models. Further examination of these terms may give some indication of why these terms are important in predicting landscape scenic preference.

As stated in Section 6.2, all photograph landscape components' area and perimeter values are measured in units corresponding to a photograph 40 units wide and 27 units high; for the purpose of this analysis, the units will be named "Wherrett's landscape component units", abbreviated to WLCU. The original images all measure 580 by 395 pixels.

6.7.1 Landcover variables

Vegetation and non-vegetation variables

Only one model, E, uses any of the vegetation/non-vegetation variables. In this model the combination of PFN.AFV is a positive predictor. This term suggests that a mixture of vegetation and non-vegetation in the distant zone if preferable to a zone which has one or the other exclusively. Despite having a high individual predictive power, PMN/AMN does not appear in any of the six models.

The lack of significance of these variable types was unexpected. The Shafer model predicted preference using these terms, and it was presumed that a similar model would result from the regression analysis. However, landform and colour variables were more significant in determining landscape preference.

Sky variables

Sky terms appear in two models, with the exception of ratio of sky to water terms, which are discussed separately. In Model D, sky is represented in three terms: R_SKY, INV_SKY and SKY. The graph in Figure 6.7.1 shows that the sky terms are positive predictors of landscape preference.

It should be noted that the sky variables are useful only in predicting preferences for photographs of landscapes; in terms of landscape planning applications, this variables is not a useful factor.

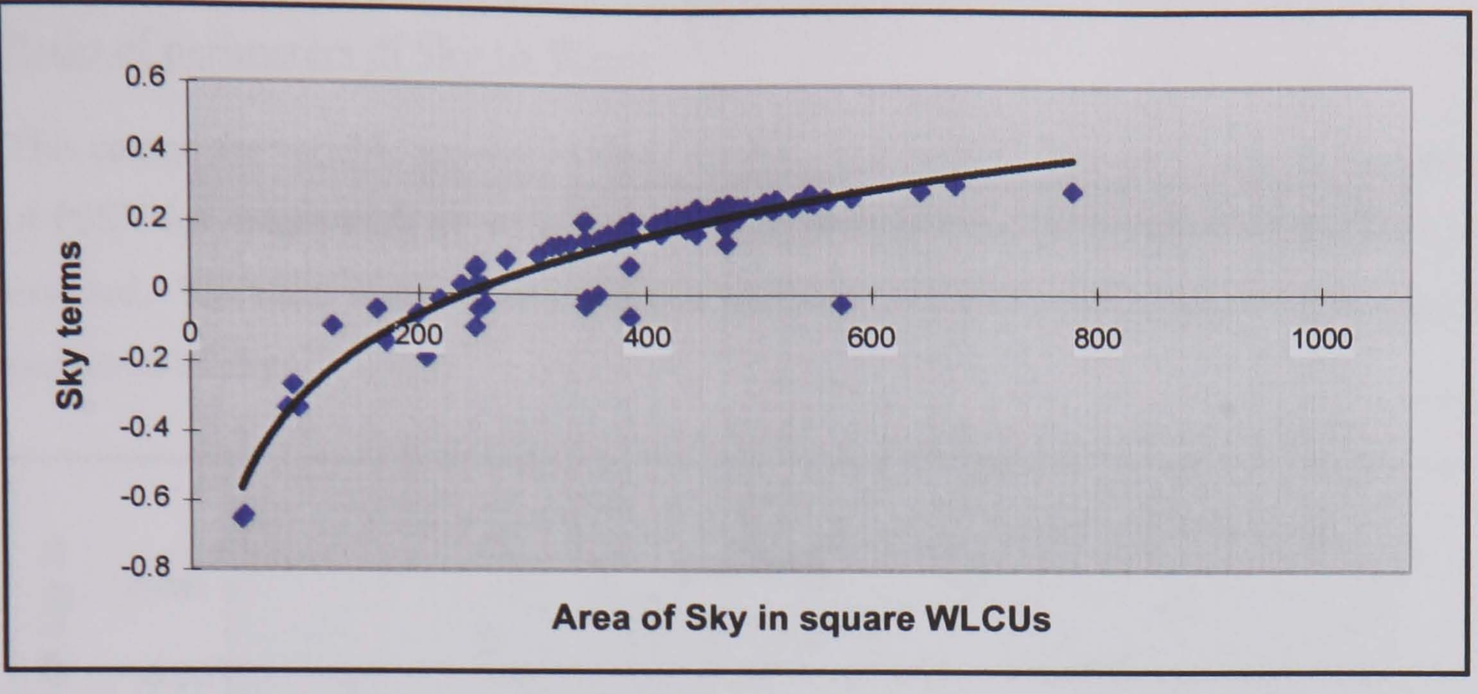


Figure 6.7.1 Area of Sky vs. Sky terms: Model D

Model F has two sky terms, LN_SKY and SKY. When plotted (Figure 6.7.2) the sky terms show a clear polynomial relationship to the area of sky, with a maximum around 275 square units of sky, which represents one quarter of the total scene. Therefore, it can be said that there is an ideal amount of sky, and that areas greater or lesser than that will produce less scenic landscapes.

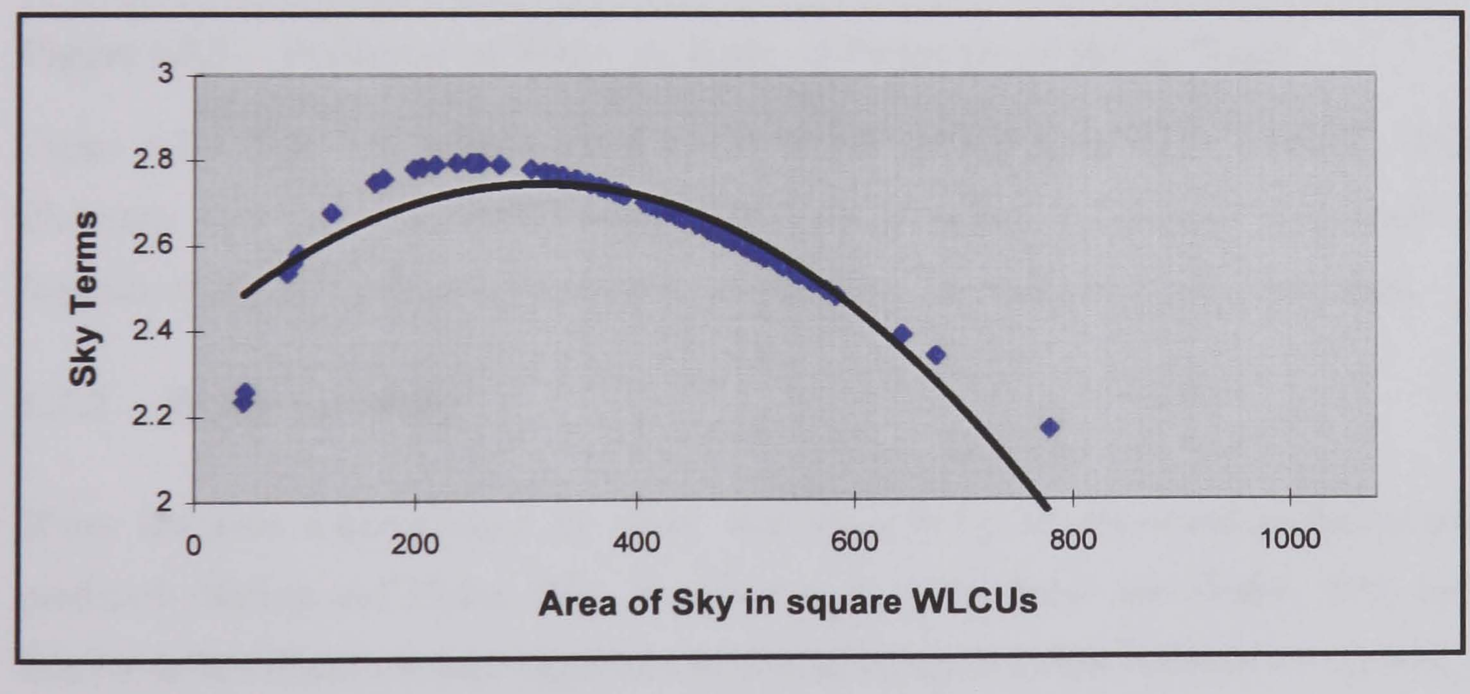


Figure 6.7.2 Area of Sky vs. Sky Terms: Model F

Ratio of perimeters of Sky to Water

This composite variable appears in three models, B, C and E. The term takes the negative value of PSKY for scenes with no water content, and therefore the preference score for such scenes is lowered. The term is therefore a positive predictor for water, but a negative predictor for the perimeter of sky.

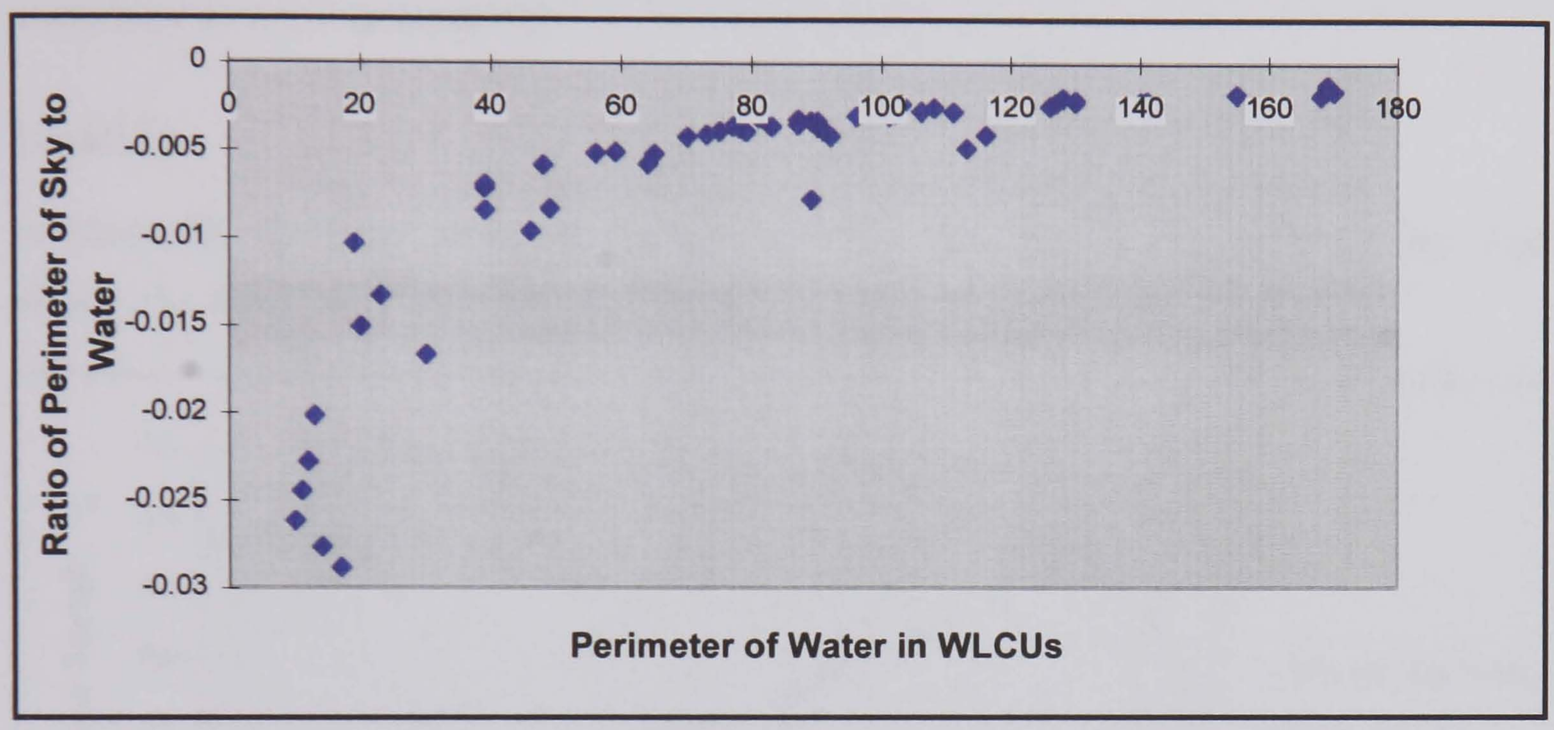


Figure 6.7.3 Perimeter of Water vs. Ratio of Perimeter of Sky to Water

Figure 6.7.3 does not include those scenes which do not have water content. This figure illustrates that the contribution of the perimeter of water to landscape preference increases logarithmically towards an asymptote as the perimeter increase towards its maximum.

6.7.2 Water variables

Water has been acknowledged by many authors as being an important landscape preference predictor (Bishop and Hulse, 1994; Hammitt *et al.*, 1994; Brush and Shafer, 1975) and is also known to be sub-consciously important to human beings as a vital resource for survival (Ulrich, 1977). Water is the only variable to appear in all six models. In analysing the landscapes used in the surveys, water was sub-divided into three types: still, moving and sea. No landscapes had more than one type of water in them.

In Model A, water is represented by a negative INV_WATER term, water therefore being a positive landscape preference predictor. In Models B and C, water is represented by the R_PSKYPWATER term, as discussed in the previous sub-section. The remaining three models use a combination of water terms, both water of any kind, and water of specific types.

As mentioned in Section 6.4, the inverse and R_PSKYWATER terms represent the effects of the presence or absence of water. As the terms have negative coefficients this implies that the absence of water of any kind produces a negative impact on landscape preference. The presence of water has a corresponding positive impact on preference, which does not alter considerably with a change in the amount of water, for example in Model A the contribution of water terms from scenes with water ranges from approximately -0.001 to -0.075, while the terms without water have a contribution of -0.3.

Model D

In Model D, the water terms can be separated into two, in order to examine their effects. Firstly, the WATER, PWATER and PWMOVE terms can be plotted

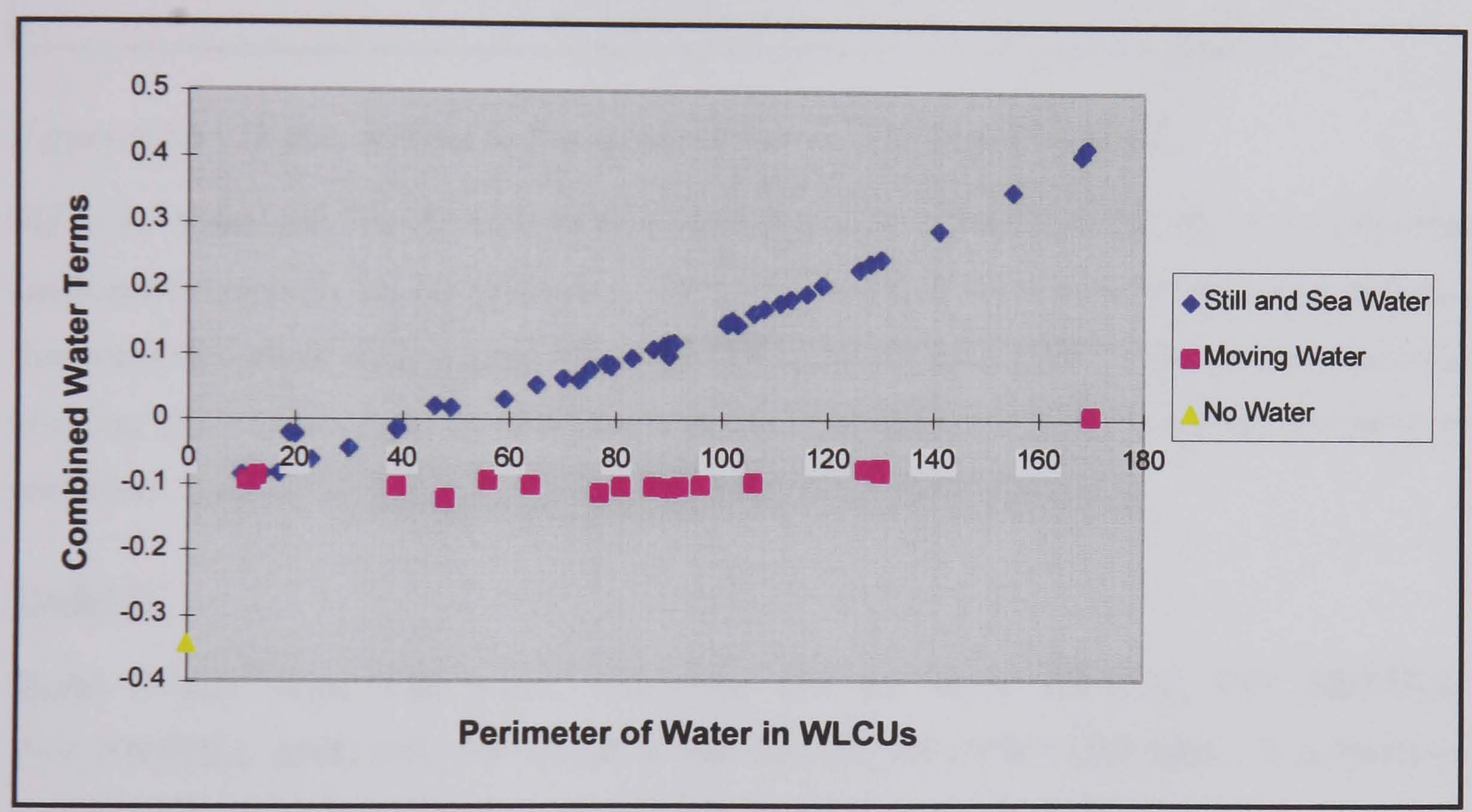


Figure 6.7.4 Perimeter of Water vs. Combined Terms: Model D

Figure 6.7.4 shows that still water and sea are positive preference predictors with the still and sea water landscapes displaying a linear relationship to the perimeter of water. Moving water is polynomial predictor. Again the INV_WATER term is causing the landscapes without water to have a relatively negative contribution to landscape preference.

Moving water appears to have a polynomial relationship with preference, with scores gradually increasing with higher perimeters of moving water. A figure of 80 WLCUs would represent a straight river crossing a landscape horizontally: this type of river would detract from the landscape compared to still or sea water.

Secondly, the two sea water terms can be examined.

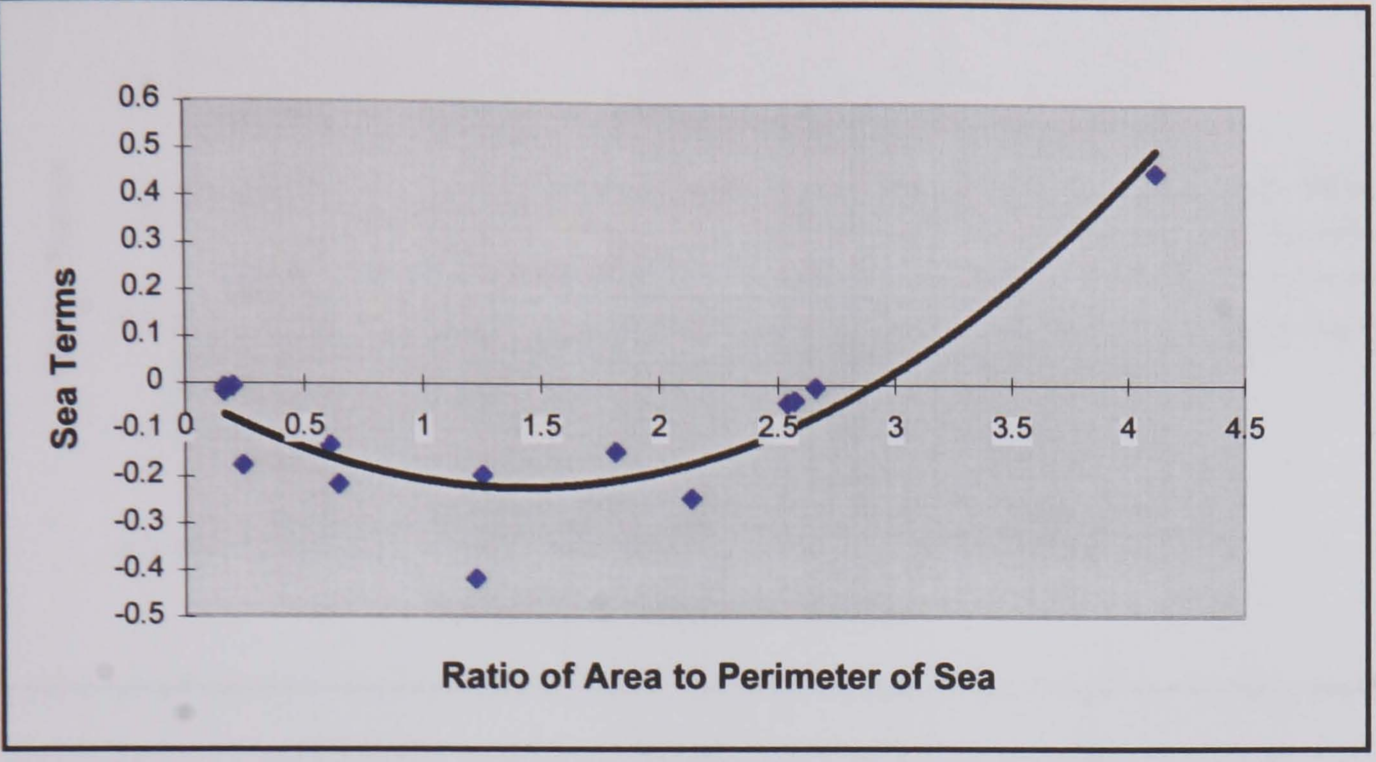


Figure 6.7.5 Ratio of Area to Perimeter of Sea vs. Sea Terms: Model C

Figure 6.7.5 indicates that the ratio of sea area to perimeter is related to the sign of the effect this landscape component has on preference. Plotting the area of sea against the sea terms indicates that when the area of sea is around 300 square WLCUs, the sign of the combined terms becomes positive; this would suggest an ideal measurement of roughly 100 WLCUs for the perimeter of sea water.

Model E

Model E uses terms with water, still water and sea water: $AWSEA^2$, INV_AWSTILL, INV_PWSTILL AND INV_PWATER, it also has a R_PSKYPWATER term. It is therefore possible to examine the effects on each of the three water types separately.

Figure 6.7.6 shows the different effects of the three water types and includes the ratio term of perimeters of sky to water. Scenes with no water score lower than scenes with water for all scenes with sea and moving water, and for scenes with over 40 WLCUs in perimeter of still water. This strongly suggests that water of any kind is a positive predictor for landscape preference.

Still water has a logarithmically increasing positive effect on preference; sea water has a polynomially positive effect. The moving water landscapes show little variation in their contribution to the preference score.

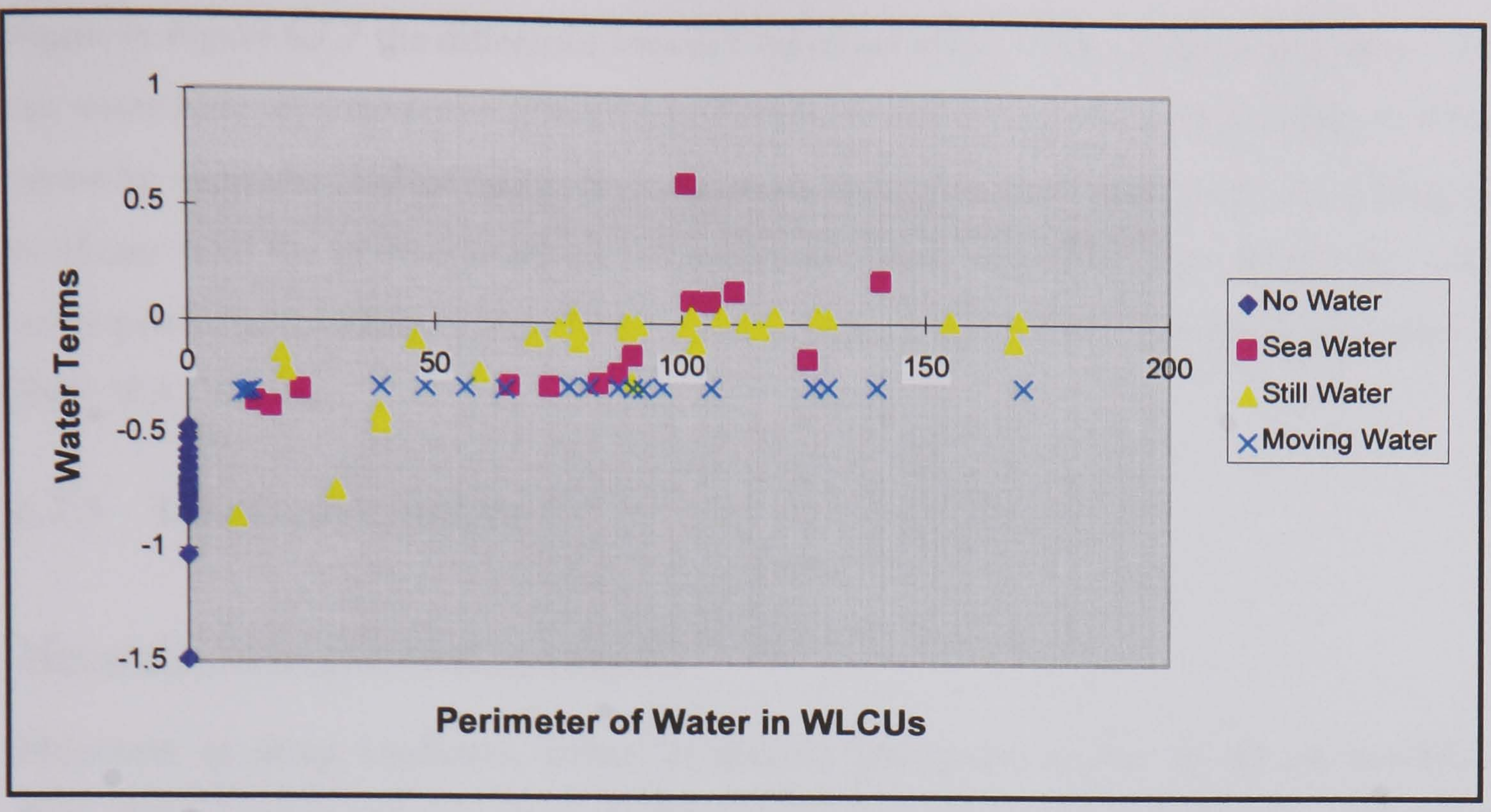


Figure 6.7.6 Perimeter of Water vs. All Water Terms: Model E

Model F

The separate effects of the water types can again be seen in Model F. In Figure 6.7.7, the three different water types are shown. The scenes with no water content are left out, the score for these would be below the minimum score for a scene with some water content, therefore making any amount of any type of water a positive preference predictor.

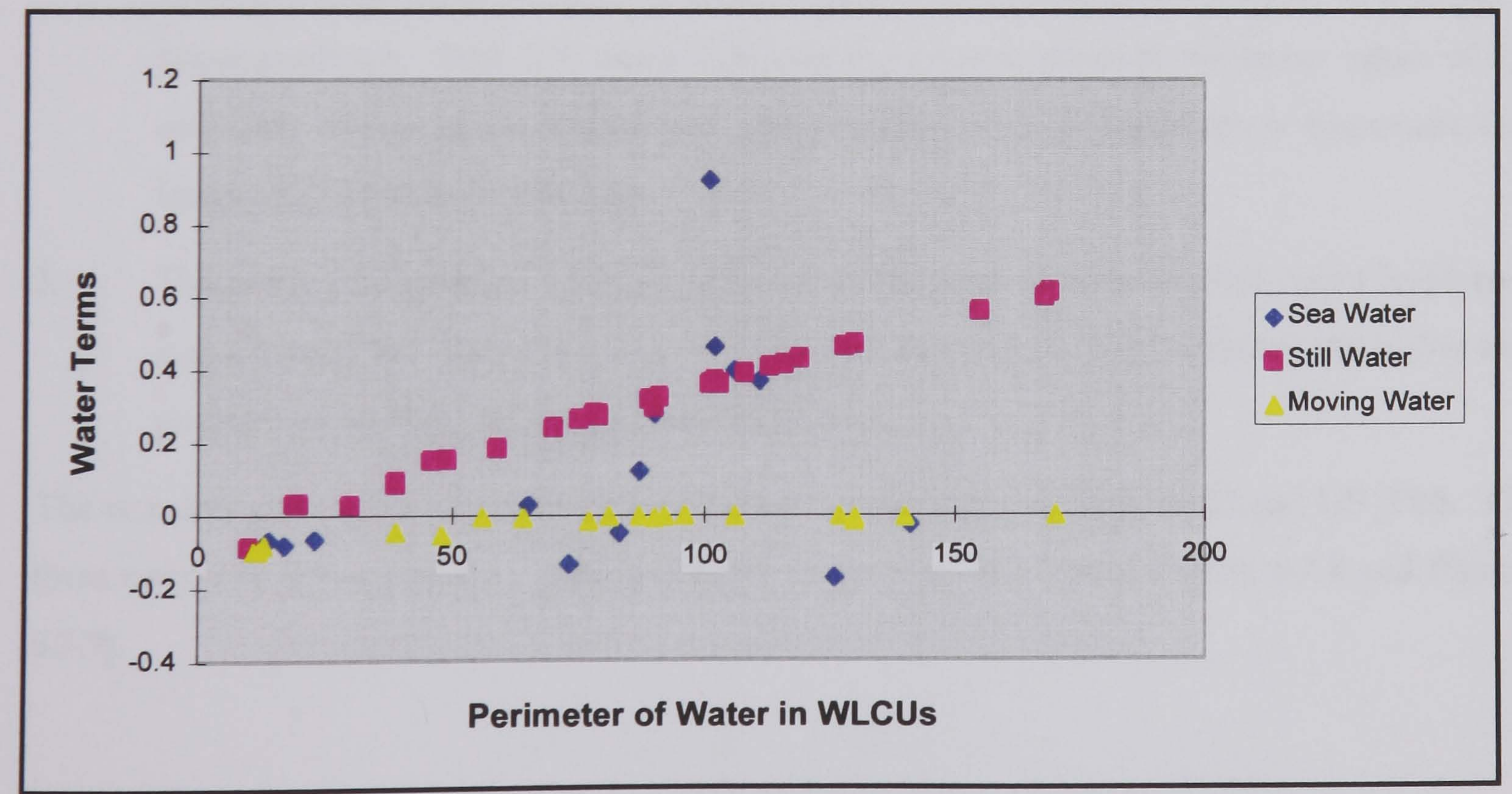


Figure 6.7.7 Perimeter of Water vs. Water Terms: Model F

Again in Figure 6.7.7 the difference between the three water types can be clearly seen. Still and sea water have separate terms (PWSTILL, R_WSEA and $PWSEA^2$), moving water is then given terms by a process of elimination (there is also a INV_W term). Still water is a strong positive predictor with the perimeter of water linearly associated with the water terms. Sea water is a cubic predictive variable, which may be due to several anomalies. Moving water takes on the INV_WATER term.

6.7.3 Landform variables

Mountain, Steep and High Landform

Mountain or steep landform, either in area or perimeter, appear in all six models. The INV_PLM term appears in four models, and LN_LM and LN_LS in two. LN_PLS, and LHIGH also appear once each. There are four of these terms in Model D, which will be discussed separately.

1. INV_PLM is a negative term, inferring that the perimeter of mountain landform is a positive scenic predictor, which intuitively makes sense. This term also implies that the presence of mountain landform, of any size, is important for high scenic preference.

2. LN_LS, as it appears in Model A, is also a positive predictor. Again this is intuitively sensible - steep land is scenic. Similarly LN_LM, appearing in Model E, is a positive linear predictor. Both LN terms will have the greatest affects at the lower values of LS and LM, which again implies that the presence of high landform is important for landscape preference prediction.

3. The composite variable, LHIGH, the sum of the areas of steep and mountain landform, is again positive. This term is linear; the larger the area of high landform, the higher the positive effect of the landscape preference score.

The remaining variables all occur in Model D: LN_LM, LN_LS, INV_PLM and LN_PLS. Of these only LN_LS is positive. The combined terms may be plotted (Figure 6.7.8 and Figure 6.7.9).

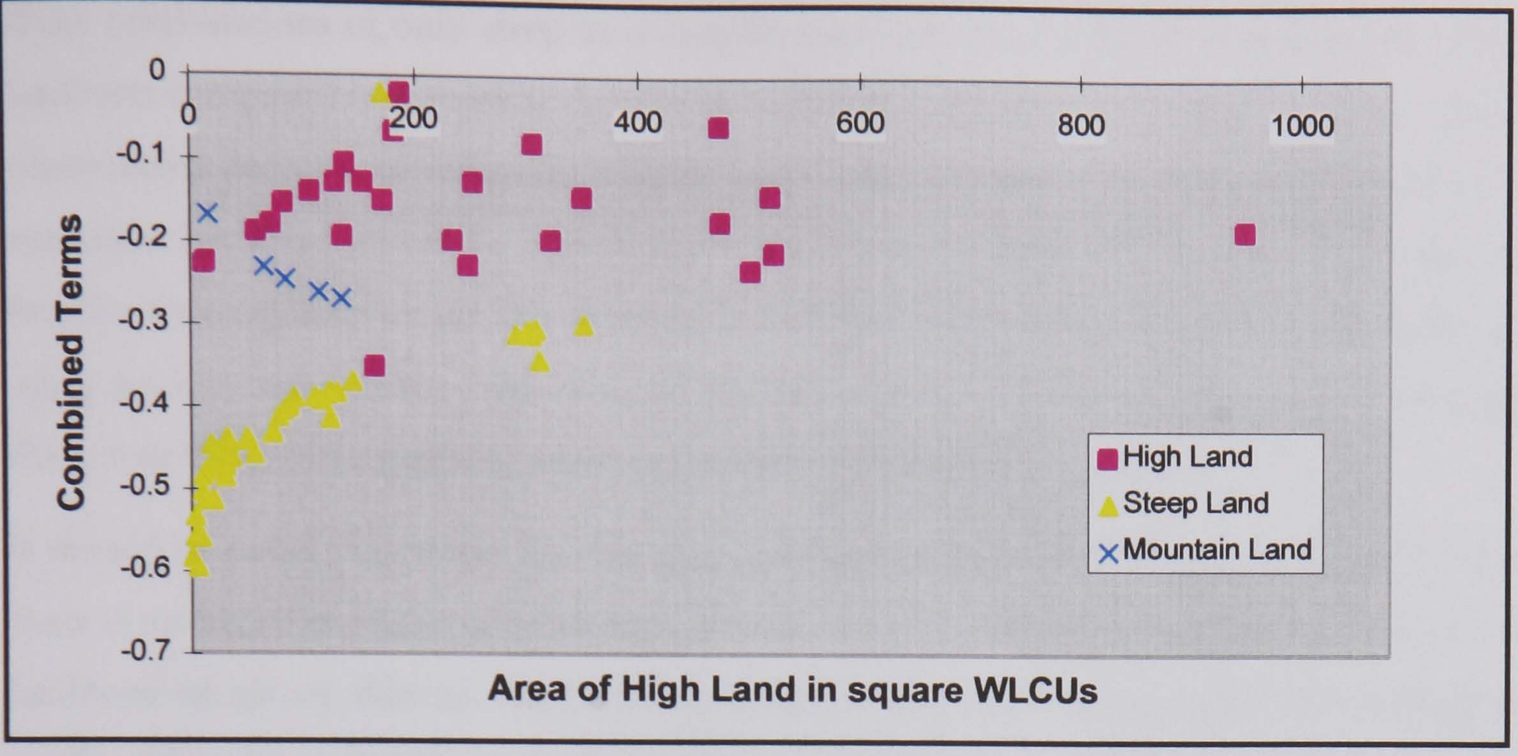


Figure 6.7.8 Combined Terms vs. Areas of High Landform 1: Model D

Several comments may be made about Figure 6.7.8. The photographs have been divided into three types: scenes with steep and mountain (high) landform, scenes with only steep and scenes with only mountain. This shows that scenes with steep landform only score lower than mountain landform only scenes. Both steep and mountain landform show logarithmic trends, with the mountain terms driven by the PLM term and the steep land driven by the LS term. High landform does not appear to exhibit any non-random effect.

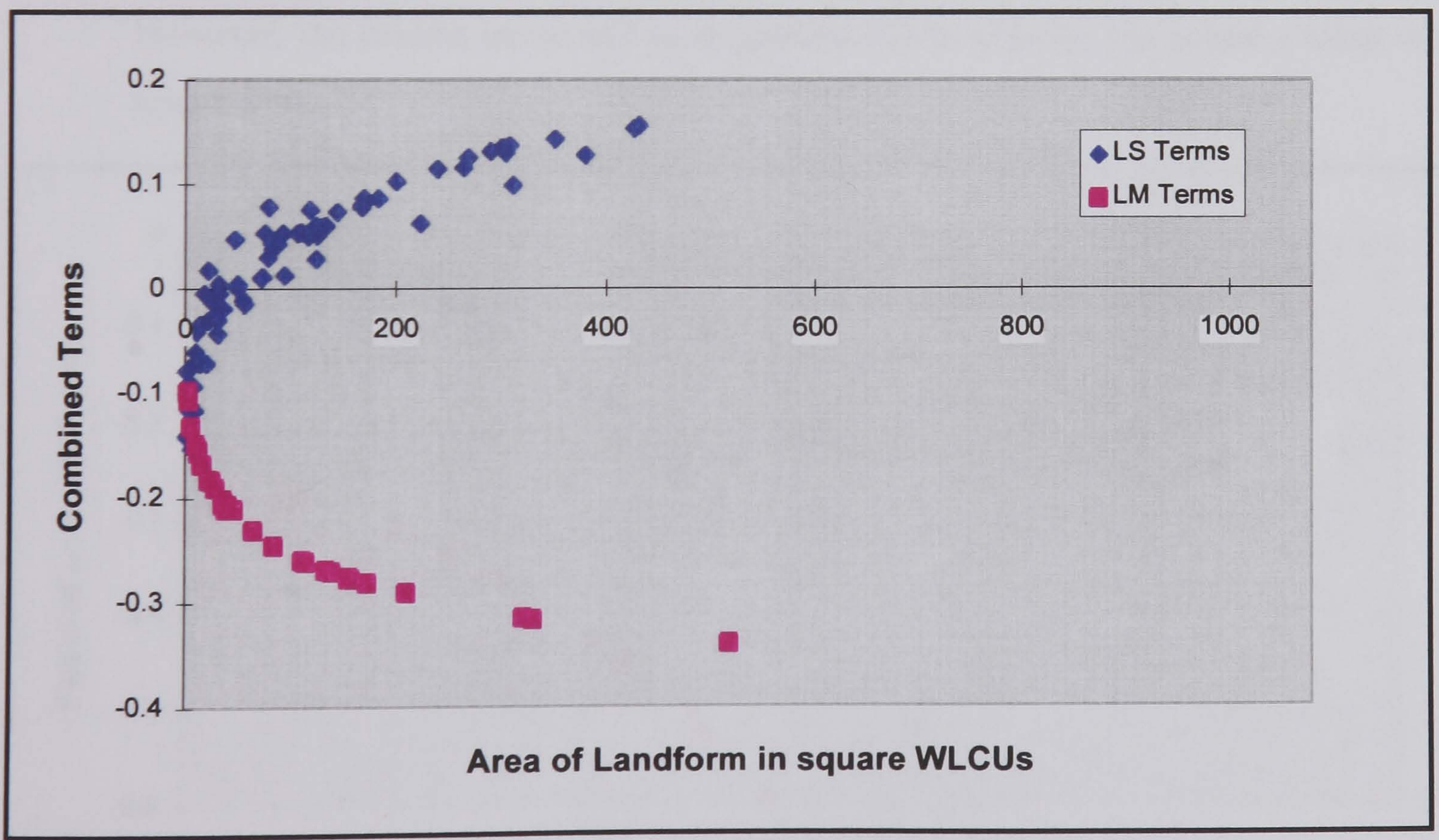


Figure 6.7.9 Combined Terms vs. Areas of High Landform 2: Model D

If the combinations of only steep or mountain landform are examined, it is seen that the steep landform components increase as the area of landform increases, but that the mountain landform components decrease as either the area or perimeter increases. It is difficult to explain why mountain landform should be a positive predictor in three models and a negative predictor in a fourth. One explanation for this anomaly is that Model D contains more terms than any of the other models, and therefore the effect of any two variables is more dilute. In only this model there is an effect of an excess of a normally positive landscape component.

It should be noted that when the two are combined in high landform, as in Figure 6.7.8, that there is no negative predictor tendency. It is the scenes which possess mountain but not steep landform which are affected. Such a scene would be unusual - the mountain area is likely to be small, and to be a singularity in the landscape, possibly thus making it a negative preference predictor.

Flat and Low Hill Landform

These variables appear in only two of the models, E and F.

1. Model E includes a negative INV_PLL term, denoting that the perimeter of low hill landform is a positive landscape predictor.

2. Model F uses three terms: LF^2, INV_LF and INV_PLL, all of which are negative. However, the inverse terms will have positive effects negating the negative effect of the square term.

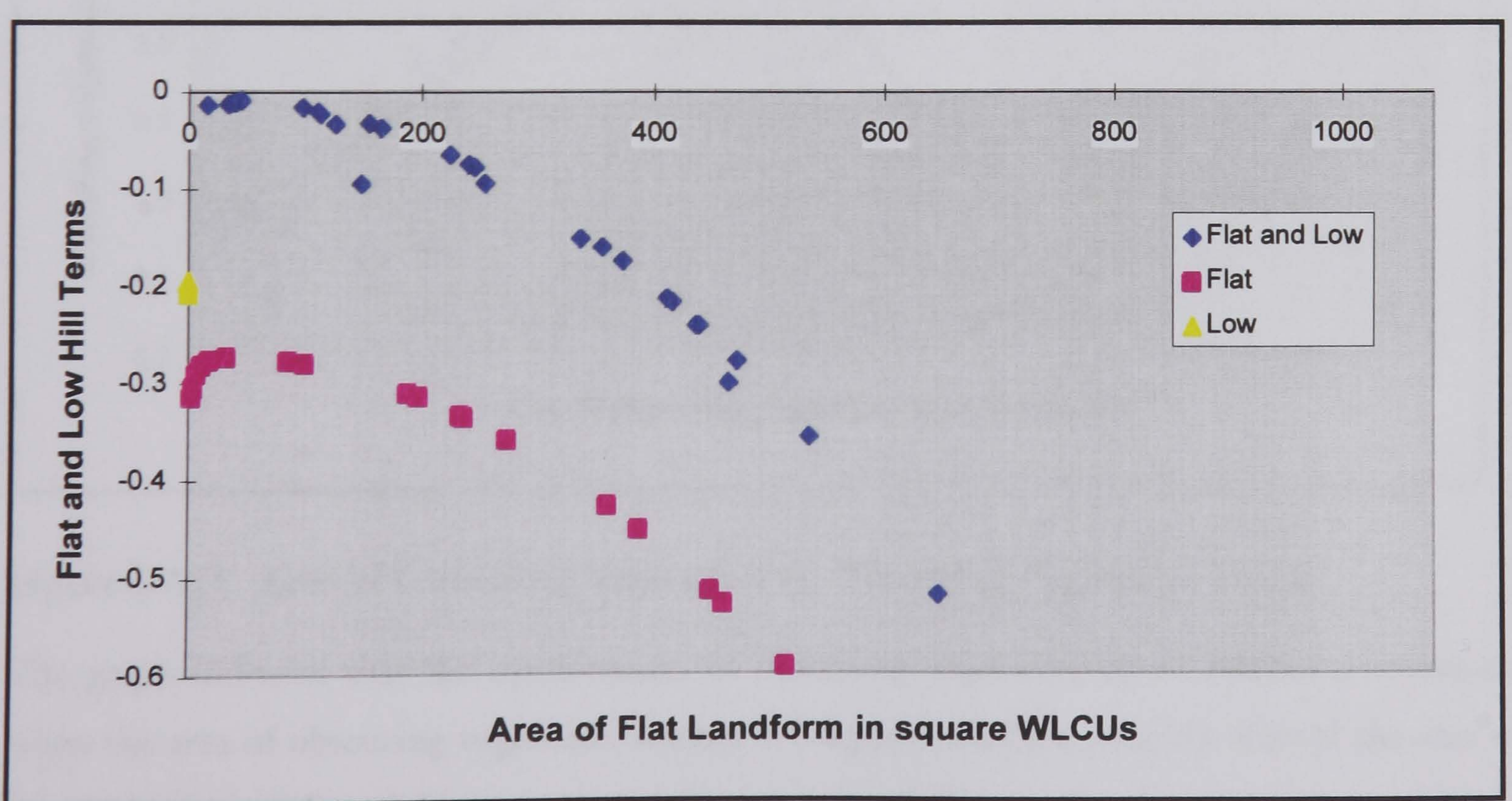


Figure 6.7.10 Area of Flat Landform vs. Flat and Low Hill Terms: Model F

Examination of the curves in Figure 6.7.10 shows that scenes with low hill but no flat landform are more scenic than areas with flat but no low hill. Scenes with only flat landform become more negative as the area increases, in the same way as scenes with both flat and low hill. However, the scenes with flat and low hill are more scenic for the same area of land. Those scenes with neither score low, on a par with a scene of 400 units of flat or 600 units of low hill and flat landform. One explanation for this is that a scene with no flat or low hill may be dominated with obscuring vegetation which may become negative predictors in excess.

