COMPUTER AIDED VISUAL IMPACT ANALYSIS

Cameron L. Purdie BSc(Hons) BArch

A thesis submitted for the
degree of Doctor of Philosophy.

Volume 1.

Department of Architecture and Building Science
University of Strathclyde, Glasgow.

September, 1983

BRITISH LIBRARY

ETHOS

Boston Spa, Wetherby
West Yorkshire, LS23 7BQ
www.bl.uk

We are unable to copy the 2 video tape volumes belonging to this thesis.

The OS maps on pages 419 & 505 of volume 2 have not been digitised at the request of the university.

Please contact the university for further information.

SYNOPSIS

Over the past twenty years or so the growing presence of industrial development in the countryside has often severely disrupted the visual harmony of the landscape. Measures for development control and public inquiry procedures may be initiated to debate visual and other key issues regarding a proposed development. However, in the case of visual assessment, such procedures often suffer from a lack of explicit visual appraisal tools to determine the full extent of a development impact. Typically, this aspect of design is addressed by means of three dimensional models or artists' impressions. Unfortunately, these methods are viewed with a great deal of scepticism by public and planning juries alike; they claim that these manual processes are highly prone to error and often incomplete in assessment.

This thesis presents a review of the visual intrusion problem, and conducts a comparative evaluation of the manual and computer-based techniques used in the solution of the problem. Computer-assisted procedures for visual assessment are gaining increasing acceptance in architectural and planning practice, and this thesis describes a number of such computer models currently in use. Subsequently, the thesis lays out the background theory and specification for a computer program to quantify some of the visual characteristics of buildings for use in visual impact studies. Finally a tentative framework for a computer-aided approach to visual assessment is described with the objective of providing a total capability in visual impact assessment.

In the main, the thesis is seen as playing a significant role in bridging the gap between architectural practice and the expanding repertoire of computer-based models for visual impact assessment.

ACKNOWLEDGEMENTS

I am indebted to a great many people who have contributed in the guidance and production of this thesis.

In the first place, my supervisors. The untimely death of the late Prof. Graeme Aylward was a loss felt deepest by his family and friends. In addition, though, Graeme's death was a considerable loss to practice, education and research in architecture and planning. I was introduced to the subject of visual impact analysis by Graeme, and as such owe him a special debt of gratitude; his enthusiasm and guidance, freely given to me, was a constant support in the early formative stages of the research.

To Prof. Tom Maver, I express my deepest thanks for his boundless encouragement and perceptive guidance throughout the research, particularly at the crisis stages.

To Mark Turnbull, I owe a debt of thanks for his time and guidance throughout the research, and especially his willingness to act as an informal supervisor after Graeme's death.

To Prof. Gordon Petrie at Glasgow University I express my thanks for his help and guidance in matters relating to Photogrammetry and terrain modelling.

To all members of ABACUS, both staff and postgrad students, my thanks for the pleasant, entertaining and healthy research environment provided for this work.

Finally, I wish to express my thanks to Grace Hunter who diligently typed the bulk of the thesis; to my mother and Margaret Clelland who respectively typed and checked various parts of the thesis.

The thesis is dedicated to my late father, whose love and practical support was a mainstay for a large part of its production.

CONTENTS

		Page
Introduction		
Land - a late 20th century resource		1
	The pressure for land	2
	The forces on land	3
Research motivation		5
	The energy crisis	5
	The environmentalist movement	6
Research objectives		7
Chapter 1 : The problem of visual intrusion		
Introduction		9
1.1	Urbanisation: the physical problem	9
	1.1.1 Energy developments	11
	1.1.2 Transportation systems	19
	1.1.3 Leisure facilities	20
	1.1.4 Summary	21
1.2	Planning and the environment	22
	1.2.1 1947-1968	23
	1.2.2 1968-to date	25
1.3	EIA legislation and the environment	35
	1.3.1 EIA in America	35
	1.3.2 EIA in Europe	37
	1.3.3 EIA in Britain	37
	1.3.4 EIA and the European Commission	40
	1.3.5 Objections to EIA	41
	1.3.6 Summary	42
1.4	Conclusions	46

Page

Chapter 2 : Methodology and modelling in architectural design

2.1	Introduction	48
2.2	Design processes	48
	2.2.1 Cyclical and two-dimensional	48
	2.2.2 Visual assessment in the design process	54
	2.2.3 Visual assessment in the design activity	56
2.3	Design methods	59
	2.3.1 Visual assessment and design methods	59
	2.3.2 Computer based methods in visual assessment	62
2.4	Design models	64
	2.4.1 Modelling in design	64
	2.4.2 Modelling at the natural/built environment interface	65
	2.4.3 Geometry - a key issue in modelling	67
	2.4.4 Visual modelling	68
	2.4.5 Visual assessment	70
	2.4.6 Computer based models	71
2.5	Summary	73

Chapter 3 : Evaluation of current techniques in visual impact analysis

3.1	Introduction	74
	3.1.1 Chapter objectives	74
	3.1.2 A case study approach	74
	3.1.3 Generalising from the particular	75
3.2	Techniques for evaluation	75
	3.2.1 BIBLE	76
	3.2.2 VIEW	79
3.3	Evaluation criteria	84
	3.3.1 Flexibility	85
	3.3.2 Design value	88
	3.3.3 Data acquisition	88
	3.3.4 Accuracy	89
	3.3.5 Time	91
	3.3.6 Cost	91

		Page
	3.3.7 Communicability	91
	3.3.8 Accessibility	92
3.4	Hypotheses	92
	3.4.1 General hypothesis	92
	3.4.2 Performance hypotheses	93
3.5	Sketch perspectives	93
	3.5.1 Flexibility	93
	3.5.2 Design value	95
	3.5.3 Data acquisition	95
	3.5.4 Accuracy	96
	3.5.5 Time	97
	3.5.6 Cost	98
	3.5.7 Communicability	98
	3.5.8 Accessibility	98
3.6	Artists' Impressions	98
	3.6.1 Flexibility	99
	3.6.2 Design value	100
	3.6.3 Data acquisition	101
	3.6.4 Accuracy	101
	3.6.5 Time	102
	3.6.6 Cost	103
	3.6.7 Communicability	104
	3.6.8 Accessibility	104
3.7	Physical Scale Models	105
	3.7.1 Flexibility	105
	3.7.2 Design value	106
	3.7.3 Data acquisition	107
	3.7.4 Accuracy	107
	3.7.5 Time	108
	3.7.6 Cost	108
	3.7.7 Comminicability	108
	3.7.8 Accessibility	109
3.8	BIBLE perspectives	110
	3.8.1 Flexibility	110
	3.8.2 Design value	112
	3.8.3 Data acquisition	112

			Page
	3.8.4	Accuracy	112
	3.8.5	Time	113
	3.8.6	Cost	113
	3.8.7	Communicability	114
	3.8.8	Accessibility	114
3.9	VIEW visibility studies		115
	3.9.1	Flexibility	115
	3.9.2	Design value	117
	3.9.3	Data acquisition	118
	3.9.4	Accuracy	120
	3.9.5	Time	128
	3.9.6	Cost	130
	3.9.7	Communicability	130
	3.9.8	Accessibility	131
3.10	Conclusions		132

Chapter 4 : Case studies in visual impact analysis

Introduction - case study projects			134
4.1	Wire line perspective drawings		134
	4.1.1	Proposed public housing, London Rd., Calton, Glasgow, 1983.	134
	4.1.2	Proposed hospital for the Dutch Government, 1982.	135
	4.1.3	Shipbuilding factory, Glasgow, 1976.	135
	4.1.1	International Conference Centre, Berlin, 1979.	135
	4.1.5	Hilton Hotel, Edinburgh, 1980.	135
4.2	Photomontaging		136
	4.2.1	Scottish Exhibition Centre, Queen's Dock, Glasgow, 1980	136
	4.2.2	Waverley Market, Edinburgh, 1981	136
	4.2.3	Strathclyde University Campus, 1981	136
	4.2.4	Castle Peak Power Station, Hong Kong, 1982	137
	4.2.5	Midmar housing development, Edinburgh, 1983	137
	4.2.6	Norit Clydesdale Factory, Glasgow, 1980.	138

Page

4.2.7 Architecture Building, Strathclyde University, 1982 139

4.2.8 Hitchin Priory Development, Hertfordshire, England, 1983. 141

4.3 Composite Visual Analysis 143

4.3.1 Transmission Line Routing, Torness, East Lothian, 1979-1982. 143

4.4 VIEW and BIBLE : a verification case study for the South of Scotland Electricity Board. 146

4.4.1 Introduction 146

4.4.2 VIEW 150

4.4.3 BIBLE 156

4.4.4 Site photography 171

4.4.5 Comparison of CAD perspectives and site photographs. 177

4.4.6 Conclusions and recommendations 180

Chapter 5 : Advances in computer aided visual impact analysis

5.1 Introduction 183

5.2 Visual impact analysis - a state of the art review 184

5.2.1 A central issue in design 184

5.2.2 Significant research and literature in recent years. 186

5.2.3 Pointers to future development 189

5.3 The sources of future development in visual impact analysis. 189

5.3.1 Visual perception theories 189

5.3.2 Definitions 196

5.3.3 Needs in architectural practice 205

5.4 Foundations for the assessment of builtform in visual impact studies. 208

5.4.1 Introduction 208

5.4.2 Visual descriptors 209

5.5 Criticisms of an objective approach to visual assessment 211

		Page
	5.5.1 Introduction	211
	5.5.2 Personality in perception	213
	5.5.3 Meaning in the built environment	214
	5.5.4 The objective/subjective debate	216
	5.5.5 Summary	218
5.6	The program suite VIDERE	218
	5.6.1 Introduction	218
	5.6.2 VIDERE model structure and elements	224
5.7	Summary	278

Chapter 6 : Integrated system for computer aided visual impact analysis

6.1	Introduction	279
6.2	Research System Specification	281
	6.2.1 Introduction	281
	6.2.2 Pre processing	283
	6.2.3 Processing	291
	6.2.4 Post processing	294
	6.2.5 System costing	301
6.3	Practice System Specification	302
	6.3.1 Introduction	302
	6.3.2 System hardware and software	303
	6.3.3 Summary	305

Chapter 7 : Conclusions and recommendations

7.1	Thesis conclusions	306
7.2	Main recommendations	307
7.3	Analogies	310
7.4	Personal criticism	313

					Page
Appendix 1 : Hunterston - some descriptive notes					315
Appendix 2 : Hunterston - some notes on climate					325
Appendix 3 : Program SURFAC					332
Appendix 4 : Report to the South of Scotland Electricity Board on the Visualisation of Alternative Pylon Lines at Torness, East Lothian.					339
Appendix 5 : Video tape on Computer Aided Visual Impact Analysis. (submitted with thesis)					350
Appendix 6 : Notes on Shadow and Colour					351
Bibliography					355
Graphics for Chapter 1	(G1)	to	(G11)		377 - 387
Graphics for Chapter 2	(G12)	to	(G36)		388 - 412
Graphics for Chapter 3	(G37)	to	(G101)		413 - 477
Graphics for Chapter 4	(G102)	to	(G196)		478 - 572
Graphics for Chapter 5	(G197)	to	(G251)		573 - 627
Graphics for Chapter 6	(G252)	to	(G253)		628 - 629
Graphics for Chapter 7	(G254)				630
Graphics for Appendix 1	(G255)	to	(G265)		631 - 641
Graphics for Appendix 2	(G266)	to	(G273)		642 - 649
Graphics for Appendix 3	(G274)	to	(G278)		650 - 654
Graphics for Appendix 4	(G279)	to	(G299)		655 - 675
Graphics for Appendix 6	(G300)				676

INTRODUCTION

Land - a late 20th century resource

"To many of us in Britain our countryside is the most beautiful in the world..... But the modern world is now destroying this countryside inherited from the past: exploding the towns, swamping the villages, tearing up the farmland and spattering the old harmonious landscape with alien intrusions." (FAIR72) p.13

Both man and nature exert a strong influence on the physical shape of our environment. The form of townscapes and landscapes may, therefore, be read as a diagram of human and natural forces, e.g. social, aesthetic, economic, political, cultural, environmental, climatic and geological. These forces give rise to particular styles and forms in architectural design. Frequently, economic, political and social issues override other factors, and tend to shape our environment for better or for worse; typical examples may include the postwar New Towns programme, and the 1960's inner city housing developments in Britain. All too often this results in seemingly less important issues, such as visual aesthetics, playing a secondary role. Only within the last fifteen years has genuine concern been expressed for the harmful effects of man's continued intrusion on the environment, most notably in the disruption of the visual landscape of urban and rural areas.