Obscuring Vegetation

Two models include terms using obscuring vegetation.

1. In Model F OBSVEG is a positive linear preference predictor. It is possible that obscuring vegetation lends an air of mystery to a landscape (*cf.* Chapter Three, Section 3.3).

2. Model D uses four obscuring vegetation terms. In order to examine their effect, the combination of the terms has been plotted against the area of obscuring vegetation (Figure 6.7.11).

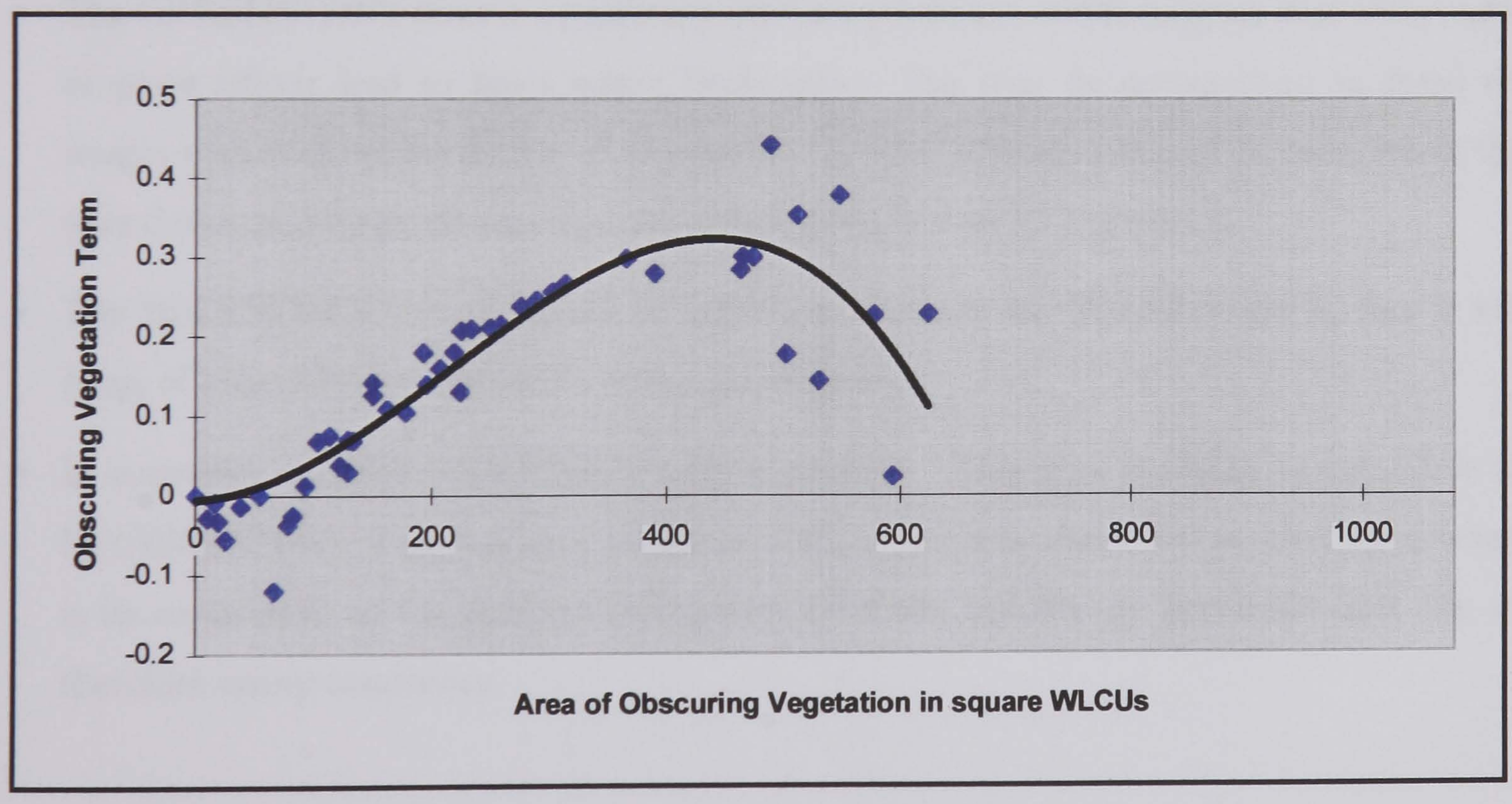


Figure 6.7.11 Area of Obscuring Vegetation vs. Obscuring Vegetation Terms

The graph indicates that the combination of obscuring vegetation terms reaches a maximum when the area of obscuring vegetation reaches 475 square WLCUs, roughly 45% of the area of the total image and a minimum at zero. Obscuring vegetation is therefore a positive predictor in moderation, but in excess becomes a negative predictor.

Total Visible Land

Model D also includes a term using total visible land - that area of landform which is neither water nor obscuring vegetation. LN_TVL is a positive predictor for landscape preference. Since the term is a natural logarithm transformation, the effect of very high amounts of visible land is not significantly greater than the effects of small amounts of visible land.

6.7.4 Colour variables

Colour variables are included in four of the models. REDVAR is seen in two models, RGBMEAN and RGMEAN are seen once each, as are GSTDEV, BSTDEV and BMEAN.BSTDEV.

- The positive REDVAR terms imply that wider variations of the red colour within an image are likely to encourage higher preference scoring.
- The negative RGBMEAN and RGMEAN terms suggest that high mean colour is a negative predictor; it is hypothesised that higher products of colour means would occur in lighter images, possibly where the colours are slightly washed out.
- The GREENSTDEV term is a positive preference predictor, which suggests that wider values of green colour lead to more scenic landscapes. This may be extrapolated to mean that images with well balanced areas of vegetation and other components may be more scenic than ones dominated by green vegetation or which have little or no vegetation.
- The BLUESTDEV term is negative, implying, contrary to GREENSTDEV, that a wide range of blue colour is less scenic than a narrow range.
- In converse, the BMEAN.BSTDEV term is positive. This term is highly correlated to the BLUEMEAN terms (correlation coefficient 0.91). One hypothesis for the effect of this term is its connection to the amount and quality of water and sky, in particular blue sky and therefore sunny conditions.

6.7.5 Photographic resolution

Bytes per pixel

Four out of the five models have a bytes per pixel term. In all of these the variable is inverse and negative ($-BPP^{-1}$). It was concluded in sub-section 6.2.3 that BPP may be used as a surrogate for complexity in a landscape. The BPP term is negatively inverse, so that as its value increases, its negative impact decreases and the overall preference score increases. Thus BPP and therefore landscape complexity is a positive predictor for landscape preference.

Landform polygon count

Landform polygon count is a positive landscape preference predictor. Appearing in one model, it increases the explanation of the variance in preference scores from 64% in Model B to almost 66% in Model C. It has been hypothesised that this variable measures a form of coherence in the landscape image.

6.8 Summary and Discussion

6.8.1 Variables

The landscape component variables used in the landscape analysis are noted below. Definitions for the subjective components (landcover and landform) were set down.

Area and perimeter of landcover:	**Area and perimeter of landform:**	**Mean and standard deviation of intensity of colour bands:**
immediate vegetation	flat*	red*
intermediate vegetation	low hill*	green*
distant vegetation*	steep hill*	blue*
immediate non-vegetation	mountain*	
intermediate non-vegetation		size of file in bytes*
distant non-vegetation*	obscuring vegetation*	(all files are 580 x 395 pixels)
still water*		
moving water*		number of polygons covering
sea water*		more than 1% of the image*
sky*		
(after Shafer *et al.*, 1969)	(after Brush, 1981)	(further variables)
* These components are used in one or more models in this thesis		

Table 6.8.1 Landscape component variables

In addition to the variables in Table 6.8.1, several combinations and transformation of variables were used, including inverses, natural logarithms and squares.

Variable measurement

The techniques used to measure the landscape component variables were based on the use of ERDAS Imagine. All photographs were digitised twice, creating 180 vector coverages, from which the areas and perimeters of the components could be calculated. These measurements were then converted into units which are not dependent on pixel, metric or imperial measurements. All photographs measured 40 by 27 units, therefore having an area of 1080 square WLCUs (Wherrett's landscape component units).

The minimum and maximum for each variable was noted. No photograph from a different data set with a value beyond these boundaries will be valid for a model if that variable appears in the model being used.

6.8.2 Statistical methodology

The scores gained from the surveys were normalised in two fashions: per questionnaire and per respondent. Following principle component factor analysis, the landscape scores were regressed against the measurements from the landscape analysis to create a series of landscape preference models. Those models best fitting the pre-defined criteria were then detailed.

The preference data was also compared to results from the Shafer model. While this model did not perform as well as might be expected, there are several possible reasons for this, including the difference in the size of the original photographs, the different method of measuring the landscape components and the use of colour, rather than black and white, photographs.

6.8.3 Model variable investigations

The six models were further examined to look at the predictive trends of groups of variables found within the models. Models A, B and C do not have more than one term for any one variable, whereas models D, E and F have several cases each which may be examined. There is some concern these latter models may be overfitted to the data and their analysis, particularly in the case of Model D, may produce spurious results.

Landcover

The landcover variables originally used by Shafer *et al.* (1969) were rarely significant in the models created which fitted the stated criteria. Only one term in the six models used these components. This was surprising, as many models have used such variable types since the research undertaken by Shafer and colleagues.

Sky

Sky variables were used eight times. Conclusions regarding this component were that it can become a negative predictor at larger areas and that the perimeter of sky is a negative predictor. This finding has implications for the ratio of sky to land in photographs taken for landscape perception purposes.

Water

Water variables appear in all models. In many of the models, the use of inverse terms suggest that the presence of water is of extreme importance for landscape preference. As an individual variable water can predict over 35% of the variance in preference scores. This fact alone is extraordinary and emphasises the importance of water as a predictive variable.

Water is uniformly a positive predictor, however the three different water types have very different types of positivity. Still water is polynomially positive. Sea water shows cubic trends regarding its influence on landscape preference, and starts adding to, rather than detracting from, a score at around 300 square WLCUs, or 100 WLCUs in perimeter (equating to approximately one third of the scene). It should be noted that many of the highest scoring photographs were from a mountainous area of Scotland surrounded by sea lochs. Moving water appears to have a low variation in its influence on scenic preference.

Landform

High landform, *i.e.* steep or mountainous landform, is a positive predictor for landscape preference. However, on further examination, it is seen that while scenic value increases as steep landform increases, scenic value declines as mountain landform increases. Landscapes with both steep and mountain landforms are generally more scenic than ones with only one of these landforms.

Low hill and flat landform are negative predictors, although scenes with neither score lower than scenes with one or the other. Similar to mountain landform, their scenic value declines as they increase. The perimeter of low hill is, however, a positive predictor.

Obscuring vegetation is also a positive predictor, behaving in a cubic polynomial manner. Beyond values of 475 units, higher areas cause lower preference scores and the term becomes a negative predictor. Total visible land, the sum of the four landform types, is a logarithmically positive predictor in the one model in which it appears.

Colour

The three colour bands give very different predictive values. Wide variations of red and green are ideal, while blue variation should be limited for a high preference score. Blue mean colour is required to be high for a good score, possibly this fact is linked to the colour of water and sky.

Photographic resolution

The bytes per pixel variable can be compared with the complexity of an image. This variable is a positive predictor. Due to its appearance in an inverse term, it is the very low complexity images which are the most affected; the asymptotic effect of the term means that very high complexity images do not score significantly higher than medium complexity images.

The landform polygon count is related to the coherence of the image, in terms of its landform, rather than its absolute coherence. This variable is significantly and positively related to landscape preference.

6.8.4 Psychological summary: the ideal landscape

The model variable investigations have identified positive and negative predictors. An ideal landscape photograph of 1080 square units should have around 250 units of sky, and the sky perimeter should be kept low. There should be water in the scene, preferably a contiguous block of sea water (perhaps 300 units, with a perimeter of 100 units), if not, still water will be much more scenic than moving water (as long as the perimeter is at least 60 units).

The scene should have a diverse mix of landforms: in excess of 400 units of low hill or 600 units of flat would be adverse to the scenic quality; 100 of each would be positive. There should be both steep and mountain landform and some obscuring vegetation, giving the scene a sense of mystery.

Finally, the colours within the scene: a wide range of reds and greens, but a narrow range of blues. The blue mean should be high, but without making the product of the means too large. The image should be complex, involving many edges and changes of colour.

Figure 6.2.1 and Figure 6.8.2 show an impression of landscape which incorporates the above features and the highest scoring landscape from the Main Survey. The landscape photograph shown is of the Knoydart Peninsula on the west coast of Scotland. It is interesting to note that the highest scoring image (normalising per questionnaire) was of the same area, but consisted of only water and mountainous landform.

Figure 6.8.1 Author's impression of an ideal landscape

Figure 6.8.2 Highest scoring landscape photograph (normalising per respondent)

6.8.5 Synopsis

Variables and variable measurement

All photographs were digitised in ERDAS Imagine 8.2 at a size of 580 by 395 pixels. Areas and perimeters were measured in units corresponding to a picture size of 40 by 27 units.

- Land Cover: area of distant vegetation and perimeter of distant non-vegetation
- Water: area and perimeter of still, sea and moving water
- Sky: area and perimeter
- Land Form: area and perimeter measurements
- Colour and bytes per pixel in GIF image
- Number of polygons in the landform coverage

Model creation and examination

A combination of factor analysis and multiple linear regression on the landscape variables and several mathematical transformations of those variables were used to create six predictive preference models. These models were then examined in detail.

Positive predictors of landscape preference

- area of distant vegetation x perimeter of distant non-vegetation
- ratio of perimeter of sky to water (for water)
- area and perimeter of water (sea and still water more positive than moving water)
- area and perimeter of mountain landform
- area of steep and high landform
- perimeter of low landform
- area of total visible land
- bytes per pixel in GIF image
- landform polygon count
- red and green standard deviation, blue mean

Quadratic and cubic predictors of landscape preference

- area of sky
- obscuring vegetation

Negative predictors of landscape preference

- ratio of perimeter of sky to water (for sky)
- area of mountain landform (in model D only)
- area of flat landform
- product of red, green and blue, and of red and green means, blue standard deviation

Chapter Seven

Landscape Preference Questionnaire (Part III)

Weather, lighting and other refinements

7.1 Introduction

In addition to the Pilot, Main and Validation surveys, the flexibility of the Internet survey methodology allowed several other aspects of landscape preference to be examined. These include: the effects of weather, season and lighting; the effect of cultural buildings; the effect of different photographers; the effect of colour difference; the effects of camera focal length; and the effects of right/left bias.

Six different surveys were run to determine the effects of these various criteria. These surveys were undertaken over a time period of approximately one year (from June 1997 to September 1998) and encompassed three different groups of respondents: Internet respondents; visitors to the MLURI Open Days (June 1997); and visitors to the Edinburgh International Science Festival exhibition hall at the Royal Botanic Gardens in Edinburgh (April 1998).

The majority of surveys used identical methodologies to those described previously. In cases where alternative systems were used, the reasons and details are provided.

7.2 Weather and Lighting Survey

The photographs used in the original survey encompassed a wide range of weathers, seasons and lighting conditions. Due to the nature of the Scottish climate it would have been impossible to collect a sufficiently large range of photographs with similar weather conditions within a reasonable time scale. This survey examined the effects these different conditions have on landscape preference.

7.2.1 Photography Sites

Twenty-three sites were selected for monthly visits, for one year (from November 1996 to January 1998), and a total of thirty-three photographs were taken each month of identical scenes from identical positions. These sites were chosen following the collection of photographs around a circular route from Aberdeen; the images and sites chosen represented a wide collection of landscape types within a reasonable driving distance (around 150 miles/240 kilometres for a round trip). This collection of photographs was then able to be used to examine the effects of weather, season and lighting on landscape preference.

Due to camera equipment failure, several sites were missed in July and August of 1997. The position of the sites is shown in Figure 7.2.1, with the significant towns and villages marked.

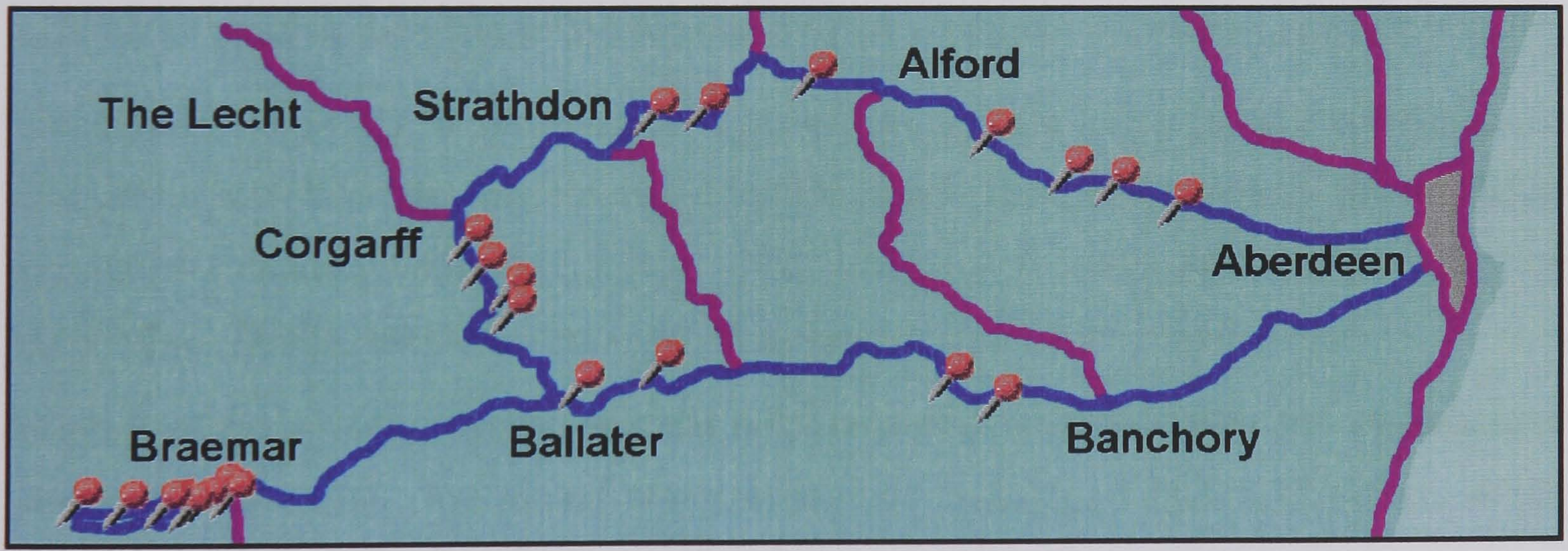


Figure 7.2.1 Geographical position of sites: Weather and Lighting Survey

7.2.2 Variables measured

For each photograph the following information was collected:

- Time of day (converted to Greenwich Mean Time (GMT) during summer months)
- Light-level (in EV, using a lightmeter)
- Cloud cover, in both local (directly above the photographer) and distant sky (in eighths of visible sky)
- Temperature (degrees Celsius)

7.2.3 Questionnaire survey design

Two different questionnaires were created. The first was an adaptation of the survey used for the Validation survey; the major differences being in image size (as mentioned in Chapter 4) and in the use of a JavaScript to determine screen resolution for Netscape users. Ten versions of the questionnaire used twelve of the scenes each, with scenes appearing in the same order in each version. The photograph date was then randomly assigned to the questionnaire versions.

The first survey used twelve scenes to examine the effects of different lighting, seasonal, weather and time of day effects. One photograph from each scene, with summer or autumnal vegetation, was digitised. The colour variables for each of the 120 photographs were also calculated. This gave each photograph a score from each of the seven models. The results could then also be analysed to examine the effects of the weather and lighting data on the preference scores.

The second survey directly compared two photographs of the same site taken at different dates. This survey was undertaken in order to confirm the results from the first survey, and to validate any models containing temporal variables. This survey used the LCJ method of data gathering (see Chapter Three), and results are displayed as a percentage of one of a pair chosen.

The first of these surveys took place in the early months of 1998, following the completion of photograph collection. The second survey took place in spring of 1998, with visitors to the Edinburgh Science Festival requested to take part in the survey.

7.2.4 Respondents from the first survey

Responses from 243 people across 35 different countries were obtained over a four month period in early 1998. The log-in times of these responses have been analysed, as in Section 5.3, and the socio-demographic profiles broken down. The figures for these profiles are detailed in Appendix XIII.

The gender ratio, of forty females to sixty males, is similar to that found in many Internet surveys (see Section 5.7), and has a slightly higher female proportion than the previous two surveys. Age band analysis shows similar results to both those obtained previously and to those obtained by other Internet surveys. The nationality breakdowns, however, show some differences to the counts obtained previously. There are fewer North American respondents and more European respondents. This result is partly explained by several northern European institutes contributing a large number of responses. However, overall the sample of respondents is comparable to those of previous surveys.

Resolution	Number	Percentage
640 x 480	0	0.00%
800 x 600	178	73.25%
1024 x 768 and above	65	26.75%

Table 7.2.1 Screen resolution used by respondents

The results in Table 7.2.1 are markedly different from any previous results found. In the results described in Chapter Five, only the screen size was recorded, based on the assumption that screen size and resolution were related (as discussed in Chapter Four, Section 4.3), an assumption which was revised in light of subsequent experience.

7.2.5 Regression analysis

Using the data from the 12 scenes and the preference scores gathered, analyses of variance were run on the actual scores and the weather and lighting variables. This analysis was designed to select variables which might improve the existing models by the addition of further variables.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Intercept	2995	1	2995	848.2	0.000***
Site	1040	11	94.59	57.41	0.000***
Month	66.84	11	6.076	3.688	0.000***
Light	44.66	14	3.190	1.936	0.019*
Local Cloud	21.89	8	2.736	1.661	0.103
Distant Cloud	61.81	8	7.726	4.689	0.000***

Table 7.2.2 Analysis of variance: Weather and Lighting Survey

The results show that the month or season in which the photograph is taken and the amount of cloud in the distance are significant in the scores given to the images. Since month/season is not a quantitative variable it was decided to further test only the distant cloud variable. Multiple regression analysis was run on the original data from the Main Survey with the added cloud variable.

Measurement of distant cloud cover was done by eye, estimating how many eighths of the sky were cloudy, following the technique used in the weather and season photograph data collection. It is acknowledged that it would be preferable to have digitised the skies of each photograph to gain a more accurate figure for the proportion of cloud in the sky.

One model, based on Model B, was created which fitted the criteria set out in Chapter Six (Table 7.2.3). The addition variable representing the number of eighths of cloud cover is called DISTANT_CLOUD.

Model	R^2 (R^2 adjusted)	Form of mathematical equation
Model W	0.655 (0.634)	Constant - INV_BPP + REDVAR - INV_PLM - R_PSKYPWATER - DISTANT_CLOUD

Table 7.2.3 Form of mathematical equation: Weather and Lighting Survey

The negative DISTANT_CLOUD term implies that clear, blue skies or skies with few, well defined clouds, will produce landscape photographs which have a higher aesthetic value to observers. However, it should be noted that the significance of the DISTANT_CLOUD term in the model is lower than any other variable in any other model (P=0.082) (see Appendix XIII). It is therefore not expected that this model will have a significantly greater utility than Model B, on which it is based.

Model W was correlated against results from both the Validation survey and the Weather Survey itself; all correlations are significant at the 0.001 level. The results are detailed in Table 7.2.4.

Dataset	Scores	Ranks
Validation Survey	0.646	0.632
Weather and Lighting Survey	0.574	0.584

Table 7.2.4 Correlation with Validation and Weather Survey results

7.2.6 Results: First weather survey

The scores from the first survey were compared to the predicted scores from the seven models. The models were broken down into colour (including BPP) and non-colour components, as the consequences of changes in the date of the photographs show up only in the colour variables of the photographs.

Model	Without-colour terms	With-colour terms	Ranks of all-terms
Model A	0.684	0.651	0.656
Model B	0.658	0.614	0.612
Model C	0.635	0.585	0.554
Model D	-0.093	-0.039	0.155
Model E	0.666	0.577	0.613
Model F	0.670	0.670	0.646
Model W	0.634	0.574	0.584

Table 7.2.5 Comparison of actual to predicted scores

Table 7.2.5 shows a marked difference between the correlations of the with-colour and without-colour terms to the actual scores. All correlations are significant at the 0.01 level with the exception of Model D. In all but one case, the addition of the colour terms actually reduces the correlation. This leads to a hypothesis that changes in colour may not be highly significant in determining scenic beauty. The findings of Bishop (1997) suggest that respondents are able to perceive colour difference accurately; perhaps this is only significant when comparing the colours of artefacts within a scene and does not influence the scoring of an image when seen individually.

7.2.7 Results: Second weather survey

Table 7.2.6 shows the percentage of photographs which were correctly ranked (either first or second) by the models. Model F is not used as it cannot distinguish between the different seasons of the photographs.

Model	Number correct	Percentage correct
Model A	13	45%
Model B	15	52%
Model C	14	48%
Model D	18	67%
Model E	16	59%
Model W	13	45%

Table 7.2.6 Correctly predicted ranks of weather validation images

The percentages which the models are accurately predicting are extremely low, only three out of the six managing over 50%. Considering that a random model should predict close to 50%, this is a poor result from the models. Model D predicts almost two-thirds of the pairs correctly; however, this is not seen as a significant result due to its poor performance in predicting the results of the first weather survey (Table 7.2.5).

Model W does not perform any better than its counterparts, predicting correctly less often than Model B, on which it is based. This implies that while cloud cover is a significant preference predictor, it is no more important to scenic beauty than steep landform or coherence (Models A and C).

These results also agree with the findings of the first weather survey: colour is not highly significant in determining scenic beauty. Models which use colour terms cannot predict the difference between scenes taken at the same site at different times, it is therefore not only the changes in colour in these scenes that is driving the scenic preference. Similarly, cloud cover is not crucial in determining scenic preference.

7.2.8 Discussion

Both surveys showed that the models were poor predictors of landscape preference when the difference in landscapes is temporal rather than geographic. In the first survey the changes in colour predict almost none of the variance in scenic preference. In the second survey, the results are no better than a random choice would be.

Although Model D predicts the results of the second survey well, it predicts almost none of the results of the first survey, and is therefore not considered to be a good predictor of landscape preference for this survey.

It is hypothesised that the reason for none of the weather, lighting or season variables affecting the preference scores of the images is due to the familiarity and experience factor. The respondents may see the photograph in poor, wintery lighting, but they are able to subconsciously translate that scene to another time of year and so to better conditions. Therefore all photographs may be being scored as if they were seen in the same conditions. This implies that it is the geographical landscape which is being given a preference score, rather than any temporal anomaly associated with that landscape.

While distant cloud was a significant predictor as used in Model W, such a model is only useable for predicting preference for landscapes which have already been captured on film; the variable can explain some of the variance in landscape perception but is not practical for use in landscape planning.

On examining the socio-demographic results it was found that proportions of ages and genders were similar to those found in previous surveys, however, the results also found that none of the respondents used the smallest screen resolution (640 by 480 pixels). As this survey used a JavaScript to determine screen resolution for all users of Netscape (currently the most popular WWW browser; used by over 80% of respondents), it can be said that the assumption of Chapter Four, that screen size and resolution are correlated, is now incorrect. This does not invalidate previous results, but merely notes that the size of image shown may not have been maximised for all respondents.

7.3 Cultural Structures Survey

7.3.1 Methodology

Seven photographs of scenes which included some cultural building or structure were gathered during the field trips in mid-1997. As Bishop and Leahy (1989) note, cultural modifications can be clearly outlined but the effect of different types of modification is highly subjective. In this study, cultural buildings were defined as older and traditional buildings such as castles and cottages, both functional and ruined, while cultural structures were represented by prehistoric artefacts. One photograph with a modern structure was also included. Four of the scenes were then digitally altered to remove the building from the photograph.

A survey was run, during the MLURI Open Day and subsequently on the Internet, and again at the Edinburgh International Science Festival, to examine the preferences for these images. A survey was designed that mixed the twelve images with the 36 images used in the validation survey.

The geographic distribution of the images can be seen in Appendix XIV.

7.3.2 Analysis and Results

Images used in the Validation survey

A total of 43 replies were received for this survey. The scores for the 36 validation images were compared to the scores obtained within the Validation Survey in order to examine the level of consensus between the two samples of respondents.

Correlation	Cultural Buildings Survey		Normalisation
	Scores	Ranks	
Validation Survey	0.779	0.745	per respondent
	0.669	0.587	per questionnaire

Table 7.3.1 Correlation between normalised preference scores: Validation and Cultural Structures Surveys

The correlations between the two sets of scores and ranks for the images used in the Validation survey are significantly correlated at the 0.01 level.

Regression modelling

The cultural structure images were used to create the models; the manipulated images were not used in the regression modelling. The seven images were added to the ninety images used in creating the models described in Chapter Six. The variables used in each of the models previously created along with the addition of variables describing the cultural structures were regressed against the actual scores.

The measurements of the structures were mathematically transformed, as previously described in Chapter Six. The exceptions to this were the inverse term, $(X+1)^{-1}$, which was replaced by $X^*(X+1)^{-1}$ and the ratio terms where both area/perimeter and perimeter/area were used. This was done to ensure that all cultural terms in the modified models would revert to zero if no cultural buildings were present.

Code	Variable
ACULT	Area of cultural buildings
PCULT	Perimeter of cultural buildings

Table 7.3.2 Variables codes: Cultural Structures Survey

Several statistically significant models were found. Those which fitted the original criteria the best are detailed below. Both of these models use the variables from Model B and preference data which is normalised per questionnaire.

Model	R^2 (R^2 adjusted)	Form of mathematical equation
Model X	0.701 (0.670)	Constant - INV_BPP + REDVAR - INV_PLM - R_PSKYPWATER - ACULT*INV_ACULT + PCULT*INV_PCULT - $ACULT^2$ + $PCULT^2$ - R_PCULTACULT
Model Y	0.653 (0.634)	Constant - INV_BPP + REDVAR - INV_PLM - R_PSKYPWATER + PCULT*INV_PCULT

Table 7.3.3 Form of mathematical equations: Cultural Structures Survey

If Models X and Y are tested against the data for the validation data from the cultural survey, as well as the cultural buildings data, the following correlations are found (Table 7.3.4). To obtain these figures, scores for 36 photographs without buildings and seven with, were tested against the two models. It should be noted that this was not done with new cultural structure photographs, as none were available at the time of analysis.

The results from this analysis show that Model X is poor at predicting scores (not significant) while predicting ranks to a significant level, while Model Y gives significant correlations (0.001 level) with both scores and ranks (Table 7.3.4). Therefore, Model X will be discarded and Model Y retained. Further details of these models are available in Appendix XIV.

Model	Scores	Ranks
Model X	0.098	0.445
Model Y	0.546	0.527

Table 7.3.4 Correlations between actual and predicted results: Cultural Structures Survey

7.3.3 Effects of removing the cultural item

We may examine the difference in actual scores caused by the removal of the cultural item. It should be noted that the majority of people will not have realised that these photographs had been digitally altered; Stamps (1992) found that only 14% of respondents could correctly identify a photographic alteration. Table 7.3.5 compares the actual and predicted ranks for the cultural (c) and removed (d) photographs.

Code	Normalised per respondent		Model Y	
	score	rank	score	rank
c2	-0.1493	1	0.1744	1
d2	-0.5498	2	-0.0476	2
c3	0.1928	1	0.4303	1
d3	-0.1137	2	0.2102	2
c8	0.7860	1	0.2867	1
d8	0.4347	2	0.0862	2
c10	-0.0638	1	0.1765	1
d10	-0.3216	2	-0.3257	2

Table 7.3.5 Comparison of photographs with and without cultural structures

It is found that in each case the model correctly predicts that the score will rise with the addition of a cultural structure.

7.3.4 Discussion and Summary

The addition of cultural structures to photographs of natural landscapes was examined. The results showed that the addition of these artefacts increased the preferences for the landscapes. A regression model was formed which included measurements of these structures.

'Cultural' has therefore been taken to mean those images which are connected with our cultural heritage, rather than those structures which have been placed in the landscape within the last two or three generations. These structures are not necessarily those which are either aesthetically pleasing nor those which are transparent in their purpose.

It is suggested that the reason for the cultural structures improving the scenic value of the landscape is due to respondents reacting to such structures. Rather than seeing them as being intrusive to the landscape, as being an addition to an otherwise natural scene, the respondents view such structures as part of the natural landscape. In the survey respondents are not asked to give scores for 'natural landscapes' but for 'scenic preference'; therefore it can be hypothesised that cultural structures are as much a part of our landscapes as the mountains and the lochs. Perhaps we should be referring to 'cultural landscapes' as opposed to 'natural landscapes' throughout this thesis - it can be argued that there are no truly natural landscapes in Scotland as all the land has been influenced by humanity at some point in time.

7.4 Postcard Survey

7.4.1 Methodology

As all photographs in previous surveys had been taken by the same person, a comparison was made with photographs taken by a professional photographer, by comparing actual scores to predicted scores from the eight landscape preference models. Twelve scenes were used, scanned from postcards obtained from the photographer Michael MacGregor, one of the foremost postcard manufacturers in Scotland.

The twelve scenes were placed into a survey where each respondent saw all twelve postcards, four different versions used differing orders of images to eliminate any possibility of ordering bias. This survey was then run at the MLURI Open Day, along side the Validation Survey, and then left on the Internet from July until November 1997.

7.4.2 Analysis and Results

There were a total of 23 respondents for this survey. Table 7.4.1 below details the correlation coefficients between the actual and predicted scores and ranks for the postcard survey. It should be noted that the postcards used were not of an identical aspect ratio to the photographs used previously. To eliminate this difference the postcards were resized to 580 by 395 pixels before digitising.

Model	Scores	Ranks	Number of valid images
Model A	-0.081	-0.055	10
Model B	-0.024	-0.224	12
Model C	-0.031	-0.189	12
Model F	0.308	0.286	7
Model W	0.166	0.112	12
Model Y	-0.007	-0.126	12

Table 7.4.1 Correlation between actual and predicted results: Postcard survey

The models were all very poor at predicting landscape preferences for these images, with little or no correlation between the actual and predicted results, with the exception of Model F, which does not produce a significant correlation. Models D and E were not able to be used, as there were only two images each for which they were valid.

These results imply that either the models are highly biased to photographs taken by one particular person; or that there is something significantly different about photographs taken by Michael MacGregor. The positive correlation between Model F and actual scores allows the hypothesis that the poor correlations are connected to the use of complexity and red standard deviation variables in Models A, B, C, W and Y.

7.4.3 Discussion

It is hypothesised that photographs taken by different people may have very different compositions. This can be examined by looking at the distribution of the percentage of each landform type in the pictures and the distribution of colour means and standard deviations in the photographs.

Figure 7.4.2 and Figure 7.4.3 show that, the distributions of the landform types, water and sky appear very different. The photographs used in the Main survey have smaller amounts of flat, low hill and mountain landform, more obscuring vegetation and sky. The photographs also instinctively have very different colourations. It is possible to examine the correlations between these distributions for three of the surveys: Main, Validation and Postcard, as displayed in Table 7.4.2.

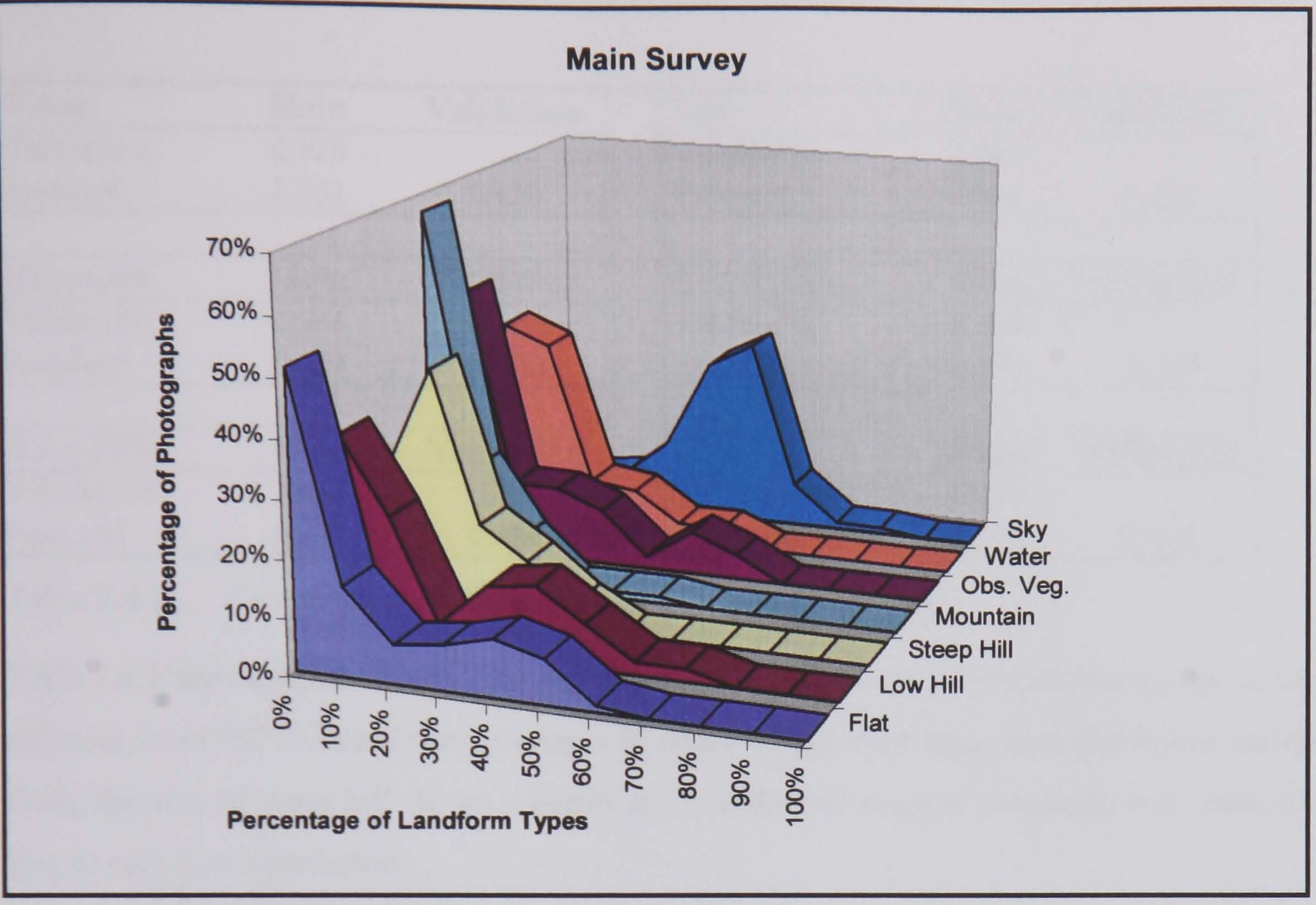


Figure 7.4.2 Distribution of landform types: Main Survey

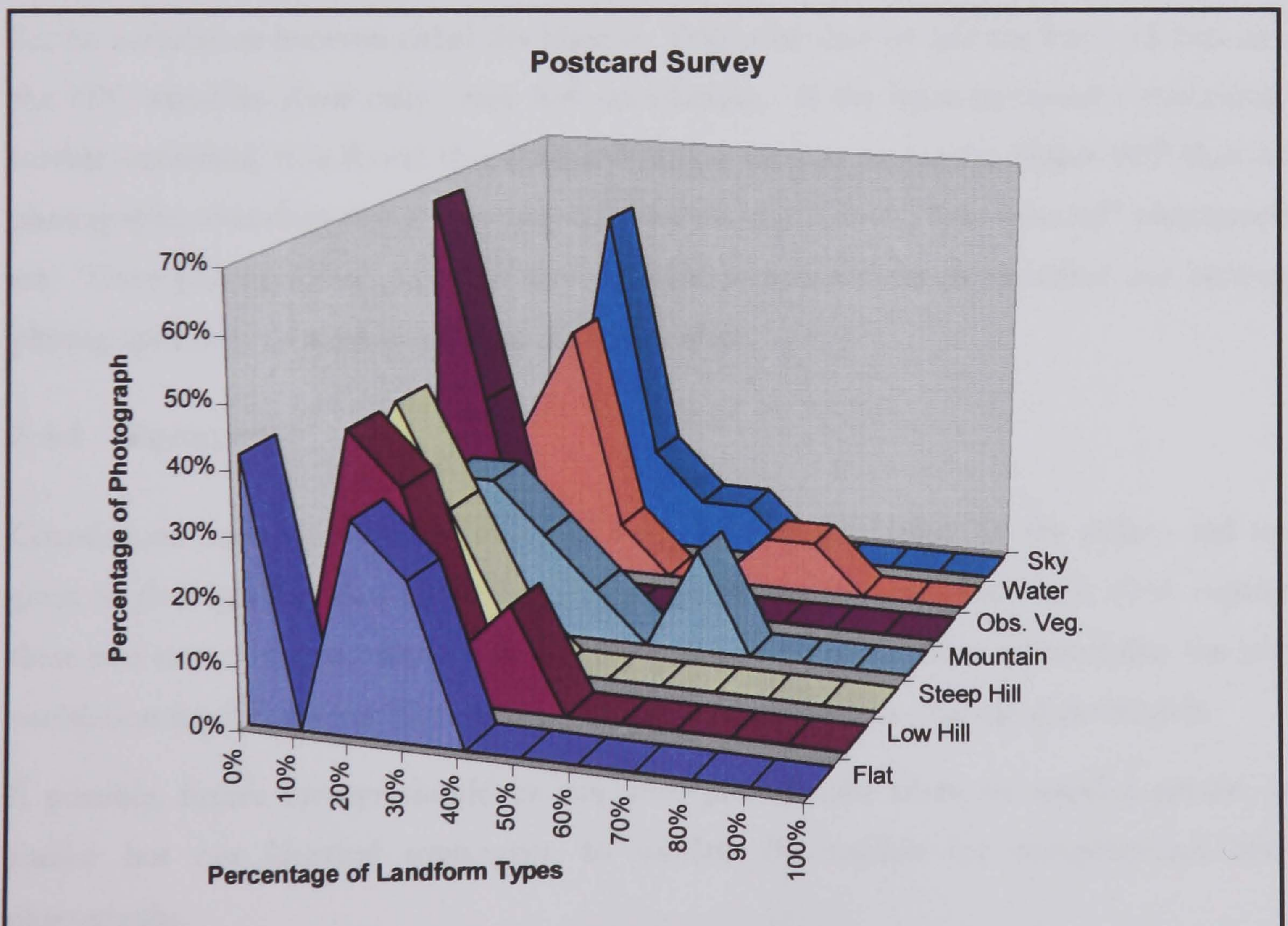


Figure 7.4.3 Distribution of landform types: Postcard Survey

Water	Main	Validation
Validation	0.928	
Postcard	0.351	0.420

Mountain	Main	Validation
Validation	0.956	
Postcard	0.124	0.166

Steep Hill	Main	Validation
Validation	0.978	
Postcard	0.974	0.966

BPP	Main	Validation
Validation	0.987	
Postcard	0.033	0.052

Red St.Dev.	Main	Validation
Validation	0.869	
Postcard	-0.393	-0.383

LPC	Main	Validation
Validation	0.963	
Postcard	0.184	0.094

Table 7.4.2 Correlation coefficients: Landform distribution

Table 7.4.2 demonstrates that the photographs used in the Main and Validation survey are quite different from the Postcard survey images in terms of the most important predictive variables. Only the area of steep hill shows a significant correlation; areas of mountain and water show low to very low correlations.

Red standard deviations shows a negative correlations, implying a significant difference in red tones between the photographs taken by the author and the Postcard images. The BPP variable has no correlation between either the Main or Validation data set and the Postcard data set and the LPC variables show only very low correlations. If the bytes per pixel correlations are further examined, it is found that Postcard images tend to have a far higher BPP than other photographs, therefore complexity is greater which may reflect a "professional" photographers art. These photographers may use very different criteria for the composition and lighting of photographs than an amateur photographer would do.