This thesis is concerned with the methods used to describe and assessthe visual characteristics of large scale developments in urban and rural environments. The aim is to advance thinking and research in the preservation of high quality visual landscapes,despite the presence of man made intrusions. The ideas presented must be seen against the background of two dominant factors affecting the way in which our environment is managed in the latter half of the twentieth century.

i) the pressure for land.

ii) the forces on land.

It is fitting that this thesis should commence by focussing on the problem of land, since land is, of course, the central issue in all planning and environmental debate.

i) The pressure for land.

'Man and nature are two parts of a whole, not two opposing wholes' (ECKB69) p.31

In most developed countries since the Second World War the development activities of man have degraded the quality of our environment to such an alarming extent that much effort is now being devoted to redressing the balance of many ecological systems. In particular, this situation has arisen as a result of the industrial and urban expansion of the 1960 s and 1970 s (DAVI78) p.25. Nowadays, in Britain one of the most vexed questions in planning issues concerns the growing shortage of land, as a corollary of continuing pressure to allocate space for such land uses as:

:forestry
:agriculture
:large scale industrial complexes
eg. petrochemical plants.
:urban expansion
:transportation networks
:recreation and leisure developments
:mining extractive industries
:search for and exploitation of primary energy resources.

Underlying these activities are economic, social and political forces, whose expansionary aims are not under question. The problem has been exacerbated by the growth of the Environmentalist Movement over the last twenty years. In the U.K. this pressure group has, thankfully, some marginal success to report in the way in which our landscape is managed. Development projects are increasing in size, becoming costlier and often more environmentally damaging either through their construction or operation. Consequently, man is seen very much against nature, rather than with her. This is not a helpful starting point for amelioration; it is difficult to imagine an opencast quarry as man and nature in harmony. Therefore, a longterm view of the way in which our landscape is managed must prevail, recognising land as one of the most basic and valuable of all our resources. This would allow controlled or limited exploitation of the landscape resource and enforce restoration procedures to redress environmental balance and landscape harmony.

ii) The forces on land.

'Form is a diagram of forces.' (ALEX64) p.21.
The forces of man and nature may operate at different levels in influencing planning and design.
a) national and regional.
b) local or district.
c) site.

a) At a national or regional scale socio-economic and political factors will predominate; these may be exercised through national planning guidelines and development plans. Environmental issues are taking a stronger role in the decision making process at this level, though this is a recent phenomenon which many see as already too late to protect much of our landscape quality. Natural forces have created distinct regional landscape characteristics, and these may modify the scale or feasibility of development.

b) Locally, the range of forces influencing site selection and design are a little more evenly emphasised. The existing services infrastructure, land acquisition, conservation policies, land use planning strategies, employment prospects and the ecological balance of the wildlife and plant life in the area may well impose significant design restrictions: the water table and microclimate are equaly important as design constraints. The interaction of these issues is often debated and resolved through the channel of a local public inquiry.

c) On site, the detailed form of a building may be influenced by the microclimate and construction technology available while its location may be determined by access, soil characteristics, eg. drainage and depth to bed rock, and its relationship to existing site features eg. trees and water courses.

Some of the forces described above are extremely influential, others are impotent or insignificant. The degree of importance varies from context to context, however, those aspects which tend to dominate are often those which offer some tangible return of human interest or gain, eg. social or financial. Often environmental aspects act out a minor role, reflecting the intangible or qualitative gains such measures might create.

At the national or regional level the solution is very often political; on site, the ingenuity of the architect or engineer is called for. Clearly the local level is most problematic; many contentious issues are raised as politicians, public and designers enter the forum of debate. In recent years Impact Assessments have sought to bring some structure to the debate of local issues, eg. Environmental Impact Analysis (EIA). This thesis addresses itself to one aspect of EIA; the degree to which man made structures visually intrude in the landscape - visual impact analysis (VIA).

Although the thesis is argued at the project appraisal level, the author recognises that visual analysis methods exist at the more strategic or regional level of large scale planning. Successful visual analysis may only result from a recognition that there is a continuous impact analysis system, tiered from national policy making scale, to single site project appraisal. (LEE 78c) p.101-110, (CLAR 80b) p.29,30.

Research motivation

The motivation behind the research work stems from a personal concern as to whether the architectural profession can gear itself to meet the demands of two late 20th century leviathans; 'the energy crisis' and 'the environmentalist movement'.

i) 'The Energy Crisis'

The 'energy crisis' has resulted in a marked increase in the number, scale and size of energy related industries in the environment. This has been an obvious feature of such developments during the late 1970's and early 1980's, and is seen by some as a dangerous course of action in which short term expediency is taking precedence over long term resource planning (DAVI78) p.82. More often than not, rural, coastal and estuarine locations are acting as host environments to cope with this increased demand for, and exploitation of, energy resources. The associated artefacts of energy extraction, generation and distribution litter the countryside. Bearing in mind that changes in national or international energy policies will have a direct effect on the environment it is timely for the design professions to recognise two important aspects of the future energy impact on the environment.

a) That future development is likely to be concentrated on sensitive landscapes that have been previously avoided, e.g. Vale of Belvoir(ARCH80b) p.187; coastal and estuarine locations are also highly at risk.

b) The range of developments is broad: from power stations to large scale solar collectors and wind turbines. Thus, whichever way our energy resources are exploited, it will be impossible to avoid making some measure of impact on the environment. (DAVI78) p.72-82

While techniques have been developed for most environmental considerations, it has been noted in recent planning inquiries that methods for visual assessment are less than satisfactory. (GLAS82) (ARCH83a).
The challenge which faces the profession is to restore credibility in the field of visual analysis, by actively pursuing techniques for more rigorous and objective visual impact assessment.
Interestingly, this challenge has been highlighted recently in a series of letters and replies printed in the Architects' Journal following the opening of the Sizewell 'B' Nuclear Power Station inquiry.

ii) 'The Environmentalist Movement'

During 1960s the 'Environmentalist Movement' in America assumed a more vocal role in political decision making, scoring a notable victory at the beginning of 1970 with the passing of the National Environmental Policy Act (NEPA). Chapter one of the thesis will look in close detail at the effect of this Act in the field of visual assessment. Suffice it to say, for the moment, that inter alia, the Act required the preparation of Environmental Impact Statements (EISs) for certain classes and types of development. Many countries awaited with interest the effect of such legislation; the European Community commissioned a number of monitoring studies, before itself issuing directives to member states recommending some form of integration with existing planning procedures. Again, this will be developed further in Chapter 1. To date, the UK has baulked on full integration; however, a number of ad hoc EISs have been conducted, mostly in Scotland and concerned with North Sea oil and gas developments.

There is a considerable lobby in favour of environmental analysis and it must be considered reasonable to surmise the possibility of some future form of EIA in the UK planning system. It must also be considered timely for the architectural profession to review its position with regard to involvement in such studies.

The profession exists to promote architecture by solving technical functional and aesthetic problems in building design. Despite this the techniques which address the aesthetic problems are frequently criticised at planning inquiries on account of their ability to depict design intentions accurately (BELL74). The profession must recognise that conventional methods of visual analysis are fast becoming outdated, certainly out of keeping with current environmental thinking and desire for comprehensive, reliable and explicit impact procedures. New methods must be devised which will match the requirements of possible future legislation. This criticism reflects the changing mood at local planning inquiries which has resulted in an informed and motivated public demanding complete and accurate analyses of the visual and environmental effects of large scale developments in sensitive environments. The recent inquiry held by Strathclyde Regional Council over the siting of the Trident Missile System at Coulport in West Central Scotland is a case in point. From consultancy experience in recent years the author has witnessed a marked growth in the uptake of computer based methods for visual analysis studies. The implication, therefore, is that future visual analysis techniques must be

1. more flexible in application
2. more explicit in investigation
3. more accurate in presentation

Only then can designers hope to equip themselves properly to satisfy increasingly scrupulous and exacting public inquiries. The challenge is therefore to develop new methods for visual assessment which will instil a confidence in decision making processes and allow architects to articulate their visual design intentions a little more clearly at planning inquiries.

Research objectives

The objectives which lie at the heart of this thesis are a personal response to the concern for our landscape heritage and in particular for the survival of an acceptable visual environment.

The objectives may be summarised as :

a) To review the problem of visual intrusion (Chapers 1,2)

b) To evaluate the traditional and computer-based techniques for visual impact analysis (Chapter 3)

c) To establish, through the use of case studies, the needs in design practices for visual assessment (Chapter 4)

d) To develop the theoretical basis of a computer program for investigating the visual characteristics of man made structures in the natural environment. (Chapter 5,6)

Land Decade, 1980-1990, has prompted the possibility of formulating a national policy for the countryside. This thesis aims to make a partial contribution to the development of this "official ethic of responsibility towards land" (ARCH80a) p.12 by concentrating on the means by which human intervention on the countryside can be assessed visually.

CHAPTER 1

INTRODUCTION

This chapter aims to review the problem of visual intrusion under three broad headings:

1.1	Urbanisation:	the physical problem
1.2	Planning:	past and present planning procedures
1.3	EIA legislation:	future planning controls on development

A great deal of literature already exists on these three topics (COWA70) (LOVE79) (CATL76). The author, therefore, seeks only to identify the key issues in the range of literature and discuss their relationship to the problem of visual intrusion.

Our understanding and development of the visual assessment of man made structures appears to be less well advanced than many other environmental analysis techniques. Indeed, there still exists a heavy reliance on the subjective intuitive judgement of designers at planning inquiries and other such meetings; if a more objective approach to visual assessment is needed, then it seems reasonable to review the problem field with the intention of sifting common characteristics of visual intrusion. The chapter also serves as a timely summary for the architectural profession on the past, present and future problem areas for building design in the landscape.

1.1 Urbanisation: the physical problem

"Urbanisation has an increasingly adverse impact on the countryside, and has become the core of our social and environmental problems". (ARVI78) p.361.

In the past communities evolved in close harmony with topography and resources: the need for defence and water, and activities such as farming and fishing determined the location, growth and pattern of settlements. Development was on a scale and at a rate of change that had little longterm environmental damage.

The Industrial Revolution and the problem of housing an increased town based population invoked urbanisation on a much greater scale of impact. Initially, industrialisation caused problems of health and living standards as housing was densely concentrated close to or around factories in the towns and cities. Only since the beginning of the twentieth century, marked by Sir Ebenezer Howard and the 'suburban' planning ideal, has there been a major erosion of the rural countryside (ASHW54). Towns and cities in Britain are classic examples of this twentieth century suburban development, as many escaped the pressures of urban-based life to find sanctuary in the country.

Throughout the twentieth century, as urbanisation sprawled across more and more of the countryside, there arose concern for the injurious effect on the environment (G1). In recent years, however there is perhaps hope for a reduction in the development of green field sites around the cities. The national problem of inner city decay and recession are limiting the effects of urbanisation, and in many cities, e.g. Glasgow, private housing and light industrial developments are now appearing in inner city areas. A number of urban commentators are even advocating a ban of developments on green field sites, e.g. in Edinburgh. Despite these recent trends, however, several development types will almost inevitably require locations in rural environments.

a) Energy developments

Extraction

Generation

Distribution and Storage

In the future it is unlikely that many non-energy-related heavy industrial developments will be constructed in sensitive rural settings. The emphasis will be on light engineering and microelectronic factories in city and suburban gap sites.

b) Transportation Systems

Road and rail networks

c) Leisure facilities

Entertainment centres, such as Theme Parks.
Activity centres for ski-ing and other outdoor pursuits.

Undoubtedly these development pressures will require well tested and tried visual analysis procedures. In order to form an impression of the most suitable future techniques, it is necessary to review the nature of the visual difficulties the above developments might create.