7.4.4 Summary

Correlations between the models created using photographs taken by the author and scores given to photographs taken for commercial purposes are very low. However, when examining these two sets of images, they are noticeably different. It is therefore assumed that the lack of correlation stems from the differences in the two sets rather than a failing of the models.

If possible, future surveys should be run with photographs taken by another person, with similar but not identical equipment, to validate the models for compositional bias in photographs.

7.5 Colour Change Survey

7.5.1 Methodology

Photographs taken with an alternative camera were used to examine the effect of different colours on landscape preference. Six scenes from the weather experiment were used. One set of photographs were taken with the standard 35mm compact camera (Nikon RF) and ISO 200 Kodak print film, as used throughout the research. The other set was taken with a fixed-focus panoramic camera (Miranda Panorama), using a generic own-brand film, also ISO 200, which is manufactured by Agfa. The two sets were then cropped to show the same scene (as one set was in panoramic format). As the two sets were taken on the same day at identical times, the only difference between them was the film and camera used and therefore the final colour of the photographs.

7.5.2 Analysis and Results

The photographs used for this survey were processed in the same manner as before and then digitised and interpreted, in order to calculate the preference scores from each model. As the images were of a different length-height ratio to previous images, and would have changed considerably if forced to the standard size, the images were resized to 710 by 320 pixels, thus giving them a total number of pixels less than one percent different from the number used by all previous images. The images could thus be digitised in the same manner as previously.

Normalisation	Scores	Ranks
per questionnaire	0.653	0.771
per respondent	0.842	0.886

Table 7.5.1 Correlation between scores and ranks: Colour Survey

From Table 7.5.1 it can be seen that the two film types are scored and ranked similarly by the respondents, with high correlations produced. The scores and ranks for normalisation per respondent are significant at the 0.05 level, and the ranks for normalisation per questionnaire are significant at the 0.1 level. This is a positive result, meaning that different film types may be used within the same preference study without creating a significant change in preference responses.

It is also important to examine how the images are ranked by each model. The correlations for each model with the actual scores and ranks were calculated (Table 7.5.2).

Model	Correlation (Kodak film)		Correlation (generic film)	
	score	rank	score	rank
Model A	0.840**	0.943**	0.796*	0.886**
Model B	0.830**	0.886**	0.769*	0.886**
Model C	0.811**	0.829**	0.796*	0.886**
Model D	0.426	0.771*	0.065	0.657
Model E	0.785*	0.829**	0.600	0.657
Model F	0.765*	0.771*	0.765*	0.771*
Model W	0.822**	0.829**	0.775*	0.886**
Model Y	0.823**	0.829**	0.780*	0.829*

Table 7.5.2 Correlations between actual and predicted results: Colour Survey

The results from Table 7.5.2 show that all of the models (with the exception of Model D) predict the scores and ranks of the actual preference data well. Significant correlations are marked (**0.05 level, *0.1 level). Each of the models predicts the Kodak scores and ranks more accurately than the generic ones. This result can be attributed to the use of Kodak film throughout the research to create the models.

Using a univariate analysis of variance, the significance of the different film types was examined.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Respondent	97.74	44	2.221	1.358	0.081*
Photograph Site	74.59	5	14.92	9.119	0.000***
Type of film	1.729	1	1.729	1.057	0.305

Table 7.5.3 Univariate analysis of variance: Colour survey

The significance of the various sources in Table 7.5.3 implies that the type of film is not a significant factor in determining the score for a photograph while the photograph is a highly significant factor. The respondents are slightly significant in determining score.

7.5.3 Discussion

The results show that the models predict the ranks of images within one film type with a satisfactorily high correlation and that the results from the two types of film produce highly correlated results. The analysis of variance further suggests that film type is not a significant factor in determining preference scores. This result implies that specific colour is not highly significant in determining scenic preference, as long as the image is in colour. This does not however mean that black and white images would give similar results to colour images, as shown by the research of Daniel (1997). In summary, the film type does not influence scoring significantly and more appear to be robust in terms of changes in film type.

7.6 Focal Length Survey

7.6.1 Methodology

A compact camera with a zoom capability was obtained (Samsung AF Zoom). Four scenes were then shot, with each taken at four different focal lengths, from 105mm to 38mm, determined by the step function of the camera. One scene was taken in the winter; the remaining three were all shot during the summer months. The four sites used were all within the Deeside/Strathdon area, as displayed in Figure 7.2.1 in Section 7.2 of this chapter. The images were then placed into a questionnaire to examine the effect of differing focal length on landscape preference.

This survey examines one of the cognitive criteria identified in the literature review. The greater focal length views show a more detailed vision of the landscape; it could be said that they show the part of the landscape which may install a sense of mystery in respondents viewing a wider angle photograph. Appendix XV shows an example of one site at all four focal lengths.

The survey was undertaken, together with the second weather and lighting survey, at the Edinburgh International Science Festival. Respondents were shown each scene, with the focal length chosen at random, and then asked to rank the images from one to four. Respondents were then asked to rank a selection of photographs from the other survey before seeing another four images, again with random choice of focal lengths, and ranking these images.

7.6.2 Analysis and Results

Thirty-five responses were gathered over a six day period. The ranks of the four focal lengths for each scene were compared to the predicted ranks for each model (Table 7.6.1).

Model vs. actual ranks	Scene A	Scene B	Scene C	Scene D	Mean
Model A	-0.2	-1	-0.4	0.8	-0.2
Model B	-0.2	0.8	-0.4	0.8	0.25
Model C	-0.4	0.8	-0.8	0.8	0.1
Model D	-0.4	-0.4	0.4	1	0.15
Model E	0.6	0.8	-0.2	1	0.55
Model F	0.8	-0.8	-0.8	0.8	0
Model W	-0.2	0.4	0	0.8	0.33
Model Y	-0.2	0.4	0	0.8	0.25

Table 7.6.1 Correlations between actual and predicted results per image: Focal Length Survey

Model	Correlation (rank)
Model A	0.574**
Model B	0.462*
Model C	0.488*
Model D	0.462*
Model E	0.259
Model F	0.265
Model W	0.579**
Model Y	0.391

Table 7.6.2 Correlations between actual and predicted results: Focal Length Survey

The low correlations between the ranks for the four focal lengths and the predicted ranks suggest that there may be another factor influencing the way in which people have ranked these images. Significant correlations are marked (**0.05 level, *0.1 level). However, if a univariate analysis of variance is run, focal length does not appear to be a significant factor (Table 7.6.3).

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Respondent	7.600	34	0.224	0.133	1.000
Photograph Site	20.25	3	6.750	4.058	0.540
Focal Length	0.396	3	0.132	0.159	0.920
Respondent * Site	129.3	91	1.420	4.103	0.000***
Respondent * Focal Length	46.97	79	0.595	1.717	0.022*
Site * Focal Length	5.203	9	0.578	1.670	0.122

Table 7.6.3 Univariate analysis of variance: Focal Length Survey

The analysis of variance shows that the respondents are interacting with the site and with the focal length, implying that different people are reacting differently to the increased focal length at some sites. The examination of the individual sites in Table 7.6.4 will assist in understanding how people react to the increased focal lengths.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Site A					
Respondent	71.27	34	2.096	3.751	0.011*
Focal Length	0.689	3	0.230	0.382	0.767
Respondent * Focal Length	13.81	23	0.600	0.772	0.708
Site B					
Respondent	52.27	34	1.537	6.239	0.006**
Focal Length	0.714	3	0.238	0.944	0.441
Respondent * Focal Length	4.286	17	0.252	0.945	0.548
Site C					
Respondent	49.44	34	1.454	2.906	0.021*
Focal Length	4.113	3	1.371	3.106	0.051*
Respondent * Focal Length	8.387	19	0.441	1.640	0.183
Site D					
Respondent	37.82	34	1.112	1.295	0.255
Focal Length	0.549	3	0.183	0.231	0.874
Respondent * Focal Length	21.45	27	0.794	2.648	0.140

Table 7.6.4 Univariate analysis of variance: Individual sites

Table 7.6.4 shows the effects of the respondents and the camera focal lengths on the preference scores for each site. Both sites A and B have a significant respondent effect, which is not connected with any interaction with the focal length. Site C has effects from both the respondents and the focal length, although again these are not interacting. Site D has no significant effects from any source. If the images used in sites C and D are examined, possible explanations become clearer.

The components of site C change to a much larger extent than those of site D, the lower amount of extra information gathered by zooming into site D may cause changes in focal length to be less significant, On the other hand, zooming into site C provides a much more detailed view of what is there, and shows several components not visible from the widest angle focal length.

7.6.3 Summary and Discussion

The analysis shows that the predictive models fare badly in predicting the ranks of photographs of different focal length in this survey. However, focal length does not appear to be a significant factor in determining the rank given to an image.

The definition of mystery used in Chapter Three is "the degree to which you gain more information by proceeding further into the scene" (Lynch and Gimblett, 1992), *i.e.* it is the degree of change in the scene corresponding to the increase in focal length. Therefore those images which change to a greater extent with the change in focal length should have a greater level of mystery at the shortest focal lengths.

It is hypothesised that the sense of mystery is playing a role in the scoring of these images, with the nearer, more detailed, images being more attractive than those with the lower focal lengths (*i.e.* those that show more of the scene in less detail) and those with the greatest change in scene showing the largest difference in scores at the four different focal lengths. Ulrich (1977) agrees with the former statement, noting that images with high mystery should have a negative effect on preference, a result also found by Baldwin (*pers. comm.*). Kaplan, S. (1987) found that scenes with a sense of mystery were more preferred than those without. This has not been studied in this survey, as scenes were only compared to the same scene at a different focal length.

7.7 Left and Right Survey

7.7.1 Methodology

It has been suggested that there may be an effect on landscape scenic preference which depends on which side of an image a piece of major vegetation was positioned. Patsfall *et al.* (1984) discovered that left and right foreground vegetation had significant but opposing regression weight signs; left being negative and right being positive (as notes in Chapter Three). Bourassa (1988) explains that the attitudinal model emphasises the distinction between the left and right sides of the neocortex; left side of the neocortex specialises in verbal and mathematical abilities which the right side is concerned with spatial concepts, patterns, textures and so forth. The left side tends to be rational while the right is intuitive.

This effect was examined, using photographs which had been mirrored, which had significant left/right bias, in terms of either vegetation or major landscape features. Respondents were then asked an extra socio-demographic question: whether they were right-handed, left-handed or ambidextrous. This survey examines the hypothesis that left and right-handed respondents will differ in which side shows a positive regression weight.

7.7.2 Analysis and Results

Forty responses were gathered at the Edinburgh International Science Festival. The photographs were run through a univariate analysis of variance.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Respondent	163.2	34	4.799	2.978	0.000***
Photograph Site	154.8	21	7.372	4.574	0.000***
Left or Right Handed	0.000	0	#	#	#
Left or Right Bias	0.343	1	0.343	0.060	0.828
Handed * Bias	11.99	2	5.993	3.718	0.025*

unable to calculate

Table 7.7.1 Univariate analysis of variance: Left/Right Survey

The results from the analysis of variance in Table 7.7.1 suggest that it is the interaction of handedness and the bias of the picture which is a significant source of variation in the results. On examining those landscapes which had the largest difference between average scores for the left bias and the right bias image, it is seen that only two images have an average score difference of more than one. Both these images have a dark area to one side and a light area to the other.

It could be hypothesised that this difference in brightness is causing differences in scoring; no hypothesis can be made with regard to this and the handedness of the respondents.

7.7.3 Discussion

The results from this survey show that the overall response of the general public to a landscape image is not affected by the bias of the image i.e. whether there is more of one component on one side of the image compared to the other. However, there is some interaction between which hand a person uses and the photograph bias. This is a different result from that found by Patsfall *et al.* (1984) who note that the side of the image vegetation falls is significant; that was not found in this study.

If it is believed that those who are left-handed are more likely to have enhanced abilities on the right-side of the brain and vice versa, then the results found in this survey suggest that right-handed people may prefer bias to the opposite side of an image than left-handed people. The analysis here does not allow any conclusions to be drawn regarding whether the bias is required to be specific to one type of landscape component (such as mountain landform, water or major vegetation) or whether the bias can be generic. Further research is required to gain a more in-depth knowledge of the differences in preference of due to the handedness of respondents.

7.8 Summary

This chapter has looked at several different aspects of landscape, and has answered several issues originating in the previous three chapters. With these answers it is now possible to move towards further applications of the methodology and the landscape preference models; as displayed in the flow chart in Chapter One of this thesis.

Weather and Lighting

The first survey showed that neither weather, season nor lighting affected the preference score given to an image. It was hypothesised that this is due to the effects of familiarity and experience of respondents with these factors and the changes they cause to landscape images. It was found that the proportion of cloud cover was a predictive variable, although a model using the variable did not produce significantly higher correlations with actual preference scores than other models.

A further result from this survey is the confirmation that screen resolution is not correlated to screen size (as suggested in Section 4.3 and refuted in Section 5.7).

Cultural Structures

The significant result from the cultural structures survey was that the structures improve the landscape preference value. As only older structures were used in the survey, this result does not apply to structures built within the 20th century. It is suggested that many respondents see these buildings and other ruins as a part of the landscape, rather than as an intrusion into it. An eighth model was created following this survey.

Postcards

The purpose of this survey was to test the landscape preference models on the photographs taken by a person other than the author. Results showed the models were unable to predict responses to these images. The images were then examined and found to be significantly different, in terms of composition and colour, than the original images. It is therefore hypothesised that this is the cause of the poor correlations between the models and actual results.

Colour

Two different film types were examined to look at how respondents react to colour. It was found that the slight change in colours between the two film types did not effect preference scoring. This agreed with the first survey (Section 7.2) and it is thought this is due partly to a familiarity factor and partly to the fact that the exact colours are not important as long as photographs are viewed in colour.

Focal Length

Four camera focal lengths were used to take pictures of the same scene, thus producing images in increasing detail. While focal length was not a significant factor, respondents interacted with the focal length and with the site. When the sites were examined separately, it could be seen that those sites which changed more with the increasing focal length were more susceptible to focal length based differences in scoring.

Left and Right Bias.

The final survey examined the effects of left and right biases in the images. Respondents were also asked to state their 'handedness': whether they were left or right handed, or ambidextrous. Results showed that left and right biases are not significant indicators of landscape preference, but that there is some interaction between handedness and image bias.

7.8.2 Summary of findings from this Chapter

Several points have been made throughout this chapter with regard to both the taking of photographs for the creation of landscape preference models, and the factors to be considered in analysis and creation of predictive models.

It has been shown that neither weather, lighting, not season are significant factors in determining landscape preference; with the corollary that colour is not a highly significant factor, despite its inclusion in five of the six original preference models. However, large changes in colour, such as shown in the survey of postcards, will affect the utility of models. Focal length has also been examined, with the result that while not being significant overall, it can be a significant factor for images with a high degree of mystery. It is therefore concluded that models created and tested with photographs taken by the same person, using the same film and camera lens, will be the most robust.

The remaining surveys examined photograph composition, which was also a factor in the postcard survey. That survey showed that major compositional differences, attributable to differences in photographer, can cause otherwise good models to predict preferences poorly. The analysis of models using left and right bias showed that handedness can be a significant factor for some images. This problem could be overcome by ensuring any sample was stratified to contain the correct proportion of left and right-handed people. The final conclusion that can be drawn regarding composition, is that cultural structures, which are part of the heritage of the countryside, do not negatively affect landscape preference, and in the majority of cases, will enhance preference. This leads us to note that 'natural landscapes' are in fact cultural landscapes in semi-natural settings.

CHAPTER EIGHT

REVIEW OF LANDSCAPE VISUALISATION ISSUES

8.1 Introduction

> "Visualisation can be defined as the use of computer imaging as a tool for comprehending data obtained by simulation or physical measurement".

This definition, by Haber and McNabb (1990), sets visualisation in context for this review. It is a form of communication which is universal, and which has the ability to form abstractions of the real world into graphical representations comprehensible to a wide range of people. Visualisation has emerged as the most effective tool for communicating large quantities of information (Loh *et al.*, 1992). Increasingly, computer visualisation is used to communicate the implications of natural and management changes in biological systems (Orland, 1994b) and society is becoming dependent on information presented in three-dimensional visual format (Faust, 1995) - "virtual reality" is no longer a term only applicable to computer games.

A newly emerging role of environmental managers is to mediate between the environment and its many users. That role has four important components (Orland, 1992), in all of which visualisation may play an important role:

1. to identify and interpret the complex interactions of environmental systems;
2. to communicate their implications to environmental scientists, other managers, policy makers, decision makers, and the general public;
3. to enable the testing and evaluation of alternative management scenarios by experts and non-experts; and
4. to implement resource plans.

The aim of researchers and managers should be to ensure that the visualisations meet the requirements of their purpose, this will be greatly facilitated if visualisations are tied to underlying databases, and that the links between visualisations and data are verifiable, reliable, and accurate. Rather than being limited to being mere pictures of landscapes the visualisation should be a view of the landscape as represented in the database (Imaging Systems Laboratory, 1995).

8.1.1 Use of visualisation

For natural resource managers to plan for a more healthy environment, and to elicit public and political support for such plans, two needs have been identified by Orland (1994a):

1. To predict the responses of public groups to changes in the environment, for some of which the visual impact may be the dominant indicator, and to plan to minimise any negative impacts;
2. Once a plan is developed, to communicate the effects of proposed changes to other agencies and the public to facilitate support for the decision-making.

It is possible to visualise the landscape impacts of changes in the building code or engineering standards as well as in natural resource management. Models may be used that predict changes in landscape preferences, economic behaviour, ecological succession, wave erosion or rises in sea level. All such models have implications for the assessment of landscapes and as a result they may be used to produce new landscapes which may be visualised as a part of, or following, the modelling process (Mayall and Hall, 1994).

8.1.2 The technology of visualisation

Visualisation technology depends on the integration of older technologies: computer graphics, image processing, computer-aided design, geometric modelling, perceptual psychology and user interface studies (Haber and McNabb, 1990). Traditional tools for visual communication of resource issues have included simple graphic devices such as maps, line charts, sketches, photographs, and renderings. The new tools include coloured computer maps, 3-D models, animations, and interactive virtual reality environments used to explore design ideas (Imaging Systems Laboratory, 1995).

Photomontage techniques use a combination of photographs, renderings and artistic skills. Kennie and McLaren (1988) define photomontage as "a physical or image composite of photographs of the existing landscape with a registered computer generated image of the proposed design object(s)". This approach to visualisation is widely used, increasingly with the output of other visual techniques.

In practical terms, computer graphics is incapable of representing all the details recognisable in the immediate surroundings. The visual simulation program must therefore be considered as a support system to help a designer to outline the basic features of the environment (Pukkala and Kellomäki, 1988). The closest images will be produced by reproductions of the phenomena based on the laws of physics (Kennie and McLaren, 1988) - it is up to the scientist to decide which laws to include and which to exclude in the simulations. Whatever the choice, the image will still be an idealisation of the real system (Haber and McNabb, 1990).

8.1.3 Present uses of technology

It is possible to simulate landscapes as they might look as a result of environmental impacts such as building or forestry developments, or to test environmental models (Fisher *et al.*, 1993). Modelling of terrain and landscape views is possible in a range of different guises from the simple vector (or wire-frame) surfaces displayed as rectangular or triangular matrices, to sophisticated colour perspectives generated from complex hidden-line and hill-shading algorithms (Moore, 1990).

Commercially available, generic toolkits, such as PV Wave, AVS and Explorer (Precision Visuals, Inc., 1991; Advanced Visual Systems Inc., 1992; NAG, 1998), can be used for the production of visual displays of different types of data. This generation of dedicated graphics software epitomises the visualisation revolution in computer graphics (Fisher *et al.*, 1993). It is the ever decreasing cost to performance ratio of newer workstations which has allowed this revolution (Rohlf and Helman, 1994). More recently, software such as VistaPro for the PC and Macintosh platforms have allowed even greater accessibility to create realistic visualisations of landscapes.

8.2 Photo-realism, Schematic Images and Validity

The importance of realism is noted by Buttenfield and Ganter (1990):

> "Realism provides the visual context within which constraints and externalities may be considered."

If the intent is to convey the potential impact of proposed management actions, with the goal of informing public review and approval processes, then more realism and detail may be demanded in the visualisation (Orland, 1994a). Consideration of the validity of substituting computer-generated simulations for photographs only makes sense if it is accepted that photographs are themselves an adequate surrogate for direct experience of the landscape in question (Bishop and Leahy, 1989). This question has been discussed in the review of psychophysical landscape preference models (Chapter Three).

There are also financial considerations in the realism of images. As Zewe and Koglin (1995) put it:

> "In the search for true realism, a compromise must be found between reality and costs".

8.2.1 Perceived realism

A question to address in producing photo-realistic simulations is "how good is good enough?". Such an image is one that has a high degree of perceived realism, conveys maximum quality, contains enough data, yet is efficient in terms of equipment costs, storage and management (Perkins, 1992). Perceived realism may not necessarily vary directly with image quality; image quality may be very high in technical terms, while perceived realism is not (*ibid.*). Although image quality will affect perceived realism, so will the content of the image, the viewpoint of the image and the receptivity of the viewer.

Some basic understanding of the factors that influence the perception of image quality is therefore needed to increase the 'fit' between computer-generated images and real world conditions (Perkins, 1992). Public perception studies have been conducted with images and they indicate that simulations are achieving a high degree of validity (Orland, 1994b), for example, where defoliation effects can be linked to public preferences relating to wooded landscapes. A recent study by Lange (1998) has shown that simulated images of background (rather than middle or fore-ground) landscape give the highest degrees of perceived realism, following photographs and composite images of real foregrounds with simulated backgrounds.

8.2.2 Schematic images

Many studies have tended to focus on the realism or accuracy of simulation (Oh, 1994). But simulation cannot comprehensively reproduce reality. Rather, it selects critical aspects of that reality for the particular purpose at hand (*ibid.*). In practice the simplification, or abstraction, of detail is directly related to the savings of effort, time and costs of simulation.

In many ways, schematic images, those which do not attempt photo-realism, are often as useful as more realistic images. They do not require the technical complications of photo-realistic visual simulation and do not have the theoretical problems associated with defining realism. These views are approximations - more realistic than plan views, but more schematic than photorealistic renderings or presentation drawings (Ervin, 1993).

In schematic renderings the images are course; colours are shaded, the ground is segmented according to some schema, and features (such as trees and buildings) are alike and rather diagrammatic. There is no provision for subtleties of texture or curved surfaces. These representational conventions are no more limiting than any others commonly encountered in design, and they are no more difficult to understand (Ervin, 1993). For some purposes, the visualisation media may intentionally be highly abstract and intended to convey information most effectively to experts within the same discipline (Orland, 1994a).

8.2.3 Photo-realistic images

Computer image editing methods can be more realistic than hand rendering and less expensive than photo-retouching. They do much to convey a realistic visual experience of the scene. The realism and transparency of photo-realistic images to a non-expert viewer is high, but the accuracy and validity are less easy to defend (Orland and Daniel, 1995). In a study by Oh (1994) only image processing was successful in separating the visual attractiveness of one landscape from another in simulations; no other method was capable of producing an image which the respondents could rank according to visual beauty. The other methods used were wire frame; surface modelling; and combined surface modelling and scanned photographic images.

8.2.4 Validity

There are two questions which need to be answered when the validity of computer simulations is discussed (Daniel, 1992):

1. What is the validity of data visualisation systems?
2. What level of data visualisation is sufficient for environmental planning and management?

The primary concern for data visualisation intended for decision support in environmental management is to achieve credible representations of existing and projected environmental conditions. The validity and sufficiency of a given data visualisation system, therefore, depends in part on the purposes for which it is intended (Daniel, 1992). The validity must be high, because the power of visualisation to convince is high, and any misrepresentation has the potential to mislead or bias the opinion of the observer.

The resolution and fidelity of environmental simulations is limited only by the computer resources and peripheral devices allocated to the task. However, the validity of data visualisation systems is not necessarily related to judgements of realism, believability, or other such qualities. Neither is there any necessary dependence upon resolution, colour fidelity or other technical criteria (Daniel, 1992).

The answers to the questions above (Daniel, 1992) are that the visualisations are valid to the extent that responses to environmental representations correlate with appropriate responses made directly to the environments represented. Landscape visualisations are sufficient to the extent that adding detail, higher resolution, colour fidelity, animation or other features does not improve the match between representation based and direct responses.

8.3 Rendering

In this section a number of aspects of landscape simulation, in particular the rendering of landscape models, will be discussed. These include techniques used in rendering, issues concerned with rendering, image enhancement and techniques for tree and forest simulation.

8.3.1 Techniques in rendering

The degree of realism of a view or simulation is dependent on several factors including: the nature of the application, the objective of the visualisation, the capabilities of the visualisation, the capabilities of available software/hardware package and the amount of detail required and/or available (Kennie and McLaren, 1988). There are a number of points to consider when rendering a landscape visualisation. In addition to the model and associated landscape features, a number of other parameters need to be defined:

1. viewing position and direction of view;
2. lighting model to describe illumination conditions;
3. 'conditional modifiers' *e.g.* wet, snowy;
4. 'environmental modifiers' *e.g.* atmospheric conditions such as haze; and
5. sky and cloud model representing the prevailing conditions.

Some of the specific techniques used in rendering landscapes are discussed in the remainder of this section.

Spatial sampling

Many GISs use one of three types of spatial sampling. These are, in order of increasing smoothness of the final image:

- nearest neighbour;
- bilinear interpolation;
- cubic convolution.

The same three options exist for the sampling of overlay images; nearest neighbour produces the "blockiest" surface, whereas cubic convolution produces a smoother surface with more mottled appearance, particularly in the foreground.

Anti-aliasing

The majority of computer graphics techniques have been developed to address the visualisation of objects that have their geometry defined using a mesh of planar surfaces such as triangles. This can lead to 'edges' on curves, which is often solved using anti-aliasing techniques (Kennie and McLaren, 1988). The anti-aliasing for montage methods should be different from other usual ones because the background scene includes pixels which change pixel by pixel, and image overlay operation is performed several times (Nakamae *et al.*, 1986). The aliasing problem also occurs when foregrounds are superimposed onto the computer-generated images.

Texture mapping and appearance

Particular problems are posed by the realistic rendering of landscape because of the amount of detail required. Fractal methods have been proposed to allow database amplification, which is the generation of controlled random detail from a fairly sparse description (Miller, 1986). An alternative approach is to use texture mapping methods on a few simple primitives. The texturing is defined procedurally, which may be expanded without loss of high frequency detail, or shrunk without the occurrence of aliasing artefacts. Fractal subdivision methods are slow and generate defects due to what is known as the 'creasing problem'. The texture map methods, on the other hand, display visible discontinuities in texture gradient where two surfaces intersect (Miller, 1986).

The appearance of a surface is dependent on several factors: type of light; condition of atmosphere; surface colour; reflectance and texture; position and orientation of surface relative to the light source; other surfaces; and the viewer (Kennie and McLaren, 1988). Normal lighting models are simplified by assuming only a single parallel light source located at infinity (the sun).

Variable object representation

An accurate representation of each feature in a scene is not possible and also not necessary (Gross, 1991). The creation of perspective views using only satellite data, observer positions close to the ground or narrow fields of view typically result in large quadrilaterals in the foreground due to perspective foreshortening. Therefore, resolution should be high towards the foreground or local zone, but the resolution should decrease towards the background (Graf *et al.*, 1994). Further from the observer it is sufficient to present the scenery at a low level of detail using hierarchical data sets in order to limit the corresponding data.

Geographic registration

Since all topographic data are a projection onto an assumed flat reference plane, it is necessary to reference all elevations from the specified view point to take into account the curvature of the earth and refraction of light, if the survey area is greater than 2 miles (3.2 km) (Aylward and Turnbull, 1977). For applications where the geometric fidelity of the rendered scene is of vital importance such as a photomontage for a Visual Impact Assessment (VIA), it is necessary to incorporate both earth curvature and atmospheric refraction corrections into the viewing model (Kennie and McLaren, 1988).

In order to use aerial photographs and satellite images for perspective viewing, they must refer to the same geometric reference system as the digital elevation or terrain model (DEM/DTM). Although a vertical aerial photograph provides a map-like view of the earth's surface, it differs fundamentally in geometric terms from a map (Graf *et al.*, 1994). There are many geometric distortions of satellite image data which cause severe geometric distortions, such as the satellite (platform) monitor and earth rotation, the imaging geometry of the sensor and the terrain variations in the scene.

Atmospheric attenuation

Due to scattering effects by water molecules, dust and pollution, objects appear to lose their colour and intensity with increasing distance. The reduction rate of colour and tone depends on the various factors such as seasons, weather conditions and time. The colour and tone become greyer as the distance becomes large. The hazing affect created by atmospheric moisture content leads objects to undergo exponential decay of contrast with respect to distance from the viewpoint (Kennie and McLaren, 1988; Nakamae *et al.*, 1986; Graf *et al.*, 1994).

The perception of depth requires an interpretation of cues such as colour fading and the relative size of objects in the landscape. Therefore, in order to enhance realism and to maintain the estimation of distance, atmospheric effects must be included in the model of a view in addition to topographic data (Graf *et al.*, 1994). Fog effects increase the sense of perspective in montages; within perspective view visualisations, fog and haze effects can increase realism but do not increase the sense of distance in the same manner.

The shading and shadows of computer generated images help a montage match to the background scene (Nakamae *et al.*, 1986). In non-montaged visualisations, *i.e.* computer simulations, the application of shadows and shading can significantly increase the impressions of relief, and of detail, quite considerably.

Illumination controls on landscape visualisation packages are standard. It is normally possible to set the sun angle and strength, to alter the time of day, and to increase the atmospheric attenuation caused by fog or haze. One further sophistication still lacking is a parameter to allow the incorporation of the effects of pollution in the atmosphere.

8.3.2 Issues concerned with rendering techniques

Scale and resolution issues

There are spatial interactions between feature size and levels of detail of representation, both within databases and subsequently visualisations. There is little value in representing all features at all possible levels of detail. Therefore, some degree of generalisation and simplification is required.

Terrain data, and other spatially referenced sources of textural information, are projections onto a horizontal plane. The scale of this source data, and the resolution at which they may be represented, varies for a combination of historical (such as military or defence needs), technical (such as method of data collection) and economic reasons. There are also inherent issues about the quality of the data: 'acceptable' quality at a large resolution (10m and greater) is only now becoming available.

Satellite data available for Scotland is predominately 30m, although 10m (panchromatic) and 20m (colour) is now also available. The frequent collection of such data is not possible, except over longer time periods (such as a decade) due to weather conditions. This has impacted on the quality of the imagery that is available for use as texture maps.

Image size

The geographic extent of images viewed using GIS software may be sufficiently large to ensure that they include the natural horizons to many view points, although this will also depend upon the nature of the topography of the area. Although file sizes may seem large by today's standards, it is foreseen that within a short time span this limitation will no longer exist. For example an orthophotograph of a 20km by 20km square at one metre resolution with three colours will be 1.2Gb in file size. However, the actual image size needed to view a horizon may only be 36 square kilometres at 1m resolution in three colours, such an image will occupy 108Mb, a size which will fit onto a CD ROM. The size of the aerial or satellite overlay images may be as large as these images while in the format required by the GIS, but they may often be stored in smaller file sizes in alternative formats.

8.3.3 Image enhancement

Image processing techniques

Image processing techniques can be used to enhance the sources of imagery for texture overlays. This allows particular features, which may be indistinct on the image, but are significant for the visualisation, to be seen.

Spectral enhancement enables an improvement in the appearance of the content of an image by altering the spectral signatures of the imagery. Linear stretches reassign the colour values to the maximum range available (0 to 255) according to a linear relationship; non-linear stretches use a polynomial relationship. These techniques may not improve the visual impression of the overall scene, but can be used to target specific spectral ranges of the image.

Spatial enhancement techniques may be used to improve the apparent level of detail of small features and variation within a scene using high frequency filters. Low frequency filters may also be used to 'smooth' an image and reduce the variability in a scene. The former filtering is useful for enhancing foreground textures, and the latter for background or distant textures.

Aerial photography image enhancement

If the area to be visualised is greater than the area covered by one photograph, it is necessary to mosaic two or more aerial photographs together. This can be problematic, due to differing illumination effects resulting from time of day and direction of flight. It is necessary to enhance the images in order to improve the match. Software is available to do this automatically for photographs (LivePicture, 1997), but aerial images are often altered using a series of histogram matching algorithms.

Where two or more photographs are required, the contrast levels are matched and the line of intersection between the photos is clipped to follow, if possible, linear surface features, which can be used to camouflage any mismatch at the boundaries. In an afforested landscape, there is plenty of scope for this. However, tree canopies provide another problem. The pattern of the canopy, in a location which has been viewed from two directions, may result in a mis-match; when mosaicing images this can be mitigated by mosaicing the photos along a line, approximately bisecting the area of overlap (Miller and Wherrett, 1998).

8.3.4 Tree and forest simulation

Much of the current work on landscape visualisation is driven by forestry issues; this can be related to the fact that forestry is a landscape component which has a high visibility yet is easily changeable by mankind within a short space of time. Examples of work currently being undertaken in areas of forestry include: remote tourism in Northern Ontario (Orland *et al.*, 1994; Daniel and Orland, 1994; Orland, 1997); work using the SmartForest visualisations (Orland, 1994b; Uusitalo and Kivinen, 1998); research in the Dixie National Forest, Utah, USA (Kitagawa De Leon and House, 1994) and in New Zealand (Thorn *et al.*, 1997; Thorn and Daniel, 1998).

It is important that any landscape visualisation system allows realistic simulation of features and in those driven by forest application this means the realistic visualisation of trees and forests. The symbols used can be very effective in improving the visual realism of a rendering. Forestry visualisation projects typically tackle two complex tasks - systematically representing a range of issues of forest management practices, and communicating those issues to an audience of non-specialists (Orland and Daniel, 1997). Logged areas which are visible before trees are drawn will become invisible once tree symbols are added; the occluding effect of trees is especially noticeable in gently sloping landscapes (Smart *et al.*, 1991).

At a basic level, trees have been reproduced as simple geometric forms, circles or spheres with thin cylinders as trunks, or as pattern of branches rotated through 360 degrees to give wire-line form skeletons. When images are drawn on colour raster devices, more impressive effects are possible: shapes can be flood-filled in subtle green hues, textured patterns can be applied and give a naturalistic, organic quality to the vegetation (Moore, 1990).

Some examples of tree and forest simulation are discussed below, including block draping (a method often used by the UK Forestry Commission) and 2.5D rotating trees.

Tree simulation

In the method of tree simulation described by Nakamae and Tadamura (1995), two textures digitised from two photographs taken from the right side and from above the tree were mapped onto a set of transparent planes. For shading and shadowing, the shape of a tree is approximated by a transparent polyhedron surrounding it. Shadows cast onto trees, as well as tree shadows cast onto objects, look natural whether the trees is lush or has sparse leaves.

Shadowing is available for the following four cases: shadows cast by trees onto their own trunks; shadows cast by trees onto objects; shadows cast by objects onto trees; and shadows cast by trees onto other trees (Nakamae and Tadamura, 1995).

Block draping

Block draping is a technique which uses a digital terrain model, and then in regions of forest stands, the elevation values are increased by the height of the trees (Evans, 1993). Stylised trees use wire frame symbolised trees created using the simple graphical entities of lines and filled circles and triangles. Coniferous and deciduous trees are easily distinguishable using different symbol trees. Using colour on the terrain model and within the filled symbols provides a greater degree of realism.

Texture versus solid colour

There are several pros and cons about the nature of the texturing used in simulations of landscape features. The advantage of using textures is their 'apparent detail', which gives increased realism, while not necessarily being 'correct'. Solid colour is less realistic, but has an increase ease and rapidity of rendering. In general, if there is sufficient data available for the texturing of landform then draping a model of the terrain with such imagery is desirable; however, in some cases this may be a case of simply giving the observer what they wish to see, rather than a justifiable cost in terms of time and data.

2.5 and 3D tree patterns

If close range drawings of trees are required, 2D tree patterns are not sufficient; using 3D tree patterns, however, requires much computational time and memory storage. If the location of the viewpoint is fixed, some areas will not be visible. It is not necessary, therefore, to use the memory with unnecessary information (Sasada, 1987).

Two and a half dimensional tree patterns are a logical alternative to using 3D patterns. A 2D tree pattern that rotates around a vertical line passing through the centre of the trunk can be used, this kind of rotating 2D pattern in called a 2.5D pattern. In a program that produces perspectives, the tree pattern automatically rotates with the viewpoint's rotation so that the front view always shows. If, however, the viewpoint rotates above the tree, a 3D representation will be required to see the top of the tree instead of just a horizontal line (Sasada, 1987).

8.4 Visualisation, GIS and Decision Support Systems

The focus of management has changed to concentrate on managing ecosystems as a whole rather than focusing on specific species, in order to ensure ecosystem sustainability by protecting habitat and promoting biological diversity (Church *et al.*, 1994a; 1994b). Decision support systems (DSS) provide a valuable aid to such management and visualisation is an important part of decision support in landscape planning. By generating different views of the decision situation and by exploiting their own visual skills, that they can recognise meaningful alternatives and strategies during the problem-solving process (Angehrn and Lüthi, 1990; van Voris *et al.*, 1993).

Host *et al.* (1992) state that:

> "It is this integration of space and time in the broader context of the regional landscape that must be the focus of environmental and natural resource management ".

Visualisation of input parameters will assist the scientist in checking data for content and correctness. Visualisation of output parameters allows scientists land managers to understand better the resultant data sets as well as their relationships to other data sets. It is the ability to visualise the information over space and time that adds perspective to the scientists' and the decision-makers' understanding (van Voris *et al.*, 1993).

<u>Software integration</u>

GIS, environmental modelling and landscape visualisation can operate together in an interactive computational environment in which the modelling will feed the visualisation, which in turn influences the human operator who can then change the modelling parameters. Not many systems can currently do this. The model of Bishop and Karadaglis (1996), for example, has the decision options for the model set prior to the initiation of the visualisation, but has a future objective to create a direct link between the modelling and the visualisation, so that adjustment of controls would create new imagery.

The term 'virtual reality' denotes a system which provides the tools for users to interact with a simulated environment, but not necessarily in real time (Berger *et al.*, 1996). Such systems will combine the spatial display capabilities of GIS and GIS-based modelling with high performance visual simulation in a multi-channel graphics environment (Bishop and Karadaglis, 1996). Landscapes will be rendered as perspective views using actual elevation and land cover data, so they can depict scenery in a realistic fashion (Berger *et al.*, 1996).

GIS-based visualisation goes beyond the functionality of presenting anticipated outcomes via traditional graphic tools. It offers the opportunity to visualise relationships across time and space, and to explore more comprehensive ranges of possibility (Orland, 1994a). More flexible visualisation methods would enable users to select their own viewpoints and be free of weather, seasonal and other restrictions. However, GIS-driven image creation does not currently provide a means of integrating detailed, small area visualisation with regional views of large areas. The grain of the data source, such as digital elevation models and remote sensed imagery, drives the use of the data. Previously this made GIS most appropriate for large-scale views of resource issues (Orland, 1994b) but now that high resolution, large scale data is available, the use of GIS driven visualisation is changing.

Several GISs currently have the capability of creating three-dimensional perspective images by using elevation data for geographic areas overlaid with geographically referenced data such as land cover or land use, or with aerial or satellite imagery. In most cases this view is illustrative only and is considered the final output rather than an image for further analysis. Perspective images are generally well received as showing the relationships of the GIS data to the natural terrain; this factor has limited the usefulness of the perspective images to 'show and tell' type applications (Faust, 1995).

Bishop and Hull (1991) have the following to say about GIS and visualisation in the future:

> "It is an attractive thought that, at some future time, we will have sufficient accumulated research to assess probable changes in visual resources entirely from a GIS without further recourse to psychophysics or video-imaging. This point is unlikely to occur, however, because even if the process of modelling from mapped /mappable information is shown to be valid and reliable, the landscape experience is dependent upon purposes and values and therefore varies from place-to-place and time-to-time. Recalibration of such models will therefore always be required."

While these concerns are still valid today, some of them are in the process of being solved. The assessment of the scenic landscape using GISs is possible with infrequent recourse to psychophysical models, and using such methodologies as described in this thesis, the recalibration of such models is increasingly straightforward.

8.4.2 Issues of time and scale within visualisation, GIS and DSS

The temporal dimension

Natural systems change slowly and impacts on them become evident only with the passage of considerable time. This apparent resilience of the impacted system may mask changes that are, in fact, impossible to halt and irreversible. At later stages in the change process the absolute level of change may be significant, but the evaluator may have habituated to the changing conditions and therefore be less sensitive (Imaging Systems Laboratory, 1995). The RELMdss system (Church *et al.*, 1994b) allows for tracking impacts forward in time. At any given time period, each activity is limited by activities of the previous time periods by relationships that revise threshold limitations and attribute levels in future periods.

Proper treatment of time is as important as proper analysis of structure. A model in which there are distinct time steps for every process is difficult to construct, and even when it is possible to control time steps from the faster to the slower components of the system, there may be many computation steps without significant state transitions of the components involved (Perestrello de Vasconcelos *et al.*,1993).

Scale

The ability to transfer modelling output to other scales without losing the validity of the information is necessary for effective decision making. It may not be valid to apply models which simulate the growth of individual trees for areas measured in metres and hectares to landscape and regional scales whose metrics are in kilometres (van Voris *et al.*, 1993).

Scale applies in the perspective as well as the orthogonal landscapes. Therefore, landscape in the foreground of a view is viewed at a different scale to that in the distance. In a visualisation of landscape, the local landscape elements could be enhanced while those in the distance are reduced. The impact and dominance of the same element will be less in the background than in the foreground. Whilst the shapes and forms of the world surface can be modelled within the GIS environment, it is not simple to define the specific boundaries of mountains and valleys, plains and plateaux for digital analysis in a perspective view (Baldwin *et al.*, 1996).

Aspinall (1994) discussed the theory and issues associated with coupling models across geographic scales and demonstrates the relationships between scale, pattern and process in ecological modelling. Similar types of issues are equally relevant in the relationship between people and their landscape habitat.

8.4.3 Data transfer

A common problem encountered in landscape modelling that may have to use multiple software packages is the exchange of data to best utilise the unique features of each package (Kuiper *et al.*, 1996). Although the modelling may be very fast, the process of data transfer can be awkward and slow (Bishop and Karadaglis, 1996). Several issues associated with data transfer found in the literature are mentioned below.

Arc/Info is a widely used GIS package. Mayall and Hall (1994) and Bishop and Karadaglis (1996) both used AMLs (Arc Macro Language) to couple Arc/Info with other packages. Bishop and Karadaglis (1996) ran their model within the GIS as a series of GIS commands in AML. Mayall and Hall (1994) found that GIS and CAD technologies are limited for the representation of regional visual landscapes, but by integrating the two, their relative strengths could be taken advantage of and used with other models to predict and simulate landscape change.

Like Mayall and Hall (1994), Kuiper *et al.* (1996) tried using DXF (the AutoCAD drawing exchange format) to transfer data between a GIS and a visualisation system. This format was inefficient and limited the combined use of the systems. The alternative approach used was to design an ASCII file format that was uniquely adapted to the visualisation system, SiteView and its data model. These were coded using Arc/Info software development libraries (ArcSDL) and C code.

8.4.4 Example systems

Finally, three example systems using landscape visualisation for natural resource management are described.

<u>SmartForest</u>

SmartForest is a visualisation system, able to visualise on both regional and local scales, which can be developed interactively using biological models. Time-scale differences can be addressed and the gradual changes over time visualised. Models representing trees can be queried directly using the mouse to display data from the underlying database as well as calculated indices of crowding, tree-to-tree competition and pest hazard (Imaging Systems Laboratory, 1995). SmartForest operates in two different modes: management mode and landscape analysis mode. The management mode is a simplified presentation of the real forest; landscape analysis mode is a more realistic presentation of the real world (Orland and Daniel, 1997).

The 3D visual modelling approach has many advantages over GIS-based visualisations. Each tree is an object with a known location in space, changes made by the user are recorded as changes to the database and all new iterations are based on the new changes (Imaging Systems Laboratory, 1995). One constraint of the software is the difficulty and costs of creating databases, another is the computing time required for three-dimensional visual modelling.

SmartForest uses three dimensional modelling based on a simple stem list to generate visualisations that can be rotated and "walked" in real time. Visualisations can be created entirely from outside sources such as GIS-based models or can be developed interactively using built in biological models for tree growth, pest spread, and various silvicultural processes (Imaging Systems Laboratory, 1995). Forest management prescriptions can be applied and the results modelled using the incorporated growth models. Although the resulting images are an accurate representation of the gross spatial characteristics of the forest, they are not realistic, neither in the sense that each tree symbol relates to a real tree, nor in the sense that the image faithfully shows the colour and texture of a photographic image. However, as discussed in Section 8.2, it is not always necessary to have truly realistic images to successfully interpret the simulation or to convey the desired message.

Forest landscape simulation model

In the model of Kellomäki and Pukkala (1989) a computer landscape is created by placing tree symbols on the surroundings of the grid points; different species and tree sizes are represented corresponding to the theoretical tree populations. The simulation of growth with specific forest treatments is based on the theoretical tree populations created for each compartment on the basis of field data. The growth is simulated by increasing the diameter, height and age of each tree using models and a time step of 5 years. The cuttings are simulated by decreasing the tree density and canopy layers and regeneration is taken into account by adding new trees to the selected compartment via keyboard input.

The Sulphur Pass Project

The Sulphur Pass project showed that landscape visualisation using DTMs produces realistic and geographically accurate images. Of the variety of enhancements used to increase realism, the use of tree symbols seemed to be the most effective. Not only did they make the landscape more credible, but they also improved the accuracy of the model. An alternative means of improving accuracy would have been to allow trees in different polygons to have different average heights to correspond to their ages (Smart *et al.*, 1991).

CHAPTER NINE

LANDSCAPE VISUALISATION TECHNIQUES

9.1 Introduction

Traditionally, techniques for simulating realistic representations of landscapes have relied on artists and graphic designers to produce either pictures or montaged photographs of landscapes, as described in Chapter Eight. Abstract plans and simulations may not be easy for the lay person to interpret but are often familiar to experts in the field of landscape architecture.

Modern landscape simulation techniques allow realistic representations to be created with relative ease. Geographical Information Systems (GIS) may be used to produce three-dimensional perspective views from a set of elevation data; these views can be draped with either satellite or aerial imagery to produce a simulation. Although these simulated landscapes are not photo-realistic, they are able to convey a coherent impression of the landscape to the lay person and expert alike.

In this study, through use of dedicated software on the Silicon Graphics and PC platforms, landscapes were simulated and objects placed within the landscape, such as individual trees, forestry blocks and buildings. This further improves the realism of the models, by enabling vegetation to be visualised and changed according to land use prescriptions. A user can then 'walk through' such models of the landscapes, under a variety of lighting and weather effects. Such simulated landscapes may be converted into virtual reality modelling language (VRML) and placed on the WWW.

Within this chapter examples will be used to demonstrate the use of a number of different methods of simulating landscape. The pros and cons of each methodology will be discussed and methodologies for visualising future potential landscapes will then be demonstrated and debated.

9.2 Methodologies for Visualising Actual Landscapes

The definition of simulation is "an image of a proposed project shown in perspective view in the context of the actual site" (Lange, 1994). This definition includes both traditional techniques, such as: diagrams, perspective sketches, renderings, modified photographs and scale models and computer-based simulation techniques, such as: two-dimensional drafting and painting, three-dimensional wire-frame models, solid and surface modelling, image processing and animation techniques (Oh, 1994).

Lange (1994) states five criteria which good simulations should fulfil:

1. *Representativeness* - a simulation should represent important and typical views of a project;
2. *Accuracy* - the similarity between a simulation and the reality after the project has been realised;
3. *Visual clarity* - detail, parts and overall contents have to be clearly recognisable;
4. *Interest* - a simulation should hold the attention of the viewer; and
5. *Legitimacy* - a simulation is defensible if it can be shown how it was produced and to what degree it is accurate.

9.2.1 Traditional techniques

Hand drawn images

The most traditional method of landscape simulation is the painting or drawing. This method has been in widespread use world-wide for several millennia as a means of conveying imagery. In the Victorian era landscape art became more popular, as the public's perception of natural landscapes changed from places to be feared to places to be revered. Artists drawings are a very subjective form of landscape simulation, and are often influenced by the cultural trends of the time.

Figure 9.2.1 shows an example of a landscape painting by John Bathgate. This image is of Loch Lomond with Ben Lomond in the distance.

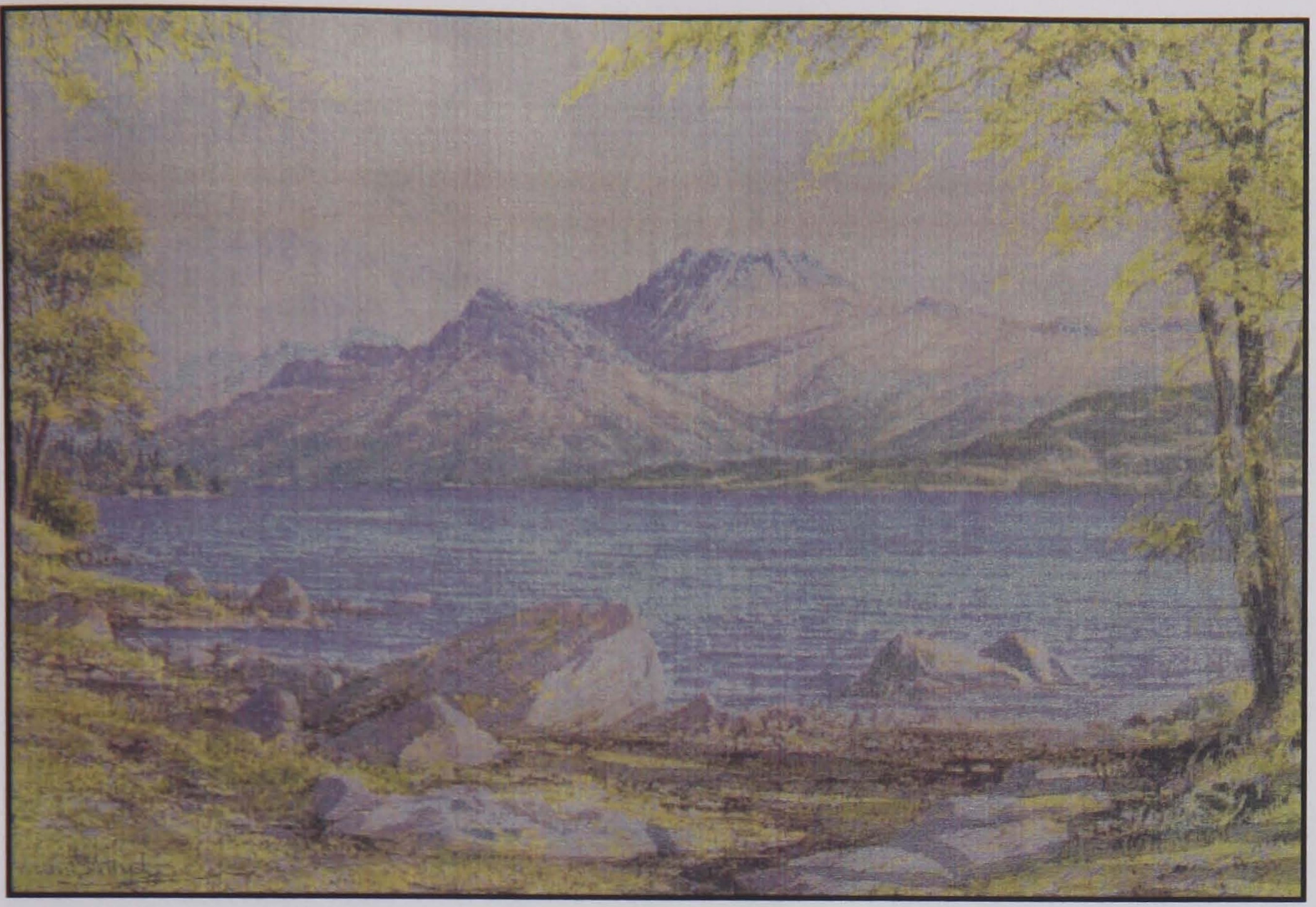


Figure 9.2.1 Painting of Loch Lomond and Ben Lomond (by John Bathgate)

Photographs

The camera was invented in the 19th century. Nowadays, colour print and slide film are easily obtained and a wide range of cameras, from the very simple to the high complicated, are available. Recent advances in technology have increased the ease of use for the general public; digital cameras are currently becoming more commonplace as photographic equipment. Many photographers now make a living from photographing landscapes. Prime examples in Scotland are Colin Baxter and Michael Macgregor, both of whose postcards may be found in any Scottish town.

The examples show landscape images taken with colour print film (Figure 9.2.2) and with a digital camera (Figure 9.2.3).

Figure 9.2.2 Colour print film: Loch an Eilein, Aviemore

Figure 9.2.3 Digital Camera: Cairnpapple Burial Mound, West Lothian

9.2.2 Landscape simulation

Most GISs can produce simple, wire-frame or shaded block images. Such images are often used by experts to examine management options, however, the images are unlikely to be transparent to any other audience. The data that is required is the same as the data which can produce any of the images seen in next two sub-sections: an elevation dataset and a texture image. These images can also be produced in 'false' colour, using thematic data such as land cover or soil datasets, or any other spatially referenced dataset.

Many of the older GISs are based on data models which are two-dimensional and have notoriously poor user interfaces and development tools (O'Brien, 1997), while the production of three-dimensional images is possible, it is unlikely to have a high level of realism. The use of three-dimensional display formats, combined with colour, shade and scales can support the exploration of more complex relationships and the animation of a series of such images can be used to convey the size and shape of objects, spatial dependencies *etc.* However, in most cases this form of visualisation produces a relatively abstract display and tends to be used for expert viewers (Orland *et al.*, 1997).

Both computer power and software sophistication are constraints on the quality and type of visualisation that have been produced by GIS packages. The wire-frame images produced by the ESRI ArcInfo package are typical and widely used. They provide a geometric basis for modelling perspective views. However, rapid changes in technology have been accompanied by rapid changes in expectation, aspirations and thus actual or perceived needs and wire-frame models fail to meet with many such needs.

The creation of 'solid' models in environmental applications was initially progressed by the image processing and remote sensing community (Legg, 1992). Historically, this community had access to low resolution satellite imagery, which could be used for textures in landscape views, although initial work in this area was rooted in a need to apply illumination models for satellite imagery using DEMs.

Figure 9.2.4 shows an example of a wire-frame image with coloured blocks and an example of the same image fully rendered using Map Maker Prospect™ (Map Maker Ltd, 1998).

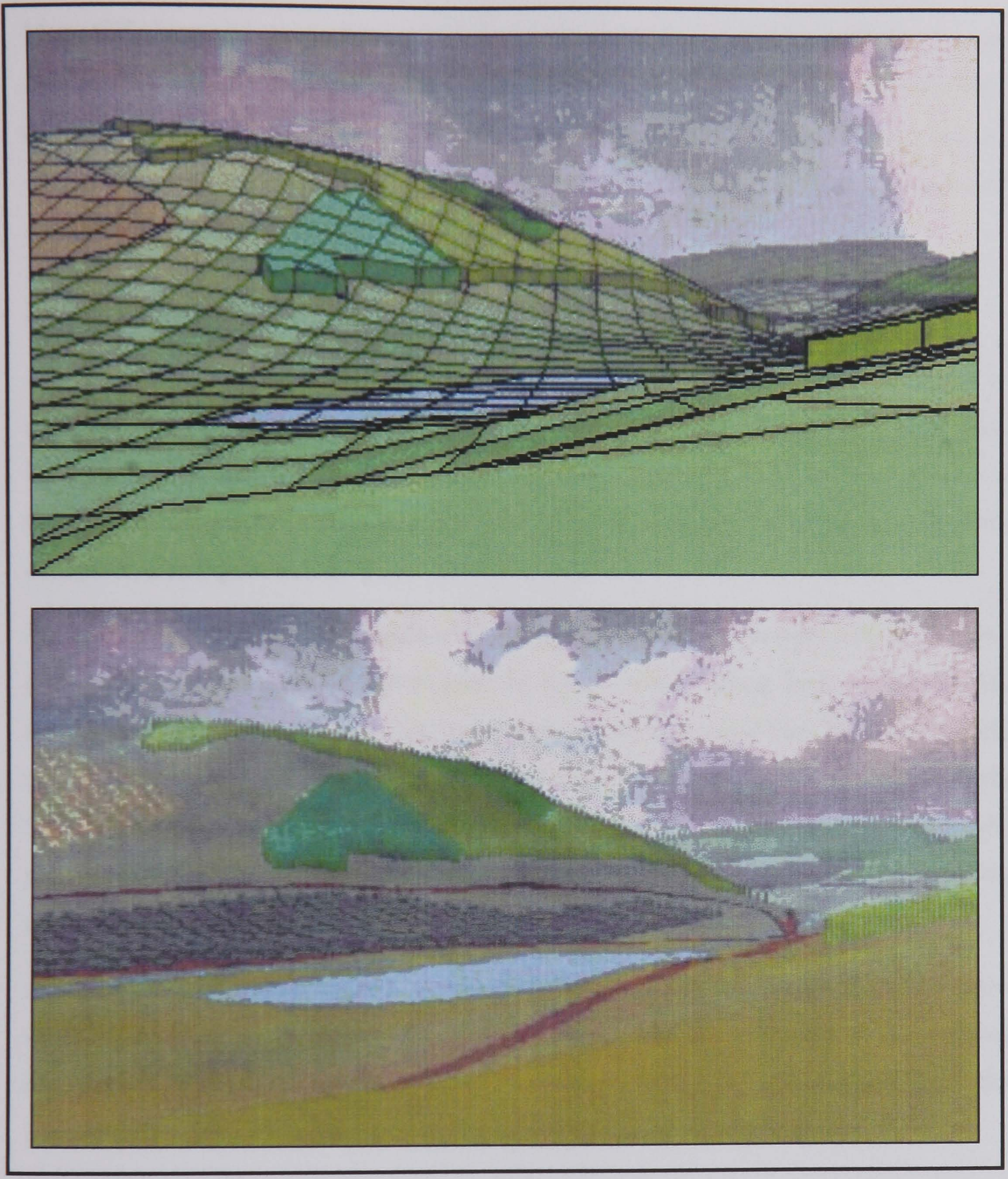


Figure 9.2.4 Map Maker Prospect™: example of wire-frame and rendered forest

9.2.3 Visualisation using GIS methods

Many GISs have add-on modules which allow the user to view their coverages in perspective, or even in real-time. Examples of such software include the perspective viewer of ERDAS Imagine, and the visualisation module of ESRI ArcView Visual Analyst (ESRI, 1998). These systems often run on more than one platform, thus reducing problems of data transportability and accessibility to a range of users.

Data sources

Access to digital elevation data has improved greatly over the last decade. DEM coverages are available for most countries, for example the Ordnance Survey produce 10m resolution DEMs for the whole of Scotland. An alternatives to buying data from such an organisation is to derive the elevation data in-house; for example using photogrammetric techniques to gain actual height data (as used in Figure 9.2.5).

Images that provide textural details of the ground are also increasingly easy to obtain. Aerial photography is available for many parts of Great Britain dating back to the World War II (Miller and Wherrett, 1998) and for many parts of Europe and Africa back to the early 1930s, unfortunately much of it is monochrome. High resolution satellite data, such as that from SPOT and Space Imaging, will soon be available at 5m, 2m and 1m resolution which will provide another source of textural data, but also for the derivation of elevation models, where stereo cover is available.

A high quality of spatial registration between the elevation and texture datasets is necessary; if there is significant error in the registration, it is likely that the coherence of the simulation will be reduced. Examples of the effects of such errors include roads being projected onto the edge if a forest stand, or a river being projected onto land adjacent to its actual route.

Resolution

Visualisation using the ERDAS Imagine software, as with all other commercial GIS packages, is constrained by the inability to use multiple spatial resolutions. The system does not allow areas in the background to be rendered at lower resolution, thus incurring extra processing time to create images which cannot be viewed at the detail at which they are available. This constraint means that the resolution in the near ground is relatively low in comparison to the ideal; while the resolution in the far ground is relatively high.

Where there is the option to decide upon the resolution to use, a balance is needed between the general constraints between hardware and software: what does the user require to see and how big an image can the system deal with while still maximising the resolution of the data.

ERDAS Imagine

ERDAS Imagine offers two tools for landscape visualisation: the perspective viewer and virtual GIS (VGIS). These two modules use the same data but allow it to be viewed in different manners. The perspective viewer gives the user very detailed placement data, it is possible to specify your viewing position to an accuracy compatible with that of the input data. However, this module is static, only one view can be seen with each rendering. The VGIS module gives the user the opportunity to move through the landscape in real-time, with different options for manoeuvring and viewing. Such systems are less useful when producing static images, but more useful for dynamic viewing of the landscape.

Nearest neighbour sampling is used for the visualisations of the DEM and image data in this section and in Chapter Ten, Section 10.3. Ideally cubic convolution would have been used, however, in Imagine VGIS there is a software bug which places peaks around a DEM using this form of spatial sampling.

The landscape below is created from a DEM and geo-referenced aerial image (Figure 9.2.5). The plain blue sky provided by the software has been replaced by an image of the sky using photomontage techniques.

Figure 9.2.5 ERDAS Imagine: Caemaes, Ceredigion, Mid-Wales

9.2.4 Dedicated visualisation software

Dedicated visualisation systems offer a far greater flexibility for image rendering than GIS based systems. Systems such as MultiGen (MultiGen Inc., 1995) (for the Silicon Graphics platform) and Vistapro (Hinkley, 1997) (for the PC) allow the user to place objects into the landscape. The user may define, or even design, these objects and manipulate their position, size and colour. Many of these systems, like CAD software, do not allow the user to walk through the landscapes in real time, but let the user save an animation file along a set path. One exception to this is IRIS Performer (Silicon Graphics Computer Systems, 1996), which allows the user to fly-though a model created using MultiGen software.

Many of these dedicated systems, such as MultiGen and IRIS Explorer, also allow the user to export files to VRML format. Unlike the GIS software, dedicated systems often use dynamic level-of-detail switching, so that images are drawn with decreasing resolution as the distance from the observer point increases. This both retains the realism of the visualisation and decreases the amount of processing time required.

The ideal landscape visualisation system would include:

- the functionality of a GIS, particularly its data storage and analysis abilities;
- the availability of environmental and decision support models; and
- a realistic, real-time, interactive visualisation system all working together under one interface.

One approach to this type of integration has been presented by Tang *et al.* (1998) - implementing a two-way communication between the existing software packages of ArcView, IRIS Performer and applying this combined system to a resource management situation.

<u>IRIS Performer and IRIS Explorer</u>

IRIS Explorer may be used to overlay terrain models with aerial or satellite imagery. The models created using the software may then be exported to a format readable by IRIS Performer. Iris Explorer can also be used to render the models, but does not have the full rendering capabilities of a system such as Iris Performer.

Iris Performer is a high-level tool-kit for building real-time simulation applications which provided commonly needed routines in building a simulation application (Silicon Graphics Computer Systems, 1996). The software, based on the C programming language with its own command library, allows models to be rendered and walked-through in real-time. Performer also allows movement within the models, such as animated objects, or real-time input of features, such as buildings, trees or fires.

In the example shown, an untextured terrain model of the area near Mar Lodge in the Cairngorms was overlaid with an aerial photograph using IRIS Explorer. The terrain model was then compared to the actual scene and trees and other structures were placed into the correct geographical position, as texture-mapped billboards (objects which rotate to face the observer). It can be difficult to place objects at the ground level, and some trees were left either "buried" or "floating" above the landscape. Nevertheless, the model displayed a degree of realism, to the extent that the course of the River Dee was identifiable, there was terrain relief and images of surface features were identifiable. A 'snapshot' of this terrain model may be seen in Figure 9.2.6.

Figure 9.2.6 IRIS Explorer and Iris Performer: Mar Lodge Estate, Braemar

<u>MultiGen</u>

The MultiGen II modelling package allows digital elevation data to be imported and overlaid with aerial or satellite imagery. This package has a major advantage over Performer and Explorer in the ease of data conversion. Once imported the terrain models may then be treated as any other 3-D data set.

Vegetation is treated in a similar fashion to the methods used in Performer, that is the 'billboard' technique. However, unlike Perfomer, MultiGen II allows the 'planting' of these models onto the surface of the terrain, so preventing time-consuming placement using individual lines of code in a Perfomer model. Any other model may be placed into the scene using the same principle.

A major advantage of using models created in MultiGen II is that they can include level-of-detail switching. The theory behind levels-of-detail is variable object representation, as mentioned in Chapter Eight. Although a model might be shown in detail in a close up view, in the distance the human eye cannot tell the difference between a highly detailed model and a simple one. If the models can be switched as they become smaller, from a highly detailed to a less detailed one, then a large saving can be made in processing time. In MultiGen II, models may be given several levels-of-detail, as may terrain, and a 'morph' (automatic, smooth transition between the two models) set up, so that the transition from one model to another becomes invisible.

Vistapro

Vistapro (Hinkley , 1997) is a dedicated landscape rendering tool, using USGS (United States Geological Survey) DEM data to produce either static images or animated walk-throughs. The package also allows the user to define climatic variation, such as tree and snow lines; to generate cloud patterns; and to place user-defined objects into the landscape, such as trees, roads, rivers and buildings. The software runs on PC and Macintosh platforms; while it is possible to run the package on lower-level specification machines, the time delays in creating the rendered images can be considerable.

Figure 9.2.7 is an example of a landscape rendered with Vistapro. The example uses the topographic data from the Feshie area, near Aviemore, and then sets the snow line, tree line and lake level to an appropriate level.

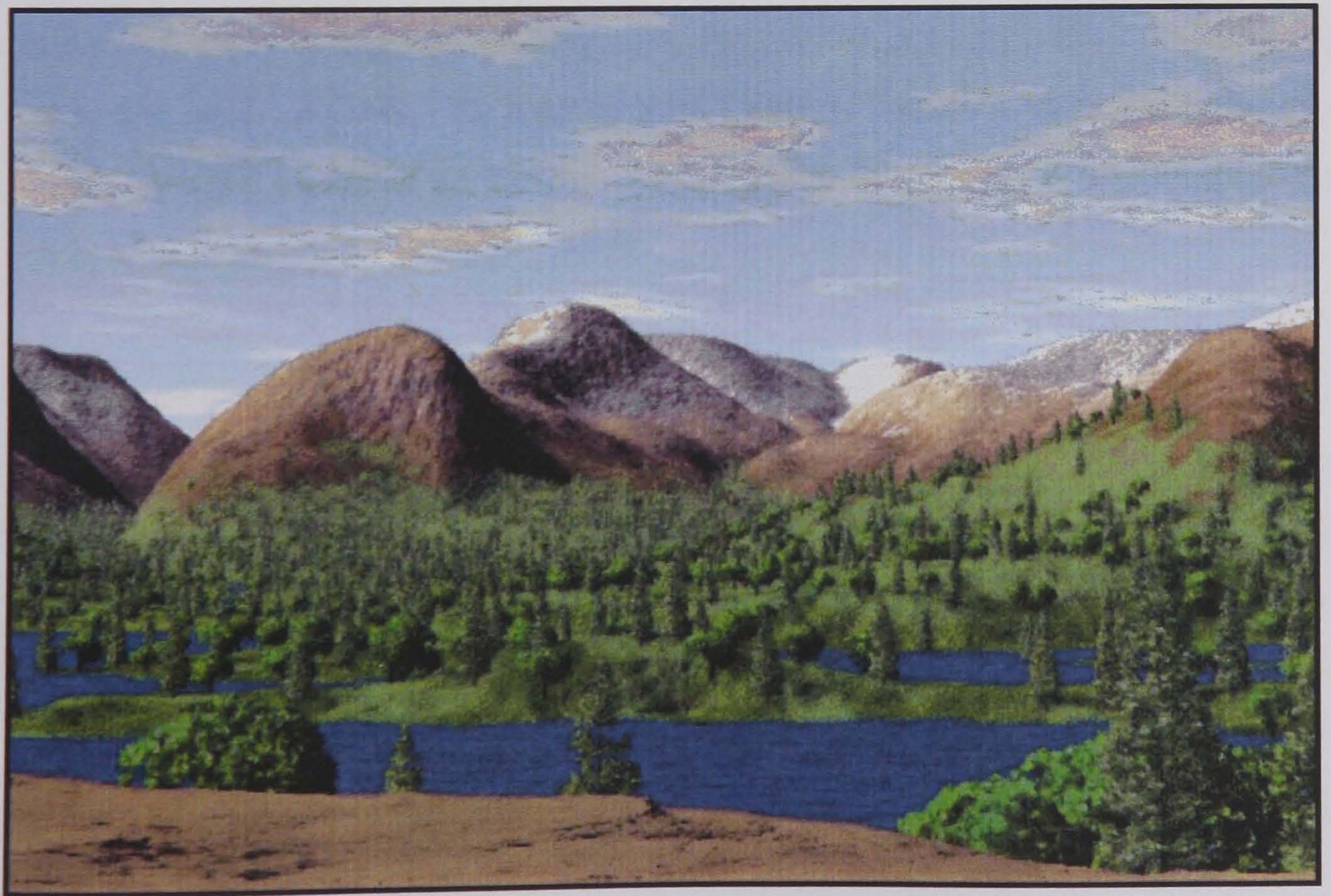


Figure 9.2.7 Vistapro: Glen Feshie, Aviemore

9.3 Methodologies for Visualising Potential Landscapes

Visual simulation is only descriptive; it does not release the planner from the difficult task of evaluation nor does it provide an evaluation in itself in a publicly based evaluation approach. However, visual simulation is, or at least should be, the prerequisite to predict and to evaluate the visual consequences of planned alterations (Lange, 1994).

9.3.1 Photomontages and artists impressions

Photomontages are often used to get an artists impression. However, it is a relatively expensive method and is restricted to fixed observer locations (Zewe and Koglin, 1995). Computer-aided photomontage is the use of computer graphics to merge synthetic images of proposed developments into photographs of their intended sites. These montages are realistic in appearance and can be demonstrated to be accurate both geometrically and in their representation of the effects of distance on colour. The outputs from such methods have been widely accepted as evidence at public inquiries.

Photomontage techniques

Direction and quality of light in computer-generated images are carefully matched to the actual lighting in the photograph. Images quality may be adjusted to match the photograph by blurring it slightly, by reducing its contrast and by making it slightly blue. Panoramas may be made of a series of separate photographs, spliced together digitally. This technique is useful to represent 'wide' objects. Computer-generated line drawings showing underlying landform in outline can be useful as an aid to understanding the geometry of the proposed development without distracting details (TJP, 1998).

Image enhancement

Once digitised photographs may be manipulated to appear as close to reality as possible. The processing technique, and the type of film used, can alter the colour of a photograph quite significantly, as has been seen in Chapter Seven. A variety of techniques are available to reduce this alteration. Histogram equalisation is often used when images are to be seen on a monitor to ensure all photographs have an equal level of contrast. Alternate colour palettes can also be used to emphasise or de-emphasise certain colours, or to brighten a scene (Bishop and Leahy, 1989).

9.3.2 DEMs and aerial or satellite overlays

Digital elevation data may be modified to reflect changes in terrain height in one of two ways: an updated DEM may be derived using ground sources or aerial photographs; or an existing DEM can be modified based upon some knowledge of the processes and rates of change in height. For example, the later method might use forest growth models to calculate the increase in height of a forest stand, either uniformly or varied spatially, or might reduce the heights in the elevation models to reflect tree felling. The limiting factors to this approach are the quality and resolution of the original DEM and the quality and applicability of the growth model.

Any change in a feature through time that affects its height will also have some affect on the overlay image. For example, the colour or texture of a taller, older tree may be different from a smaller younger tree. Therefore, there may be a need to process the existing imagery to better reflect the change in texture of the feature in the scene being modelled. Such changes may be to the tone, contrast or colour of the data or some photomontage techniques may be used on the aerial or satellite imagery before it is draped across the elevation model. Similar techniques could be used to examine quarry building or the construction of a reservoir.

9.3.3 MultiGen and Performer/Perfly

The placement of models with MultiGen is straightforward. The addition of a block of trees, or a wind farm, or any other available model, is an inbuilt module of the software. With the addition of Performer to render the images, the changed landscapes can not only be explored in real-time, but may be changed interactively. It is possible to add or remove features, structures or textures dynamically, using the keyboard as a control panel.

In effect, this means it is possible to explore two different management scenarios or to examine how a landscape will age in a very interactive and comparable manner.

9.3.4 Vistapro

It is possible within Vistapro to 'grow' a forest, or to flood a region. The following examples show some of this capability. These images represent a generic landscape (Figure 9.3.1) into which pine and oaks trees have been placed up to the tree line, at a user-defined density and average size (Figure 9.3.2). The final landscape (Figure 9.3.3) represents the same landscape with a higher water level, effectively what the landscape could look like if the water in the original image was a reservoir whose level could be changed.

Figure 9.3.1 Vistapro: example landscape

Figure 9.3.2 Vistapro: Modified landscape - tree growth

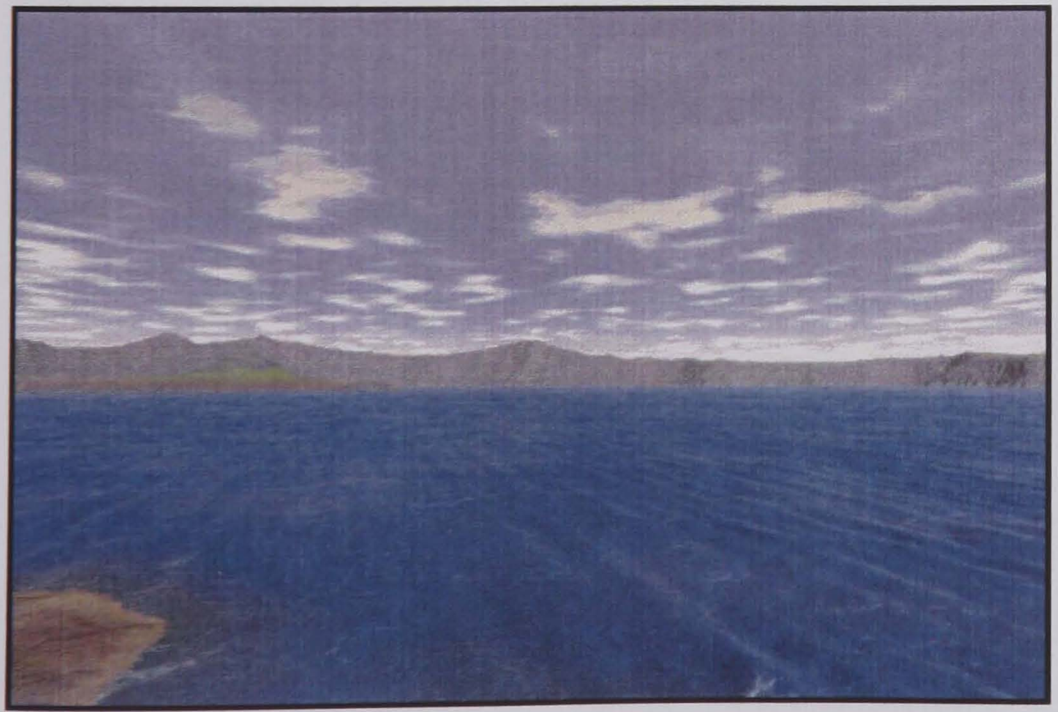


Figure 9.3.3 Vistapro: Modified landscape - raised water level

9.4 Discussion

There are many techniques for simulating the visual landscape, from traditional hand drawn images through to visualisations rendered using dedicated software packages. All of the methods discussed within this chapter concentrate on the static landscape, and it must not be forgotten that this excludes many facets of the landscape: sound, smell, weather such as wind or sunshine, and dynamic effects.

Yet more sophisticated techniques exist in many architectural research programs, often using CAD packages. However many of these also suffer from being predominately visually based. Some packages, however, do offer some level of multi-media effect; examples include the real-time walk-throughs available in newer versions of ERDAS Imagine VGIS and Iris Performer. The use of VRML allows cross-platform viewing of 3D landscapes in real-time, and may include animations which convey a sense of dynamism or recorded sounds which can be played when an area is viewed.

Given the current rate of change in technology, far more immersive, real-time, three-dimensional landscapes models are likely to be developed in the near future. Already virtual field-courses are being designed - generic virtual environments for the exploration of natural resources (VFC, 1998) which will save considerable cost within the academic world. Perhaps before we jump onto this 'high-tech bandwagon' it is necessary to remember that nature and the great outdoors is best experienced first hand and that virtual reality will always be 'virtual' not 'reality'.

CHAPTER TEN

LANDSCAPE PREFERENCE MODEL (PART IV)

REAL AND SIMULATED LANDSCAPES

10.1 Introduction

The techniques described in Chapter Eight provide different means of creating simulations of landscape. The final surveys of this research examine the use of landscape images that have not been produced by conventional (*i.e.* analogue photographic) means. This chapter will include a look at the use of digital cameras, which provide an improvement to photographic data input to digital media, in terms of the time and effort required to create a digital image.

Several different methods for simulating landscape images have been examined using a variety of software, three of these techniques will be used to simulate landscapes and then compare these images to photographs of the actual landscape. A questionnaire survey is again used to gather data on preferences for the different types of landscape images.

Chapters Four to Seven have detailed a technique for evaluating natural landscapes in terms of scenic preference and Chapters Eight and Nine have explored a variety of methods for simulating landscapes and landscape change. The final section of this chapter will build on this work by examining how landscape visualisation and evaluation might be combined to produce a decision support tool for landscape planning and impact assessment.

10.2 Digital Camera Survey

10.2.1 Methodology

The use of a digital camera would greatly reduce the time and expense required to process and scan print film photographs. However, it is recognised that the resolution of an image taken digitally may not match that of an image taken by a standard camera and then scanned. It is therefore necessary to test these differences by comparing identical photographs taken by a standard and digital camera.

The digital camera used was a Kodak DC210, using 1152 x 862 pixel resolution and 24 bit colour at a focal length between 28 and 58 mm; the standard camera used was a Samsung AF Zoom at a focal length between 38 and 50 mm. Photographs were taken from the same points at the same times, with focal lengths as close to equal as was possible. The results from Chapter Seven, Section 7.6 showed that focal lengths which are close to each other do not affect preference scoring.

The prints were then scanned at 200 dpi and converted to GIF 87 format. The digital images were converted to the same format and physical size as the print images. The photographs were taken in the summer of 1998, from a variety of locations in Scotland.

10.2.2 Format problems and image choice

It became apparent that the images taken with the digital camera comprised a smaller section of the view than the images taken with the standard camera, despite having been at the same focal length. In order to show respondents the same picture, the images taken from the print camera required to be cropped. However, this resulted in some images having a very poor resolution at the required physical size of the image (580 by 395 pixels).

Test were run on the set of 24 photographs which had been gathered. It was found that many had a complexity score (number of bytes per pixel) below that of the lower limit set in Chapter Six. On examining the colour variables found in the print and digital images, it was also found that many of the digital images had mean and standard deviation colour levels below that of the set limits.

Therefore, the choice of images was limited to those which best fit the criteria set in Chapter Six, Section 6.3. This left ten images which could be used and which were subsequently placed on the Internet. A survey was run using each set in a different questionnaire, so allowing the ranks of the images taken by the two camera types to be compared. This survey was run in the summer of 1998, and results gathered from 45 respondents. Details of the socio-demographic breakdown of respondents can be seen in Appendix XVI.

10.2.3 Analysis and Results: comparison of digital and print film cameras

Correlations between the two sets of scores and ranks were calculated for the actual preference data and for the predicted results (Table 10.2.1).

Correlation between image types	Scores	Ranks
Average	0.911	0.915
Normalisation per respondent*	0.911	0.903
Normalisation per questionnaire*	0.935	0.976
Model A	0.844	0.830
Model B	0.788	0.709
Model C	0.827	0.709
Model D	0.762	0.786
Model E	0.791	0.794
Model F	0.956	0.927
Model Y	0.855	0.842

* these will not be numerically equal, as normalisation per respondent uses complete data sets

Table 10.2.1 Correlations between preferences for print film and digital images

The correlations between the scores and the ranks in Table 10.2.1 are high, with the majority significant at the 0.01 level (correlations over 0.765). The intergroup reliability for the two groups was 0.968 for the scanned images and 0.877 for the digital images; both these results imply that the sample had a high degree of consensus. The models did not predict this close correlation; this can be attributed to the differences in the colour variables between the two types of images.

An analysis of variance using repeated measures was run on the preference score data to assess the significance of camera type on landscape preference (Table 10.2.2). The results show that the type of camera used is not a significant factor in the score given to an image.

Between-Subject Effects	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Intercept	8887	1	8887	2376	0.000
Camera Type	7.119	1	7.119	1.904	0.175
Error	157.1	42	3.740		

Table 10.2.2 Analysis of variance: Digital Camera Survey

Variable	Correlation between image types	Print Film		Digital Camera	
		Average	St. Dev.	Average	St. Dev.
Red Mean	0.319	141	45.087	83	54.955
Green Mean	0.590	137	11.392	84	13.141
Blue Mean	0.243	114	12.447	88	11.066
Red Standard Deviation	**0.731**	**87**	**13.408**	**59**	**9.534**
Blue Standard Deviation	0.711	88	5.731	59	9.333
Green Standard Deviation	0.777	100	7.264	78	7.613
BPP	**-0.287**	**246**	**3.957**	**543**	**7.792**

Table 10.2.3 Correlations between colour variables for digital and print images

Table 10.2.3 shows that the mean colour variables of the two image types were not well correlated, while the standard deviations show far greater agreement. On average, the print film has a higher mean colour and standard deviation, implying that the print film images are lighter and have a greater width of colour than the digital images.

As the majority of the models (the exceptions being D and E) use red variance as the only colour variable, the difference in colour will not affect them to any great extent. However, the complexity (BPP) term has a negative correlation, reflecting a far high complexity in the digital images - each pixel requiring over twice as many bytes in the digital images than in the scanned images. In part, this is an artefact of the photographic cropping required when formatting the survey images, but it is also an artefact of the method of capturing the image, because of the difference in resolution between a digital camera image and a scanned print film image.

10.2.4 Analysis and Results: use of landscape preference models

Model	Print Film Camera		Digital Camera	
	with colour	without colour	with colour	without colour
Model A	0.746**	0.845***	0.614	0.737**
Model B	0.636**	0.783***	0.587	0.703**
Model C	0.702**	0.819***	0.605	0.685**
Model D	0.486	-0.005	0.420	0.579
Model E	0.623	0.808***	0.627	0.748**
Model F	0.771***	n/a	0.793***	n/a
Model W	0.645**	0.799***	0.590	0.755**
Model Y	0.879***	0.588	0.640**	0.311

Table 10.2.4 Correlations between actual and predicted scores: Digital Camera Survey

Model	Print Film Camera		Digital Camera	
	with colour	without colour	with colour	without colour
Model A	0.745**	0.794***	0.612	0.733**
Model B	0.636**	0.756**	0.534	0.794***
Model C	0.636**	0.756**	0.534	0.697**
Model D	0.370	-0.079	0.500	0.679**
Model E	0.588	0.661**	0.661**	0.491
Model F	0.782***	n/a	0.758**	n/a
Model W	0.782***	0.782***	0.527	0.709**
Model Y	0.842***	0.612	0.648**	0.515

Table 10.2.5 Correlations between actual and predicted ranks: Digital Camera Survey

Table 10.2.4 and Table 10.2.5 show that the models achieved a high level of correlation with the preference data for both the print film and digital cameras (***0.01 level, **0.05 level). With the exception of models D and Y, the correlation with the models that do not include the colour variables is higher for both scores and ranks.

The models predict the scores better for the print film than for the digital camera in all cases (excepting Model D), and predict the ranks better for all models using normalisation per respondent (again excepting Model D). The two models using normalisation per questionnaire have better correlations with the digital camera preference data.

These results suggest that the models are more suited to predicting the preferences for print film images which have been scanned than for digital cameras. However, the correlations achieved by the models for the digital camera images are still high.

10.2.5 Discussion

The high correlations between both the scores and ranks given to the digital and print film camera images implies that the use of a digital camera is justifiable. Although the models have higher correlations for print film images, this can be attributed to the fact that the models were created using data from scanned images and are designed to be used with such images. It has been shown that the colours of the two sets of images are different and therefore the models can be said to have shown their robustness by producing high correlations for this set of images.

It is clear that the difference in camera type has not affected the scoring of the images, again implying that the precise colours of the image are not of high importance. Future use of a digital camera would improve the overall efficiency of using an Internet survey questionnaire framework, as it would negate the requirement for film processing and photograph scanning. It is perhaps necessary to further investigate the settings on digital cameras to find the most suitable image format, pixel resolution and level of compression.

10.3 Comparison of Real and Simulated Landscapes

10.3.1 Methodology

This survey examines the hypothesis that people will rank a set of simulated landscape images in the same order as a set of photographic images. A site was chosen for comparison to actual landscape photographs around Braemar in north-east Scotland; the site was chosen for its accessibility and the availability of large and detailed datasets at MLURI. A DEM at 5m resolution exists for an area of approximately 20 square kilometres to the west of Braemar and colour orthophotography also exists for the entire of this area, at 2m resolution. Using techniques discussed in Chapters Eight and Nine, several landscapes within this site were simulated. Due to technical difficulties, there were some problems with aerial photograph colour and geometric registration in the Vistapro images.

Three techniques were used to simulate the landscapes.

1. EDRAS Imagine Perspective Viewer;
2. Vistapro™ (using aerial imagery as ground colour); and
3. Vistapro™ (using automated terrain colouration and manual object placement).

The sites were extensively photographed in the summer of 1998 from all positions which were viable for landscape simulation, in terms of having complete horizon views. Skies were not required to be simulated due to the cloudless weather conditions on the fieldwork days. The simulated models were then manipulated to produce snapshots of identical scenes. Ten of these scenes were then input into four sets of questionnaires for preference scoring. An example image in all four formats is shown in Figure 10.3.1.

Analysis of the simulation images was undertaken in the same manner as for photographs (Chapters Six, Seven and Ten). All colours variables were measured and the simulations using methods 1 and 3 above were digitised using ERDAS Imagine.

These images were then placed on the Internet and results gathered over a two week period in October 1998.

The following example shows all four methods of landscape simulation. The view is taken from the Linn of Corriemulzie towards Creag Bhalg, in the area west of Braemar, Aberdeenshire.

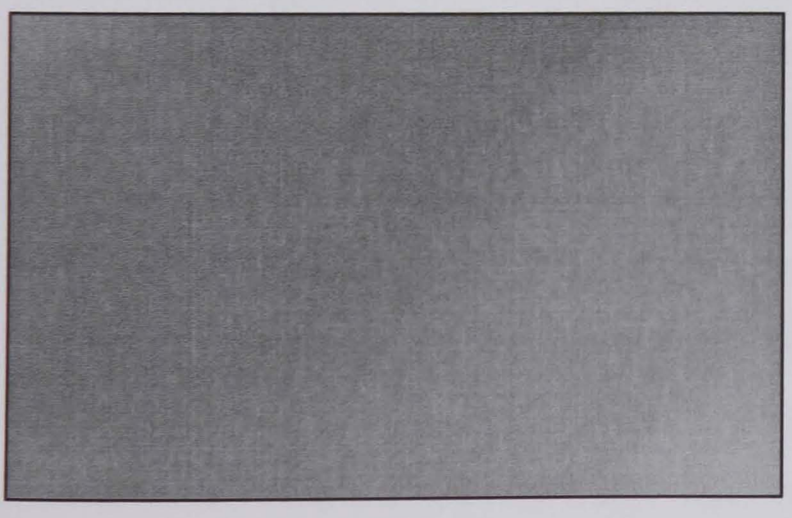
Scanned Print Film Photograph

Simulation using ERDAS Imagine

Simulation using Vistapro with overlaid ground colours

Simulation using Vistapro with automated terrain colouration and manual object placement

Figure 10.3.1 Four methods of landscape simulation



Section from DEM

Section from orthophotograph

Figure 10.3.2 Data used for landscape simulation in Figure 10.3.1

10.3.2 Analysis and Results

A total of 89 replies were received; their distribution between the four questionnaire versions and corresponding Intergroup Reliability is shown in Table 10.3.1. The socio-demographic breakdowns of the respondents is shown in Appendix XVII.

Visualisation Method	Intergroup Reliability	Sample Size
Photograph	0.930	23
Imagine	0.663	20
Vistapro (ground colour)	0.864	21
Vistapro (manual placement)	0.731	25

Table 10.3.1 Intergroup reliability

The reliability of the results for the photographs is higher than that for any of the visualisations (Table 10.3.1) although all are significant at the 0.05 level. This is not unexpected, as the visualised landscapes will require a far greater degree of interpretation by the viewer than a standard photographic image. Nevertheless, the intergroup reliabilities are still significant, and do not reflect a lack of consensus among the respondents.