1.1.1. Energy developments

In Britain, it is generally recognised that the energy shortfall caused by the reduction in output of oil and gas reserves from the North Sea may only be met by one or more of four energy options:

i) Greater exploitation of coal reserves. Coal is fast becoming more dificult and therefore more costly to mine; this is principally due to the fact that coal resources won in the past were the easiest to extract, i.e. limitations on technology or land ownership. Nowadays, coal reserves are to be found under some of the most valuable landscapes in the country. The problem of visual intrusion in such cases is clear, e.g. the Vale of Belvoir.

ii) Development of primary electrical supply; by coal, hydro-electric or nuclear power. Again the visual implications for the environment with this option are clear. The present Conservative Government's policy for a nuclear-based electrical supply industry has placed, through Sizewell, and will, if pursued, continue to place a serious visual threat on the countryside.

iii) Development of alternative energy sources: wind, wave, solar and tidal. The environmental implications of structures designed to trap these renewable energy sources are major; in particular wave and tidal energy collectors could have widespread visual implications.

iv) A programmed campaign for increased domestic and industrial building insulation and other conservation measures. This is the only one of the four options which will have a null effect on the visual quality of rural landscapes. However, this option, by itself, is not widely held to be a sufficiently adequate measure to meet the energy shortfall in oil and gas.

What is clear, therefore, is that whichever way Britain decides to develop its energy policy, the environment is likely to play host to some alien energy-related development intrusions. Five major implications for planners have been identified (PLAN79).

a) The large scale of the developments proposed.
b) Growing public concern for the natural environment and resistance to development.
c) The ability of existing planning procedures to cope with energy developments.
d) A growing competition for space, especially around coastlines and estuaries.
e) Acquisition of land identified as desirable.

What is the nature and scale of the visual impact such energy installations may have on the environment? Four aspects of energy may be reviewed:

i) extraction
ii) generation
iii) distribution and storage
iv) renewable energy resources

i) Extraction

a) Coal

Many future productive locations are in controversial areas, e.g. Vale of Belvoir. The visual problems include siting and design of:

i) pithead facilities

ii) winding headgear and machine house (60m high)

iii) spoil tipping areas

iv) transport connections: road and rail

v) open cast mining of coal (G2)

> "Major coalfields are geographically concentrated and future developments will be located within existing coalfields. Environmental impacts will be regional as well as local in character, in particular from open cast mining,spoil tipping, and shifts in mining community locations. The Yorkshire and Midland coalfield areas may be the regions most affected". (WATT79) p.4

b) Oil and Gas

At present, concentrated in North East Scotland, from Aberdeen to Shetland, where the environment acts as host to the landfall of gas and oil reserves. During the 1970s the west coast of Scotland was also a focus for oil development projects with the siting of many platform construction yards in the deep sea lochs. Other developments for oil and gas exploration around the UK coast are likely as the rising cost of energy makes previously uneconomic sites feasible for exploitation, encouraged by recent tax concessions from central government.

> "Continuing exploitation of British oil and gas resources may result in new petroleum-based facilities and extended pipeline distribution networks. There may be an extension of activity in the west of the country and further development of petro-chemical complexes in certain geographical areas". (WATT79) p.4

Visual intrusion may arise from:

i) landfall terminals on coastal sites with high landscape value (G3)
ii) pipeline distribution networks
iii) oil refineries
iv) petro-chemical developments

A number of the construction elements are low and horizontal, e.g. oil tanks; however, a major intrusive feature are the towers and stacks of the processing plants. Temporary visual impacts may be experienced from platform construction sites, and the construction phase of oil and gas installations.

c) Deep mining and quarrying for raw materials

The visual effect of open cast pits and spoil tips on the environment has been well documented and reviewed in (TAND75), (LOVE79) p.229 and the Stevens Committee Report, Department of the Environment 1976. The location of mining and quarrying operations is determined by resources; sandstone, limestone, metal ores, clays and fuels etc. While such operations may have ancillary buildings on site, the major visual intrusion is clearly the scar on the landscape. This presents another aspect of visual impact: as distinct from man-made built intrusions, there are man-impaired landscapes causing visual degradation. In recent years, many quarry and spoil sites have undergone landscape reinstatement. Disused quarries are often used as refuse landfill sites, while spoil tips are remoulded to create parklands. This has had a beneficial effect on landscape quality, together with influencing the phased strategy of future quarrying and mining works. (G4)

ii) Generation

a) Thermal and Nuclear Power Stations

Existing coal, oil and nuclear power stations are dominant features in their environments. The locational restriction of access to large quantities of cooling water has almost visually saturated the river, estuary and coastal environments with such structures. The visual problems centre on the form and siting of:

: the main generation plant building
: chimneys
: cooling towers (G5)

Very often the sheer size and scale of such buildings deceive the designer; there are notable exceptions where the skill of the architect has triumphed, e.g. Hunterston A Nuclear Power Station in Ayrshire, Scotland.

> "The demand for the requisite number of thermal and nuclear power stations will put greater pressure on the limited available site locations on main inland rivers and on estuaries or coasts. With nuclear power stations this poses particular problems, with the requirement that they be suitably removed from population and hazardous industry". (WATT79) p.4

iii) Distribution and Storage

a) Pipelines

Pipeline networks fromNorth Sea oil and gas landfall terminals will continue to impact a strong linear incision on the landscape. (G6)

b) Transmission lines

All electrical generation installations require transmission lines for energy distribution. Such structures will continue to have a conspicuous impact on the countryside (G7). The visual aspects are often highlighted in the planning of pylon routes, though health and safety standards and economics are frequently to the fore at inquiries. While underground cables may alleviate the visual intrusion;

: the cost is 12 to 14 times more expensive than conventional pylons (LOVE79) p.236

: there are greater technical difficulties (WATT79) p.29

: land loss is greater (WATT79) p.29

c) Pumped storage schemes

These energy storage schemes, using an upper and a lower water reservoir, perform a dual function:

i) enable peak electricity demands to be met with economy and flexibility

ii) provide the means to utilise fully the most efficient power stations at times of low load, to store their low cost electricity (WATT79) p.29.

This type of storage would be possible for many of the renewable energy resources, according to their own daily and seasonal variations in output. The visual intrusion would stem largely from the upper and lower reservoirs, the associated structures and the off-site electrical distribution.

iv) Renewable energy sources

a) Solar

> "Solar resource development is possible in the limited scale envisaged with minimal impact, with the exception of large-scale biomass conversion which could require substantial areas of land with agricultural or amenity value". (WATT79) p.5

Large scale solar collectors are not thought viable, due to Britain's cloudy skies; if such collectors were built then a serious visual problem would arise from the scale of the collector arrays and energy storage.(G8)

b) Tidal

> "Those areas suitable for tidal barrages, such as the Severn and the Solway Firth, could undergo environmental impact on a substantial scale". (WATT79)p.4

The impact from tidal energy schemes is again concentrated on coastline and estuary locations. The concern expressed by the Watt Committee above, reflects the large physical scale of tidal barrage schemes with an associated visual impact from nearby lock systems and power plant.

c) Wave

As with tidal, wave power is coast-and estuary-based and very large scale. The wave power collectors do not constitute a problem for visual analysis, unless close to the shoreline; though what will undoubtedly be a moot visual point is the intrusion of onshore storage, maintenance and energy distribution.

> "Major development of wind and wave resources will have implications for specific regions such as the north and west of Scotland. Links to the national grid will be required and major problems of visual impact and other environmental issues will arise". (WATT79) p.4

d) Wind

The size and location of wind turbines presents a visual challenge to designers (G9)

Size: 60m diameter blade span
: 45m high tower
: 75m overall height

Location: For maximum wind exposure, coastal ridge top sites are preferred. On such sites the visual impact is clear, with maximum visibility in the area.

Initially wind turbines might serve island communites, e.g. Orkney where there is one currently under construction at Burgar Hill. Energy storage presents a problem due to daily and seasonal fluctuations of wind speed. Pumped storage schemes are regarded as the most effective means of storage; the visual impact of these schemes was discussed earlier. Together with wave energy, wind power schemes are most effectively sited in north and west Scotland, where there is high landscape value: serious visual intrusion is inevitable.

Energy and the environment

While land availability and environmental factors are likely to have a limiting effect on development, the Watt Committee Report recognised the over-riding socio-economic and political issues in UK energy futures. The planning profession was identified in the Report as the key agency for co-ordinating the diverse interests in energy development. To facilitate this, however, three aspects of the planning process were suggested as in need of review or increased efficiency:

i) planning and development lead times
ii) existing regional and local planning procedures
iii) public inquiry system (WATT79) p.46

The existing planning process is geared to match local needs and proposals; the ability to balance national benefit with local impact is more demanding. It is clear that the energy/environment conflict will continue to bring into sharp focus the inherent weaknesses of the present planning system in forging satisfactory arrangements between national energy and local impact issues.

The increasing importance of the visual and landscape quality of the countryside, in relation to energy development was reflected in the conclusions of the Watt Committee Report: three points dealing with visual intrusion and landscape quality, demonstrate the strength of concern now felt to limit the visual impact of energy on the environment.

i) Protected land

> "There will be pressure on protected land but since this is increasingly valued, the feasibility of development will again be made progressively more difficult". (WATT79) p.5

ii) Alterations to landforms

> "Scenarios requiring high level development of certain resources will result in substantial physical alterations to land forms. This may be resisted by conservation and amenity interests." (WATT79) p.5

iii) Visual intrusion

> "Visual intrusion will inevitably occur, much of it quite acceptable. In certain areas however, this may be unwelcome and again may make the achievement of certain energy development difficult". (WATT79) p.5

1.1.2 Transportation systems

The infrastructure of transport systems, air, road and rail networks may significantly disrupt the harmony of the environment; (LOVE79) p.173 provides a good summary. The UK motorway network, built up during the 1970s, best portrays the visual consequences of increased transport communication around the country. (G10). With the exception of a third London airport and an English Channel tunnel, road networks are likely to provide the greatest transportation pressure for land in the countryside.

The problem of visual intrusion by roads was identified in a Department of Transport publication (TRAN76), known as The Jefferson Report: in section 5, the visual effects are discussed. The document aims to quantify environmental issues with regard to highway design. In reviewing visual aids to design, the report uncovered a singular lack of comprehensive and robust visual assessment procedures applied in road design. Therefore, if future motorway systems are to be ameliorated with the landscape, more sophisticated techniques for visual assessment will be required; the application of the solid angle subtense method described in (TRAN76) may only address one aspect of visual issues in highway routing and design, that of the percentage impact on the visual field.

1.1.3 Leisure facilities

The impact of leisure on the environment is perhaps better understood as the impact of people, as ever increasing amounts of our time become available for leisure and recreational pursuits. There is a two-fold need to provide adequate outdoor facilities (FOST79) p.153.

i) <u>Access to land for the enjoyment of the countryside</u>

The designation of National Parks, Sites of Special Scientific Interest and Nature Reserves has had a beneficial impact in terms of large scale preservation. However, car and human access, to and in such areas is not without its visual consequences; soil erosion, road intrusion, accretion of litter, parking and building facilities (G11).

ii) <u>Exploitation of land for specific pleasure purposes</u>

The development of the ski industry in Scotland typifies this type of impact; ski lifts, runs and associated facilities. The debate on the impact of such structures is frequently a confrontation between the national need for environmental preservation and the local need for social and economic survival. The need for impact assessment techniques is obvious, if only to demonstrate the beneficial and adverse implications of tourism for a particular district or community affected.

1.1.4 Summary

a) Most of the energy-related forms are large scale, simple and bold elements in the landscape, e.g. chimneys, oil tanks etc. This should make the assessment of visual form easier.

b) Many of the developments require coastal or estuarine sites for a variety of reasons, not least access to water. Siting proposals in such areas will mean that the resulting visual impact could extend over a wide area; adjacent river banks and island communities could have a severe visual impact.

c) Prominent vertical features, e.g. power station chimney stacks, wind turbines and pylons are likely to prove an easier task in visibility determination, than, for example, oil tanks. In fact the criterion of visibility is a simple but major key to understanding the visual impact of buildings on the environment:

i) can an object be seen?
ii) if so, how much can be seen?
iii) and to what extent is the visible portion seen against background landform and/or the sky?

Such assessment is likely to yield an understanding of the visual absorptivity of the host landscape in which the development is to be placed.

d) The visual assessment of certain landscape developments, e.g. quarrying and forest planting, requires the ability to model the landform and the land use, in particular forest belts and plantations where tree heights can interfere significantly with the visual character of an area. This type of problem is distinct from that of siting a man-made artefact in the countryside.

e) The visual aspects of development will become an increasingly important issue in public feeling, since the future expansion of development is likely to intrude on sensitive areas. There is a clear need, therefore, for visual issues to be heard with more authority and demonstrated with more conviction at planning inquiries, if future proposals for energy, transport and leisure are to be properly integrated with the landscape.

f) The continued and increasing stream of energy-related planning applications has already effected and will hopefully reinforce the need to:

i) review existing planning procedures
ii) create a stronger lobby in favour of some form of environmental analysis procedures in the British planning process.