Visualisation Method	Normalisation per respondent		Normalisation per questionnaire	
	scores	ranks	scores	ranks
Imagine	0.347	0.370	0.338	0.285
Vistapro (ground colour)	0.316	0.188	0.369	0.333
Vistapro (manual placement)	0.529	0.479	0.653*	0.588*

Table 10.3.2 Correlations between preferences for photographic and simulated images

Table 10.3.2 shows the correlations between the scores and ranks of the ten photographic images and the three types of visualised images. At best these correlations are modest, with the Vistapro (manual placement) images the only set to achieve significance at the 0.1 level. These results suggest that the images are not being scored in the same manner as the photographs; it is hypothesised that while a respondent may be able to see a photograph and 'translate' that image into a level of aesthetic quality, it is not possible for them to 'translate' a simulated image into a 'real' image in order to give the landscape an aesthetic value.

Model	Photograph score	Photograph rank	Vistapro (manual placement) score	Vistapro (manual placement) rank
Model A	0.749**	0.818***	0.202	0.107
Model B	0.768***	0.794***	0.180	0.179
Model C	0.708**	0.709**	0.095	0.107
Model D	0.738**	0.794***	0.238	0.100
Model E	0.632**	0.661**	-0.387	-0.500
Model F	0.632**	0.770***	0.223	-0.466
Model W	0.761**	0.782***	0.255	0.107
Model Y	0.785***	0.818***	0.190	0.179

Table 10.3.3 Correlation between actual and predicted results: Simulation Survey

Table 10.3.3 shows the correlations between actual preference scores and the scores predicted by the models for the photographs and for the Vistapro (manual placement) images. The correlations for the photographs are uniformly high (all correlations are significant at the 0.05 level), while the correlations for the Vistapro images are, in the majority, very poor. The models were also tested with the exclusion of the colour variable terms; in some cases this increased the correlations but not in each case, so no conclusions can be drawn regarding the potential use of non-realistic colours in the landscape simulations.

10.3.3 Colour variables

Variable	Correlation between Photograph and Simulation: ERDAS Imagine	Vistapro	Vistapro (manual placement)
Red Mean	0.374	0.135	0.618
Green Mean	0.228	0.760	0.078
Blue Mean	0.410	0.228	0.700
Red St. Dev.	**0.601**	**0.720**	**0.704**
Blue St. Dev.	0.951	0.688	0.586
Green St. Dev.	0.535	0.457	0.096
BPP	**0.847**	**0.278**	**-0.022**

Table 10.3.4 Correlations between colour variables for simulated images

If the correlations between the colour variables are examined, it can be seen that the level of red standard deviation in each simulation type is similar and has a moderate correlation with the photographic images. However, the BPP variable shows very different levels of calculated complexity in the images, with the Vistapro (manual placement) images having no correlation with the photographs.

10.3.4 Discussion

Clearly, people do not respond to computer simulations of landscapes in the same way that they respond to photographic images. This finding is backed up by the work of Daniel and Orland (1997) who also found low consistency in ratings of scenic beauty for abstract management views. They noted that such views were "insufficient for the purpose of obtaining public judgements of perceived scenic beauty". The work of Lange (1998) has suggested that terrain models with aerial photography overlaid can produce images of very high perceived realism, when only the background is viewed. It is possible that the use of all distance zones has decreased the level of realism in the simulated images to a point where they cannot be perceived as a realistic landscape image.

At this point it is necessary to ask ourselves again what we want from such visualisations? Do we wish to show these images to the general public in order to gain information about their preferences, or do we wish to use them in a management driven way. Perhaps the question that should be asked is: can predictive preference models, applied to visualised images of landscapes, predict preferences for the landscapes those images are simulating?

Model	ERDAS Imagine		Vistapro (manual placement)	
	Scores	Ranks	Scores	Ranks
Model A	-0.913	-1	0.911***	0.929***
Model B	-0.939	-1	0.901***	0.857**
Model C	-0.941	-1	0.914***	0.929***
Model D	n/a	n/a	0.147	0.100
Model E	n/a	n/a	0.661	0.750*
Model F	0.220	0.079	0.755**	0.855**
Model W	-0.953	-1	0.900***	1.000****
Model Y	-0.945	-1	0.870**	0.857**

Table 10.3.5 Correlations between predicted (Imagine and Vistapro) and actual (photographs) results: Simulation Survey

The results in Table 10.3.5 show that the preference models, using the data from the Vistapro simulations, are able to predict the preferences of respondents for the actual photographs. The data from the ERDAS Imagine simulation is unable to predict preferences (negative significant correlations) and it is unknown why the negative correlations occured. It is not possible to create a visualisation close enough to the actual scene using non-dedicated landscape visualisation software to be able to predict preference simulated images.

However, the dedicated software (Vistapro) is able to simulate landscapes to the degree of realism necessary to be able to use predictive preference models (significant correlations marked). The correlations for four of the models (Models A, B, C and W) are very good (significant at the 0.01 level), with another two models (Models F and Y) producing good correlations (also significant at 0.01 level, Model F score significant at 0.02 level), although it is a little disconcerting that the correlations are higher than produced from the photographs themselves.

If the form of the two types of simulation are examined (DEM with draped imagery and object placement techniques), it can clearly be seen that the techniques using placement of objects is closer to reality in the ability to judge elevation and obscuring vegetation. However, there is also an artefact of the method of simulation in the results; the ERDAS Imagine software used the data available to create visualisations of the landscape from the same position as the photograph was taken from. The Vistapro software improved on this by allowing the landscape and objects within it to be manipulated to match the photographs as closely as possible. Nevertheless, this does not explain lack of correlation between the predicted results from the Imagine visualisations and the photographs.

This leads us to several questions about the future for simulations in landscape preference prediction. The use of simulations may lead to increased efficiency in use of predictive models, through the automation of the calculation of landscape variables and the use of process-based environmental models to derive landscape changes. However, simulations cannot be as good as pictures and will never be able to fully convey the information that is contained within a photograph to an observer. For systems such as SmartForest (Imaging Systems Laboratory, 1995) and the Forest landscape simulation model (Kellomäki and Pukkala, 1989) as described in Chapter Eight (Section 8.4), the simulations produced should be able to drive preference models, created from photographs, with a high degree of success.

10.4 System for Landscape Visualisation and Evaluation: Sy*LVi*E

SyLV*i*E combines a visualisation facility (either photomontage or landscape simulation) with a predictive preference model to produce a tool with which landscape change can be visualised while indicating the relative level of scenic beauty of the changed landscape.

10.4.1 Example of the use of Sy*LVi*E

An example image was photomontaged, with a hypothetical landscape change, to demonstrate how the system for landscape visualisation and evaluation (SyLViE) would function. The images and the corresponding scores from the eight models are shown below (Figure 10.4.1, Figure 10.4.2 and Table 10.4.1).

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. Figure 10.4.2 shows 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 all predictive preference models, it is expected that this will decrease the scenic quality of this landscape.

10.4.2 Analysis and Results

The change in predicted scores can be calculated using the digitising techniques described in Chapter Six. The scores from the eight models are noted in Table 10.4.1.

Scene	Model A	Model B	Model C	Model D
Original image	0.435	0.394	0.410	0.756
Photomontage	0.117	0.154	0.145	0.266
Change in preference	negative	negative	negative	negative
Scene	**Model E**	**Model F**	**Model W**	**Model Y**
Original image	-1.111	0.668	0.442	0.410
Photomontage	-1.388	-0.149	0.209	0.182
Change in preference	negative	negative	negative	negative

Table 10.4.1 Comparison of preference scores: original vs. photomontage image

The results from this table show that all eight models predict a drop in landscape preference for this image. This result was verified by two groups of post-graduate environmental assessment students from a wide geographical base as part of a Landscape Evaluation course.

Figure 10.4.1 Photograph of Loch an Eilein, Aviemore

Figure 10.4.2 Photomontage of Loch an Eilein, Aviemore

All eight models were correct in their prediction that the photomontaged image would have a lower preference score than the original photograph. This example shows the potential use of the predictive preference models, with photomontaged images, to assess the scenic impacts of proposed changes in land use management.

10.5 Summary

This chapter aimed to examine the utility of the predictive preference models created in Chapters Six and Seven with landscape images created with unconventional (*i.e.* not analogue photographic) methods. Three types of simulation were examined: digital camera images, simulated landscape images and photomontaged images.

10.5.1 Digital Camera survey

The use of digital cameras in the place of print film camera was examined in this survey. Ten images were used, each of which had been taken with both a conventional and digital camera. The results showed that despite the very different colour levels in the two sets of images, the respondents scored and ranked them essentially identically. Analysis of variance strengthened this finding by showing that the type of camera used is not a significant factor in the level of preference score given to an image.

This leads to the conclusion that the use of a digital camera is justified although the models will produce better results with the same type of image as those which they were created with (*i.e.* scanned print film photographs). It would therefore be appropriate, as well as less time consuming and less expensive, to use a digital camera in the creation of any future preference models.

10.5.2 Simulation survey

Three methods of landscape simulation were examined by showing respondents either standard photographic images or simulations of the same scene. Results showed that respondents did not react the same to the photographic and the simulated images. It is hypothesised that a lay-person cannot translate a simulated landscape image into an actual landscape in the same way that they are able to translate a photographic image.

However, comparisons of the predicted scores from the simulated images with the actual scores from the photographs showed that the Vistapro (manual placement) simulations were able to produce predicted scores which correlated highly with actual scores. This result further suggests that if the simulation is changed, and that change can be measured, then the models will be able to predict the changed preference for that landscape.

In conclusion, while simulations of landscapes are not able to be used for gathering preference data, dedicated landscape visualisation software is capable of producing visualisations which may be used to predict landscape preference for current and alternative future landscapes.

10.5.3 Comparison of photomontaged images

Finally, two images of Loch an Eilein were compared: the original image of the loch and a photomontaged image where the loch has been obscured by vegetation. All eight models and the Shafer model predicted that the original image, with the loch visible, would be preferred. Results from two groups of International students confirmed this result.

This experiment has shown how photomontaged images might be used to gather information on landscape scenic preference for alternative management scenarios. By adjusting the potential images, those which are least detrimental to the scenic beauty of the landscape may be further considered by landscape planners.

CHAPTER ELEVEN

LANDSCAPE EVALUATION AND VISUALISATION

GENERAL SUMMARY AND DISCUSSION

This thesis has examined a variety of techniques for evaluating and simulating the scenic landscapes of Scotland. In discussing the results from this research, the thesis will be summarised in six sections:

1. Review: a review of literature relevant to the evaluation of landscapes, preferences and perceptions of landscapes and psychophysical landscape preference models;
2. Questionnaire methodology: the gathering of data to create a landscape preference model and corresponding issues;
3. Landscape preference models: the creation of eight models, the variables used and the factors that may influence these models;
4. Landscape visualisation techniques: a review of the issues within visualisation followed by examples of landscape simulation methods and analysis of their validity;
5. Applications: the application of this research to landscape planning and environmental assessment; and
6. Future work: areas where further work into methodological issues is required, and areas where the current research may be extended.

In summarising these areas, significant findings and results will be noted. These will be displayed in a flowchart at the end of this chapter. The following chapter will draw the thesis to a close with some final conclusions.

11.1 Literature Review

11.1.1 Evaluation, Preference and Perception

The first section of the review into landscape evaluation, preference and perception gives a broad introduction into a number of concepts. These terms tend to focus heavily on the visual; the other senses are often left out of the equation. It is a non-trivial matter to include sound, movement, texture, temporal dynamics and so on directly into work on landscape preference. Landscape is a phenomenon often taken for granted, which has great cultural significance; scenery, although it has not always been so appreciated, can produce strong responses in people who associate it with their home and their heritage (Wherrett and Baldwin, in press). It is interesting to note that Loch an Eilein, the image used as an example throughout this thesis, was, in 1929, described as a "typical scene" in a book about Scotland (Morton, 1929).

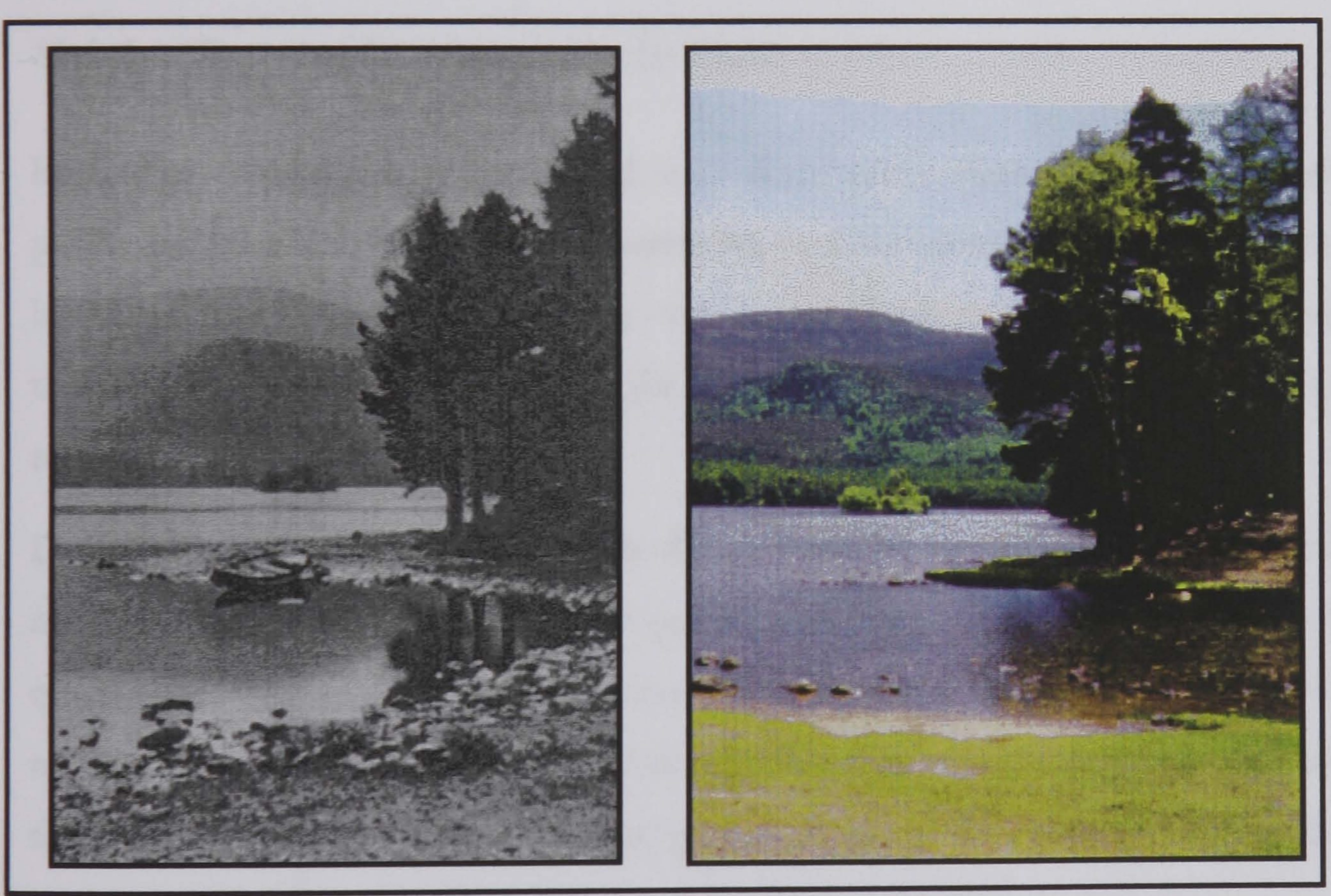


Figure 11.1.1 Loch an Eilein: 1929 and 1994

Many theories of landscape aesthetics have been put forward over the last four decades. Reviews of such work consider either theory or application, but rarely tie these two facets together. The use of psychophysical models within this thesis allows the link between theory and application to be made and demonstrated.

The general public are arguably the best source of data for landscape preference work; and in fact their input is vital to testing and proving theories of landscape aesthetics. Many socio-demographic traits have been noted as having an effect on landscape perception. Previous experience of landscapes is one of the most influential of these (Balling and Falk, 1982). Gender, education, age, environmental awareness, and cultural differences also all have effects (Harvey, 1995; Lyons, 1983; Ulrich, 1977; Zube and Pitt, 1981). However, opinion is divided among researchers: Wellman and Buhyoff (1980) found that regional familiarity did not effect preference, whereas Lyons (1983) found that preference was strongly influenced by residential experience. Results from the research, described in Chapter Five, are not conclusive.

Consensus between human observers is an issue in preference models. It has been found that this will differ depending on familiarity, the 'extremeness' of the scenic evaluation and other socio-cultural factors (Abello *et al.*, 1986; Penning-Rowsell, 1982). Consensus amoung respondents has been measured using intergroup reliability measures within this research.

11.1.2 Types of Landscape Evaluation

Evaluation methods can be divided into three main methodologies: descriptive inventories, public preference methods and quantitative holistic techniques. These methods are broadly based on three perception paradigms - the expert, the cognitive and psychophysical. It is noted that a merger of the latter two is the most likely to provide a robust landscape evaluation method.

Descriptive inventories include methods based on the overall similarity of landscape units, and methods which identify relationships between landscape components and environmental quality. Several such methods are described in Daniel and Vining (1983). Public preference methods most commonly use questionnaires or verbal surveys to sample the scenic preference of the general public. Psychological and phenomenological models are also used, both, however, are more subjective than objective.

Quantitative holistic techniques, which combine the approaches of public preference surveys with landscape feature inventories, measure landscape 'quality' as related to the physical, biological and social features of the landscape (Arthur *et al.*, 1977). The models tend to predict scenic preference rather than try to classify landscapes or to explain preference (Buhyoff *et al.*, 1994). Examples of work done under this heading include that of Shafer and colleagues (Brush and Shafer, 1975; Shafer *et al.*, 1969; Shafer and Tooby, 1973) and of many other researchers (e.g. Arthur, 1977; Buhyoff and Riesenmann, 1979; Buhyoff and Wellman, 1980; Carls, 1974; Tan, 1997).

There are problems and errors in all types of modelling; some mathematical and others more philosophical. There is a question over whether people give preference for quality or for beauty, and whether or not their preference is the same as their judgement of scenic beauty (Arthur *et al.*, 1977; Jacques, 1980); this issue has not been examined as part of this thesis.

11.1.3 Psychophysical Landscape Preference Models

These models combine the approaches of descriptive inventory and public preference models by systematically relating measures of landscape quality or preference to physical, biological and social features of the landscape to predict the implications of environmental changes (Arthur *et al.*, 1977). Two types of measurement are commonly used: the SBE method (Scenic Beauty Estimation) and the LCJ method (Law of Comparative Judgement) (Hull *et al.*, 1984). Both are considered equally sensitive and although the emphasis is on the SBE method, both have been used in this thesis.

The medium of presentation and illustration is important; photographs are commonly used, and experiments into the validity of their use have been undertaken. Results have shown that photographs may indeed be used to accurately represent landscapes (Dunn, 1976; Shuttleworth, 1980a; Stamps, 1990). The use of computer simulated images has also been examined; image processed landscapes can elicit similar responses to real images, while wire frame simulations do not have sufficient detail to do so (Oh, 1994), this was taken into account when creating simulated landscapes for the preference studies of Chapter Ten.

The psychophysical method requires the landscape to be sub-divided; methods for doing this include using landform elements, landscape patterns, landscape character, landscape qualities, landscape dimensions and landscape preference predictors (Crofts, 1975; Gardiner, 1974; Hammitt *et al.*, 1994; Linton, 1968; Morisawa, 1971; Propst and Buhyoff, 1980; Shafer *et al.*, 1969). The importance of less tangible aspects of landscape is apparent in the literature. For example, edge effects are important in areas of contrast (Hammitt *et al.*, 1994) and the interaction between elements cannot be ignored (Dunn, 1976). There are two groups of landscape division: those related to the geology and ecology of an area - the objective properties; and those which are less measurable such as coherence, mystery and complexity - the subjective properties (Crofts, 1975; Kaplan *et al.*, 1989).

It is accepted that there are some permanent landscape characteristics which are major contributors to scenic quality: terrain, water, vegetation and cultural artefacts. It is this type of characteristic on which the predictive models rely. These types of models have been examined in some depth and the components used summarised. The explanatory abilities of these models is also of interest. Those which are of the greatest interest to this research are the more objective, measurable components (*cf.* Shafer *et al.*, 1969; Patsfall *et al.*, 1984; Hammitt *et al.*, 1994; Bishop and Hulse, 1994; Propst and Buhyoff, 1980).

There are many visual and non-visual effects on landscape preference. Labelling landscapes can affect scenic quality judgements (Anderson, 1981; Schroeder and Daniel, 1981). Sound and motion have been shown to effect results: there is an interaction between sound and other features in the landscape (Anderson *et al.*, 1983); dynamic surrogates (video) preserve the flow-related differences which the static (photographs) cannot (Hetherington *et al.*, 1993). Visual effects, such as complexity, mystery, focality, depth, prospect and refuge all effect preference, these are sometimes described as cognitive criteria (Baldwin *et al.*, 1996); these are, however, difficult to measure. Their effects are described in several authors' work (Lynch and Gimblett, 1992; Nasar *et al.*, 1983; Schutte and Malouff, 1986; Ulrich, 1977). Complexity, coherence and mystery are used as preference predictors within this research, using proxy measurements as suggested by several authors (Bishop and Leahy, 1989; Orland *et al.*, 1995; Kaplan, S., 1987; Ulrich, 1977).

11.2 Questionnaire Methodology

The surveys used throughout this research were run over the Internet, both locally and remotely, using WWW browsers to show images to respondents. The exponential growth of the Internet over the past two decades allows an increasingly large number of people access to the World Wide Web; it also allows surveys to be undertaken using the Internet which result in a sufficiently large sample of respondents.

There are several advantages to using the Internet to gather landscape preference data: the survey requires no paper or posting and is thus comparatively cheap to run; the survey also gathers its own data, particularly if being run remotely, and requires no time consuming data-input thus allowing the researcher to continue with other work; finally it is easy and quick to modify an electronic survey.

The surveys used in this research all ran on WWW browsers. They used scanned photographic images or simulations of landscapes which were shown to respondents and subsequently given scenic preference scores. The questionnaire was written in HTML and PERL programming language and was hosted at the Macaulay Land Use Research Institute WWW site.

11.2.1 Issues in using the Internet to Undertake Preference Surveys

Several important issues regarding the validity of the methodology were examined before the major surveys were undertaken. The first of these was the use of a monitor to show images to the respondents; a paper survey was used to compare results from paper and monitor-based images. Results showed that the use of monitor-based images was valid.

Several other issues are discussed in Chapter Four. These include effects due to the size, resolution and colour resolution of computer screens. Literature suggests that 256 colour displays are adequate for this type of research; subsequent examination of the importance of colour (Chapters Seven and Ten) would tend to back this up. Images were maximised for the screen resolution available, initially using assumptions regarding screen size compared to resolution, later using JavaScripts to determine exact screen size.

The questionnaire had to be designed to the lowest level of hard and software currently used. During the period of research this has altered considerably, allowing more refined techniques to be used later in the research.

One issue still to be fully addressed is that of the sample. The survey respondents were effectively self-selecting, and therefore unlikely to represent the general public. The respondent sample will not be either representative or entirely non-expert, but for the nature of this research this is not considered to be a significant problem.

11.2.2 Results from the Main and Validation Surveys

The Main survey was undertaken in order to gather the preference data required to create a psychophysical landscape preference model. This survey was followed by the Validation survey, which was designed to produce data with which the preference models could be tested. These surveys gathered data is slightly different manners: the former used the Internet, the URL was broadcast to a variety of search engines and e-mailed to a number of groups; the latter survey used a 'captive' audience at the Macaulay Institute OpenDays in June 1997.

Response to the surveys was good, with a high response rate for the Main survey. It was noted that the majority of respondents completed the survey within half an hour, and that most of the log-ins to the questionnaire occurred during the day-time and early evening, with peaks at times outside of core work hours. The socio-demographic characteristics of the Main survey sample were analysed and found to be similar to the characteristics of a sample which may be termed 'Internet general public'.

The geographical distribution of respondents was broken down by country. It was found that few respondents came from the continents of Africa, South America and Asia, with the exceptions of Japan and Korea. It is hypothesised that this may be connected to either a lack of suitable technology in these areas or a language barrier, as the questionnaire was only available in English. Appendix XVIII details the geographical origins of those who logged into the questionnaire and notes their time of log-in, which peaks during work hours, particularly during mid-morning and mid-afternoon.

11.2.3 Summary of All Surveys

Table 11.2.1 summarises each of the surveys, noting: the number of respondents and whether they were from a specific group or were an Internet sample; the intergroup reliability of the sample; the number of photographs used in the survey; and the geographic location of the images.

Survey	Number of Replies	Sample	Intergroup Reliability	Number of Photographs	Photograph Set & Location
Pilot	36	MLURI	0.854	20	Pilot (Scotland)
Paper	15	RGU and OpenDay	0.743	20	Pilot
Main	180	Internet and RGU	0.779	90	Original (Scotland)
Validation	73	OpenDay	0.570	36	Validation (Scotland)
Weather	243	Internet	0.892	120	Weather (Deeside/Strathdon)
Weather II	35	EISF	n/a	60	Weather
Cultural	43	OpenDay, Internet and EISF	0.595	12 cultural + 36	Cultural and Validation
Postcard	23	Openday, Internet	0.709	12	Postcards (Scotland)
Colour	45	EISF	0.603	12	specific (Deeside/Strathdon)
Focal-length	35	EISF	n/a	16	specific (Deeside/Strathdon)
Left/right Bias	40	EISF	0.486	24	Original and Validation
Digital Camera	45	Internet	0.924	10 + 10 digital	specific (Scotland)
Simulation	89	Internet and MLURI	0.797	10 + 30 simulations	specific (Deeside)
Total	902		0.723	442	

Table 11.2.1 Summary of all surveys

11.2.4 Comparison of Hardware and Software

In the year between the start of the Main survey and the two weather surveys, the standard for computers changed considerably. If the percentages of those with Netscape and Microsoft Internet Explorer (MSIE) are examined, we see MSIE increasing its share of the market. Similarly, there is a shift from the use of Microsoft Windows 3.1 to Microsoft Windows 95 and Windows NT.

Browser	Main Survey (January-May 1997)	Weather Survey (January-April 1998)	Chapter Ten Surveys (August-October 1998)
MSIE	10.77%	16.58%	29.18%
Netscape	87.32%	81.44%	70.82%
Mosaic	0.96%	0.00%	0.00%
ART-HTTP (Acorn OS)*	0.96%	0.00%	0.00%
Fresco (Acorn OS)*	0.00%	0.90%	0.00%
Other	0.00%	1.08%	0.00%

* Only used by one school in Edinburgh

Table 11.2.2 Changes in WWW Browser use: early 1997 to late 1998

Operating System	Main Survey (January-May 1997)	Weather Survey (January-April 1998)	Chapter Ten Surveys (August-October 1998)
Microsoft Windows 3.1	29.43%	21.08%	7.45%
Microsoft Windows 95/98	39.23%	46.85%	50.20%
Microsoft Windows NT	4.07%	10.45%	21.57%
Unix-based OS	19.38%	11.71%	6.27%
Apple Macintosh	6.46%	7.39%	12.94%
OS/2	0.00%	0.72%	0.39%
Acorn *	0.96%	0.90%	0.00%
Linux	0.00%	0.90%	1.18%

* Only used by one school in Edinburgh

Table 11.2.3 Changes in operating system use: early 1997 to late 1998

Given the considerable changes in browsers and operating systems over the past two years, it is not inconceivable that the assumption of Chapter Four regarding screen size and resolution was correct at the time (early 1997) but is now (late-1998) incorrect. It is anticipated that in another 18 months time, the numbers shown in Table 11.2.2 andTable 11.2.3 above will have changed significantly.

11.3 Landscape Preference Models

11.3.1 Summary

Six models were created following the analysis of Chapter Six, with two more models added following the Weather and Cultural structures surveys. The eight models varied considerably in regard to accuracy, number of variables and type of variable. Details of the models can be found in Appendices XII, XIII and XIV. The data in Table 11.3.1 shows the accuracy of the models.

The models used three different types of variables: landcover, landform and colour. Landcover variables used three distance zones (immediate, intermediate and distant) and two cover types (vegetation and non-vegetation), to these were added water (still, moving and sea) and sky. The landform variables were defined by slope: flat, low hill, steep hill and mountain, and also included obscuring vegetation. In both of theses cases, measurements were taken of areas and perimeters; the units used were WLCUs (Wherrett's landscape component units), each photograph measured 40 by 27 WLCUs. The colour variables included the mean and standard deviation of red, green and blue, as well as the bytes per pixel in the GIF image. Two final variables were bytes per pixel, representing the level of complexity in an image and landform polygon count, representing coherence, which counted the number of polygons (over 1% of the total image) in the landform measurements.

All variables (with the exception of the final two) were measured using modules in ERDAS Imagine 8.2. Several possible errors in the measurement of the variables are noted; for example, the classification of the variables is subjective, and thus open to high degrees of error. Rules were set down in an attempt to overcome this problem, however, error due to misinterpretation of areas of the photographs which may be in shadow or subject to haze, will still occur.

Each of the photographs from the Main survey was analysed for all thirty-eight variables, these measurements were then regressed against the preference data collected to create a number of models. Set criteria for models was then used to choose the best models to further examine, these criteria included having a high predictive power without overfitting the model, and having a high degree of correlation with the Validation survey preference data. In addition to this, it was decided to create at least one model which could be used without the aid of a GIS package to undertake the analysis (*i.e.* one that did not contain any colour variables).

Model	R^2	Correlations with different preference datasets (score, rank)			
		Main	Validation	Weather	Postcard*
Model A	0.658	0.811, 0.814	0.604, 0.605	0.651, 0.656	-0.081, -0.055
Model B	0.642	0.801, 0.795	0.651, 0.635	0.614, 0.612	-0.024, -0.224
Model C	0.658	0.811, 0.807	0.644, 0.618	0.585, 0.554	-0.031, -0.189
Model D	0.832	0.912, 0.898	0.641, 0.711	-0.039, 0.155	n/a
Model E	0.779	0.881, 0.892	0.684, 0.675	0.577, 0.613	n/a
Model F	0.724	0.851, 0.865	0.630, 0.583	0.670, 0.646	0.308, 0.286
Model W	0.655	0.809, 0.820	0.646, 0.632	0.574,0.584	0.166, 0.112
Model Y	0.653	0.800, 0.786	0.638, 0.624	0.582, 0.565	-0.044, -0.133
Model	**R^2**	**Correlations with different preference datasets (score, rank)**			
		Cultural	Colour	Focal-length	Left-right Bias
Model A	0.658	0.518, 0.495	0.820, 0.902	0.574	0.605, 0.625
Model B	0.642	0.553, 0.497	0.804, 0.853	0.450	0.330, 0.187
Model C	0.658	0.547, 0.477	0.804, 0.818	0.440	0.520, 0.328
Model D	0.832	0.501, 0.548	0.245, 0.608	0.308	0.677, 0.726
Model E	0.779	0.484, 0.565	0.672, 0.671	0.385	0.000, -0.094
Model F	0.724	0.449, 0.421	0.760, 0.734	0.164	0.629, 0.546
Model W	0.655	0.502, 0.608	0.801, 0.867	0.579	0.324, 0.146
Model Y	0.653	0.522, 0.479	0.804, 0.867	0.391	0.268, 0.112
Model	**R^2**	**Correlations with different preference datasets (score, rank)**			
		Print Film/Digital	Simulation Photographs	**Average***	**Standard Deviation***
Model A	0.658	0.627, 0.663	0.749, 0.818	0.682, 0.678	0.099, 0.123
Model B	0.642	0.548, 0.559	0.768, 0.794	0.643, 0.605	0.149, 0.194
Model C	0.658	0.587, 0.603	0.708, 0.709	0.655, 0.596	0.104, 0.153
Model D	0.832	0.370, 0.324	0.738, 0.794	0.520, 0.566	0.287, 0.237
Model E	0.779	0.412, 0.436	0.632, 0.661	0.536, 0.551	0.251, 0.267
Model F	0.724	0.777, 0.794	0.632, 0.770	0.649, 0.595	0.176, 0.222
Model W	0.655	0.570, 0.591	0.761, 0.782	0.623, 0.623	0.167, 0.211
Model Y	0.653	0.706, 0.746	0.785, 0.818	0.642, 0.607	0.170, 0.228

* average does not include results from the Postcard Survey or the simulated images

Table 11.3.1 Summary of model correlations with preference data

11.3.2 Important Variables

The analysis of the variables undertaken in Chapter Six highlighted the predictive powers of the variables. It was discovered that landcover variables were not good preference predictors, and appeared in only one of the six models. Sky was found to have an 'ideal' level, at between one quarter and one third of the image. Water was an overall positive predictor and showed some interesting properties when split into the three types; still and sea water were stronger positive predictors with their areas being related to preference; moving water was positive although area was not related to preference.

Both water and mountain landform, as mentioned below, exhibit presence/absence phenomena, producing far higher preference scores when present in a landscape than when absent, irrespective of their quantity. Their presence in all models further emphasises the importance of these two landscape component variables.

The landform variables can be split into two types: high and low. The high landforms (steep hill and mountain) were positive predictors while the low (low hill and flat) landforms were not. In both cases, however, a mix of the two gave a higher scenic preference than one of the pair alone. Obscuring vegetation was found to be a positive predictor in moderation, while total visible land (sum of the four landforms) was also a positive predictor, implying that a mixture of both would be ideal - this introduces the sense of mystery in a landscape.

The colour variable analysis implied that wide ranges of red and green and narrow ranges of blue were preferable. The analysis also showed that lighter shades of blue in a scene were more scenic, but that an overly light scene would decrease landscape preference. The bytes per pixel term consistently appears as a positive predictor, implying that high complexity is necessary for a scenic landscape; the landform polygon count variable is in agreement with this.

11.3.3 Modifying Factors

A series of surveys examined a variety of modifying factors, which could be added to the existing models, or which could be confounding the previous analysis. The effects of different weather, lighting and seasonal conditions was not found to be important in determining scenic preference for the landscapes. This result implied that colour was not as important as previously thought, a result backed up by the survey of different film types. In this latter survey the difference in colour caused by the different film types was found to be insignificant in determining scenic preference.

The effects of cultural structures, such as castles, cottages and standing stones, on landscape preference was also examined. It was found that these structures raised the scenic preference of the landscape. This leads to the theory that the landscape the respondents are scoring is not the 'natural' landscape, but a cultural one, in which artefacts from that culture will not seem out of place.

Two final elements were examined, in relation to the survey methodology. The photographs used in the surveys were taken with cameras of the same focal length and by the same photographer. It was not known if different focal lengths would have been comparable. A survey addressed this question and showed that similar focal lengths are comparable to each other, but the wide angle and telephoto images should not be mixed due to the differences in levels of mystery resulting from more detailed photographs. Finally left-right bias in photographs was examined. Photographs were mirrored to see if vegetation or major topography on one side produced any bias. Results showed that there was no major effects, but that there was a inter-relations between a respondent's handedness and photograph left-right bias.

11.3.4 Best Models

If the results in Table 11.3.1 are examined, the model which predicts preference the most consistently is Model A, which has a high average correlation and low standard deviations for both scores and ranks (0.682 and 0.678, and standard deviations of less than 0.15). Models B, C, W and Y also predict scores and ranks well (score correlations of over 0.62). These figures take account of correlations with the original dataset. Both models A and F mirror the minimum, maximum and average scores of the actual datasets well (see Chapter Six, Section 6.6).

In contrast, models D and E show low utility, and erratic predictive powers. Both of these models fail to mirror the results well. Due to the high number of terms in Model D, it is not unexpected that this model behaves somewhat oddly.

In conclusion, Model A would be preferred if digitised images are being used, while Model F would be highly functional if used 'manually', *i.e.* with no digitising necessary. Both models use simple terms involving only mathematical transformations of single variables. Model A includes a term representing complexity, only high landform types and water of any form. Model F requires all four elevation levels of landform and obscuring vegetation, and uses water separated into three types.

It should be noted that models B, C, W and Y all also have a high functionality, with models C, W and Y all being variations on Model B. For photographs with a large variation in cloud cover, Model W may be more suitable; for a selection of photographs containing cultural structures, it would be wise to consider the use of Model Y

11.4 Landscape Visualisation Techniques

11.4.1 Literature Review

The chapter on visualisation techniques examined various aspects of rendering and vegetation simulation, and looked at some of the issues concerning realism and validity of images.

Traditionally, visual communication utilised two-dimensional graphic devices, such as maps and sketches; recently the use of three-dimensional models, animations and virtual reality has become viable. Computer visualisations are becoming increasingly used to represent the implications of natural and management changes in landscapes (Orland, 1994b), to the extent that society is becoming increasingly dependant on information presented in three-dimensional format (Faust, 1995). Orland (1994a) identified two needs for such visualisations: to predict the responses of public groups to changes in the environment and to communicate the effects of proposed changes to other groups. GISs are now capable of creating such three-dimensional perspective images (Faust, 1995).

Realism in visualisation is important, if the image is not transparent to the non-expert viewer, then it cannot be used as a basis for judging preference. However, it must be recognised that there is a compromise between realism and cost - the greater the realism, the higher the cost (Zewe and Koglin, 1995). Simulations can simplify and abstract in such a way as to save effort, time and cost (Oh, 1994), indeed, for some purposes more abstract or schematic images may convey sufficient information (Ervin, 1993).

The technical aspect of rendering has been examined. It is recognised that there are many generic software packages capable of three-dimensional rendering, both for high-end hardware, such as Silicon Graphics machines, and for the lower-end hardware, such as PCs and Apple Macintoshes. The different techniques used to increase realism have been noted, such as anti-aliasing (Nakamae *et al.*, 1986); variable object representation (Graf *et al.*, 1994); and geometric transformations (Aylward and Turnbull, 1977; Kennie and McLaren, 1988). The details which must be taken account of when producing landscape visualisations have been applied in the design and creation of images in Chapter Ten: lighting models, colour and texture, objects and atmospheric effects are all important (Kennie and McLaren, 1988; Nakamae *et al.*, 1986).

The methods of tree and forest simulation were discussed. Trees can be simulated in very basic to very complex manners, as simple geometric forms using cones and cylinders, to complicated methods based on actual tree growth. Examples include: block draping *i.e.* increasing the elevation on a digital terrain model (DTM) by the height of a forest (Evans, 1993); three-dimensional tree models; and two and a half dimensional models. It is the 2.5-D models which are of most interest for use in this project for the simulation of vegetation. A two-dimensional image is rotated to face the observer's view point, so that the observer always sees the same image, irrespective of angle of view (Sasada, 1987), this type of model is most commonly used in tree simulation.

11.4.2 Examples of Methods

A variety of methods of simulating scenic landscapes were discussed in Chapter Nine. These techniques ranged from the traditional drawn images and photographs, to images produced by dedicated visualisation software. The use of GISs to produce perspective views from DEMs was noted, with respect to both simple wire-frame models and more realistic images comprising DEMs with draped aerial or satellite imagery.

Visualisation using GIS was further discussed, with several issues becoming significant. Data is a major issue - access to DEMs of increasing resolution is constantly improving, and is now readily available for much of the World. Increased storage capacity on all computer platforms is allowing finer resolution and larger areas to be visualised. Many of the GISs have the ability to control atmospheric conditions within the viewers, and some will also allow sky textures to be used, so further increasing the realism of the views.

Dedicated visualisation software has also been discussed. Three systems were noted in particular: Iris Performer and MultiGen for the Silicon Graphics platform and Vistapro for the PC and Macintosh platforms. All of these systems allow the user to place objects into the landscape, both automatically (Vistapro) and manually (Iris Performer). These systems may also allow real-time viewing of the landscapes in three-dimensions (Iris Performer and ERDAS Imagine VGIS) or allow flight-paths to be saved as animation files (Vistapro). One advantage of these software packages over GIS modules is the ability to change levels-of-detail, that is to render only nearby objects at the highest resolution.

The various methodologies were then discussed with reference to the visualisation of future, potential landscapes. Photomontage, particularly computer-generated images, are often accepted in public enquiries as accurate impressions of the impact of a development. These images are usually geometrically correct and any objects carefully matched to the light conditions in the original image. There are many ways of enhancing such images digitally, to enable their use on digital media (such as a computer screen).

GIS packages which allow visualisation also allow the input data to such visualisations to be changed. Therefore by changing either the base DEM or the overlaid terrain imagery, a landscape change can be visualised.

Dedicated software has the most advanced capabilities for altering landscapes. Modules are included in such packages for the placement of objects, such as trees or buildings, the alteration of texture maps, the raising of water levels (*e.g.* Vistapro) or the interactive addition or removal of features (*e.g.* MultiGen with Iris Performer as a rendering tool).

11.4.3 Validity of Methods

In order to test how well the various methods of digital landscape simulation compare to print film photographs, two experiments were undertaken. The first looked at the differences between photographs taken with a standard print film camera and then scanned, and photographs taken with a digital camera (Kodak DC210 Zoom). The second experiment compared four methods of landscape simulation: photographs, ERDAS Imagine perspective viewer, Vistapro with aerial imagery, and Vistapro with manually placed vegetation and water.

<u>Digital images</u>

Ten images were taken with both a digital camera and a print film camera. The images were placed in a questionnaire to examine if they would be scored and ranked similarly. On examining the images, it was seen that they were quite different in terms of colour composition and complexity level, despite having identical physical composition.

The results from the questionnaire showed that the observer's responded in almost identical manners to the two sets of images, despite the wide differences in colouration and complexity. However, when compared with the predicted preference scores from the models, the images taken with the standard camera correlated better than the digital images. This result does not detract from the high correlations of the digital images, but merely points out that the models were created with images taken using standard photographic equipment.

Simulated images

Three different types of landscape simulation along with photographs were used in this experiment. The same ten scenes were simulated using each methodology (ERDAS Imagine DEM draped with aerial imagery; Vistapro DEM draped with aerial imagery; and Vistapro DEM with terrain colouration and manual object placement).

Results showed that respondents did not rank the visualised scenes in the same way that they ranked the photographic images. Comparison with predicted results also showed that the models have poor utility at predicting preference for simulated landscapes. However, the Vistapro (manual object placement) images were able to produce predicted scores which correlated very well with the actual scores from the photographs. This result implies that the use of some simulated landscape images to predict changes in landscape preference is valid.

Further research is required to examine what the criteria are for simulations to be used in landscape preference prediction.

Photomontaged images

Previous research (Stamps, 1992) showed that many respondents cannot identify photomontaged images. Given the assumption that this is correct, two images of Loch an Eilein were shown to two groups of students; one image was unaltered, the other a photomontaged images with vegetation obscuring the loch. The observers were asked to indicate which image they preferred. In both sets of students, the preferred image was also the image which was predicted by all seven models to be of a higher preference.

The significance of these models for landscape design and planning applications is discussed overleaf.

11.5 Critical Evaluation of Approach

Following the evaluations of Daniel and Vining (1983), the approach to landscape preference modelling will be evaluated by reference to the criteria for assessment systems: validity; repeatability; sensitivity; and utility, and the areas where further work is necessary will be noted.

11.5.1 Validity and Repeatability

A test of the validity of the approach to landscape preference modelling used in this thesis, is the level to which the models can predict preferences for landscapes, rather than photographs of landscapes. The results have shown that the models are valid for photographs which have been taken by the author; however, they have not been shown to be valid for images taken by an alternative photographer. The use of postcard images in Chapter Seven, Section 7.4 showed that the models did not function well for landscape photographs taken by a professional photographer. To further investigate this point, it is necessary to test the models on photographs taken by a wide range of people.

The repeatability of the methodology will depend largely on the image digitising process. If this process can be automated, and hence made less subjective, then the methodology will be deemed repeatable.

11.5.2 Sensitivity

The sensitivity of psychophysical modelling has been discussed in Chapter Three. The models created within this thesis have not been examined in terms of their sensitivity, and examples given have not included the subtle changes which might be expected from a small land use change. This would be the logical next step in the testing of the landscape preference models.

11.5.3 Utility

There are several areas where the utility of the models may be improved. A GIS approach to landscape component measurement would increase the objectivity and the easy application of the methodology. It is also important to note that by using a GIS approach, it is not necessary to produce a visualisation of the proposed landscape changes, as changes may be modelled within a GIS layer, and subsequently used to drive the prediction of landscape preference scores.

11.6 Applications

This thesis has aimed to create both a methodology and a landscape evaluation system which may be applied by researchers and planners alike.