1.2 Planning and the Environment

In reviewing the problem of visual intrusion, it is pertinent to trace the emergence of environmental concern and action in Britain. This may only be worthwhilely traced from the Town and Country Planning Act of 1947, the first milestone in planning in post-war Britain. There are two distinct eras of planning since 1947.

a) 1947 -1968

b) 1968 - to date

1.2.1 1947 - 1968

The evolution of the statutory planning process in post-war Britain stems largely from the Town and Country Planning Act (1947). The Act was principally concerned with controlling industrial and urban expansion in the national recovery and redevelopment after World War II. Development Plans were required to be submitted by each local planning authority and reviewed quinquennially: a development plan was described in the Act as a plan 'indicating the manner in which the local planning authority propose that land in their area should be used'. Thus Green Belt policies around cities and land use allocation were considered major issues.

By the 1960s a growing concern for the appearance and quality of the physical environment being created under the 1947 Act led to criticism that the Act was insufficiently detailed in controlling local development. Since 1947 the scale and intensity of physical change had increased so rapidly that the Act was, without question, outworn and ineffective. (ROYA76). This was identified by the Planning Advisory Group (PAG) in their review of the Statutory Planning Process in 1965: "development plans make no contribution to the quality of urban design or the quality of the environment". (ROYA76). The PAG recommended, therefore, the introduction of local plans in addition to development plans. In addition a survey by the National Parks Commission found "sufficient evidence of widespread erosion of coastal and rural landscape quality to merit recommendations for further special measures of protection and management" (CHER76) p.184. The awareness of the inadequacy of strategic development plans to regulate detailed and sensitive issues at the local level of planning precipitated the passing of the Town and Country Planning Act of 1968 (Town and Country

Planning (Scotland) Act 1972). This Act remains the basis of current planning legislation in Scotland, as amended by the Town and Country Planning (Scotland) Act of 1977 and other minor amendments.

The criticisms of the 1947 Act were rectified in the 1968 Act, primarily through the introduction of a new type of development plan, consisting of two main levels of plan formulation:

a) structure plans
:regional scale policies in diagrammatic form showing broad pattern of development and transport.

b) local plans
:outlining proposals in local detail through district plans, action area plans or specific subject plans.

The Structure Plans, then, acted as a link between national and regional policies and local planning issues. The 1968 Act also recognised the growing problem of large scale development on the environment, and the need for landscape management. Local and regional authorities were to "have regard to the desirability of conserving the national beauty and amenity of the countryside". (ROYA76)

Provision was made for ad hoc inquiries by special commissions into major development projects e.g. power stations and natural gas installations. (ARVI78)p.241.

Increased public participation and accountability were also required of local planning authorities.

In support of the Town and Country Planning Act 1968 (Scotland 1972), the Countryside Act 1968 (Scotland 1967) established the Countryside Commissions, replacing the National Parks Commission created in 1949 to designate National Parks and Areas of Outstanding Natural Beauty (AONB).

Shortly after implementation, the 1968 Town and Country Planning Act was seen to be:

a) too slow in initiating Structure Plans.
b) weak in its application.
c) too broad in content and not sufficiently detailed to deal with specific problems.
d) imperfectly related to other systems of local government activity.
e) planning is more a political decision making activity than actual physical decisions. The Act needed revision in this area (ROYA76) p.15.

Consequently the Act was consolidated in 1971, amended in 1972 1974, 1977, 1980 and 1981 (HEAP82). Some of the criticisms above still feature in current planning debate.

Up until the late 1960 s, British planning had tended to concentrate on urban questions rather than rural problems. This was reflected in the inadequacy of statutory planning legislation to control large scale physical intrusions in the countryside. During the 1970 s the pressure of development was to change the whole means by which planning control was effected. It is interesting to note that around the same time, the late 1960's, the environmentalist lobby in America was bringing pressure to bear on the U.S. Government to instigate measures for greater environmental control over large scale rural and urban developments. This resulted in the passing of the National Environmental Policy Act (NEPA) at the outset of 1970.

1.2.2. 1968 - to date.

Between 1970 and 1980 there have been a number of Acts, and Planning Institute and Government sponsored investigations into the effectiveness of the planning system and the control of landscape development. The reports, Acts and investigations selected for discussions are intended to trace the emerging problem of visual intrusion during the 1970 s and early 1980 s.

A fair proportion of these reviews are centred on Scotland due mainly to the North Sea oil and gas industry. Since the author is also more familiar with planning law as it affects Scotland there is emphasis placed on a Scottish viewpoint in this section.

1. In 1971, the Government set up a National Park Policy Review Committee to review the role of National Parks. Reporting in 1973, the committee found that 'all too frequently, National Park landscape values had been adversely affected by major developments - reservoirs, large scale afforestation with conifers, electricity power stations and transmission lines, mining and quarrying, and major road improvements to accommodate long distance traffic.' (CHER80). There was also a recognition of increased pressure on the visual amenity of rural and coastal landscapes by the accessibility of the public to the countryside on account of increased car ownership.

2. In 1975, the Dobry report on Development Control was submitted. The report claimed that 'the planning system had achieved a great deal', but 'overall the planning machine was too cumbersome and complex'. (DOBR75). The report also encouraged planning authorities to demand the submission of an impact study on significant development proposals: these studies might appraise the comparative advantages of alternative sites. Delays in forming Structure Plans and Local Plans inevitably led to delays and errors in decision making concerning Development Control. By the mid seventies, therefore, it became clear that national economic measures from industry, energy, and communications networks were severely impinging on valuable landscape resources, even National Parks and Areas of Outstanding Natural Beauty.

3. In 1976, the Royal Town Planning Institute (RTPI) issued a document reviewing the state of planning legislation (ROYA76). The booklet identified many attractive features of the existing planning legislation and cited areas for improvement in

the light of past experience. This evolutionary approach to planning was critical in dealing with the environmental issues and arguments emerging as a signifcant factor in the planning debate towards the end of the 1970s. From a visual and environmental impact standpoint, several important recommendations were made:

a) reassessment of Public Inquiry procedures.
b) the Development Control System needed to alter from negative control to managing change
c) the quality of decision making was to be improved:

'by requiring full development briefs and impact studies: better information systems; and increasing the skills both of professionals and clients in relation to the visual quality and impact of developments' (ROYA76) p.49.

The RTPI, therefore, favoured restructuring the planning process and in particular the Development Control System, to accommodate Environmental Impact Studies.

4. Throughout the 1970 s the Project Appraisal for Development Control (PADC) Unit at the University of Aberdeen has addressed itself to the problem of appraising major development proposals as part of the UK planning process. Their work is influenced by American experience of Environmental Impact Analysis. Indeed EIA and its integration in UK planning legislation is a common thread throughout both their work and other planning reports in the 1970s. The work of the PADC unit and the British attitude to EIA is covered in greater detail in section 1.3. Amongst other documents and reports, three studies commissioned by the Department of the Environment will be considered: Research Reports 11,13 and 26.

5. In response to the Structure and Local plan requirements of the Town and Country Planning Act (1968) a great many county councils, notably all in England, developed landscape evaluation techniques eg. Hertfordshire, Hampshire and Bedfordshire. A good review of the methods devised may be found in (LOVE73) p.19. The techniques are essentially qualitative landscape assessments; they seek to describe or grade the physical or visual character of the landscape. Their ad hoc nature and regional/district level descriptions are not suited to single site or project appraisal for visual analysis.

6. In 1976 the Scottish Development Department published a document describing the Scottish experience in Environmental Impact Studies connected with the North Sea oil and gas industry (SCOT76). Ten major oil related proposals, each the subject of an impact study between 1973 and 1975, are described.

a) Oil platform construction at Loch Carron (Drumbuie).
b) Oil platform construction at Loch Broom.
c) Oil related activities at Arnish Point, Stornoway.
d) Oil refinery at Nigg, Easter Ross.
e) Oil handling terminal at Flotta, Orkney.
f) Oil related activities at Sullum Voe and Swarbacks Minn area, Shetland.
g) Comparative analysis of oil platform construction sites, Loch Carron area.
h) Sites for concrete platform construction in the Firth of Clyde.
i) Oil related activities; feasibility study at Loch Eriboll.
j) Oil related activities; Buchan impact study.

Piggot has reviewed this document in relation to the visual impact assessment procedures employed (PIGG79) p.7. Analysing Piggot's description of the various impact studies, the following aspects of visual assessment are clear.

i) The range of techniques and the degree of rigour applied to the visual assessment in each study varied enormously. The most comprehensive analysis having been undertaken by W.J. Cairns and Partners in their proposals for an oil handling terminal on Flotta, Orkney.

ii) The low priority placed on visual impact assessment is clear from the short and superficial analyses conducted -

:a qualitative verbal report by an acknowledged expert in a design profession.
:a site check on visibility from specific chosen locations, eg. roads and townships. Such a study is by no means comprehensive,and may be at best frequently misleading.
:with the exception of two studies, Flotta and the Firth of Clyde, there was a notable lack of drawing sketches indicating proposals.

iii) In general there seemed to be a lack of concern for accurate visual analysis procedures.

iv) Local visual impact was often discounted in favour of the national interest for oil development. Scant regard was given to the fact that many of the sites analysed were surrounded by land recognised by the Countryside Commission for Scotland, the National Trust for Scotland and the Scottish Development Department as having national scenic importance.

7. During the 1970 s three national guidelines for development were published in Scotland. Piggot has again reviewed these documents in relation to visual analysis (PIGG 79) p.24

a) North Sea Oil and Gas: Coastal Planning Guidelines. Scottish Development Department 1974. (SCOT 74) Preferred Conservation Zones are identified; however, these may be overridden at will by national issues and interest.

b) National Planning Guidelines for large Industrial Sites and Rural Conservation.
Scottish Development Department, 1977. (SCOT77)
a document outlining general principles for developments in sensitive rural environments.

"In general planning guidelines have had little to contribute to the discussion of the criteria to be applied, and less to consideration of methods, for assessing visual impact." (PIGG79) p.26.

c) Scotland's Scenic Heritage.
The Countryside Commission for Scotland. 1979 (COUN79)

"The Commission do not advocate any specific method of visual impact assessment, nor do they advocate any specific technique of landscape quality assessment." (PIGG 79) p.27.

In concluding his review of planning guidelines and impact studies Piggot states that:

"The low level of use of credible and demonstrable techniques for assessing visual impact is apparent even from a limited investigation of public inquiry and impact study evidence available. The reliance on expert opinions, supported by either no visual evidence or by evidence relying on the credibility of the 'expert' concerned, is the dominant feature of practice in this area of visual impact assessment... The planning guidelines and advice notes available on a range of issues are notably silent on visual impact assessment. The imbalance which clearly exists between the level of sophistication which has been achieved in practice for measuring other environmental impacts and that of visual impact assessment is a central feature of environmental impact assessment in recent times." (PIGG79)

8. Lurcher's Gully Public Inquiry 1981.

In 1980 the Cairngorm Chairlift Company submitted a proposal for outline planning permission for an extension of downhill ski-ing facilities at Coire na Ciste and Coire Cas into Coire an tSneachda, Coire an Lochain and Lurcher's Gully. Eighteen months later, an EIA was commissioned before the public inquiry took place in 1981: the EIA was prepared by the Anderson Semens Houston Partnership.

In recommending to the Secretary of State for Scotland that planning permission should be refused, the reporter argued that:

1. the site was of outstanding scientific, scenic and recreational importance.
2. the proposal would have a detrimental effect on the quality of the area.
3. the detrimental effect outweighed the advantages in consenting to the proposal (CAMP82) p.228.

As part of their evidence, the Cairngorm Chairlift Company produced findings from the EIA. An assessment of the visual impact was made through on-site intervisibility studies to determine those areas which would see the development. Several maps were prepared summarising the visibility from significant locations, eg. chairlift stations: a composite map showed the total visibility in the area. From close range, the visual quality of the landscape would be impacted, though largely contained in the shape of the gullies: from the middle distance, views are obscured due to afforestation and topography; from distant views across Loch Morlich, it was accepted that the structures would be largely indiscernible.

Considering the timescale, for the EIA, and the nature of the application - for outline planning permission, the level of visual assessment undertaken was adequate to offer a good impression of the visual intrusion such a development might have. In arguing for the proposal, the Cairngorm Chairlift Company suggested measures to be taken in the design of the structures to ensure minimum visual impact in both construction and operation. These suggestions were most praiseworthy; however, like so many other inquiries, the design aids necessary to achieve those aims, the author considers to be neither sufficiently comprehensive nor objective. "Ski developments in Scotland are notorious for not siting well in their environment." (CAMP82) p.112.

9. Torness Transmission Line Routes, East Lothian. Public Inquiry 1982.

The growing interest and concern for the visual amenity of landscapes was reflected in this inquiry. The pylon routes, as proposed by the South of Scotland Electricity Board, had a significant impact on a sensitive rural environment and drew a number of objections. The SSEB were seeking permission to route new, and realign and upgrade old transmission routes in East Lothian as a result of the Torness Nuclear Power Station, in the process of construction. Of the two routes suggested by the SSEB, the Torness/Eccles and the Torness/Dalkeith, there was little if any disagreement over the Torness/Eccles route. Objectors were principally concerned about the impact on the countryside of the proposal for the Torness/Dalkeith route, which was known as the Hillfoot route. The main objectors to the Hillfoot route, East Lothian District Council, put forward an alternative route for consideration at the inquiry; this was known as the Dipslope route. This route was favoured by a number of interested parties, notably the Countryside Commission for Scotland, despite the increased cost and length of the line, additional engineering problems and limited access for maintenance. From a landscape impact viewpoint the Dipslope line was seen as preferable since the visual amenity loss or impact on the higher moorland of the Lammermuir Hills was more expendable than that of the lower Hillfoot route.

Visual assessment formed a substantial part of both the SSEB and objectors' evidence (MAYC83) p.51-82. Included in the evidence submitted by Humbie East and West Saltoun and Bolton Community Council were a selection of computer based visibility maps and photomontages by the Bill Love Partnership.

These were used in evidence against the East Lothian District Council's Dipslope line. The accuracy of this evidence was not in question since it only sought to represent a fair impression of the Dipslope line which had not yet been planned in detail.

Taken together, the visual evidence presented was highly subjective, a comment directed particularly at the findings of the SSEB's landscape consultants, W. Gillespie and Partners (MAYC83) p.124.

The production of acceptable and objective visual evidence at inquiries still remains an unanswered problem. Numerous techniques exist and claim some degree of authority; the lack of a consensus of approach however appears to militate against acceptable standards in procedures for visual analysis and decision making. In conclusion, the Reporter appeared to be still uncertain as to the full extent of the visual impact from the pylons (MAYC83) p.371, and the lack of rigorous visual assessment caused disagreement on objective matters regarding pylon visibility (MAYC83) p.182.

10. Sizewell Nuclear Power Station. Public Inquiry 1983.
A public inquiry began earlier this year concerning the proposal by the Central Electricity Generating Board (CEGB) to build a second nuclear power station at Sizewell, Suffolk. Six coloured photomontages constituted the evidence presented by the CEGB concerning the visual aspects of the design. Although the power station is generally accepted as a highly intrusive element in the coastal scene, there is a distinct lack of evidence submitted to summarise the effect of various screening and landscaping proposals objectively from a number of road or settlement locations. Documents P30 on architecture and P31 on landscape are highly subjective, reflecting an opinion clearly influenced by the CEGB. (ARCH83a).

11. In recent years, a number of journals and papers have discussed the idea of introducing a Preliminary Inquiry as distinct from a local public inquiry. (SIEG80), (HICK80), (THOR83).

The intention of a preliminary inquiry would be to establish the main issues for discussion at the local public inquiry, and perhaps set the boundries or scope of an EIA.

> " A two stage process of investigation should be adopted for specific types of substantial development proposals, the first stage to be inquisitorial and to explore need, design, and environmental impact, with the second stage adversarial and exploring objections and views of relevant bodies and the public." (THOR83).

> " A major inquiry will work best if precognitions of evidence are circulated beforehand, and these can note points of disagreement with the impact analysis statement. The impact statement would aid identification of the key issues requiring examination at the inquiry and would help witnesses to structure their evidence on the basis of these issues". (HICK80) p.76

Preliminary investigation would hopefully speed up and improve the public inquiry procedure since,

1. the main facts would be agreed
2. the main issues would be identified

The Vale of Belvoir is a typical example. The Secretary of State for the Environment appointed an Inspector (or Reporter) and initiated a local public inquiry to assess the need for development, alternative locations and to balance the national economic issues with local environmental implications (JOUR79). Before this was held, however, a preliminary meeting identified the main issues relevant to the inquiry and indicated where further investigation was required before the inquiry began. The implications for visual analysis are that more explicit and objective techniques need to be developed and implemented in Environmental Assessments to provide quantitative information for debate at public inquiries.

1.3 EIA Legislation and the Environment

Since 1970 and the passing of the National Environmental Policy Act (NEPA) in America, there has been growing worldwide interest in Environmental Impact Analysis (EIA). Britain is no exception, and a number of publications have appeared during the 1970s and 1980s assessing the role which EIA might play in the planning process: in this respect (CATL76) is recommended as a good text. The problem of environmental impact is well documented; methods and procedures (BISS80), ecology and pollutions (CHER77) (FOIN76). The author recognises the substantial volume of EIA research and application undertaken during the past ten years; notably at the Project Appraisal for Development Control (PADC) Unit at Aberdeen University, (CLAR76) (CLAR78) (BUIL78) (BARR80), and at the University of Manchester by Norman Lee and Christopher Wood (LEE 78a) (LEE 78b) (LEE 78c). With this in mind, this section of the thesis may only seek to draw from these and other reports those aspects which bear a direct and important relationship to visual impact analysis.

1.3.1 EIA in America

The National Environmental Policy Act (NEPA) which became effective in America at the beginning of 1970, directed federal agencies to submit an impact study for certain major development proposals, as defined in the Act, which would have a significant effect on the quality of the human environment, Clark et al (CLAR78) pp1-18 provides a good summary of NEPA. The four objectives of NEPA are statements of positive action, indicative of the need to allay the environmental fears and concerns at the time:

a) Declare a national policy to encourage harmony between man and his environment
b) Promote efforts to prevent or eliminate damage to the environment.
c) Enrich the understanding of major ecological systems and natural resources.
d) Establish a Council on Environmental Quality (NATI69)

The over-riding impression of the Act is that federal agencies were required to prove or demonstrate the effects of development proposals and take a more positive role in land use and landscape planning. In order to achieve this, administrative procedures for implementing NEPA were laid down in Subchapter 1, section 2 of the Act. The procedures were to involve the preparation of an Environmental Impact Statement (EIS) considering five main aspects of developments:

a) outline the environmental impact of a projected action
b) indicate any adverse environmental impacts which cannot be avoided
c) consider alternatives to a proposed action
d) discuss the relationship between local short term use of man's environment and the maintenance and enhancement of long term productivity.
e) describe any irreversible and irretrievable commitment of resources. (NATI69)

(These points were revised and extended in guidelines of the Council on Environmental Quality in 1973 (CEQ 1973))

The words underlined are those of the author, intended to emphasise the positive nature of an EIS. In considering these requirements under visual impact, a number of factors are clear:

i) qualitative descriptions and subjective opinions cannot meet the rigorous demands within an impact statement.
ii) quantitative and objective techniques require to be developed, especially in relation to points a), b) and c) above.
iii) An EIS is both descriptive of existing conditions, and predictive of the likely future impact of proposals on those conditions. Thus there is a need for accurate and comprehensive visual techniques or methods to model future reality and evaluate the effect of certain actions to promote confident and well grounded project decision making.

1.3.2 EIA in Europe

Other countries throughout the world observed American progress under NEPA. European interest resulted in two countries introducing EIA legislation for certain types of development e.g.

France: Nature Protection Act 1976
EIA mandatory for both public and private projects.

Eire : Local Government (Planning and Development) Act, 1976, EIA mandatory for private developments only.

A comprehensive review of the European uptake of EIA may be found in (CLAR80a) p.445. At the European level, an important first stage review of EIA was initiated by the European Commission in 1976. Norman Lee and Christopher Wood, Department of Town and Country Planning, Manchester University, were asked to prepare a report for the European Commission on EIA procedures, examining how such procedures might be implemented in the decision making and planning processes of member states (LEE 78c). Although the topic of visual analysis is not referred to specifically in Lee and Wood's paper, the availability of robust methods and procedures for analysis is identified as critical to the formulation of an effective EIA system, either separate from or integrated with the existing planning process.

1.3.3 EIA in Britain

In Britain two events during the 1970s brought the problem of environmental impact sharply into focus (CLAR80a) p.393.

i) A recognition that traditional assessment techniques were fast becoming outdated and unable to cope with the varied and rigorous appraisal required by large scale developments.

ii) The development of the North Sea Oil and Gas Industry. The requirement for platform construction sites and onshore facilities placed a heavy demand on the environment in Northern Scotland, and many impact statements were initiated under the Town and Country Planning (Scotland) Act 1972.

These two factors were instrumental in the setting up and sponsoring by Government of two key research projects.

a) Project Appraisal for Development Control, University of Aberdeen. Under the directorship of Brian Clark, the PADC unit has been involved in a number of EIA related research projects since 1973, including EIA methods and EIA in Forward Planning. The unit has produced two main publications.

i) <u>The Assessment of Major Developments - A Manual (CLAR76)</u>

An updated version of this manual was published by the Department of the Environment in 1981. The study began in 1973 with the objective of compiling a guide for the identification and description of major development impacts for use by planners in assessing major industrial applications. While the manual is extensive and detailed in describing technical advice e.g. for water and noise pollution, the section devoted to visual impact assessment as distinct from landscape evaluation, is relatively short. The method described in the manual is that developed by Hebblethwaite (HEBB75) at the Central Electricity Generating Board. Since publication, this technique has been improved to allow automatic visibility determination, based on a computer model of the terrain and sight line searching procedures from an observer location in the terrain model. The lack of objective visual assessment procedures to report was evident.

ii) Environmental Impact Assessment in the U.S.A: A Critical Review (CLAR78)

The remit of this study did not involve any direct appraisal of visual assessment techniques. Its importance lies in the fact that it addresses itself to the structure and content of American EIAs, affording a "state of the art" critique.

b) In 1974, J. Catlow and C. Thirwall were appointed by the Secretaries of State for the Environment, Scotland and Wales to prepare a report on Environmental Impact Analysis. First published in 1977 the report reviewed the need for and suitability of EIA in Britain, with regard to its integration in the statutory planning process. One of the more specific objectives was

> "to survey techniques now being used or developed to measure the environmental impact of large scale projects "(BUIL78) p.87

In consideration of visual analysis in chapter 3, the report rightly distinguishes between methods of objective visual assessment and subjective measures of landscape or visual quality: further objective measurements of landscape value were correctly regarded as unattainable. After only passing mention of the traditional techniques, three methods of visual assessment are discussed:

i) Solid angle method by the Urban Motorways Committee. The method calculates the solid angle subtended by developments in the field of view.

ii) Zone of Visual Intrusion (as described in (CLAR76) p.91)

iii) Environmental Decision Making using Quantified Social and Aesthetic Values. This procedure is principally used for comparative studies, Two photographs, before and after views of the site are used to assess a score for visual degradation when the development is added.

Methods i) and ii) have been used widely in the UK for highway design and single site projects respectively. The review of visual assessment techniques in the Catlow Thirlwall Report serves to emphasise the poor state of the art in competent visual assessment.

1.3.4 EIA and the European Commission

The Action Programmes of the European Communities on the Environment dated, 1973, 1977 and 1981 have maintained a commitment to environmental protection; they state that "effects on the environment should be taken into account at the earliest possible stage in all the technical planning and decision-making processes". The main method in achieving this aim within member states is seen as Environmental Impact Analysis (EIA). A draft directive on EIA prepared by the European Commission and issued to member states, after twenty revisions, would require an EIA to be prepared for certain types of development proposals (PLAN81a). The draft has still to receive final approval by the Council of Ministers of the European Parliament, however it seems likely that EIA will,in some form, be integrated into the UK planning system (BUIL80).