11.6.1 Application of methodology

The methodology used in this research could be recreated for any geographical area. While the models have been developed to be generic to Scotland, the same process could create models for other areas of the United Kingdom, mainland Europe or the other continents. Alternatively, the methodology could be applied at a smaller scale for a region or district within a country, or to a particular type of landscape. This flexibility, in terms of both the methodology for preference data gathering and the methodology for the creation of landscape preference models, is one of the strengths of the methodology.

The Internet survey approach to preference data gathering has far wider applications than landscape preference modelling. Many visual and textual subjects could be investigated this way. The methodology is not confined to the Internet: the survey may be taken to respondents, it may be taken to any public place, such as a school or library, where there are members of the public who wish their opinions to be counted.

There are limitations in the incorporation of this approach into the planning environment. The preference models created use the macro form of the landscape, and may not respond well to subtle changes in the landscape. There is also a question of the generic nature of the models. There may be a requirement to create new models for certain planning problems, thus increasing the time and expense needed to use the methodology. Finally, the approach is limited to predicting visual landscape preferences, and does not try to include the emotive side of landscape preference, which is of great importance in many landscape development proposals.

11.6.2 Landscape planning and Sylv*ie*

The penultimate section in Chapter Ten detailed the use of the landscape visualisation and evaluation system on a hypothetical landscape change. The landscape scenic preference models have shown significant predictive ability throughout this thesis, they may be used singly (perhaps using the simplest or the most reliable) or they may be used together, to give an overall impression of the change in landscape preference.

A variety of alternative scenarios may be examined, and the change from the original image calculated - this work may be desk-based, using simulated landscape images created with dedicated visualisation software, to derive preference scores. Such simulated images are also more accurate and less time consuming than the use of photomontage techniques; they may also be driven by environmental models, such as tree growth or vegetation succession, or used to assess the visual impact of landscape change on the general public.

11.7 Future Research

Further research that may be undertaken falls into two main categories: further methodological research and extension and application of the current research.

11.7.1 Additions to Scientific Knowledge Base

The current work has added to the scientific knowledge base in several areas. The use of an Internet preference survey to collect data on a visual subject is a novel methodology, and has been proven by this work to be a useful method of data collection. However, the problems of sampling with such a methodology have also been recognised.

Much of the landscape preference modelling has been original in methodology while utilising concepts from a number of researchers. The surveys looking at modifications to the landscape preference models have added to the knowledge base in terms of the effects of weather and season on preference, and in terms of the effects of different film types and focal lengths in landscape preference work.

11.7.2 Further Methodological Research

The methodology used in this research is subject to several flaws. The two most critical are the sample bias in the gathering of preference data and the subjectivity of the landscape variables measurements for the land cover and land form variables.

In order to further investigate the importance of the sample bias, it is necessary to examine the influence of different socio-demographic factors on landscape preference. If these factors can be eliminated as being non-significant, then the use of an Internet general public sample will be fully justified for further landscape preference research.

The second methodological problem stems from the manual digitising of the landscape images. There are a variety of methods by which this could be automated. Software could be used which identifies areas of similar colour in an image to automatically segment and classify the areas of different land cover. However, the GIS approach is currently more promising; by altering the methodology of landscape variable data gathering to one linked to a spatial database, elevation and land cover data could be used to predict landscape preference directly from such a database. This method would allow the calculation of preference scores for a large number of sites within an area.

By combining a GIS approach to landscape variable data gathering with dedicated visualisation software which is able to utilise elevation and land cover raster coverages (such as Vistapro), the investigation of the aesthetic effect of large number of management alternatives will be possible. The use of a GIS approach, as mentioned previously, also allows the derivation of landscape preference measurements directly from the GIS, without the necessity for production of simulations of landscapes.

11.7.3 Extension and Application of Current Research

The current research can be extended in several directions. Using the methodology for landscape variable data gathering described previously, it should be possible to map scenic areas, within a region or for a nation. This type of map could then be used to assist in the designation of scenic landscapes, or to examine how current designations of landscape beauty or nature conservation correlate with scenic landscapes. Further to this, such a map of scenic beauty could be compared to other land appraisals, such as wilderness mapping or ecological sustainability, or be used to assist in targeting areas as tourism 'honey-pots'.

The use of different dimensions in the gathering of preference data should be examined. All images shown in this research were two-dimensional, static views. There are several methods of creating three-dimensional, static views or two-dimensional, dynamic views currently available. VRML allows the viewer to explore the landscape in a highly interactive format; PhotoVista allows a viewer to rotate their observing position enabling them to see a 360° panorama of the landscape. The use of animated images can increase a sense of dynamism in the landscape; the use of sound files could improve the sense of 'connection' with the viewed image.

This thesis has only considered landscapes within the national boundaries of Scotland. The models created therefore are applicable to Scotland, but may have a high utility in the rest of the United Kingdom or on the continent. Given the simplicity of the most functional models, it would seem appropriate to test their 'generic-ness' on the landscapes of other countries. It is not expected that the models would be functional for any landscape, but for countries whose landscapes have a similar geological history to Scotland, they may well be highly relevant.

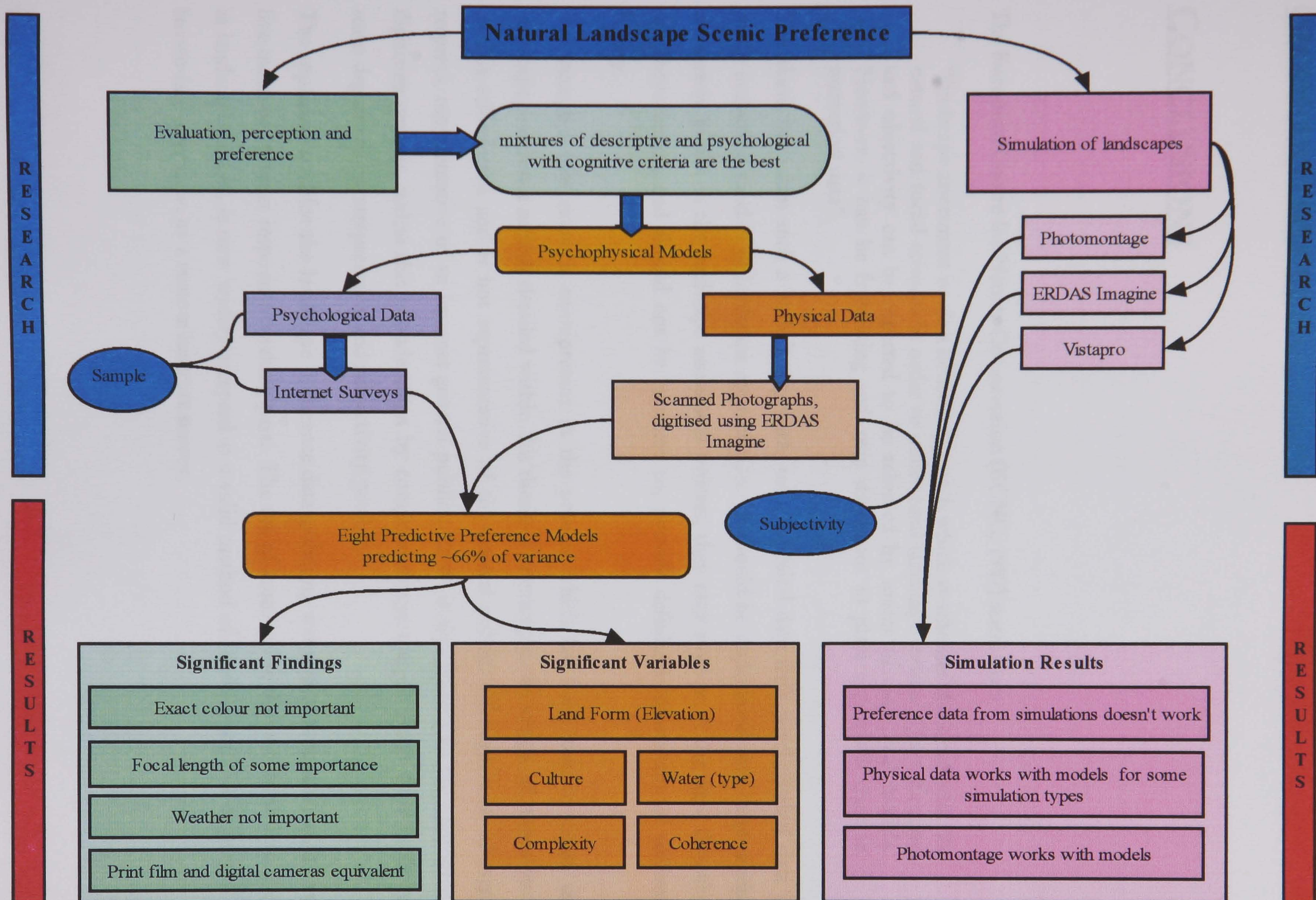


Figure 11.6.1 Thesis conclusions

CHAPTER TWELVE

CONCLUSIONS

The European Centre for Nature Conservation (ECNC, 1997) states that:

> "landscape assessment needs a holistic approach which synthesises elements from the natural and social sciences in order to understand landscape values. Quantification and objectivity can be expected to be achieved by means of numerical models. However, it can be frustrating and even dangerous to place too much trust in numerical data".

This thesis has taken such a holistic approach, using physical data with psychological data to create numerical models of landscape appreciation. It should be understood that these models are merely guides in the landscape assessment process, they may steer us in the right direction but they cannot, and should not be expected to, provide definitive assessments of aesthetic beauty.

It is accepted that error is omnipresent in the process which has been used to create the landscape preference models detailed within this thesis. For example, the sample of respondents used is self-selected and is not representative of the general public, although it is, in many respects, representative of an Internet general public. Error is also present in the photograph digitising process, unless this is undertaken by computer image analysis alone there is always some degree of misinterpretation and subjectivity present.

The approach used for the landscape preference data gathering was highly successful, with over five hundred Internet respondents taking part. The use of monitors to display visual data, such as landscape images, is now widely accepted as a valid method of display, whether as part of a face-to-face interview, or a remote Internet survey.

"Alba nam beanntan ard
Nan acraichean lom
Thairis air na lochan mointich
Nan coilltean 's nan gleann"

"I see Scotland of the high mountains
And the empty glens
Flying low across the moorland lochs
The forests and the glens"
(Macdonald and Macdonald, 1987)

Analysis of the landscape preference models has shown several variables to be key preference predictors. Of special note are water and mountainous landform; both these variables appear in all eight models, and in the majority take the form of inverse relationships to preference. This type of relationship is significant with respect to the effects of the absence of the variable on the preference score given by the model. It can therefore be said that the presence of water and mountainous landform will be important for landscapes of a high scenic value.

Two qualitative variables have also been shown to be important predictors of landscape preference. These variables, which are proxies of complexity and coherence within a landscape, can be measured objectively. Neither of these terms can be assessed by respondents - those researchers who have measured actual against perceived complexity have often found that the two do not correlate. It is not a natural instinct to consciously judge complexity within an image, yet humans respond to this within imagery.

It has been found that respondents need to see landscape images in colour in order to assess scenic beauty - respondents do not judge black and white versions of the same image in the same manner. However, the research has shown that the exact colours are not important, even the different colours produced by different seasonal conditions do not affect landscape preference scores significantly. It is hypothesised that this is due to the experience factor in respondents. Perhaps subconscious memory of landscape colour can be superimposed onto a landscape image to create an ideal condition for the landscape to be viewed in.

The sense of mystery has been found to play a part in landscape preference. If scenes are shown at increased focal lengths, the preference scores alter in a manner not predicted by the preference models. It is possible that scenes which have been photographed with wide angle lenses leave much to the imagination, and perhaps instil some sense of frustration at the inability to further explore an image. It is thus important that similar focal lengths be used throughout preference surveys.

This thesis has been titled 'natural scenic landscape preference'. This is perhaps inaccurate for one interpretation of 'natural'; there are no truly natural landscapes in Scotland, the influence of man is ubiquitous. When respondents are asked to score a landscape in terms of scenic preference, it is not the natural landscape they are scoring, but the cultural landscape, the landscape which they understand. This is seen in the eighth model (Model Y); the additional cultural structure term acts as a presence/absence term, increasing landscape preference when a cultural artefact is present in the landscape, irrespective of it size.

If all eight models are looked at together, it is seen that the simpler models consistently predict approximately two-thirds of the variance in landscape preference, whereas the more complex models fail to consistently predict preference well. Therefore it is concluded that there are a few, highly important factors which humans subconsciously look for in a landscape: water, high landform, complexity. All other variables merely modify this primitive tendency, which gives strength to the Biophilia hypothesis, that humans are genetically predisposed to prefer certain landscape types.

The following diagram summarises this theory of landscape perception.

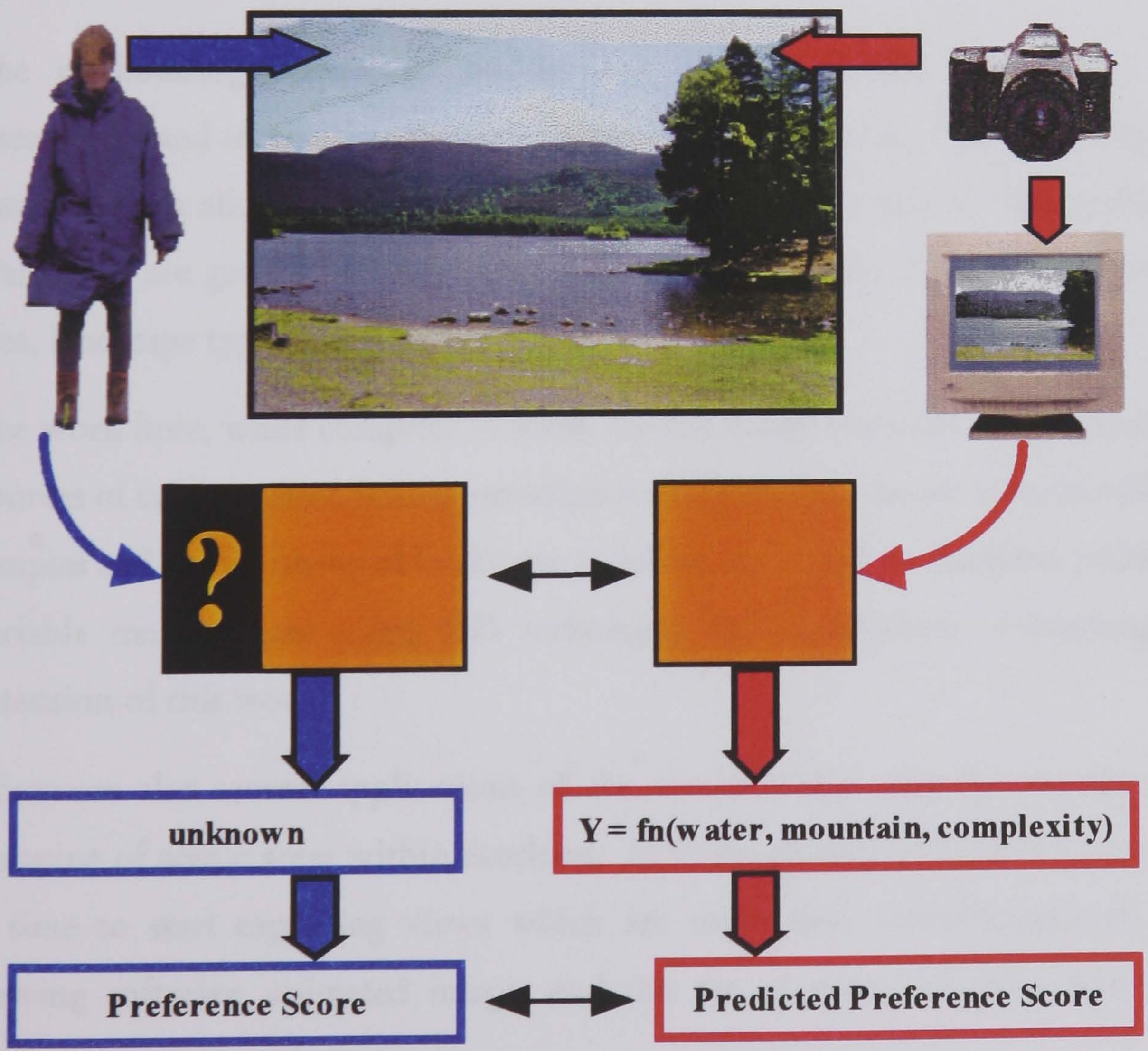


Figure 12.1 Explaining the landscape perception "black-box"

The second section of this thesis is concerned with the simulation of landscapes. There are many methods of creating images which convey the sense of landscape to us. The camera is most often used in landscape preference research, but increasingly researchers are examining preferences for computer visualisations of landscapes. The research undertaken here has suggested that people cannot give realistic preference scores for non-realistic images of landscapes, probably because the level of photo-realism is not yet high enough. It is presumed that this is due to a difference in how a photograph, which the majority of people are used to, and a visualisation, which people may find artificial, are interpreted.

However, this does not mean that computer visualisations of landscape have no place in the landscape assessment process. Simulations produced by dedicated landscape visualisation software can produce predicted preference scores which correlate highly with actual preference scores. It is simple to alter such a simulation and it is proposed that this is where the future of landscape visualisation may lie, until such time as truly photo-realistic representations of landscapes are available. Indices of landscape preference, of sustainability, of economic potential or of biodiversity, may be constructed from simulations which represent alternative land use scenarios.

The methodology described within this thesis is widely applicable, both to landscape assessments and to visual preference survey work in general. The flexibility of the approach to data gathering allows it to be tailored to suit many applications. The techniques for landscape evaluation are generic in their theoretical foundation, and could be applied to any landscape area, landscape type or region.

The work here, while complete in itself, has left many branches of the research tree unexplored. Sources of error require further investigation, particularly in the areas of self-selected respondent samples and the digitising of landscape variables. In regard to the latter point, the automation of variable measurement using GIS techniques and simulations of landscape is an important extension of this work.

There are also several applications of the results which may be considered, for example the mapping of scenic areas within Scotland. In terms of methodological improvements, perhaps it is time to start exploring views which are more than two-dimensional. VRML, dedicated viewing software, animated images and the use of sound all offer new ways of presenting landscapes to respondents.

Finally, the techniques should be tested on the landscapes of other countries; if the results from such experiments show similar results to those reported here, *i.e.* that there are a few, highly important, predictors of landscape preference, then we have indeed come one step closer discovering what people respond to in the scenic landscapes of the World.

One important fact to remember is that the enjoyment of scenic beauty is a human right; political and economic policies may alter that beauty, but they may not stop people from enjoying it. In 1909, Marr left us with these words:

> "Let us believe that the time is now at hand when the national importance of the question of our natural scenery will be fully appreciated."

Perhaps, now is finally the time when our scenery can be accepted as a natural and cultural resource of national and international importance.

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I Glossary

Bandwidth How much you can send through a connection. Usually measured in bits-per-second.

Bit (Binary DigIT), a single digit number in base-2, *i.e.* a 1 or 0. Bit is the smallest unit of computerised data.

Browser A client program (software) that is used to look at various kinds on Internet resources.

Byte 8 bits.

CGI Common Gateway Interface, a set of rules that describe how a Web server communicates with another piece of software on the same machine, and how the other piece of software (the CGI program) talks to the web server.

Usually a cgi-program is a small program that takes data from a web server and does something with it, like putting the content of a form into an e-mail message.

Client A software program that is used to contact and obtain data from a Server software program on another computer, often across a great distance. A web browser is a specific kind of client.

Dial Up Connecting to another computer via a telephone line.

Domain Name The unique name that identifies an Internet site. Domain names always have 2 or more parts separated by dots.

Download Transferring a file from another computer to your computer.

E-mail Electronic mail, messages, usually text, sent from one person to another via computer.

GIF Graphic Interchange Format, a common format for image files, especially suitable for images containing large areas of the same colour.

Hit As used in reference to the WWW, "hit" means a single request from a web browser for a single item from a web server.

Homepage The main or introductory page of a WWW site for a business, organisation, person or simply the main page out of a collection of web pages.

Host Any computer on a network that is a repository for services available to other computers on the network.

HTML HyperText Markup Language, the coding language used to create Hypertext documents for use on the WWW. HTML looks a lot like old-fashioned typesetting code, where you surround a block of text with codes that indicate how it should appear, additionally, in HTML you can specify that a block of text, or a word or image, is linked to another file on the Internet.

HTTP HyperText Transport Protocol, the protocol for moving hypertext files across the Internet. Requires a HTTP client program on one end, and an HTTP server program on the other end.

Hypertext Generally, any text that contains links to other documents, words or phrases in the document, that can be chosen by a reader and which cause another document to be retrieved and displayed.

Internet The vast collection of inter-connected networks that all use the TCP/IP protocols and the evolved from the ARPANET of the late '60s and early '70s.

IP Number Internet Protocol Number, a unique number consisting of 4 parts separated by dots. Every machine on the Internet has a unique IP number.

ISP Internet Service Provider. A commercial company that offers individual access to the Internet.

Janet Joint Academic NETwork: network connecting UK Universities and Colleges.

Java Java is a network-oriented programming language invented by Sun Microsystems that is specifically designed for writing programs that can be safely downloaded to your computer through the Internet and immediately run without fear of viruses or other harm to your computer or files.

JavaScript JavaScript is a compact, object-based scripting language developed by Netscape, for developing client and server Internet applications. The scripts are placed within HTML documents and interpreted by Netscape Navigator.

JPEG Joint Photographic Experts Group, JPEG is most commonly mentioned as a format for image files.

Log-in Process of getting on-line, usually with an ID and password.

Mosaic The first WWW browser that was available for Macintosh, Windows and UNIX all with the same interface.

Netscape A WWW browser and company. Netscape is widely recognised as the best and most popular web browser.

Ping Packet Internet Groper, a program that tests whether a particular host is currently on line and reachable by sending a request and waiting for a reply.

Quadrulogy A work in four parts.

Server A computer, or a software package, that provides a specific kind of service to client software running on other computers.

TCP/IP Transmission Control Protocol/Internet Protocol, this is the suite of protocols that defines the Internet.

Unix An operating system developed by AT&T in the late 1960s. Much of the Internet was established on Unix machines and Unix is still often used as a base for large scale Internet access.

URL Universal Resource Locator, the standard way to give the address of any resource on the Internet that is part of the WWW.

Web see WWW

WWW World Wide Web,

1. The whole constellation of resources that can be accessed using Gopher, FTP, HTTP, telnet, USENET, WAIS and some other tools.
2. The universe of hypertext servers which are the servers that allow text, graphics, sound files, *etc.* to be mixed together.

Source: Internet Literary Consultants ™, 1998

TEP, 1998

II The Geography of Scotland

The landscapes of modern Scotland

Scotland is a small country, of only 30,414 square miles (78772 square kilometres) and close to 5 million inhabitants. The climate is influenced by the surrounding seas, causing mild winters and cool summers; there is a wide range of levels of rain fall, from the wet west coast to the relatively dry eastern coast.

The landscapes of Scotland are very diverse, ranging from the flat agricultural land of Banff and Buchan to the north of Aberdeen, to the spectacular mountains of Glencoe, near Fort William. Historically and topographically the country is divided into lowlands and highlands by a line running from the north of Aberdeen to the south-west coast (Anon., 1996).

The south-east of the country is mostly agricultural with a few areas remaining of relatively undisturbed land to the north of the Highland boundary fault (a fault line running from Inverness to Fort William). The eastern areas contain lowlands, coastal plains and cliff scenery of significant conservation value while the western areas, such as the vast Rannoch Moor and the arctic-alpine flora of Ben Lawers are without doubt important landscapes (Baxter, 1987).

The south-west is also divided between high and low lands, from the mountains of Ben Lomond and Ben More near Loch Lomond, Britain's largest stretch of inland water, to the rolling hills of the lowlands in Dumfries and Galloway. There is a large range of landscapes in this area, including native deciduous woodlands, coastal strips, marshes and granite uplands (Baxter, 1987).

The north-east of Scotland is dominated by the Monadh Rhadh, the red mountains of the Cairngorms, a high sub-arctic plateau which still contains remnants of the ancient Caledonian pine forest. In contrast, the area to the north of Aberdeen consists of flat, agricultural land. There are fertile coasts to the north, and rugged coastlines further south, supporting both dune systems and estuaries (Baxter, 1987). To the far north of Scotland lie the Orkney and Shetland Isles, two island groups of very differing landscapes.

The final quarter of Scotland, the north-west, is arguably the most scenic area in Great Britain, and is without doubt unique in both Britain and Europe. It is a sparsely populated region, with crofting and fishing still exerting a major influence of daily life (Baxter, 1987). The area is both geologically and botanically interesting, with Inverpolly and Inchnadamph (both north of Ullapool) being popular areas for field studies.

The major impact on the area, in terms of its ecology and its landscape, has been the retreat of the ancient pine forests over several millennia. Remaining fragments are conserved and extended, such as at Beinn Eighe National Nature Reserve (NNR), where pine trees are reared and replanted, and many regeneration projects are underway, with land owners encouraged to re-colonise the region with native tree-species.

The many islands (186 in total) to the west of Scotland have several unique landscapes. Examples include: the water-logged scenery of North Uist; the machair of South Uist; the spectacular cliff scenery of the remote St Kilda archipelago, a World Heritage List site; and the volcanic mountains of Rum, which were known to Mesolithic hunter-gatherers and marauding Norsemen, and whose vegetation has hardly been disturbed since the last Ice Age (Baxter, 1987).

In summary, Scotland is a land of many different landscapes, each important in its own right. To its people, and to the people of many other nations, the landscape is a significant part of what makes Scotland 'Scottish'.

The history of Scotland's landscape

By 12,000BC the glaciers of the last Ice Age had retreated from Scotland. At that time Scotland was a cold, sub-Arctic land with a scrubby growth of tough northern trees. The following arrival of man and extinction of the great browsing and grazing mammals (such as the mammoth, the reindeer and the elk) paved the way for the establishment of a 'wildwood' (Marren, 1990).

Pollen analysis can tell us much about the prehistoric landscape of Scotland. Evidence from deposits in peat shows woodland at its greatest extent around 6000 years ago. Around 4000 to 3000 years ago, cereal crops became more common, with a corresponding small-scale woodland disturbance; this is found in many areas of Scotland, from the Galloway Hills in the south-west, the Ochil Hills in Fife, and the Grampian Foothills near Aberdeen (Edwards, 1993; Whittington, 1993). By the time the Romans invaded Great Britain (100AD), seventy-five percent of the woodland cover had already disappeared. By the end of the seventeenth century woodland cover was reduced to 5% or less of the land cover from a maximum of over 50%. The decay of the woods was a long drawn-out slow process, and the main agents responsible were at first the climate and then the indigenous farmer's need for land (Smout, 1993).

However, trees are not the only part of the landscape that has changed over the past few millennia. For example, the Isle of Jura, now occupied by heather moorland and blanket peat, was once capable of supporting arable agriculture. The Outer Hebrides, dominated by machair landscapes, were once covered by forest and freshwater lochs, destroyed by the encroachment of the sea (Whittington, 1993). Other areas have been affected by volcanic activity - areas in Caithness, once covered by pine forest, were denuded by the toxic effects (acid raid) caused by eruptions in Iceland in 1850BC (Edwards, 1993). It is important to remember that the natural heritage is not static. It is in a constant state of dynamic change caused by a wide variety of environmental factors, including climatic variation, geomorphological activity and the influence of mankind (Magnusson, 1993).

Scotland's place in the World

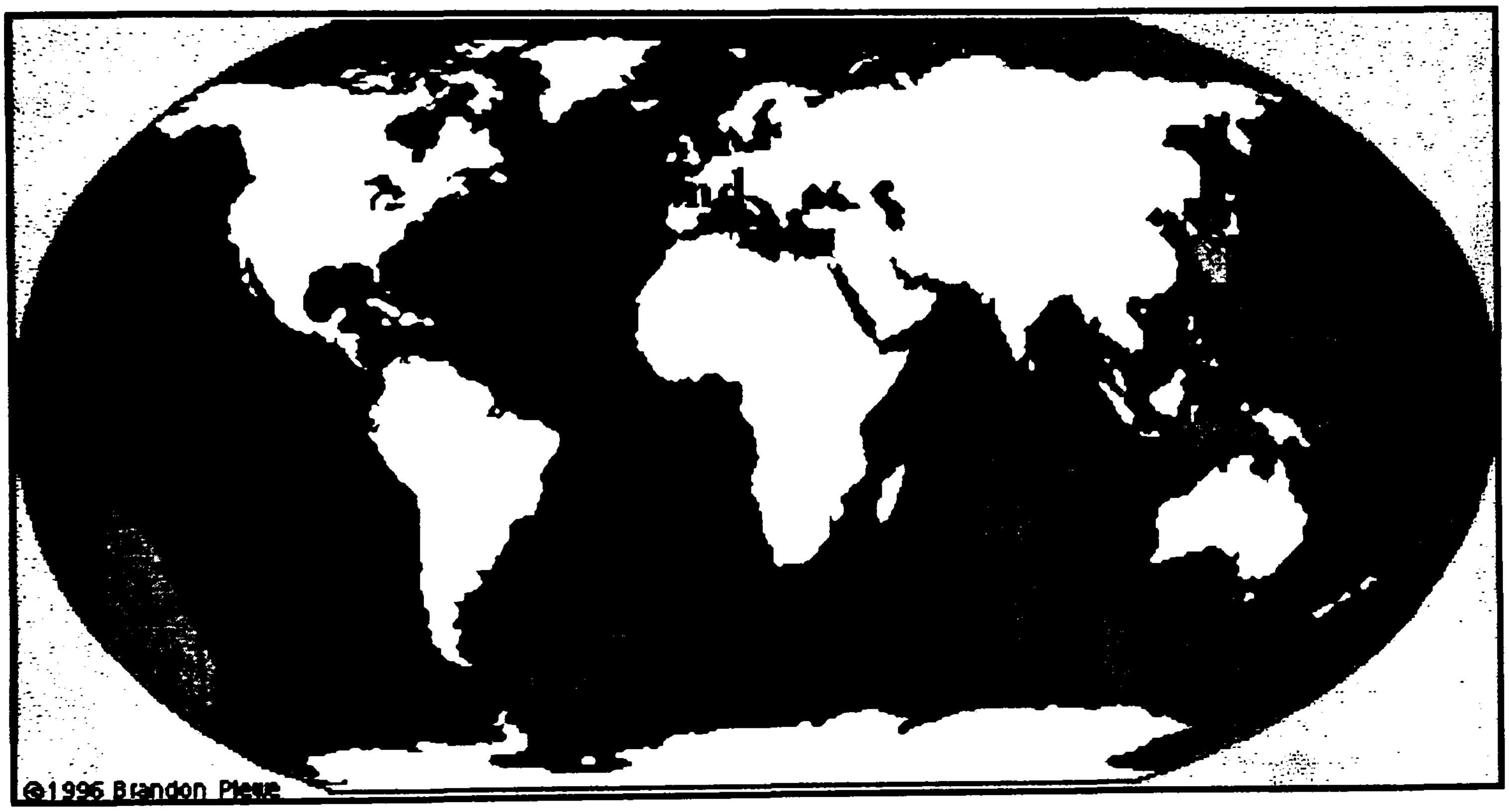


Figure II.I Scotland in relation to the World

III Project Objectives and Plan of Work

Objectives

1. To develop a tool for linking simulated and/or photo-realistic vegetational images with a GIS.
2. To test the facility with a selected change in land use management over several time periods.
3. To combine the facility with a landscape preference model, to create a quantitative indicator of change in preference level.
4. To validate the tool and preference model (objectives 1 and 3) and refine as necessary.
5. To test the utility of the system with potential end users.

Plan of Work: MPhil Stages

Stage One: Literature Review

Search and review the literature on landscape evaluation, landscape preference and perception, computer vision and visualisation, visual impact assessments and the use of visualisation in decision support systems.

Stage Two: Development of a landscape simulation tool

Develop a tool for linking simulated and/or photo-realistic vegetational images with a Geographical Information System. Test the facility with a selected change in land management (such as a change from grazing to forestry) over several time periods.

Stage Three: Landscape scenic preference model

Validate a modified, quantitative landscape preference model (such as that of Shafer *et al.*, 1969 or Hammitt *et al.*, 1994) using data collected using the Internet.

Stage Four: Combining a visualisation facility with a landscape preference model

Combine the visualisation facility previously described with the landscape preference model to create a quantitative and qualitative indicator of change in preference level. Use a GIS (ArcInfo) to map the scoring geographically and also compare to visibility map.

Plan of Work: PhD Stages

Stage Five: Validation of a combined facility

Validate the combined tool and preference model, using questionnaire methods and statistical techniques to gauge correlation between actual and predicted landscape preference. Explain differences between model and actual results and between model / results and visibility census.

Stage Six: Refining of landscape preference model

Refine model to gain maximum correlation with actual preference. Improve the human-computer aspect of the model by producing a 'front-end' user interface. Improve efficiency of system for VIA.

Stage Seven: Testing of the prototype landscape preference system

Test the utility of the prototype landscape preference system, for aiding the planning decision making process, with potential end users.

IV CD-ROM

The directory structure for the CD-ROM is as follows.

```
Wherrett_thesis_1998:

    README
    index.html
        thesis
        publications
            GISRUK96
            IALE97
            DV97
            Athens97
            GISRUK98
            RT98
        data
            pilot_survey
            paper_survey
            main_survey
            validation_survey
            weatherI_survey
            weatherII_survey
            cultural_survey
            postcard_survey
            colour_survey
            focal_survey
            left_right_survey
            digital_survey
            simulation_survey
```

V Equipment

The following equipment, hardware and software were used during this research project.

Equipment

Nikon RF 35mm Compact Camera

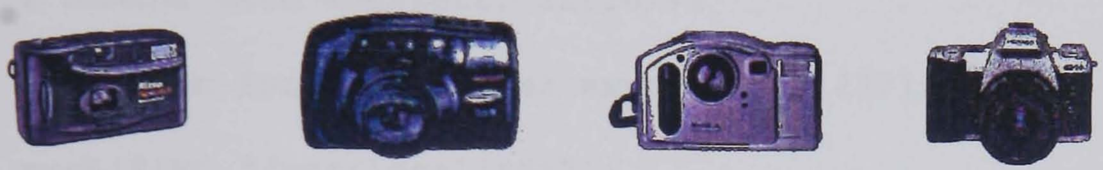
Samsung AF Zoom 38mm - 105mm Compact Camera

Miranda Panoramic Camera

Kodak DC210 Digital Camera

Pentax-clone (Sears) SLR Camera with 50mm lens

Jessops Light Meter, Model D-3



Computer hardware

X-Terminal running Sun OpenWindows

Personal Computer running Microsoft Windows 95

Silicon Graphics Onyx Reality Engine

Hewlett-Packard A4 Scanner

Computer software

Netscape Navigator versions 2, 3 and 4 for Unix, Irix and Windows 95

Pixel! FX 1.06a

XView Version 3.01

ERDAS Imagine 8.2 and 8.3 (including Perspective Viewer and VGIS modules)

Paint Shop Pro for Windows 95

Microsoft Office 95

SPSS for Windows 7.5.1

Iris Explorer

Iris Performer

MultiGenII

Vistapro 4.01

VI PERL, HTML and JavaScript Scripts

Practice pages

The PERL script below is an example of the script used in the practice pages to inform the respondent which number they have entered. This example is for the PC version of the Weather and Lighting survey. The first section details the PERL language part of the script; the second details the HTML document embedded within the PERL script.

```
#!/usr/local/bin/perl

# program that tells a person what number they entered on the
# practice page and what level of score it was
# JoAnna Ruth Wherrett, 31/10/96

# version for PC, weather experiment, 27/1/98

push(@INC,"/usr/local/etc");
require("cgi-lib.pl");

&ReadParse(*input);

$endsum = 0;

srand( );

$newsum = int(rand(10)) + 1;
$endsum=$newsum;

$num = $input{'practice'};

 if ($num == 1){$score = "very low"; $box1 = "checked";}
 elsif ($num == 2 ){$score = "low"; $box2 = "checked";}
 elsif ($num == 3 ){$score = "medium low";  $box3 = "checked";}
 elsif ($num == 4 ){$score = "medium";  $box4 = "checked";}
 elsif ($num == 5 ){$score = "medium high";  $box5 = "checked";}
 elsif ($num == 6 ){$score = "high";  $box6 = "checked";}
 else {$score = "very high";  $box7 = "checked";}



print &PrintHeader;
print <<"tag";

<html>
<body bgcolor = \"#DDDDDD\" link=\"#EEEEEE\" vlink=\"#EEEEEE\"
alink=\"#EEEEEE\">

<title> Landscape Preference Questionnaire</title>
<center>
<form>
<input type=\"hidden\" name=\"qunumber\" value=\"$endsum\">
```

```
<table border=5><tr><td valign=middle align=center>
<img src=\"http://bamboo.mluri.sari.ac.uk/~jo/landscape/lae.gif\"
width=445 height=303>
</td></tr></table><br>

<table border=5 cellspacing=3 cellpadding=3 bgcolor = \"#EEEEEE\">
<TR>
    <td width=5></td>
    <td align=left rowspan=2><h4>Low Scenic<br> Preference</h4></td>
    <td rowspan=2> </td>
    <td align=center><h4>~1~</h4><p><input type=\"radio\"
name=\"pref\" value=\"1\" $box1></td>
    <td align=center><h4>~2~</h4><p><input type=\"radio\"
name=\"pref\" value=\"2\" $box2></td>
    <td align=center><H4>~3~</h4><p><input type=\"radio\"
name=\"pref\" value=\"3\" $box3></td>
    <td align=center><h4>~4~</h4><p><input type=\"radio\"
name=\"pref\" value=\"4\" $box4></td>
    <td align=center><h4>~5~</h4><p><input type=\"radio\"
name=\"pref\" value=\"5\" $box5></td>
    <td align=center><h4>~6~</h4><p><input type=\"radio\"
name=\"pref\" value=\"6\" $box6></td>
    <td align=center><h4>~7~</h4><p><input type=\"radio\"
name=\"pref\" value=\"7\" $box7></td>
    <td rowspan=2> </td>
    <td align=right rowspan=2><h4>High Scenic<br>
Preference</h4></td>
    <td width= 20></td>
    <td align=right><a href="#_down"><img
src="http://bamboo.mluri.sari.ac.uk/~jo/landscape/arrowdown.gif"></a
></td>
</tr></table>
<BR>

<h3>
<P>The <a name="_down">score</a> you chose was $num. This is a <font
color=\"#006600\">$score</font> preference score.<p>

<table><tr>
<br>
You may now start the Landscape Preference Questionnaire<p><br>
<a
href="http://bamboo.mluri.sari.ac.uk/~jo/landscape/W/PC/$endsum/brow
se.html"><img
src="http://bamboo.mluri.sari.ac.uk/~jo/landscape/weather/start.gif"
></a>

<h3>Thank you.</h3><P>

</form>
</center>
</html>
tag
```

Browser HTML page

All questionnaires use browser pages: this example is from the Weather survey. The following figure shows how this document looks on the screen.

```
<html>
<body bgcolor = "#DDDDDD" link="#DDDDDD" vlink="#DDDDDD"
alink="#DDDDDD"> <center>

<title>Landscape Preference Questionnaire Photograph Browser</title>

<h2><blink><font color="#006600">Please wait for all the photographs
to load.</font></blink><P>

<h2>Please browse through these twelve photographs. When you have
done so you will be asked to complete a scenic preference score for
each.</h2><br><br>

<table>
<tr><td colspan=2 align=middle><h1><a name="#_land1">Landscape
One</a></h1></td></tr>
<tr>
    <td><img
src="http://bamboo.mluri.sari.ac.uk/~jo/landscape/weather/w22/w22.15
12.gif" width=445 height=303></td>
    <td valign=bottom><a href="#_land2"><img
src="http://bamboo.mluri.sari.ac.uk/~jo/landscape/arrowdown.gif"
align=right></a></td>
</tr></table><br><br><br>

<table>
<tr><td colspan=2 align=middle valign=bottom><h1><a
name="_land2"><p>Landscape Two</a></h1></td></tr>
<tr>
    <td rowspan=2><img
src="http://bamboo.mluri.sari.ac.uk/~jo/landscape/weather/w02/w02.10
07.gif"  width=445 height=303></td>
    <td valign=top><a href="#_land1"><img
src="http://bamboo.mluri.sari.ac.uk/~jo/landscape/arrowup.gif"
align=right></a></td>
</tr>
<tr><td valign=bottom><a href="#_land3"><img
src="http://bamboo.mluri.sari.ac.uk/~jo/landscape/arrowdown.gif"
align=right></a></td></tr>
</table><br><br><br>

*
*
*
*

<table border=2 cellpadding=2>
<tr>
    <td><a href="#_land1" name="_end"><img
src="http://bamboo.mluri.sari.ac.uk/~jo/landscape/weather/browse.gif
"></a></td>
```

```
</tr>
<tr>
    <td><a href="landscape.html"><img
src="http://bamboo.mluri.sari.ac.uk/~jo/landscape/weather/prefscore.
gif"></a></td>
</tr></table>

</center>
</body>
</html>
```

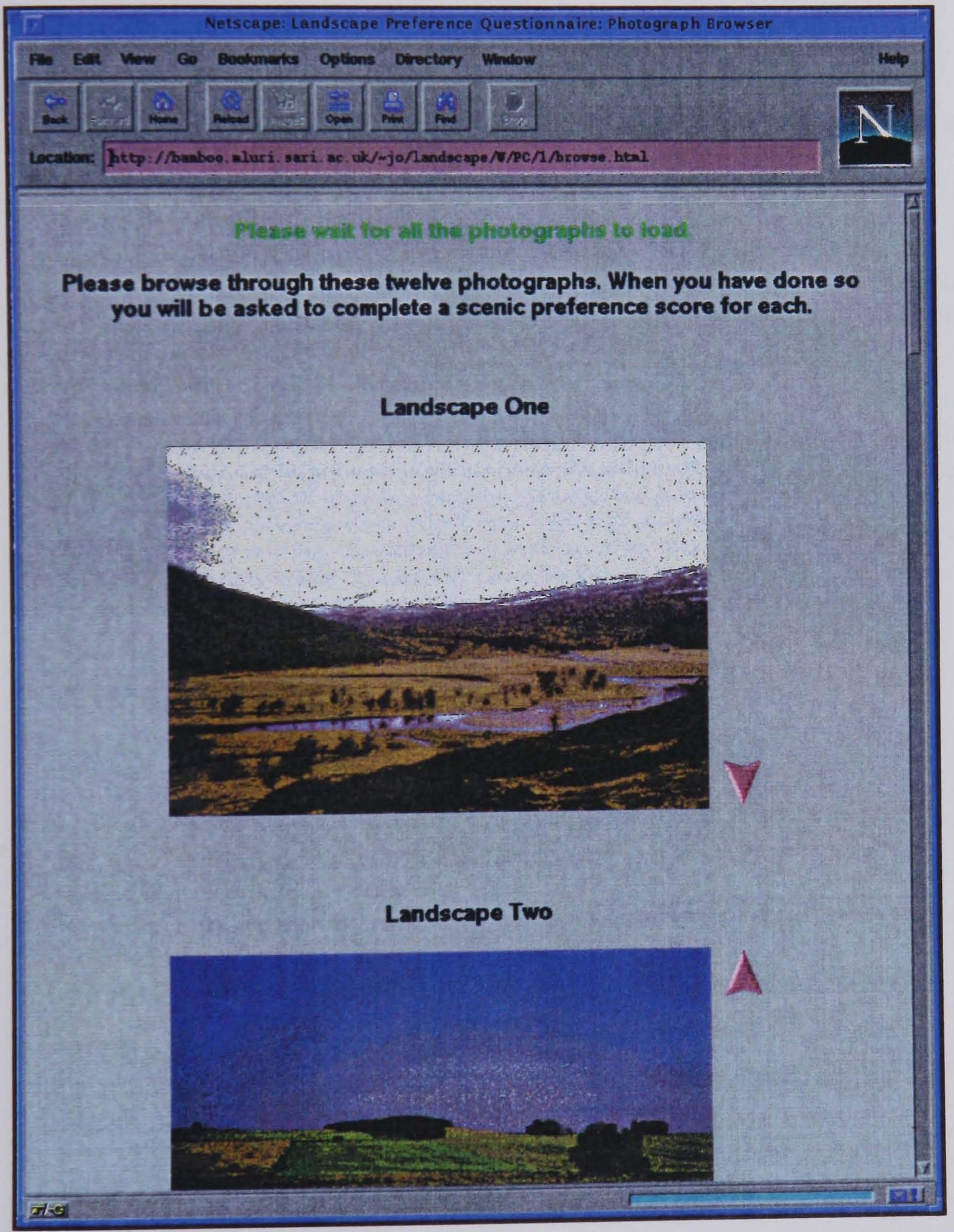


Figure VI.I Example of the beginning of a browser page

Scoring HTML page

The following script is an example of a scoring page, detailing the HTML for one image and one scoring line. The script for the socio-demographic information gathering is included in this example. The text seen in a WWW browser is shown in the following figure.

```
<html>
<body bgcolor = "#DDDDDD" link="#EEEEEE" vlink="#EEEEEE"
alink="#EEEEEE">

<title>Landscape Preference Questionnaire</title>

<center>
<form method="post" action="http://bamboo.mluri.sari.ac.uk/cgi-
bin/jo5.pl">
<input type="hidden" name="recipient"
value="jo@bamboo.mluri.sari.ac.uk">
<input type="hidden" name="redirect"
value="http://www.mluri.sari.ac.uk/~mi550/landscape/feedback.html">
<input type="hidden" name="subject" value="weather number 1">
<input type="hidden" name="env_report"
value="REMOTE_HOST,REMOTE_ADDR">
<input type=hidden name="sort"
value="order:print_config,qunumber,env_report,pref1,pref2,pref3,pref
4,pref5,pref6,pref7,pref8,pref9,pref10,pref11,pref12,age,sex,occupat
ion,city,country,nationality,display">
<input type="hidden" name="print_config" value="subject">
<input type="hidden" name="display" value="PC">

<br><br><br>

<h1>Landscape One</h1><br><br>

<table border=5><tr><td>
<img
src="http://bamboo.mluri.sari.ac.uk/~jo/landscape/weather/w22/w22.15
12.gif" width=445 height=303>
</td></tr></table><br>
<table border=5 cellspacing=3 cellpadding=3 bgcolor="#EEEEEE">
<tr>
    <td width=5></td>
    <td align=left ><h4>Low Scenic<br> Preference</h4></td>
    <td rowspan=2> </td>
    <td align=center><h4>~1~</h4><p><input type = "radio"
name="pref1" value="1"></td>
    <td align=center><h4>~2~</h4><p><input type = "radio"
name="pref1" value="2"></td>
    <td align=center><h4>~3~</h4><p><input type = "radio"
name="pref1" value="3"></td>
    <td align=center><h4>~4~</h4><p><input type = "radio"
name="pref1" value="4"></td>
    <td align=center><h4>~5~</h4><p><input type = "radio"
name="pref1" value="5"></td>
    <td align=center><h4>~6~</h4><p><input type = "radio"
name="pref1" value="6"></td>
```

```
    <td align=center><h4>~7~</h4><p><input type = "radio"
name="pref1" value="7"></td>
    <td rowspan=2> </td>
    <td align=right><h4>High Scenic<br> Preference</h4></td>
    <td width= 10></td>
    <td align=right><a href="#_land2"><img
src="http://bamboo.mluri.sari.ac.uk/~jo/landscape/arrowdown.gif"></a
> </td>
</tr></table>
```