Reaction in the UK has been mixed. The House of Lords Select Committee of the European Communities welcome the idea of a mandatory EIA for certain types of development proposal (HOUS81), while the Government has for some time maintained opposition to the E.E.C. directive, claiming that the present system is adequate: they remain "to be convinced that it is necessary or desirable to replace that eminently practical system (current planning control) with a rigidly mandatory one" (ARCH81).

Both the Town and Country Planning Association and the Royal Town Planning Institute favour the directive, claiming amongst various advantages, that EIA will be "a useful tool for enabling a full examination of the impacts of a project on the environment and identifying principal areas of compatibility or concern"(PLAN81b).

Nevertheless, there is a strong lobby in favour of EIA and the recent Government tax concessions to the North Sea Oil and Gas Industry may well precipitate some form of EIA in Britain. The effect of such legislative steps will require comprehensive EIA methods and convincing EIA techniques to be developed. Many such methods and techniques exist and are described in the various reports and texts quoted above. From a visual analaysis viewpoint, however the 'toolshed' is somewhat understocked, if not empty. There is clearly a need to develop more sophisticated visual assessment tools in response to the rigorous demands of possible EIA legislation.

1.3.5 Objections to EIA

There are a number of objections to integrating EIA into the UK planning system. These may be summarised:

a) The classification of projects for EIA and the exempting procedures (SURV81). Some projects, due to large land take or pollution will require a full EIA; whilst others, of a smaller scale, may not require assessment or undergo a simplified study. This appears to be a direct result of U.S. experience in which EISs are often undertaken unnecessarily.

b) The systematic approach of an EIA may well introduce delays in the statutory planning process. However, many argue that it would simplify and speed up decision making processes in planning (BARR80) p.13.

c) The cost of commissioning an EIA is often prohibitive, particularly when it must be borne by the developer himself.

d) Length. It is felt that the contents of an EIA should be specified in legislation, especially a maximum length, e.g. 5000 words. Further, if the contents of an EIA are to be presented in a succinct and readable form, then the techniques for assessment should be as objective as possible, to convey a reasonable impression of the extent of the impact in a short report. (GARN79).

e) Litigation. Litigation arising from EIA in America has fallen recently (PLAN 81b).

f) Revisions of UK planning system
Advocates of current planning legislation argue that it is adequate to cope with the assessment of major developments. EIA it is claimed, would only invite a revision of the entire planning control system. Some contend that EIA may be integrated through an amendment of the General Development Order (ARCH82a) (CLAR80b) p.44.

g) Bad Judgement
US and Australian experience claims that EIA can be wasted if it is subjected to bad judgement (PICK81).

These factors are currently at the centre of debate regarding the possible adoption of some form of EIA in the UK planning system. The implications for visual assessment will be significant if EIA is integrated with existing planning procedures. In particular the efficiency, accuracy and flexibility of visual assessment procedures will come under detailed scrutiny.

1.3.6 Summary

1. The current reluctance of the British Government to integrate a formal procedure for environmental impact analysis appears to run against the trend of advisors and institutes which favour its introduction. Clark also describes underlying economic reasons for resistance (CLAR80b) p.44. The ad hoc nature of initiating EIAs may leave the countryside open to further uncontrolled development,with an immediate loss of yet more high quality landscapes.

2. An increased public awareness of environmental issues will require visual assessment procedures to be;

a) more objective in analysis and appraisal.
b) more succinct in presentation
c) more flexible in application to test different sites, schemes and the effect of natural screens e.g. tree belts.
d) more systematic in appraisal.

3. EIA will promote objective discussion. Impact analysis techniques must be sufficiently developed to contribute to this discussion; in particular visual assessments must contain more than subjective value judgements if quality information is to be produced regarding various courses of action before decisions are taken.

4. EIA will require developers to prove the case for development, rather than present the idea. There is a significant difference here, and proof will consequently demand more scrupulous impact assessment techniques. Typically an assessment may involve:

i) a description of the proposal
ii) an analysis of the alternatives
iii) justification of the preferred option
iv) a description of its effects
v) limitations of the assessment (CLAR80a) p.157.

Parts ii), iii) and iv) present difficulties in their call for explicit reasons and courses of action. From a visual analysis viewpoint it would seem that more sophisticated techniques require to be developed, if (CLAR76) and (CATL76) are accurate in their review of techniques available and in use in design practice.

5. There is a need to establish guidelines and a methodology in visual analysis procedure for local public inquiries. In the same way that methodologies are devised for Environmental Impact Studies so it would be timely to set up standards for both the developer and objectors' visual assessment presentation at inquiries. This

is likely to give common ground for debate, and present the inquiry reporter with a more informed assessment of the proposals submitted allowing a better comparative judgement to be made.

6. If the main objective of an EIA study is to provide decision makers with an unbiased account of the implications of an action or alternative courses of action, then such impact assessments can no longer rely on subjective judgements based on individual intuitive feelings, however expert they may be.

7. Three comments made at a symposium in Stockholm in the summer of 1981 are appropriate at this juncture in summarising feeling towards visual analysis.

i) The process of doing a Visual Impact Study: there are no tools to do a fully comprehensive analysis.

ii) There is increasing pressure on clients' consultants to demonstrate that visual analysis work is both accurate and helpful in influencing design decisions.

iii) The applicability and reliability of visual impact procedures in tackling real problems is continually under question ; particularly the representation of proposed structures in the landscape submitted for public scrutiny (PERR81)

The inadequacies of visual assessment techniques is bound to cause delays in decision making on the part of planning authorities.

8. There is a clear distinction between the level of visual assessment detail required by an EIS and that required by e.g. an architect, in the course of design. The techniques used in the preparation of an EIA are likely to be a subset of those employed by the designer. This thesis identifies that there are a number of methods now available to satisfy the broad requirements of an EIA, and suggests the development of design aids in visual analysis work. These will

i) improve design standards, as architects become more aware of the visual consequences of design decisions.

ii) Instil more confidence in design decisions as alternative courses of action can be considered in depth at earlier stages of the design process.

These will not necessarily be shown at inquiries or included in EISs. The main submission of visual assessment in an EIA will tend to be intervisibility studies.

9. The scale of the visual assessment will largely determine the techniques used.

Regional scale: gradings of landscape quality are more appropriate in strategic planning level: area assessments for visual absorptivity and vulnerability may be undertaken.

Local/Site Scale: detailed assessment of the form and location of development. Backclothing/ skylining/ and colour studies undertaken.

10. There tends to be reliance on old techniques of visual assessment and expert verbal opinions. These are highly subjective and it is often difficult to interpret their importance and bearing in design decision making. As a consequence, visual analysis tends to be one of the less emphasised factors in project appraisal.

11. There is a clear need for visual impact statements to be presented in quantitative terms to allow unambiguous judgements, conclusions, and decisions to be made. Qualitative assessments invite debate based on subjective grounds, and hinder impartial judgements. (HICK80) p.77

12. Objective visual impact studies, as part of an EIS, will:

i) reduce the amount of time at inquiries debating over expert opinions concerning visual intrusion.

ii) reduce scepticism over the accuracy of visual impact techniques used in public inquiries, and by the same token increase confidence in decision making based on visual assessments.

13. There are three main points which may be learned from U.S. experience.

i) It is essential to define as precisely as possible those projects for which an Environmental Impact Statement (EIS) will be required.

ii) There must be a monitoring, advisory body having the duty of checking each EIS and publicising its essential and more significant features. Such a committee might advise on the content of an EIS.

iii) It is also necessary to ensure that each EIS is presented in a concise, readable and readily intelligible form. 5000 words is a suggested maximum, ensuring a succinct presentation of each impact (GARN79).

1.4 Conclusions

This chapter has summarised, under three headings

i) Urbanisation
ii) Planning
iii) EIA legislation.

the main factors in the emerging problem of visual intrusion in many sensitive landscapes in the U.K. to-day.

i) Clearly the need for energy-related developments will increase towards the end of this century and likewise development pressures for transportation and leisure facilities will continue to place greater threats on the land.

ii) Many would now advocate the need for some form of EIS procedure or updating of the existing planning procedures for large scale developments. This would place a demanding burden on existing methods of visual assessment with respect to the rigorous and comprehensive assessment of alternatives and the explicit statement of reasons for rejecting or developing certain design options.

iii) Increasingly scrupulous local public inquiries are insisting on more explicit information and accurate predictions of the impact resulting from design intentions. Many of the techniques used at recent inquiries have been criticised as being inappropriate or insufficient in the visual evidence presented. The Sizewell Power Station Inquiry (1.2.2) is a typical example. It would appear that decision makers are requesting designers to be more objective in visual analysis and often, nowadays, cast doubt on the applicability and reliability of traditional visual assessment methods.

These three factors, considered jointly, indicate that the time is now due to reflect on the utility of the traditional methods and speculate on the future techniques for visual assessment. Chapters 3 and 4 will review the current state of the art and chapters 5 and 6 will promote thinking in new directions for visual assessment.

CHAPTER 2

2.1 Introduction

This chapter aims to review three fundamental aspects of the activity of architectural design in so far as they relate to the topic of visual impact analysis:

i) Design processes
ii) Design methods
iii) Design models

In a thesis which deals with existing and new methods of visual assessment, the place and role of techniques in this field must be made clear.
Firstly, an understanding of the process of design will be set out. Methods and models in visual assessment may then be related to this broad structure.
Secondly, the range of methods in visual assessment will be described and related to the design process. Special attention will focus on computer based methods and their place in the activity of design.
Lastly, the concept of visual modelling will be addressed, again with special reference to computer based models.

2.2 Design processes

2.2.1 Cyclical and two-dimensional

Design processes are typically of two distinct kinds of structure; cyclical or hierarchical. (CROS77) p.18. There is little disagreement that architectural design is cyclical in nature since architects refine, reassess and recant as solutions are elaborated and compared. On the contrary, though, there is very little agreement as to the description of this process of architectural design.

The one-dimensional hierarchical approach can be dismissed as wholly inappropriate to describe the complex and inter-related nature of design in architecture. Markus has suggested, and it is generally accepted, that there is at least a two-dimensional structure to design:

> "a vertical structure of sequential design stages, and a horizontal structure of iterative and cyclical design procedures" (CROS77) p.21

The vertical structure will be referred to as the design process, and "regulates the development of a design (for example from outline to detail proposals)" (CROS77) p.21

design process: sequential phases or steps from inception to project completion: from the abstract and general to the concrete and particular (MARK72)

The horizontal structure will be referred to as the design activity, and "appears within most of the vertical stages" (CROS77) p.21.

design activity: a series of stages which lead the designer from analysis to evaluation and decision making (MARK 72)

In more detail the horizontal structure consists of three recognisable stages:

i) Analysis: Clarifying of goals; identifying problems,nature of difficulties; exploring relationships; producing order from random data.

ii) Synthesis: Creating part-solutions; combining part-solutions into consistent and feasible overall solutions; generating of ideas

iii) Appraisal: Applying checks and tests; applying criteria, constraints, and limits; selecting of 'best' solution from a set; testing for consistency. (MARK67)

These stages are inter-connected by feedback loops, permitting the framework to be flexible in response to given design problems; each pass through this horizontal structure culminates in decision making before moving on to the next level of the vertical design process structure. (G12) describes this notion of the design process which is shared by a number of other authors, e.g. Luckman and Jones (CROS77) p.14.

Following the same two-dimensional approach, the Royal Institute of British Architects (R.I.B.A) have proposed a map to describe the design process (G13), in which various stages of design are charted against time. This is substantiated later in (ROYA80)p.351 where a detailed plan of work is outlined (G14).
Both the Markus/Maver model of the design process and the R.I.B.A conceptualisation have received much criticism for structuring the design process as a series of successive stages. The rigid framework of the vertical structure is notably inconsistent with design practice. Indeed Duell recently identified two points of conflict between these descriptions of the design process in theory and practice:

i) the design process in practice, from outline to detailed proposals, is poorly described in the R.I.B.A 'workstage' sequence (G14).

ii) Analysis-Synthesis-Appraisal is certainly unrepresentative of the practice of design which is governed principally by style and philosophy.

"most designers quickly evolve a basic solution of the building form with little detailed analysis of all the site information, client brief, planning requirements etc. This finding is interesting because I have always believed in the importance of an 'image' of a design which can then serve as a 'structure' for the detailed analysis and design process that follows. Without this strong image the designer easily becomes lost in the volume of information that he must assimilate into a building form" (DUEL82) p.23

Two further lines of investigation are relevant at this stage.

i) Why is it difficult to model the design process? and
ii) What other descriptions of the design process exist?

The answer to the first question is contained in the definition associated to the term 'design'. Bijl's definition best accounts for the problems in modelling the design process.

"Design is not a problem solving process in the sense of problems that have single correct solutions, nor are design products defined by a precise anticipation of function. Instead, design may be viewed as a task of problem exploration and redefinition, exercising peoples' powers of intuition and judgement" (BIJL83)

Patently, designing is a complex task. Shifting objectives, changing approaches and altering criteria for judgement; stylistic content; the variety of correct solutions all contribute to the difficulty in modelling the design process.

Turning to the second question, most of the other design process descriptions favour Duell's view of 'a starting design image'. The PDI model proposed by March shows a much greater understanding of the design process, through both its structure and operation, than the two dimensional approach (MARC76) (G15). From the author's own experience of design, March's model is by far the most accurate description of the process; and this is only emphasised by the threefold agreement between March's model and Bijl's earlier definition of design:

a) design is not a problem solving activity (MARC76)
   i) design problems are generally ill-defined (ARCH79a)
   ii) the solution space is large

b) in the course of design, a designer will redefine the problem, refine the objectives and explore solutions.

   i) detailed objectives vary during design.
   ii) the problem statement does not reveal the criteria for recognising a solution (BIJL83)
   iii) design is often retrogressive. March, therefore, does not indicate arrows as a direction of flow for his model.

c) design is a learning process. (MARC76)
   i) as the multivariate nature of design decision making is discovered (MAVE75): i.e. the need to satisfy various functional and performance requirements e.g. structure and services.
   ii) Solutions rely on intuitive judgement and overt knowledge (BIJL83)

One of the main differences between March's approach and the Markus/Maver model is the fusion of the stages analysis and synthesis into what March terms Production. This merging characterises the popular approach to design in that it is unrealistic to separate analysis from synthesis. Indeed, designers hold firmly to the belief that analysis is achieved through error in the production of solutions, which, of course reflects the earlier established view of design as a learning process. Eastman summarised this understanding of design; "there is no meaningful division to be found between analysis and synthesis in these protocols (design), but rather a simultaneous learning about the nature of the problem and the range of possible solutions" (LAWS80)p.33. Darke also found this tendency to structure design problems by exploring aspects of possible solutions, rather than learning by explicit analysis.

Like Duell, Darke identifies the need for a starting point; she terms it "a primary generator" (DARK79). (G16)

Relating these concepts of design to practice, it is discovered that March, Eastman and Darke best model what actually happens in a design office. Mackinder and Marvin substantiated this view in the findings of a research project published in 1982:

> "The design process as observed during the case studies followed a fairly consistent pattern. In this, an initial concept for the building plan, form and general construction was developed rapidly, using little information other than the client's brief, the site constraints and the designer's own experience. This initial concept was then developed and refined, using more deliberately researched information and later modified as necessary in response to emerging constraints and changing requirements". (Mack82)

From the variety of models derived, the act of designing is an unclear process. There are, however, three broad points common to the processes outlined, which describe design as leading

1. from outline solution searching and image formulation
2. to detailed design and development of a particular scheme
3. with a host of production (re-analysis and re-synthesis), re-appraisal and re-decision making stages in between.

Although models such as March's most accurately define the way in which design is conducted, they tend to emphasise the nature of the horizontal design activity, and offer a less explicit description of the vertical structure than in the Markus/Maver model: in fact, it is merely defined as the cyclical nature of the model's operation. The RIBA Plan of Work and the Markus/Maver model of the design process may be criticised on the grounds of their formal interpretation of an intuitive, unpredictable and often times retrogressive process.

It is clear, therefore, that no description of the design process is wholly perfect. Yet it is necessary to choose some conceptualisation for the purposes of this thesis. Since the author is most familiar with the Markus/Maver model which has a more clearly defined vertical structure relating to the RIBA Plan of Work, this two dimensional structure of the design process will be adopted as a framework within which to discuss the place and role of visual assessment techniques in the act of design. Darke's idea of design development stemming from a "primary generator" is not precluded from the Markus/Maver model; less or greater emphasis need only be placed on particular re-analysis, re-synthesis and re-appraisal stages in the Markus/Maver model to obtain a reasonable and acceptable correspondence with Darke's theory of the design process.

2.2.2 Visual Assessment in the Design Process

Design decisions made in relation to the existing and desired visual environment are taken early on in the design process. At design inception, initial ideas and reaction to the brief frequently determine the scope and stylistic development of a solution: important visual issues may be settled at this stage, e.g. the form and visibility of the structure and its skylining. With increasing detail, less significant decisions are taken in the later stages of design with regard to the general form, layout and siting of the building (G17). In contrast, the more sophisticated techniques for visual assessment tend to be crowded towards the end of the design process e.g. detailed artists' impressions and physical scale models. These are sometimes specially commissioned by clients and can be too late to make worthwhile contributions to initial visual design decisions, e.g. form and siting.

Clearly there is an imbalance between the current need and provision of visual analysis and appraisal methods. Although sketch techniques exist to aid the designer in early solution searching and appraisal, their handcrafted nature and single viewpoint assessment militate against rigorous, comprehensive and accurate appraisal to enable confidence in the early formulation of design strategies and policies, and in decision making. The implications for visual assessment can be stated:

a) A need to develop techniques for quick, comprehensive and accurate appraisal of early design proposals.

b) A need to develop techniques which would help establish design thresholds and boundaries describing the visual limits and absorptivity of the site, eg. the height at which a building placed in a certain location will protrude above the background horizon may be identified as a boundary of site visual absorptivity or a threshold of increased visual prominence; such techniques would only seek to inform the designer of change points in the building/landscape relationship; boundary shifting would still be possible to allow design innovation.

c) Each iteration of the design activity will require increasingly more detailed visual investigation and appraisal tools. Hierarchical techniques must be developed which can adapt to the availability of resources, eg. time, money, equipment and expertise, without compromising on the quality of information obtained at each stage in assessment.

d) The objectives of visual investigation at each design stage must be clearly set out. These may be largely determined by the decisions to be made on the basis of the results, and the techniques used.

e) Visual analysis and appraisal techniques at earlier stages in the design process may make clearer the:

i) scale of the visual problem
ii) scope and feasibility of solutions, from a visual impact standpoint.
iii) and effect more objective comparisons, in visual terms, between solutions.

The further visual assessment procedures can be pushed back up the design process towards the early outline and formative design stages, the more effective will be solution searching, generation and appraisal. Particularly in the initial stages of design, designers require a controlled flow of relevant and high quality information concerning their proposals, as part of the learning process of the design problem to stimulate thinking and creativity as rewardingly as possible. The five objectives outlined above would hope to initiate a prompt and fruitful start in understanding the visual problems of a site and proposals e.g.

i) determining critical building heights below landscape horizon lines
ii) establishing planimetric limits on site to enable backclothing of land behind developments.
iii) locating critical viewpoints with maximum visual impact.
iv) the rapid visual appraisal of wide ranging design proposals.

2.2.3 Visual Assessment in the Design Activity

The design activity has been defined as consisting of three distinct phases culminating in decision-making and communication -

i) analysis of a particular problem
ii) synthesis of a solution
iii) appraisal of the solution in terms of a set of performance criteria

This design methodology is depicted by Maver in (G18). Nearly all the models developed for use in visual impact studies are appraisal techniques. Analytical procedures to aid the generation of design hypotheses are notable by their absence. The author envisages future development in the field of visual assessment being devoted to analytical and appraisal techniques:

1) Analysis: the investigation of the visual limits of a site. For example, boundary and threshold settings for backcloth and skyline protrusion analysis
2) Appraisal: the assessment of the visual form and features of a proposal. For example the degree of visibility of a structure in the landscape.

Continuous analysis and assessment of solutions by designers, clients, consultants and users throughout the design process, indicates that automation may have some significant role to play as the basis for developing techniques. Maver has reviewed the role of computer aids in the design activity, relating three types of computer processes to each of the three stages:

i) <u>Analysis</u>

Computer process:	formal mathematical processes in which relationships are modelled.
Examples :	linear programming Regression analysis
Comments :	the generalised relationship may not be wholly accurate of reality. Predicting from empirical data is fraught with danger. The limitations of the relationship may hinder design innovation.

ii) Synthesis

Computer process: heuristic processes in which search rules are modelled.

Examples : building or site layout

Comments : Solution searching within a sub-set of the whole solution space, as defined by a set of heuristics e.g. soil properties, activity net-works, communications, can lead to poor and unimaginative solutions. There is a need for 'a priori' weighting of variables.

iii) Appraisal

Computer process : simulation processes in which solutions are modelled.

Examples : simulation models for energy appraisal, cost and lighting requirements.

Comments : heuristics and 'a priori' weighting of variables unnecessary

: models can be as complicated as desired, to model reality accurately.

Computer procedures devised to aid synthesis have "serious limitations in the formal mathematical and heuristic models used". (MAVE70) p.204. The main reason that computers cannot be used in design synthesis is that architecture, by definition possesses stylistic properties. This is a meaningless notion to the computer which is programmed to solve well defined problems. Thus computers are best at analysis and appraisal; man is best at synthesis and decision making or inductive reasoning.

The development of analysis and appraisal computer techniques for visual impact assessment will effect:

i) more informed inductive reasoning. Notably in rural contexts, resort might be made to more complicated procedures of visual analysis and appraisal due to the increased visibility and heightened sensitivity of a structure in the landscape, viewed from a range of locations.

ii) Automated appraisal techniques for visual assessment will enable designers to evaluate many more solutions; in particular, those which in the past time may not have allowed for detailed assessment.

iii) The learning curve of the design problem can rise more sharply with rapid solution searching and testing by computer based analysis and appraisal.

2.3 Design Methods

2.3.1. Visual Assessment and Design Methods.

The emergent design methods of the 1960s reflected the growing complexity of architectural and other related design work. In architecture, the scale of development, engineering systems and construction techniques complicated the hitherto intuitive approach of designers.

> "in the complexity of most architectural situations the behaviour may run against intuitive expectations and become cause for surprise. And indeed as the architectural form undergoes modification (geometrical or material) then light, heat and sound appear to interact on one another through the form." (MARC76) p.xiv

The idea behind developing design methods, therefore,was to establish procedures for design which might be applied in the solution of sub problems within the overall design activity; a clearer understanding of the interaction between the design and context variables could then arise. Thus more rational and structured thinking was thought to accrue in the design process. For a time this was held to be an advantage, although a number of notable design method proponents, e.g. Broadbent, have now recanted on this view.

Design methods do not necessarily preclude intuitive or inspirational thinking, from which all innovative design stems. It is the author's contention that, if thoughtfully applied, design methods will allow better value judgements to be made, particularly in comparative situations. In themselves, design methods do not bring improvements to the end product of design, they may only seek to promote an understanding of the scope and mode of the visual problem being addressed.

The seminal work in the field of design methods was written by Jones(JONE80). In his text, Jones reviews thirty five design methods for use in any one of the three stage design process he conceived - divergence/transformation/convergence (G19). Four methods which Jones reviews are relevant in relation to visual impact assessment.

a) Searching for visual inconsistencies (JONE80) p.209
   The aim is to find directions in which to search for design improvements. This is an aspect of designing almost totally ignored in existing visual assessment procedures. If future techniques are to be developed, they must incorporate this ability to search for areas of improvement. In this case speed will be of the essence in testing hypotheses; automation ought to be considered.

b) Systematic testing (JONE80) p.246

The aim is to identify actions that are capable of bringing about desired changes in situations that are too complicated to understand. This is somewhat similar to method a) in that it involves hypothesis testing. Systematic testing of variables, e.g. sky-lining, by relaxing constraints(site limitations) will affect other characteristics of the situation; these effects may be modelled and recorded giving the designer a feel for the sensitivity of variables and decisions with regard to the visual characteristics of the site.

c) Stating objectives (JONE80) p.194

The aim is to identify external conditions with which the design must be compatible. Quite often this is an area poorly defined in visual impact studies. The definition of objectives within which a design will be acceptable can often lead to more effective and successful solution generation.

d) Boundary searching (JONE80) p.134

The aim is to find limits within which acceptable solutions lie. The ability to carry out rapid boundary searching procedures in design would be of terrific benefit in visual assessment studies. A clearer understanding of an acceptable design solution space would accrue, indicating the scale of the visual problem and the feasibility of solving it given certain objectives.