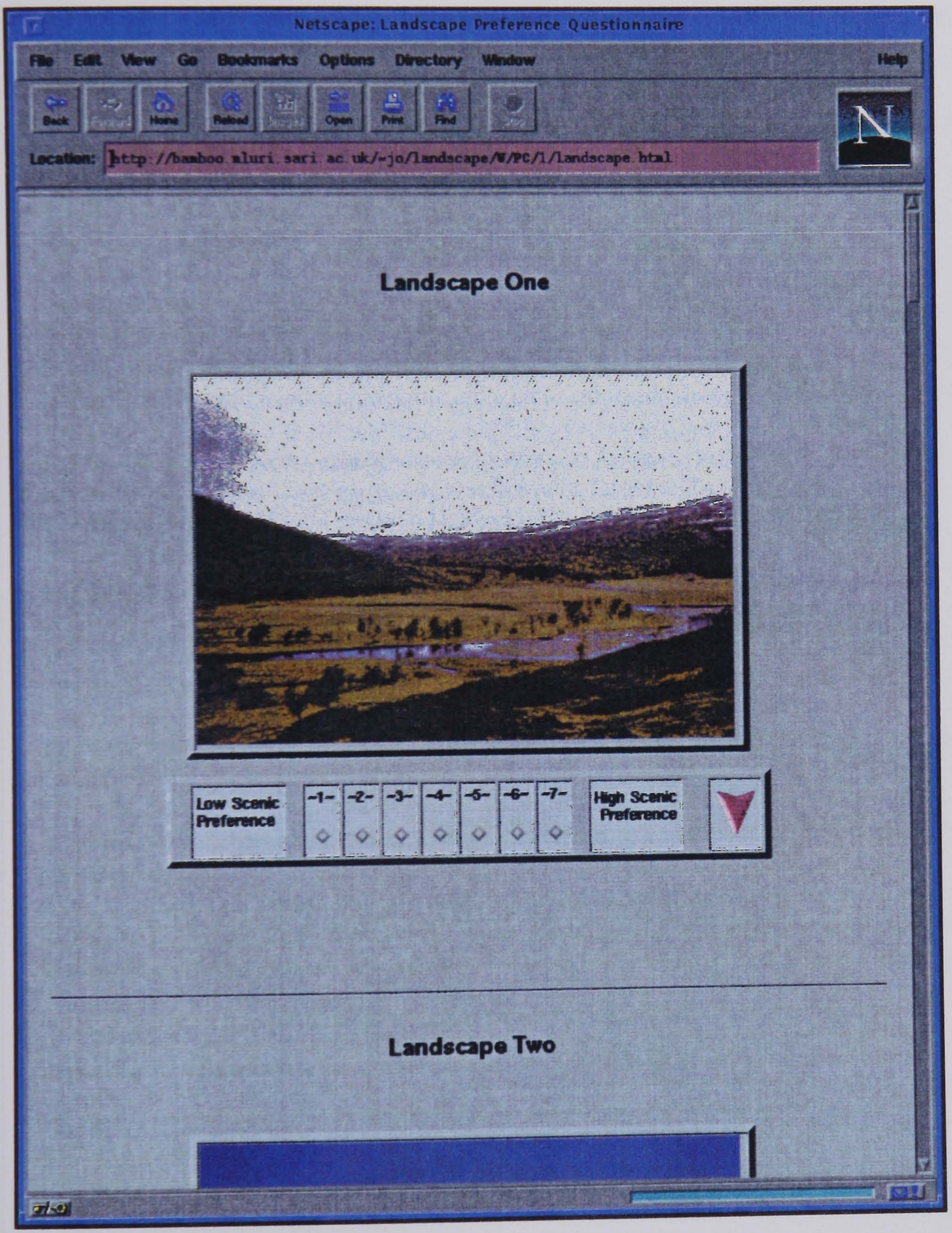


Figure VI.II Example of the beginning of a scoring page

```
*
*
*
*

<a name="_end"><hr></a><br>
<h1>Additional information</h1><P>
<h4>I would be grateful if you could now provide some information
about yourself.<br>
This information will be kept in the strictest confidence.</h4><br>

Age:<br>
<select name="age">
<option>
<option>16 and under
<option>17 to 24
<option>25 to 34
<option>35 to 44
<option>45 to 54
<option>55 to 64
<option>over 65
</select><P>

Sex: <br><select name="sex">
<option>
<option>Female
<option>Male
</select><P>

What is your occupation:<br>
<input type="text" name="occupation" size="30"><p>

Which <b>city</b> have you come from:<br><input type="text"
name="city" size="30"><p>

Which <b>country</b> do you live in<br><input type="text"
name="country" size="30"><p>

Which of the following do you consider yourself to be:<br>
<select name="nationality">
<option>
<option>British
<option>English
<option>Irish
<option>Scottish
<option>Welsh
<option>European
<option>North American
<option>African
<option>Arab
<option>Asian
<option>Australasian
<option>Other
</select>
```

```
<br><br><h3>Thank You<br><br>
Please now submit this information.</h3>
<table border=5 bgcolor="#EEEEEE">
<tr>      <td align=center><input type="submit" name="submit"
value="SUBMIT PREFERENCE SCORES"></td></tr>
<tr>      <td align=center><input type="reset" name="reset"
value="RESET"></td></tr>
</table>

</form>
</center>
</body>
</html>
```

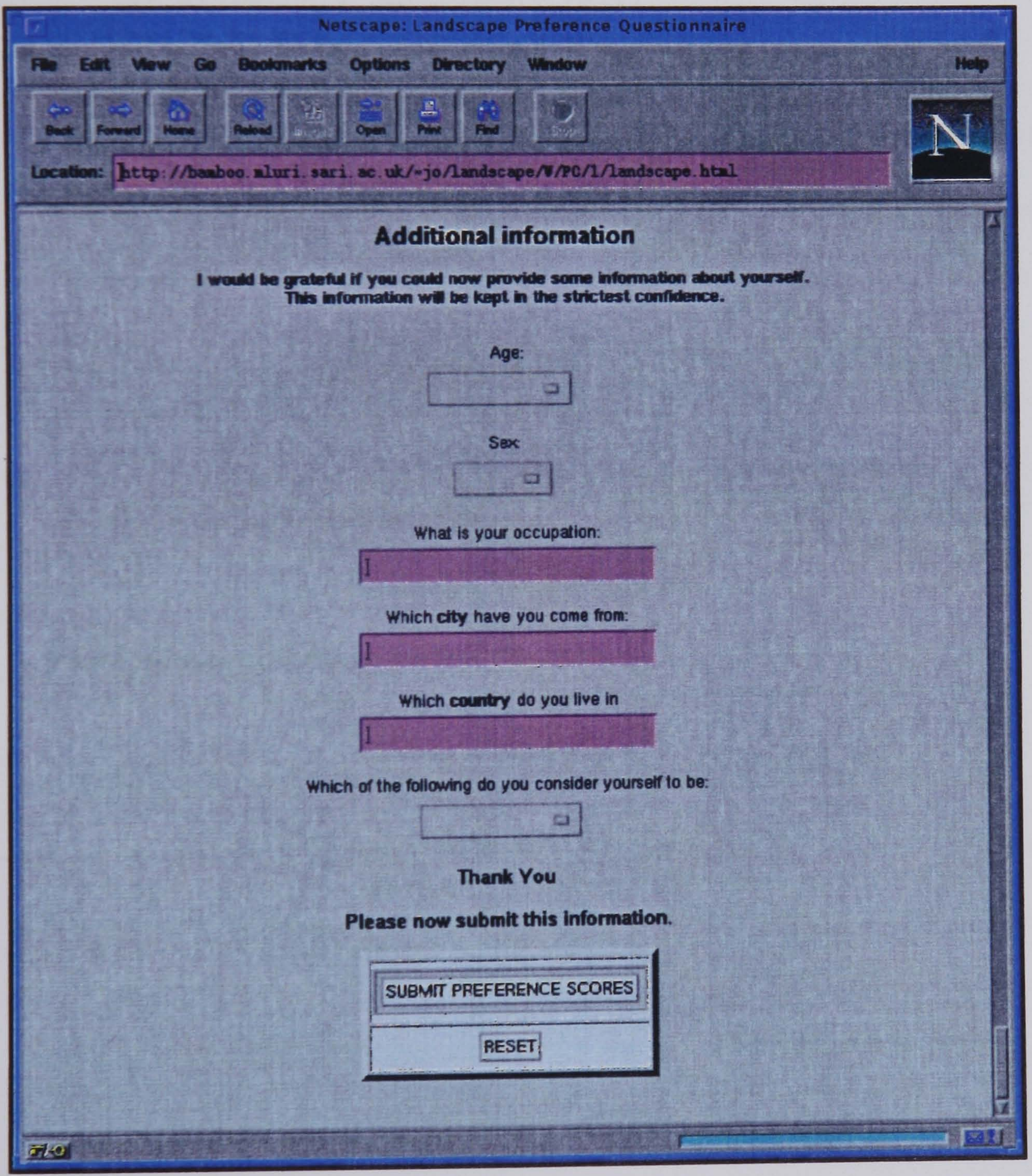


Figure VI.III Example of the Additional Information section

Screen resolution JavaScript

This JavaScript enables users of Netscape 3 or 4/Communictor to be redirected to a URL appropraite to their screen resolution. This example uses three possible resolutions: 640 by 480; 800 by 600; and 1024 by 768 and over.

```
<html>
<head>
<script language="JavaScript">
<!--
function checkres()
{
    var tools=java.awt.Toolkit.getDefaultToolkit();
    var size=tools.getScreenSize();
    w=size.width;

    if (w >= 1024) {document.location.href =
"http://www.mluri.sari.ac.uk/~mi550/landscape/practicext.html"; }
    if (w == 800) {document.location.href =
"http://www.mluri.sari.ac.uk/~mi550/landscape/practicepc.html"; }
    if (w == 640) {document.location.href =
"http://www.mluri.sari.ac.uk/~mi550/landscape/practicewpc.html"; }
}

//-->
</script>
</head>

<body onload="checkres()">
<h1><center>

****
TEXT WOULD GO HERE
****

</body>
</html>
```

VII Layout of Questionnaires

Twenty image questionnaire

Introduction to the Landscape Preference Questionnaire

Instructions

Choice of three screen types

Practice page

Score from practice page and random number generation

Download of first ten images

Browser for first set of images (nine versions for each screen type)

Scoring page for first set of images (nine versions for each screen type)

Download of second ten images

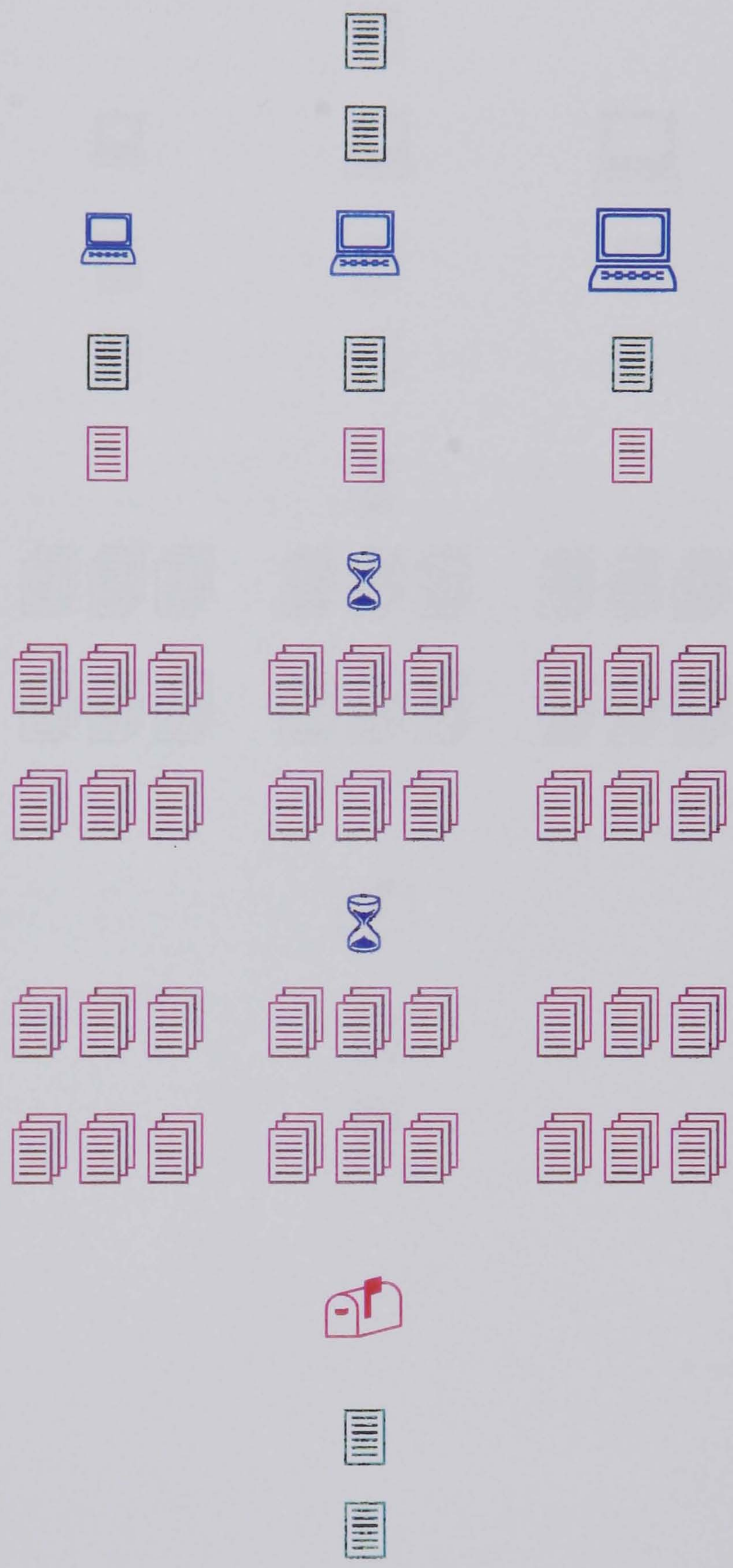
Browser for second set of images (nine versions for each screen type)

Scoring page for second set of images and socio-demographic information (nine versions for each screen type)

Submission of preference scores and other information by e-mail

Feedback page

Links out of the questionnaire



Key: html page ; perl page

Twelve or ten image questionnaire

Introduction to the Landscape Preference Questionnaire

Instructions

Choice of three screen types or JavaScript

Practice page

Score from practice page and random number generation

Download of twelve images

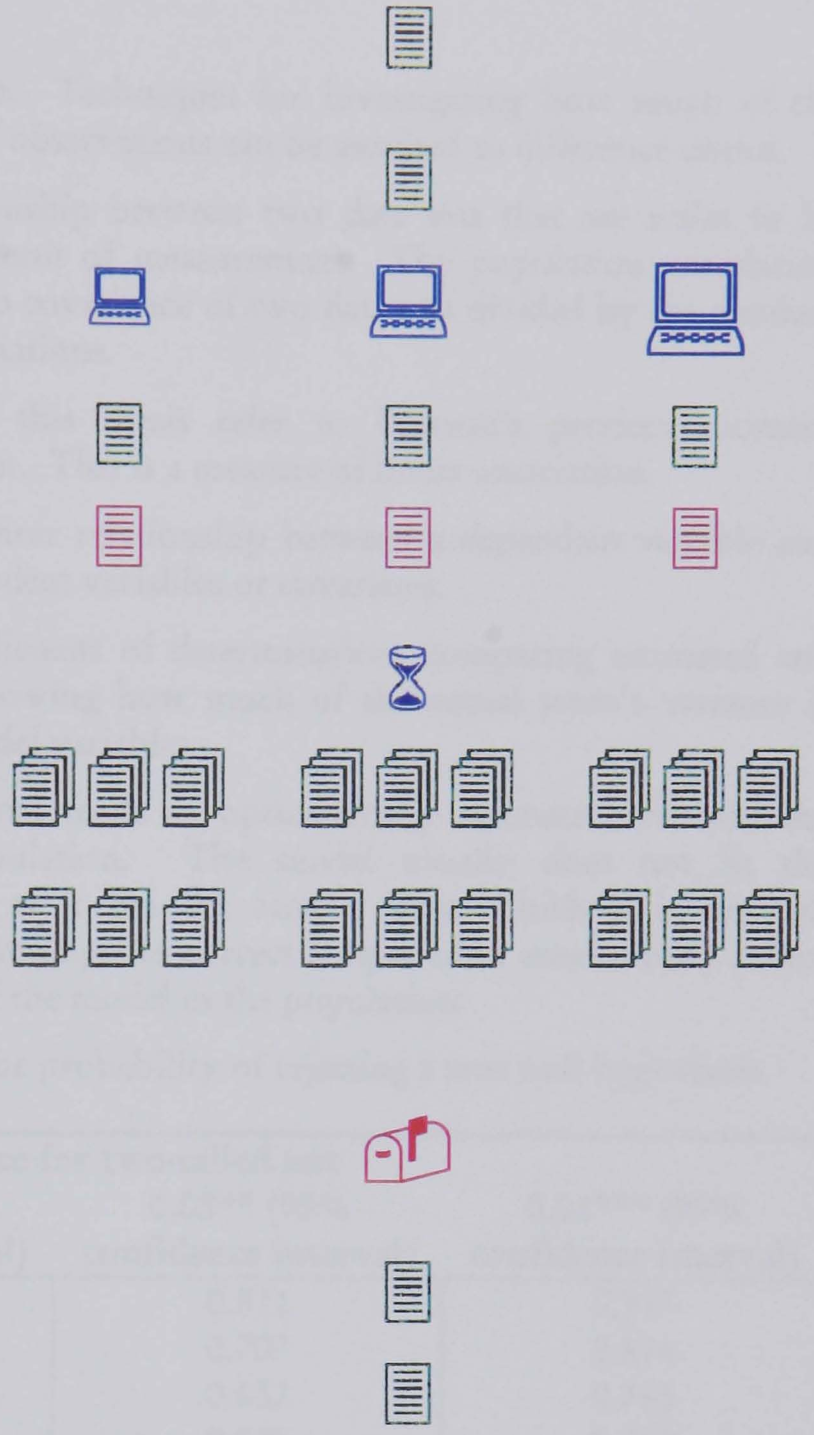
Browser for images (many versions for each screen type)

Scoring page for images and socio-demographic information (many versions for each screen type)

Submission of preference scores and other information by e-mail

Feedback page

Links out of the questionnaire



Key: html page ; perl page

VIII Statistical Definitions and Information

ANOVA Analysis of variance. Techniques for investigating how much of the variability in a set of observations can be ascribed to difference causes.

Correlation Measures the relationship between two data sets that are scales to be independent of the unit of measurement. The population correlation calculation returns to covariance of two data sets divided by the product of their standard deviations.

All correlations in this thesis refer to Pearson's product moment correlation coefficient. This is a measure of linear association.

Regression Analysis Estimation of the linear relationship between a dependant variable and one or more independent variables or covariates.

R squared R^2 denotes the coefficients of determination, comparing estimated and actual values and showing how much of the actual score's variance is explained by the model variables

Adjusted R squared The sample R squared tends to optimistically estimate how well the model fits the population. The model usually does not fit the population as well as it fits the sample from which it is derived. Adjusted R squared attempts to correct R squared to more closely reflect the goodness of fit of the model in the population.

Significance of F Significance level. The probability of rejecting a true null hypothesis.

Degrees of Freedom	Level of significance for two-tailed test 0.1* (90% confidence interval)	0.05** (95% confidence interval)	0.01*** (99% confidence interval)
4	0.729	0.811	0.917
6	0.622	0.707	0.834
8	0.549	0.632	0.765
10	0.497	0.576	0.708
20	0.360	0.423	0.537
30	0.296	0.349	0.449
50	0.231	0.273	0.354
100	0.164	0.195	0.254

Table VIII.I Critical values of the Pearson product moment correlation coefficient

Significance of F	Description of significance	Symbol
> 0.1	not significant	
0.1 - 0.01	slightly significant	*
0.01 - 0.001	significant	**
< 0.001	highly significant	***

Table VIII.II Significance of F: descriptions

Source: Microsoft Corporation, 1996

Porkess, 1988

SPSS Inc., 1996

IX Validation Survey

Geographical distribution of photographs

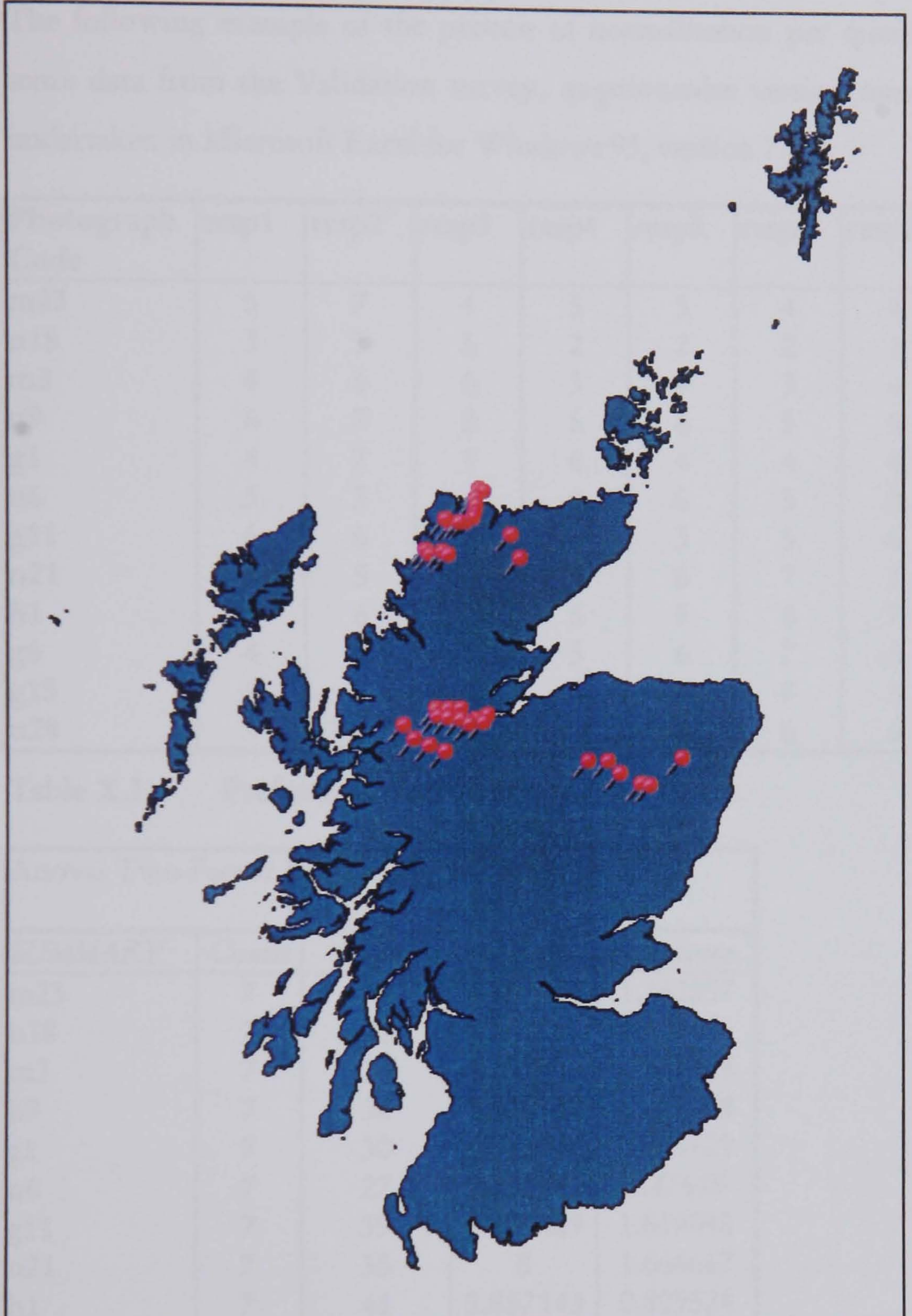


Figure IX.I Geographic distribution of photographs: Validation Survey

X Examples of Normalisation per Questionnaire and Respondent

Normalisation per questionnaire

The following example of the process of normalisation per questionnaire uses the preference score data from the Validation survey, questionnaire version number one. The analysis was undertaken in Microsoft Excel for Windows 95, version 7.0.

Photograph Code	resp1	resp2	resp3	resp4	resp5	resp6	resp7
m23	5	7	4	5	5	4	4
n18	3	5	5	2	2	2	3
m3	4	6	6	3	4	3	4
n9	6	7	3	6	6	5	5
g1	4	7	1	6	4	4	4
n6	3	5	2	4	6	5	2
g11	6	6	7	6	3	5	6
n21	5	5	5	4	6	7	3
h1	5	6	7	5	5	6	7
g6	4	5	6	5	6	7	5
g15	4	6	6	6	3	7	5
n28	4	6	5	6	4	6	6

Table X.I Preference score data

Anova: Two-Factor Without Replication				
SUMMARY	*Count*	*Sum*	*Average*	*Variance*
m23	7	34	**4.857143**	1.142857
n18	7	22	**3.142857**	1.809524
m3	7	30	**4.285714**	1.571429
n9	7	38	**5.428571**	1.619048
g1	7	30	**4.285714**	3.571429
n6	7	27	**3.857143**	2.47619
g11	7	39	**5.571429**	1.619048
n21	7	35	**5**	1.666667
h1	7	41	**5.857143**	0.809524
g6	7	38	**5.428571**	0.952381
g15	7	37	**5.285714**	1.904762
n28	7	37	**5.285714**	0.904762
resp1	12	53	4.416667	0.992424
resp2	12	71	5.916667	0.628788
resp3	12	57	4.75	3.659091
resp4	12	58	4.833333	1.787879
resp5	12	54	4.5	1.909091
resp6	12	61	5.083333	2.628788
resp7	12	54	4.5	2.090909

Table X.II Data summary output (Count and Mean in bold)

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	50	11	4.545455	2.980132	0.00287	1.936957
Columns	19.61905	6	3.269841	2.143803	0.059797	2.239481
Error	100.6667	66	**1.525253**			
Total	170.2857	83				

Table X.III ANOVA for Preference scores (MS Error in bold)

Photograph Code	Photograph Mean	Questionnaire Mean	Count	Mean Square Error (MS Error)	Normalised Score
	a	b	c	d	$(a-b)/\sqrt{(c.d)}$
m23	4.857143	4.857143	7	1.525253	0
n18	3.142857	4.857143	7	1.525253	-0.524642
m3	4.285714	4.857143	7	1.525253	-0.174881
n9	5.428571	4.857143	7	1.525253	0.174881
g1	4.285714	4.857143	7	1.525253	-0.174881
n6	3.857143	4.857143	7	1.525253	-0.306041
g11	5.571429	4.857143	7	1.525253	0.218601
n21	5	4.857143	7	1.525253	0.04372
h1	5.857143	4.857143	7	1.525253	0.306041
g6	5.428571	4.857143	7	1.525253	0.174881
g15	5.285714	4.857143	7	1.525253	0.131161
n28	5.285714	4.857143	7	1.525253	0.131161

Table X.IV Calculation of normalised score using Equation 6.1

Normalisation per respondent

The following example again uses the data from the Validation survey, questionnaire version one. The preference data from Respondent 1 only will be demonstrated.

Photograph Code	Score of Respondent 1	Score Mean	Score Standard Deviation	Normalised Scores
	x	y	z	(x-y)/z
m23	5	4.416667	0.996205	0.585556
n18	3	4.416667	0.996205	-1.422064
m3	4	4.416667	0.996205	-0.418254
n9	6	4.416667	0.996205	1.589365
g1	4	4.416667	0.996205	-0.418254
n6	3	4.416667	0.996205	-1.422064
g11	6	4.416667	0.996205	1.589365
n21	5	4.416667	0.996205	0.585556
h1	5	4.416667	0.996205	0.585556
g6	4	4.416667	0.996205	-0.418254
g15	4	4.416667	0.996205	-0.418254
n28	4	4.416667	0.996205	-0.418254

Table X.V Calculation of normalised score using Equation 6.2

XI Shafer Model

Shafer Model	$R^2 = 0.66$
Variables	Unstandardised Coefficients
	B
(constant)	184.8
PNV	- 0.5435
PMN	- 0.09298
PNV.PFV	0.002069
PNV.AMV	0.0005538
PFV.W	-0.002596
PMN.AFN	0.001634
AMV.AFN	-0.0008441*
AMV.W	-0.0004131
PNV^2	0.0006666
W^2	0.0001327

* In Shafer *et al.* (1969) there is an error in this term

Table XI.I Shafer Model (Shafer and Brush, 1977)

Variable	Maximum Value	Percentage of Photograph
PNV	320	14%
PMN	338	14%
PFV	176	7%
AMV	814	71%
W	646	57%
AFN	359	31%

Table XI.II Maximum values for use in the Shafer Model

Shafer Model	Value
Highest Predicted Score	84
Lowest Predicted Score	236
Mean	150.05
Standard Deviation	30.58

Table XI.III Further details of Shafer Model

XII Details of Models A to F

Details of predictive preference models

The predictive landscape preference models are detailed in Table XII.I to Table XII.VI. The ANOVAs for the five models are included in Table XII.VII.

Model A	R^2 = 0.658 (adjusted = 0.638)		Normalisation: per questionnaire		
Variables	Unstandardised Coefficients		Standardised Coefficients		
	B	Standard Error	Beta	t	Significance
(constant)	0.322	0.100		3.236	0.002
INV_WATER	-0.324	0.045	-0.508	-7.244	0.000
INV_BPP	-123.511	25.135	-0.352	-4.914	0.000
REDVAR	4.249 E-5	0.000	0.241	3.456	0.001
LN_LS	2.120 E-2	0.010	0.151	2.220	0.029
INV_PLM	-0.247	0.040	-0.411	-6.247	0.000

Table XII.I Model A

Model B	R^2 = 0.642 (adjusted = 0.625)		Normalisation: per questionnaire		
Variables	Unstandardised Coefficients		Standardised Coefficients		
	B	Standard Error	Beta	t	Significance
(constant)	0.406	0.090		4.486	0.000
INV_BPP	-124.565	25.436	-0.355	-4.898	0.000
REDVAR	3.923 E-5	0.000	0.223	3.196	0.002
INV_PLM	-0.252	0.040	-0.420	-6.359	0.000
R_PSKYPWATER	-2.82 E-3	0.000	-0.479	-6.889	0.000

Table XII.II Model B

Model C	R^2 = 0.658 (adjusted = 0.637)		Normalisation: per questionnaire		
Variables	Unstandardised Coefficients		Standardised Coefficients		
	B	Standard Error	Beta	t	Significance
(constant)	0.292	0.106		2.748	0.007
INV_BPP	-113.065	25.706	-0.322	-4.398	0.000
REDVAR	3.243 E-5	0.000	0.184	2.581	0.012
INV_PLM	-0.241	0.039	-0.401	-6.108	0.000
R_PSKYPWATER	-2.62 E-3	0.000	-0.445	-6.318	0.000
LPC	2.11 E-2	0.011	0.140	1.958	0.054

Table XII.III Model C

Model D	R^2 = 0.832 (adjusted = 0.780)		Normalisation: per questionnaire		
Variables	**Unstandardised Coefficients**		**Standardised Coefficients**		
	B	**Standard Error**	**Beta**	**t**	**Significance**
(constant)	-7.87 E-2	0.305		-0.258	0.797
INV_WATER	-0.343	0.047	-0.537	-7.230	0.000
LN_LM	-5.38 E-2	0.025	-0.385	-2.112	0.038
INV_BPP	-188.615	33.468	-0.537	-5.636	0.000
LN_LS	9.565 E-2	0.027	0.680	3.501	0.001
INV_PLM	-0.443	0.104	-0.738	-4.245	0.000
RGBMEAN	-6.53 E-8	0.000	-0.262	-3.050	0.003
$AWSEA^2$	4.497 E-6	0.000	0.396	4.673	0.000
$PWSEA^2$	-3.31 E-5	0.000	-0.432	-4.533	0.000
LN_PLS	-9.01 E-2	0.031	-0.544	-2.938	0.005
OBSVEG	2.334 E-3	0.001	1.485	3.263	0.002
PWMOVE	-2.45 E-3	0.001	-0.342	-4.773	0.000
POV	-2.95 E-3	0.001	-0.752	-2.542	0.013
$OBSVEG^2$	-4.76 E-6	0.000	-1.569	-3.445	0.001
OBSVEGPOV	9.437 E-6	0.000	1.102	3.080	0.003
R_SKY	0.145	0.041	0.695	3.529	0.001
LN_TVL	8.202 E-2	0.022	0.311	3.713	0.000
GSTDEV	1.908 E-2	0.004	0.585	5.265	0.000
INV_SKY	-31.14	9.180	-0.376	-3.392	0.001
$PWATER^2$	1.461 E-5	0.000	0.377	4.187	0.000
BSTDEV	-1.06 E-2	0.004	-0.329	-2.870	0.005
SKY	-7.44 E-4	0.000	-0.373	-2.000	0.049

Table XII.IV Model D

Model E	R^2 = 0.779 (adjusted = 0.748)		Normalisation: per respondent		
Variables	**Unstandardised Coefficients**		**Standardised Coefficients**		
	B	**Standard Error**	**Beta**	**t**	**Significance**
(constant)	0.645	0.164		3.936	0.000
$AWSEA^2$	5.074 E-6	0.000	0.245	4.051	0.000
BMEANBSTDEV	1.125 E-4	0.000	0.548	4.113	0.000
INV_AWSTILL	-5.050	1.209	-4.448	-4.177	0.000
INV_BPP	-210.463	47.670	-0.328	-4.387	0.000
INV_PLL	-0.179	0.070	-0.161	-2.545	0.013
INV_PWATER	1.329	0.514	1.161	2.588	0.012
INV_PWSTILL	4.771	1.180	4.292	4.043	0.000
LN_LM	0.106	0.014	0.413	7.413	0.000
PFNAFV	1.001 E-5	0.000	0.199	3.633	0.001
R_PSKYPWATER	-1.69 E-2	0.005	-1.567	-3.518	0.001
RGMEAN	-5.54 E-5	0.000	-0.685	-5.510	0.000

Table XII.V Model E

Model F	R^2 = 0.724 (adjusted = 0.681)		Normalisation: per respondent		
Variables	Unstandardised Coefficients		Standardised Coefficients		
	B	Standard Error	Beta	t	Significance
(constant)	-2.300	0.869		-2.648	0.010
INV_W	-0.491	0.094	-0.420	-5.227	0.000
LF^2	-1.23 E-6	0.000	-0.196	-2.373	0.020
PWSTILL	3.642 E-3	0.001	0.332	3.981	0.000
LN_SKY	0.620	0.186	0.631	3.330	0.001
R_WSEA	0.310	0.088	0.422	3.504	0.001
INV_PLM	-0.374	0.083	-0.341	-4.514	0.000
$PWSEA^2$	-3.45 E-5	0.000	-0.246	-1.993	0.050
INV_LF	-0.193	0.085	-0.183	-2.267	0.026
INV_PLL	-0.266	0.091	-0.239	-2.906	0.005
OBSVEG	7.156 E-4	0.000	0.249	2.611	0.011
LHIGH	5.953 E-4	0.000	0.186	2.147	0.035
SKY	-2.52 E-3	0.001	-0.692	-3.544	0.001

Table XII.VI Model F

Model	Sum of Squares	df	Mean Square	F	Significance
Model A					
Regression	4.697	5	0.939	32.384	0.000
Residual	2.437	84	0.02901		
Total	7.134	89			
Model B					
Regression	4.580	4.	1.145	38.112	0.000
Residual	2.554	85	0.03004		
Total	7.134	89			
Model C					
Regression	4.691	5	0.938	32.274	0.000
Residual	2.442	84	0.02907		
Total	7.134	89			
Model D					
Regression	5.935	21	0.283	16.029	0.000
Residual	1.199	68	0.01763		
Total	7.134	89			
Model E					
Regression	18.583	11	1.689	25.008	0.000
Residual	5.269	78	0.06755		
Total	23.852	89			
Model F					
Regression	17.277	12	1.440	16.860	0.000
Residual	6.575	77	0.08539		
Total	23.852	89			

Table XII.VII ANOVA for Models A to F

Plots of Standardised Residuals and Scatter Plots

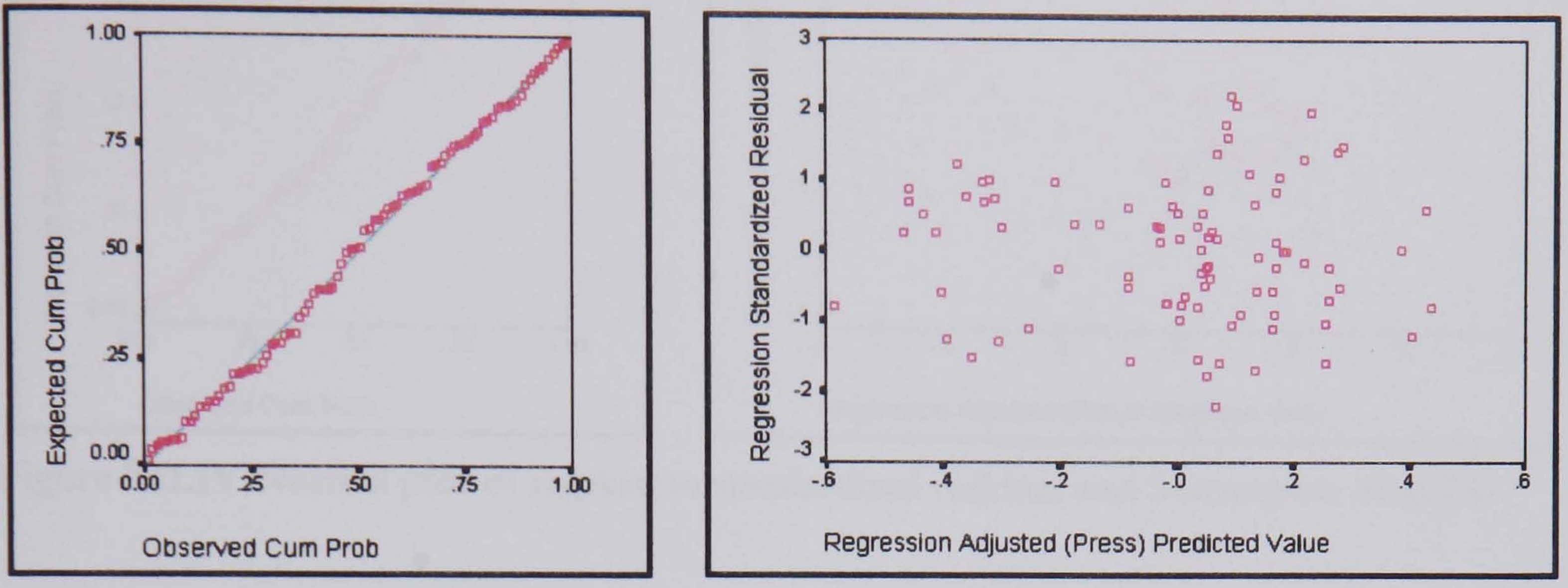


Figure XII.I Normal plot of regression standardised residual and Scatterplot: Model A

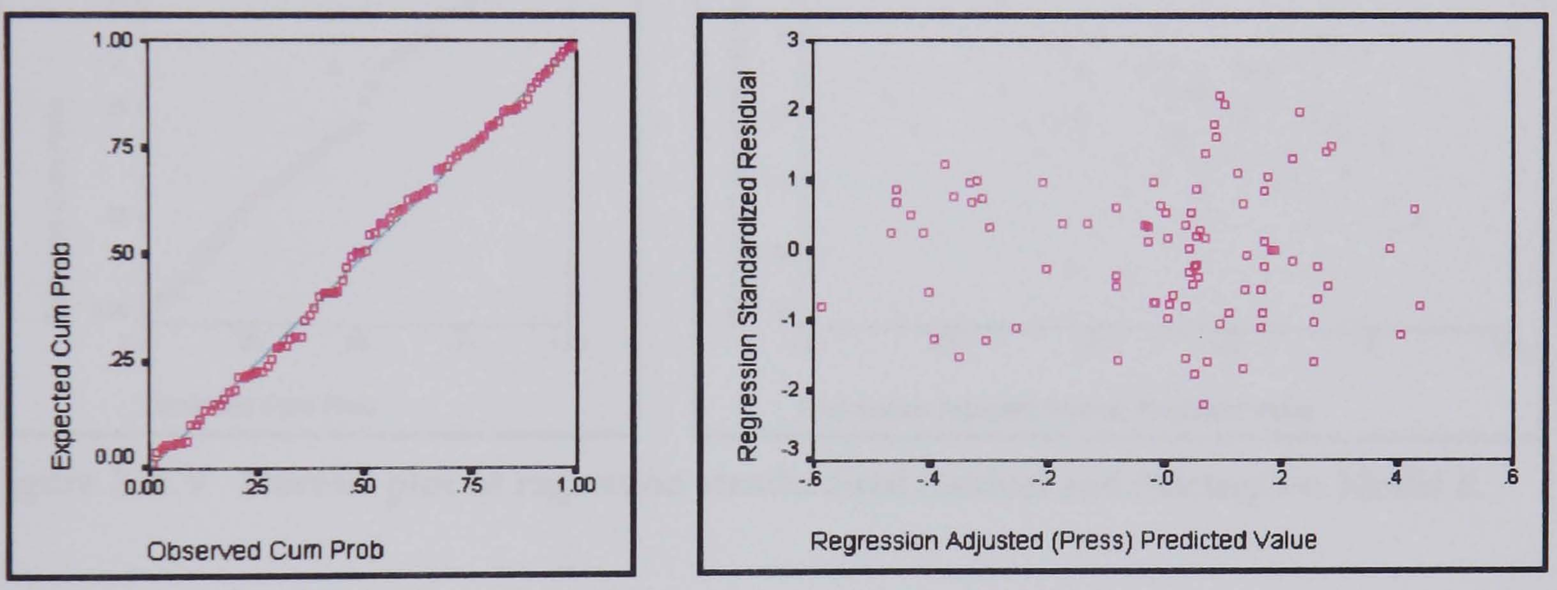


Figure XII.II Normal plot of regression standardised residual and Scatterplot: Model B

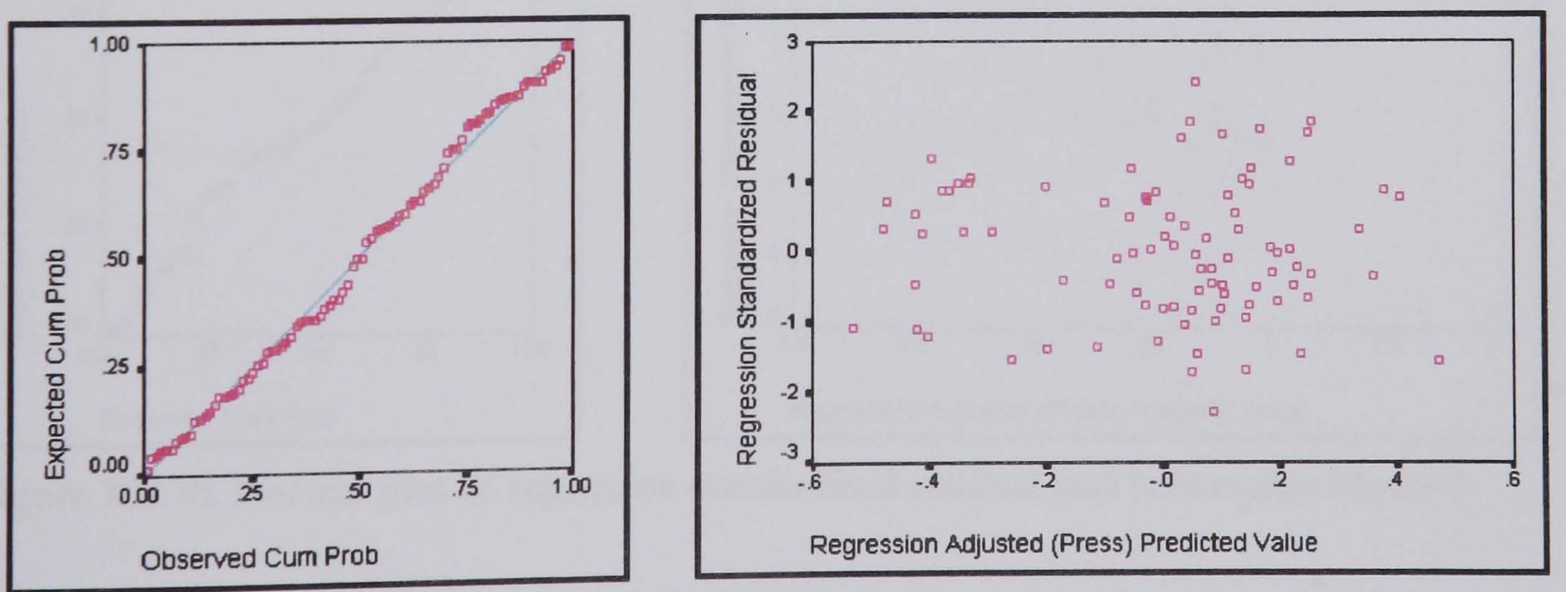


Figure XII.III Normal plot of regression standardised residual and Scatterplot: Model C

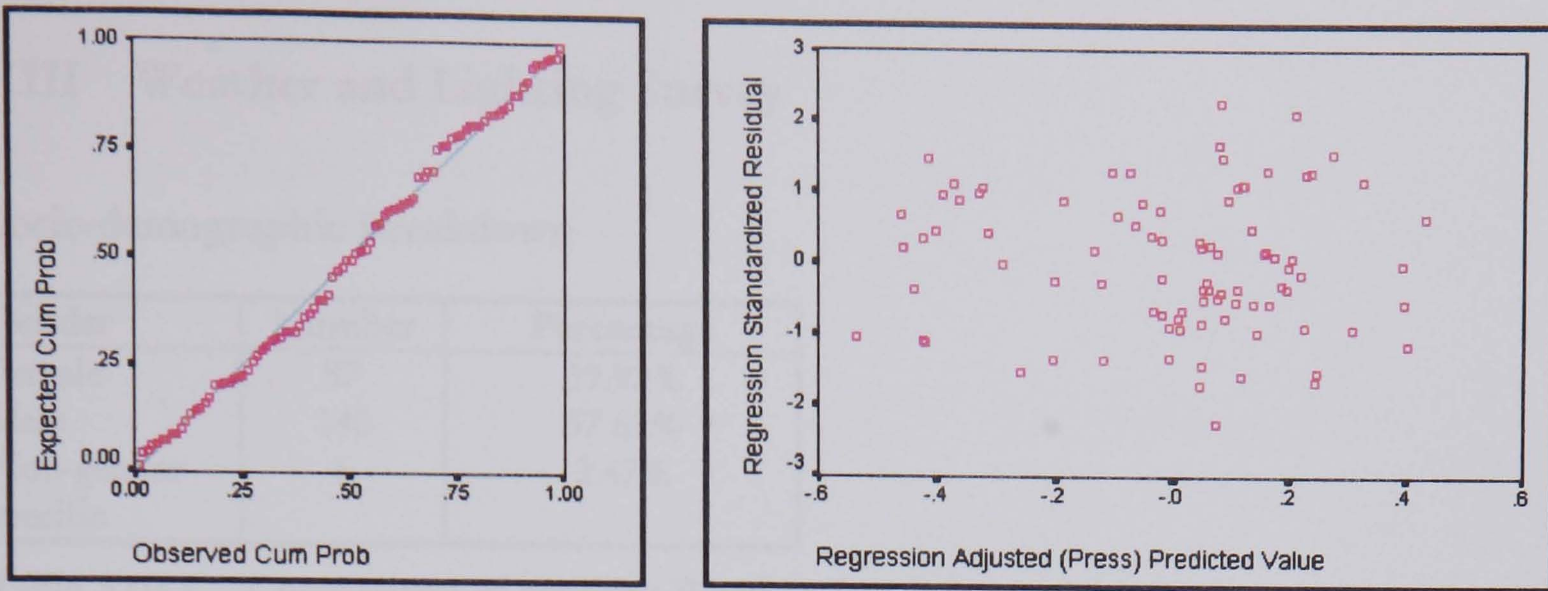


Figure XII.IV Normal plot of regression standardised residual and Scatterplot: Model D

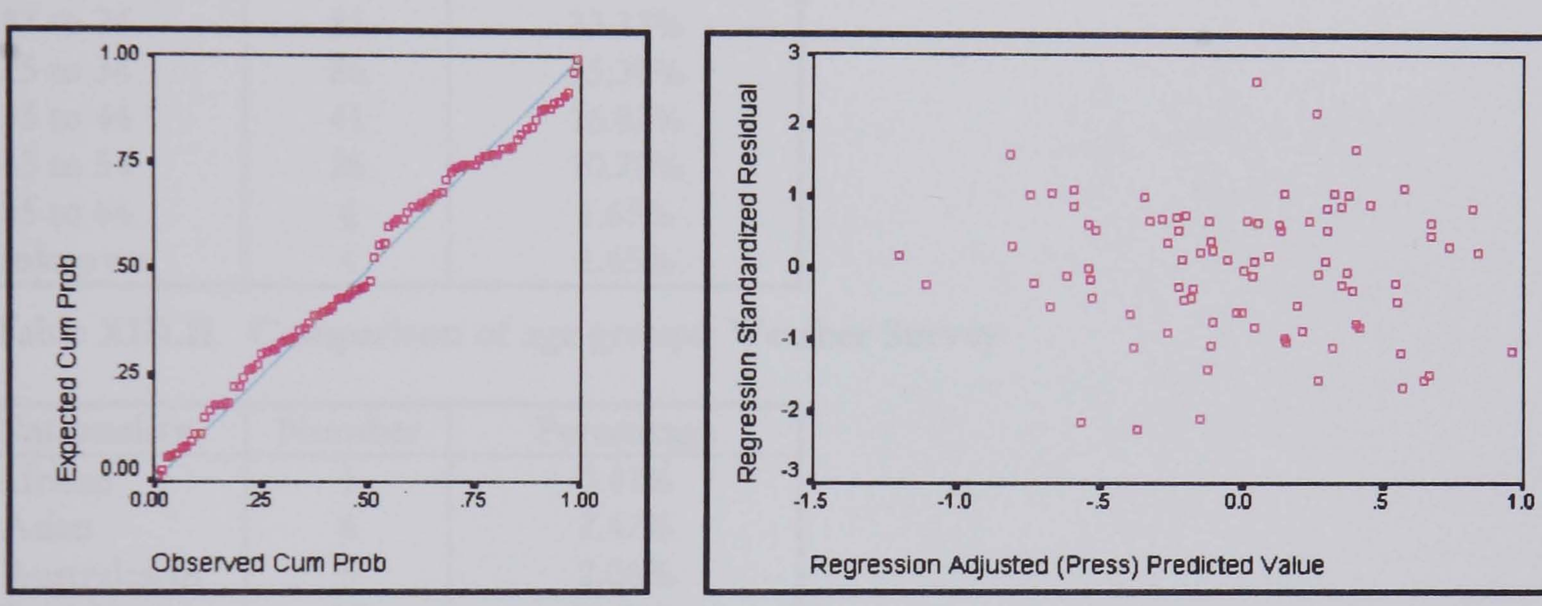


Figure XII.V Normal plot of regression standardised residual and Scatterplot: Model E

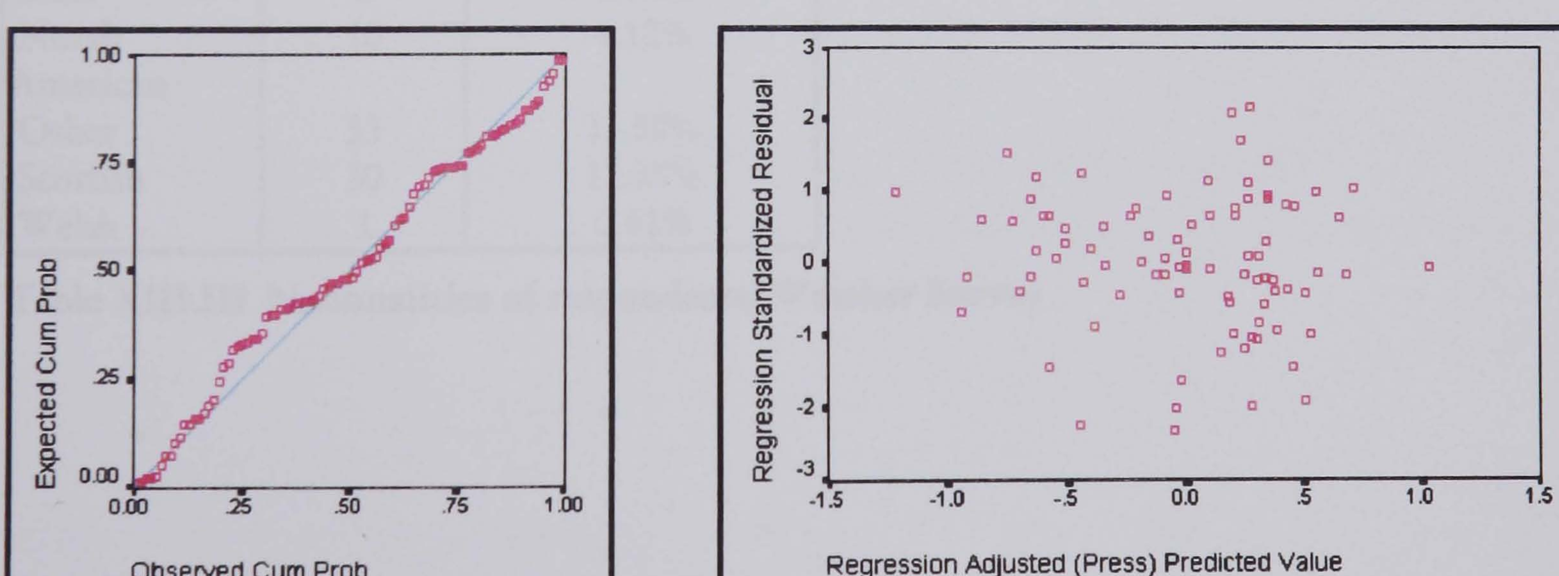


Figure XII.VI Normal plot of regression standardised residual and Scatterplot: Model F

XIII Weather and Lighting Survey

Socio-demographic Breakdown

Gender	Number	Percentage
Female	97	39.92%
Male	140	57.61%
Non-gender specific	6	2.47%

Table XIII.I Comparison of genders: Weather Survey

Age Group	Number	Percentage
16 and under	1	0.41%
17 to 24	81	33.33%
25 to 34	86	35.39%
35 to 44	41	16.87%
45 to 54	26	10.70%
55 to 64	4	1.65%
unknown	4	1.65%

Table XIII.II Comparison of age groups: Weather Survey

Nationality	Number	Percentage
African	1	0.41%
Asian	6	2.47%
Australasian	5	2.06%
British	75	30.86%
English	25	10.29%
European	55	22.63%
Irish	2	0.82%
North American	10	4.12%
Other	33	13.58%
Scottish	30	12.35%
Welsh	1	0.41%

Table XIII.III Nationalities of respondents: Weather Survey

Details of models incorporating weather dependent variables

The predictive landscape preference models incorporating the data from the weather and seaon survey are detailed in Table XIII.IV. The ANOVA for the model is included in Table XIII.V and further details in Table XIII.VI.

Model W	R^2 = 0.655 (adjusted = 0.634)		Normalisation: per respondent		
Variables	Unstandardised Coefficients		Standardised Coefficients		
	B	Standard Error	Beta	t	Significance
(constant)	0.436	0.091		4.790	0.000
INV_BPP	-128.543	25.228	-0.366	-5.095	0.000
INV_PLM	-0.252	0.039	-0.419	-6.421	0.000
R_PSPW	-2.742 E-3	0.000	-0.466	-6.748	0.000
REDVAR	5.14 E-5	0.000	0.292	3.682	0.000
DISTANT_CLOUD	-0.01502	0.009	-0.131	-1.761	0.082

Table XIII.IV Model W

Model W	Sum of Squares	df	Mean Square	F	Significance
Regression	4.671	5	0.934	31.863	0.000
Residual	2.463	84	0.02932		
Total	7.134	89			

Table XIII.V ANOVA for Model W

Model W	Minimum Score	Maximum Score	Average	Standard Deviation
Normalisation per questionnaire	-0.745	0.586	-0.000	0.283
Model W	-0.565	0.441	0.000	0.229

Table XIII.VI Further Details of Model W (compared to Main Survey data)

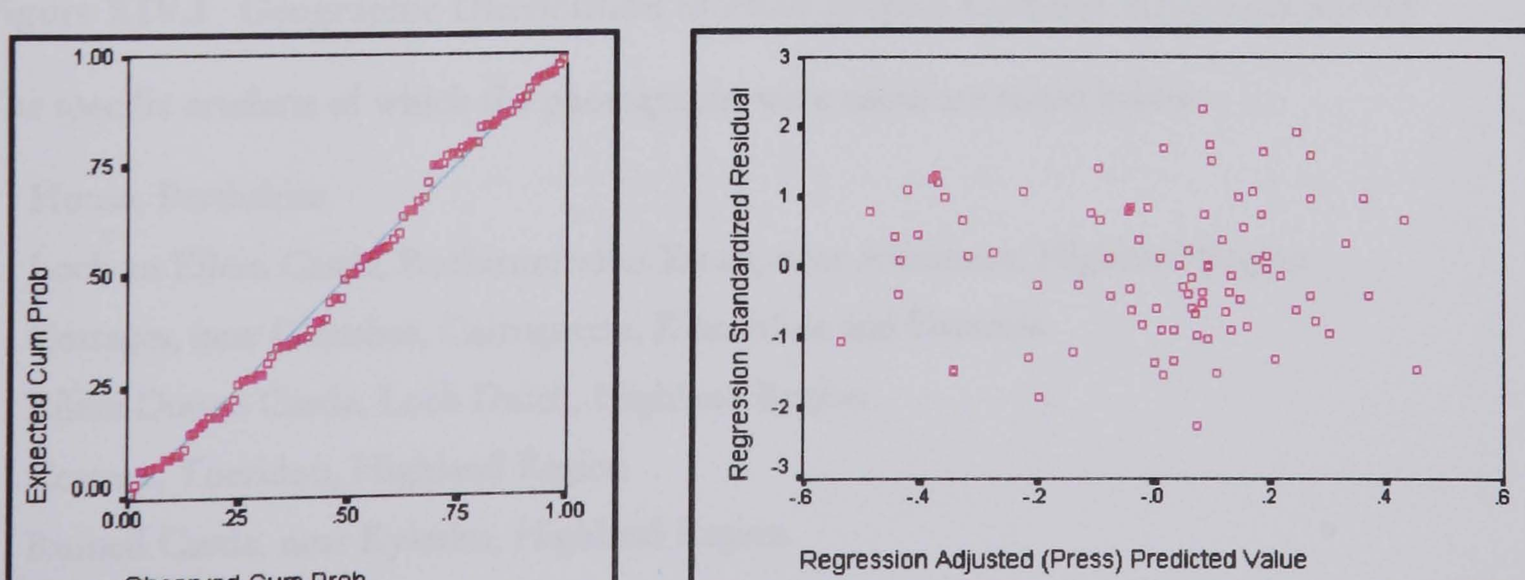


Figure XIII.I Normal plot of resgression standardised residual and Scatterplot: Model W

XIV Cultural Structures Survey

Geographic distribution of photographs

The following map shows where the photographs of the eight scenes were taken.

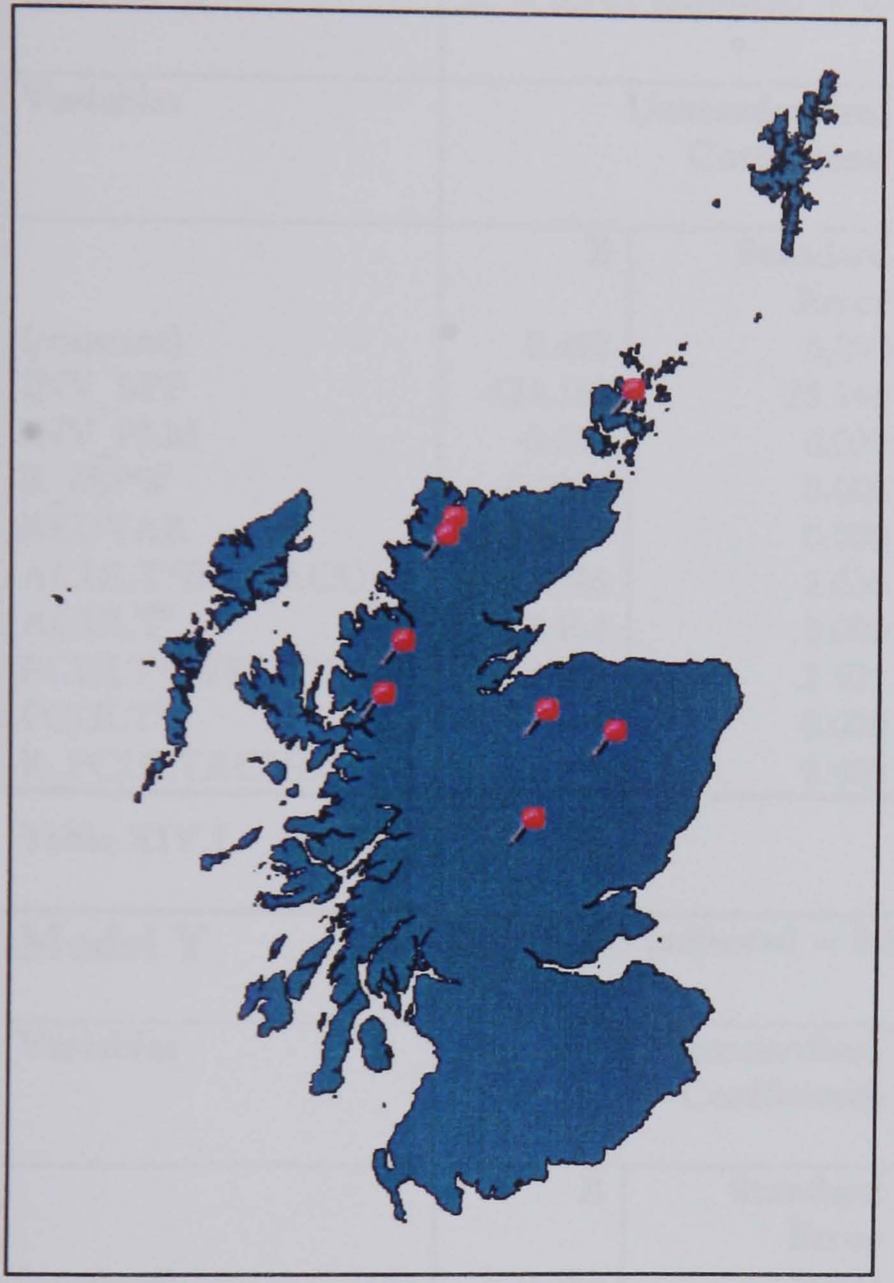


Figure XIV.I Geographic Distribution of Photographs: Cultural Structures Survey

The specific artefacts of which the photographs were taken are noted below:

- House, Perthshire
- Loch an Eilein Castle, Rothiemurchus Estate, near Aviemore, Highland Region
- Cottages, near Glenshee, Cairngorms, Kincardine and Deesside
- Eilein Donan Castle, Loch Duich, Highland Region
- Cottage, Torridon, Highland Region
- Ruined Castle, near Kylesku, Highland Region
- Modern Bridge, Kylesku, Highland Region
- Ring of Brogar, Orkney

Details of models incorporating cultural structures

The predictive landscape preference models incorporating the data from the cultural structures survey are detailed in Table XIV.I and Table XIV.II. The ANOVAs for the two models are included in Table XIV.III and further details in Table XIV.IV.

Model X	R^2 = 0.701 (adjusted = 0.670)		Normalisation: per respondent		
Variables	**Unstandardised Coefficients**		**Standardised Coefficients**		
	B	**Standard Error**	**Beta**	**t**	**Significance**
(constant)	0.402	0.090		4.482	0.000
INV_BPP	-124.153	25.240	-0.323	-4.919	0.000
INV_PLM	-0.252	0.039	-0.402	-6.395	0.000
R_PSPW	-0.0029	0.000	-0.464	-7.238	0.000
REDVAR	3.99 E-5	0.000	0.217	3.285	0.001
ACULT*INV_ACULT	-6.986	2.036	-5.129	-3.431	0.001
$ACULT^2$	-4.9 E-4	0.000	-1.810	-3.139	0.002
PCULT*INV_PCULT	8.902	2.521	7.110	3.531	0.001
$PCULT^2$	7.974 E-4	0.000	1.786	3.009	0.003
R_PCULTACULT	-1.469	0.459	-2.322	-3.197	0.002

Table XIV.I Model X

Model Y	R^2 = 0.653 (adjusted = 0.634)		Normalisation: per respondent		
Variables	**Unstandardised Coefficients**		**Standardised Coefficients**		
	B	**Standard Error**	**Beta**	**t**	**Significance**
(constant)	0.381	0.092		4.127	0.000
INV_BPP	-132.256	26.438	-0.344	-5.002	0.000
INV_PLM	-0.271	0.040	-0.432	-6.792	0.000
R_PSPW	-0.0027	0.000	-0.437	-6.622	0.000
REDVAR	4.882 E-5	0.000	0.266	4.007	0.000
PCULT*INV_PCULT	0.249	0.079	0.199	3.150	0.002

Table XIV.II Model Y

Model	Sum of Squares	df	Mean Square	F	Significance
Model X					
Regression	6.043	9	0.671	22.624	0.000
Residual	2.582	87	0.02968		
Total	8.624	96			
Model Y					
Regression	5.634	5	1.127	34.289	0.000
Residual	2.990	91	0.03286		
Total	8.624	96			

Table XIV.III ANOVA for Models X and Y

Model	Minimum Score	Maximum Score	Average	Standard Deviation
Normalisation per questionnaire	-0.745	0.586	-0.000	0.283
Model X	-0.563	0.449	-0.001	0.230
Model Y	-0.556	0.470	0.002	0.232

Table XIV.IV Further Details of Models X and Y (compared to Main Survey data)

Residual and Scatter Plots

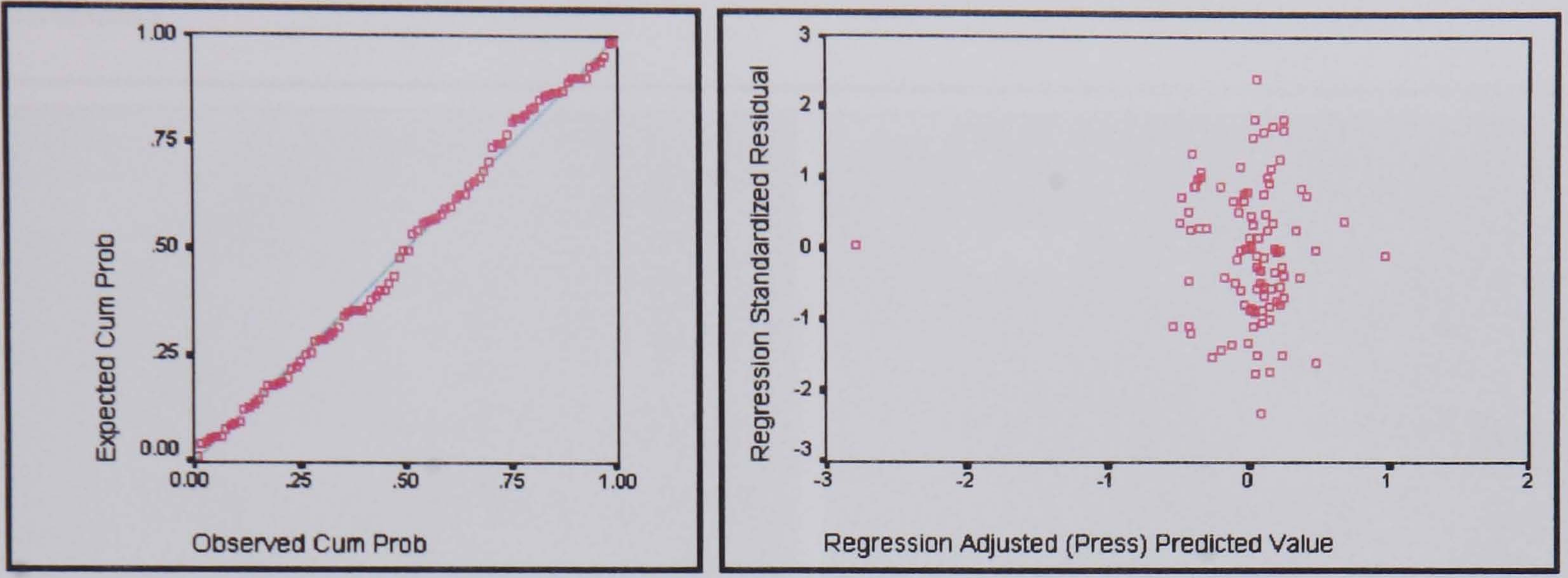


Figure XIV.II Normal plot of resgression standardised residual and Scatterplot: Model X

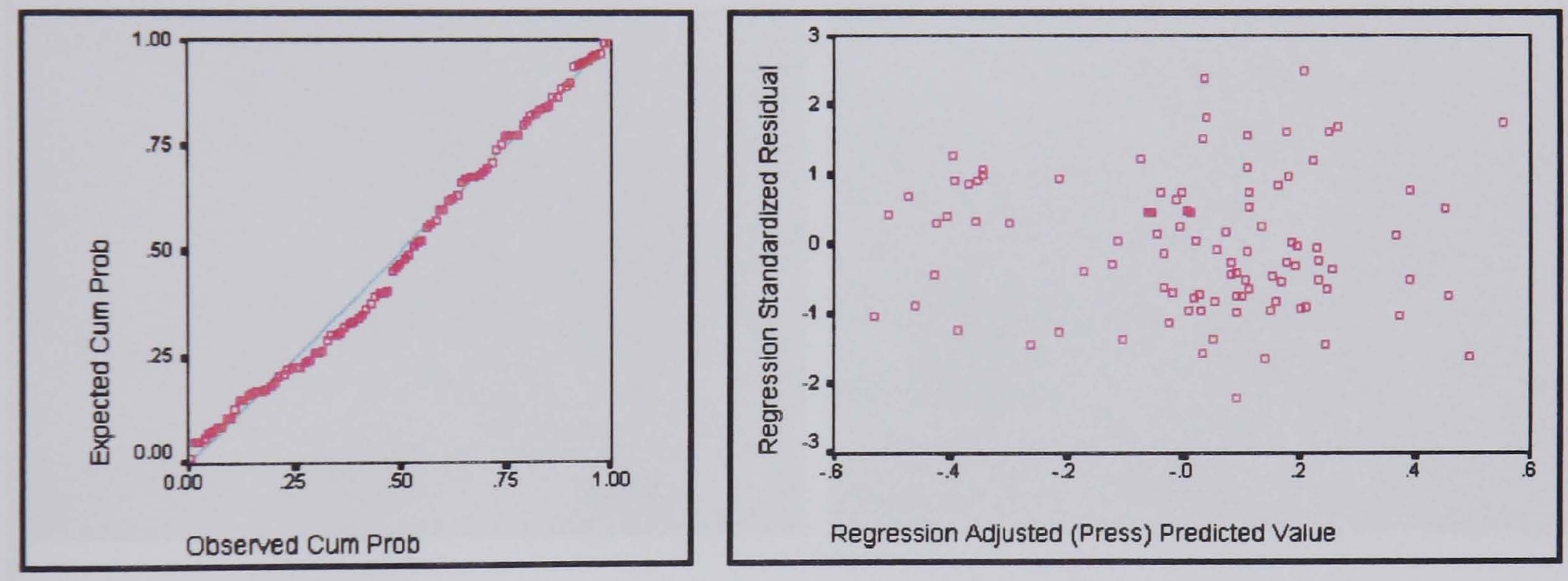
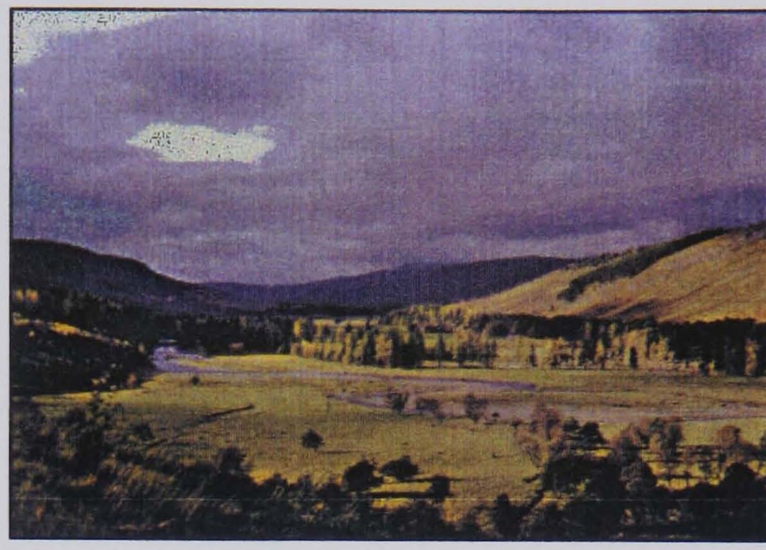


Figure XIV.III Normal plot of resgression standardised residual and Scatterplot: Model Y

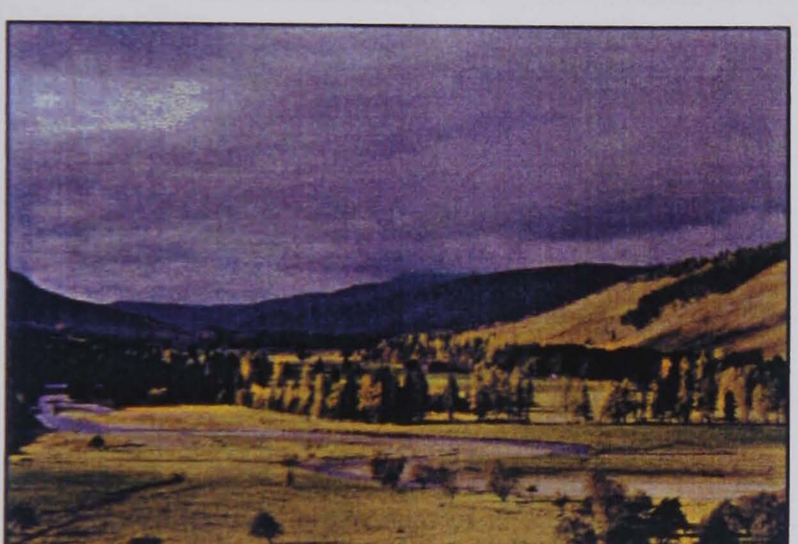
XV Focal Length Survey

The following images are examples of one site at four different focal lengths (Mar Lodge Estate, Braemar).

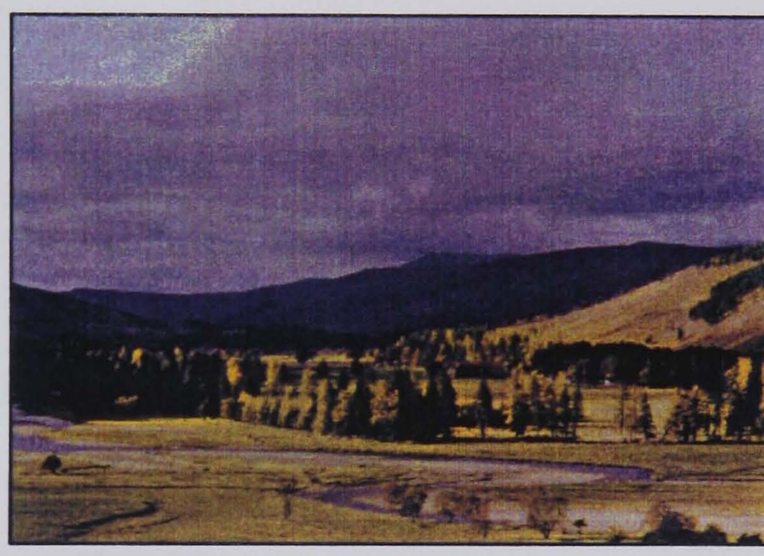
38mm focal length



60mm focal length



80mm focal length



105mm focal length

Figure XV.I Example images: Focal Length Survey.

XVI Socio-demographic Breakdown of Respondents: Digital Camera Survey

Gender	Number	Percentage
Female	7	15.56%
Male	37	82.22%
Non-gender specific	1	2.22%

Table XVI.I **Comparison of genders: Digital Camera Survey**

Age Group	Number	Percentage
16 and under	0	0.00%
17 to 24	2	4.44%
25 to 34	15	33.33%
35 to 44	19	42.22%
45 to 54	8	17.78%
55 to 64	1	2.22%

Table XVI.II Comparison of age groups: Digital Camera Survey

Nationality	Number	Percentage
African	0	0.00%
Asian	2	4.44%
Australasian	3	6.67%
British	10	22.22%
English	5	11.11%
European	13	28.89%
Irish	1	2.22%
North American	7	15.56%
Other	1	2.22%
Scottish	3	6.67%
Welsh	0	0.00%

Table XVI.III Nationalities of respondents: Digital Camera Survey

Screen Resolution	Number	Percentage
640 x 480	11	24.44%
800 x 600	11	24.44%
1024 x 768 and above	23	51.11%

Table XVI.IV Screen resolutions: Digital Camera Survey

XVII Socio-demographic Breakdown of Respondents: Simulated Images Survey

Gender	Number	Percentage
Female	24	26.97%
Male	62	69.66%
Non-gender specific	3	3.37%

Table XVII.I Comparison of genders: Simulation Survey

Age Group	Number	Percentage
16 and under	0	0.00%
17 to 24	6	6.74%
25 to 34	34	38.20%
35 to 44	28	31.46%
45 to 54	14	15.73%
55 to 64	5	5.62%
over 65	2	2.25%

Table XVII.II Comparison of age groups: Simulation Survey

Nationality	Number	Percentage
African	0	0.00%
Asian	2	2.25%
Australasian	12	13.48%
British	12	13.48%
English	6	6.74%
European	18	20.22%
Irish	1	1.12%
North American	27	30.34%
Other	7	7.87%
Scottish	3	3.37%
Welsh	1	1.12%

Table XVII.III Nationalities of respondents: Simulation Survey

Screen Resolution	Number	Percentage
640 x 480	24	26.97%
800 x 600	32	35.96%
1024 x 768 and above	33	37.08%

Table XVII.IV Screen resolutions: Simulation Survey

XVIII Questionnaire Log-ins: All Surveys

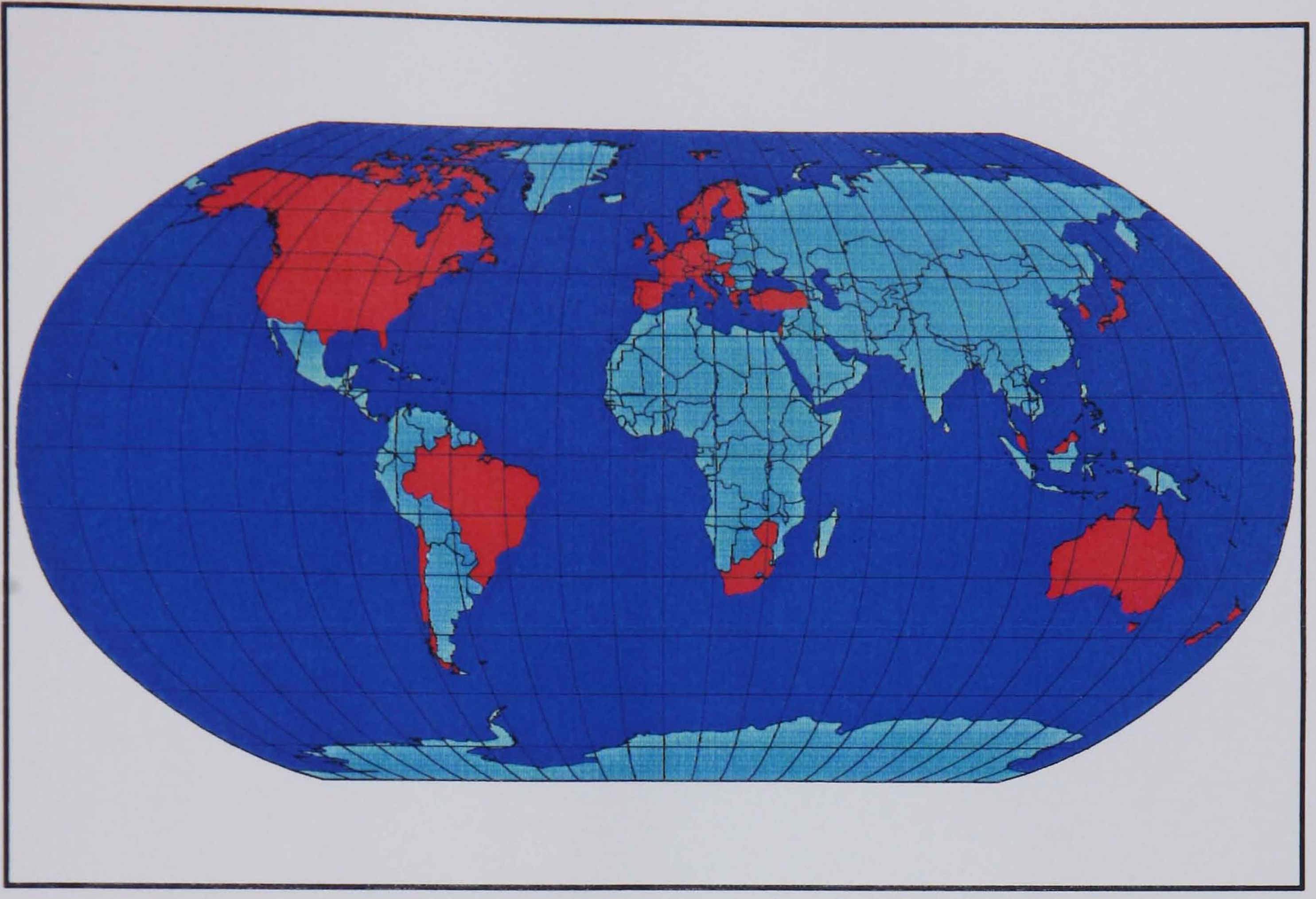


Figure XVIII.I Geographical location of questionnaire log-ins

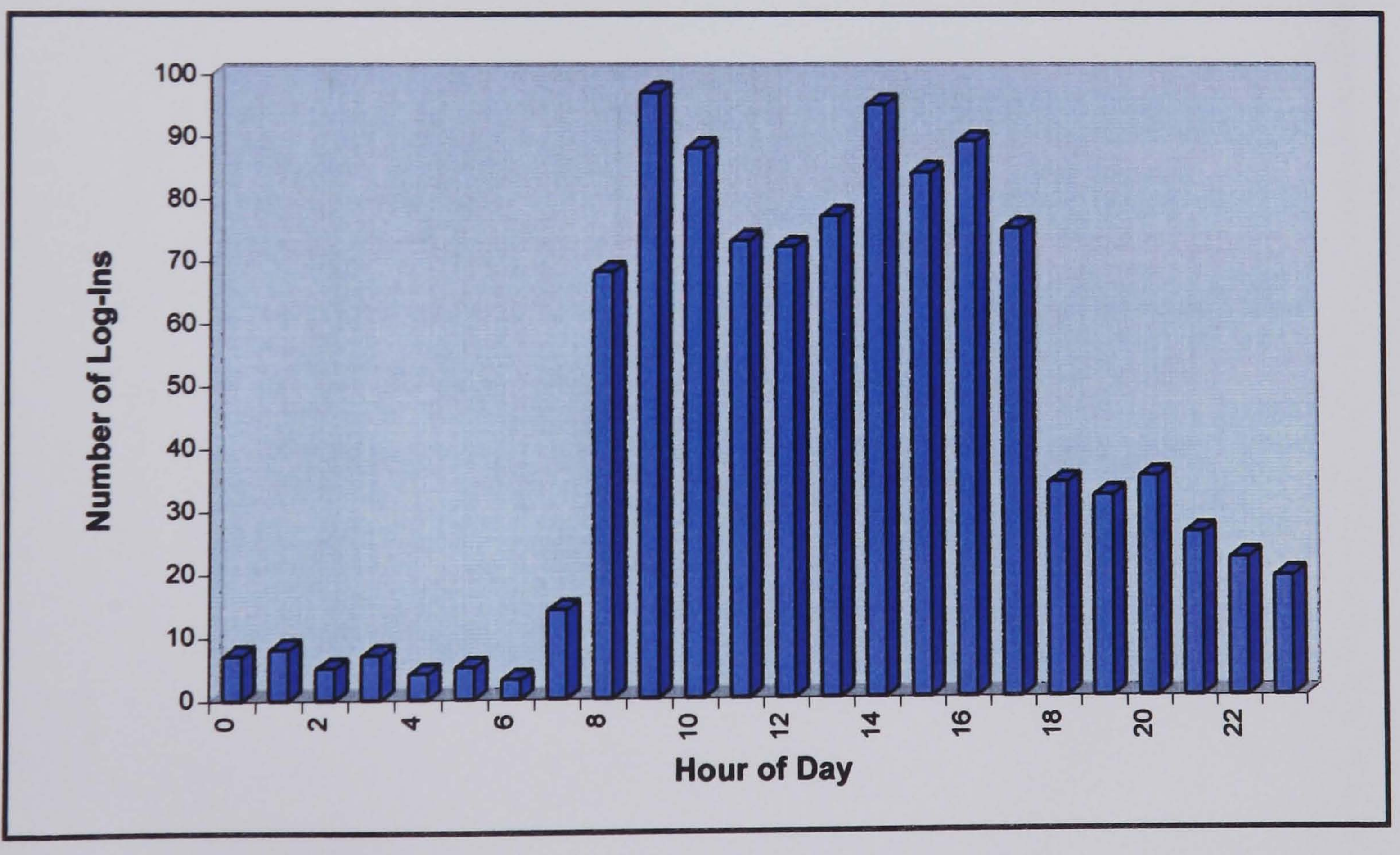


Figure XVIII.II Temporal distribution of questionnaire log-ins