These are four general methods of designing, all of which would be difficult to find in existing approaches to visual assessment.

They must, however, be seen as essential ingredients to any future successful visual assessment procedure, particularly since they are more suitable for providing answers to questions regarding the range of acceptable options that might be investigated, and the reasons for choosing any particular one. Rigorous and complete assessment may take place only when such design methods can be pursued using visual assessment tools. Their repetitive nature, ie. incremental searching for boundaries etc.can cause over commitment of time and labour resources in the course of any design project. It will be necessary to look to automation for acceptable levels of resource commitment using such methods in design.

2.3.2 Computer Based Methods in Visual Assessment

There are three application fields for visual assessment techniques:

a) As part of an Environmental Impact Analysis study. In this case, visual assessment methods may be used analytically, e.g. investigating the visual absorptivity of the environment, and the degree to which proposals will impact on the visual quality of the surrounding countryside.

b) As an analysis and appraisal tool for architects in the process of design. Visual assessment techniques may be used to appraise the visual attributes and appearance of a particular or set of alternative proposals in a specific location.

c) As a long term aid in visual resource management. Those involved in large scale rural landscape alterations over long periods of time may make continued use of such tools, even after project completion, e.g. alternative strategies for forestry and agricultural management programs can be monitored, with the effects on the visual landscape being determined well before such actions as felling and planting are taken: water management, mining and open cast quarrying operations are further examples.

The underlying and essential element in the use of visual assessment tools in these application fields is that they are predictive of future events rather than descriptive of present conditions. Computer methods are particularly suited to this role as predictive tools.

To link all three application fields by a unifying visual management procedure is most desirous. Computer-based systems seem best geared to achieving this. Topographic, land-use and builtform data bases may be prepared, modified and updated during the design, construction and operational life of a development. The idea of long-term investment in such data bases is only just beginning to be recognised outside mining and quarrying applications in Britain.

Many of the visual assessment tools developed fall into the second class of applications outlined above; some of those tools may also be used in class one. However, very few, indeed from a cost-effective viewpoint exclusively computer-based methods, are applicable in class three. The notion of using digital rather than analogue techniques, in what is a continuously changing operational data base (e.g. earthworks removal and tree growth), is wholly justified. In addition, the large data storage requirements, the complexity of data manipulation and the repetitive time consuming data processing clearly support computer techniques are applicable. Primarily, they are best able to meet current needs in visual assessment for:

a) objective appraisal
b) detailed visual consideration of alternatives
c) justification of a preferred solution

2.4 Design models

2.4.1 Modelling in Design

The concept of modelling has been around for many thousands of years, from as early as the cave paintings depicting hunting scenes. One basic fact concerning models has not changed since those days, and it is well to be reminded of it; "all models are inexact and incomplete analogies of real life" (GEOT65). Since the 1960s a number of model types and classifications have been devised: Broadbent (BROA73) p.87-96 provides a helpful review of the model classes outlined by:

a) Churchman, Ackoff and Arnoff

- i) iconic: e.g. an artist's impression or physical scale model.
- ii) analogue: e.g. two dimensional maps, in which varying heights are represented by contours.
- iii) symbolic: e.g. mathematical models expressing the relationship between parts of a system being modelled.

b) Chorley and Haggett

- i) Descriptive or predictive
- ii) Static or dynamic
- iii) Physical or theoretical

Visual models for assessment procedures are frequently descriptive, static and physical.

c) Echenique

- i) Verbal : e.g. an expert opinion
- ii) Spatial : e.g. a two-dimensional drawing
- iii) Mechanical : e.g. a three dimensional scale model
- iv) Mathematical : e.g. a numerical model of a building system.

Although each type attempts to model reality, the first three classes, verbal, spatial and mechanical, are largely descriptive and static: whereas the fourth type may be regarded as predictive and dynamic, i.e. predictive of the future behaviour of a building over time and subject to climatic stimuli. In terms of visual asssssment, the first three classes comprise the traditional techniques and models used;

class four, mathematical, is least developed and could provide designers with a new generation of modelling aids in visual assessment, in the same way that this has happened in the field of energy appraisal in buildings.

Summarising these model definitions and classifications it is possible to contrast the existing and emerging characteristics of models for visual assessment.

Traditional models	New generation models
verbal/spatial/mechanical	numerical/mathematical/spatial
simple	complex
descriptive	predictive
deterministic	probabilistic
static	dynamic
materials/paper-based	computer-based

2.4.2 Modelling at the Natural/Built Environment Interface

The ability to predict, and to some extent experience, the consequences of design proposals in terms of eg. aesthetic, functional or cost performance is a key factor in successful design solution searching. In architecture there are a variety of models which enable prediction e.g. physical scale models for structural, visual, lighting and wind studies, and complex mathematical computer models for costing and energy studies. While there are many highly sophisticated computer-based models for investigating the relationship of building properties, existing methods for visual assessment tend to be manual and openly subjective interpretations.

From a modelling viewpoint, there are two components to visual analysis.

i) Natural Environment

ii) Built Environment

The visual assessment of hypothesised solutions is that act which takes place at the natural environment/built environment interface, to understand the complex and dynamic visual relationship that exists between the landscape and man made structures. This is emphasised when dealing with buildings in sensitive rural settings. (G20) outlines how the notion of modelling fits into the natural environment/built environment interface and how different models are used to gain insight into such dynamic relationships as energy, cost and visual impact.

The natural environment system includes those characteristics of the site which form the visual appearance of the area:

: topography
: landscape vegetation
: climate

These factors will influence the outcome of a particular design solution. In addition they describe the visual quality and character of the context for design.

The built environment system comprises buildings, roads, dams etc. Such structures affect the landscape and microclimate as much as they are affected by it.

As described above, the existing natural and proposed built enviroment characteristics inter-relate as two dynamic systems during the design process; on the one hand, climate and vegetal growth vary, while on the other, the activity of design to create the built environment fluctuates widely in solution searching. It is clear therefore, that the concept of modelling is of vital importance in understanding the complex interaction between the natural and built environment. In the case of visual assessment there are very few techniques which apply rigorous appraisal to this fundamental yet complex aspect of architectural design. What is required is a highly flexible yet sensitive set of visual modelling routines to effect design objectives, either contrasting or harmonising the building in its landscape setting. This is particularly pertinent in the rural context where the amelioration of a design to its surrounds is more difficult to achieve.

2.4.3. Geometry - a key issue in modelling.

Almost all the various modelling procedures used in architectural design are based on some geometrical description of the building e.g.

i) geometry of external form: this may be used in visualisation, wind and shadow plotting experimentations.

ii) geometry of spaces: this may be used to assess plant loading, lighting requirements, cost/m^2 etc.

iii) geometry of construction: this may be used in structural, thermal and services design within the building.

Since geometry is central to all building calculations, the cost effectiveness of storing building geometry by computer is high, especially when visual, environmental, functional and structural appraisal is required. The key role of form in appraisal is outlined in diagram (G21) in which four computer programs developed at ABACUS (Architecture and Building Aids Computer Unit Strathclyde) Department of Architecture and Building Science, Strathclyde University are identified:

GOAL: General Outline Appraisal of Layouts.
functional, environmental and financial assessment conducted on form and fabric input (SUSS81)

ESP: Environmental Systems Performance. Thermal and plant load calculations within buildings; conducted on form and fabric input (CLAR82)

BIBLE: Buildings with Invisible Back Lines Eliminated. Monochrome wire line perspective drawing program; operates with form and viewing parameter inputs (SUSS82)

VISTA: Visual Impact Simulation Technical Aid colour perspective drawing program, operates on data from BIBLE and colour surface specification (STEA83)

It may be construed from (G21) that it is perfectly feasible,i.e. at very little extra cost and labour,to initiate an appraisal of the visual implications of design intentions, having perhaps originally only described the building form to appraise the thermal performance. There is a hierarchical relationship to the three types of geometries described earlier; this structure is outlined in the left hand portion of (G22). There is a corresponding hierarchy in planning. In this case, however, the geometry is that of the topgraphy and land use elements in the study area.

This notion of geometries being structured in successively more complex detail can be seen to relate to the progressively refined geometries of building and landscape design as the design process advances from outline to detailed specification. The topic of visual assessment ought then to be seen in relation to other appraisal tasks; ideally as one component of a much larger computer-based system addressing other building aspects e.g. energy and cost performance.

2.4.4 Visual Modelling

Turning to the topic of visual modelling in architecture, this may be described as the ability to visualise future design proposals in two or three dimensions, with the purpose of permitting an aesthetic judgement. The simplest level of this visual communication consists of the standard architectural presentation drawings of plans, sections and elevations i.e. orthographic projections. Despite the high levels of accuracy required in these drawings, the two dimensional representation of space is not readily understood by a lay audience, and additional pictorial evidence is often necessary for adequate explanation. This is usually in the form of sketches and physical scale models. The different modes of visual communication in architecture may be summarised.

a) Two dimensional presentation

- i) 2-d building representation
  - :orthographic projections
- ii) 3-d building representation
  - :Isometric/Axonometric/Oblique projections.
  - : Perspective projections
    - - artists' impressions
    - - photomontages, e.g.

      photomontage panorama, e.g. Gordon Graham and Partners for British Gas (GRAH77) (G23) (G24)

  Stereo image viewing

b) Three dimensional presentation.

- i) Physical scale models e.g. Physical Model/Site Photograph Montage. A system developed by A.C. Murray for power station siting. A colour slide of the site is simultaneously projected on to a screen with an image of the physical scale model taken from the same view direction (MURR67) (G25)

and

"Drive-thru" simultations using a modelscope,as at the Berkeley Environmental Simultation Laboratory at the University of California (G67)

- ii) Laser beam holograms

2.4.5 Visual Assessment

The techniques outlined in 2.4.4 are essentially descriptive of the building or structure. There is a second generic group of techniques used in visual impact studies which addresses itself to more general questions of building intrusion on the surrounding landscape e.g. the visibility of the structure, and the extent to which it is backclothed by hills. Such techniques may only model a very simplistic description of the building e.g. its height, in contrast to the wealth of information also required to describe the surrounding topography. There are a number of such techniques:

a) <u>Helium filled balloons</u>. Used on site to simulate to height of a chimney or pylons. Observers may tour the surrounding area to establish the visibility of the balloon (simulated structure). (BURE80) p.37 (G26)

b) <u>Subjective Field Judgements</u>
Qualitative assesments of the landscape e.g. Manchester University Landscape Evaluation Project (MANC76). This technique and other landscape evaluation methods are well summarised in (LOVE73) p.17-50

c) <u>Visual Intrusion Contours</u>
Contour mapping based on calculations for the solid angle subtended by objects from viewpoints. Typically this would be applied to assess the intrusion of a highway (TRAN76) Appendix (G27).

d) <u>Zone of Visual Influence</u>
R.L. Hebblethwaite, Central Electricity Generating Board (HEBB75) (G28) (G29)

e) <u>Visual Intrusion Index</u>
R.G. Hopkinson (HOPK71) (G30)

f) <u>Isovist Visual Assessment</u>
A.C. Hardy and C.R.V. Tandy (TAND75) p.75 (G31)

g) <u>Zones of Visual Proximity</u>

A technique devised by William Gillespie and Partners and used in the visual assessment of pylon lines for the South of Scotland Electricity Board.

i) Zones of visual proximity to pylon lines determined.

ii) Field assessment:

: choose observation points

: locate object in view

: assess impact effect

(WHIT81) (G32)

2.4.6 Computer-based models

Computer-based models in visual impact assessment fall into two broad classes :

i) visualisation of buildings/topography/vegetation. (TAND75)p103 (BENS77) (ERVI82). (G33)

ii) mapping of the visual characteristics which buildings impact on the surrounding countryside, eg. visibility or skyline protrusion. (HEBB75) (BURE80). (G34)

Visualisation may be subdivided into two sections ; simple monochrome wire line perspectives, and fully coloured and textured visual simulations.

During the course of this thesis the author was privileged to have access to three computer programs, covering the range of applications listed above :

i) visualisation

a) BIBLE (Buildings with Invisible Back Lines Eliminated). wire line perspective drawing program (SUSS82)

b) VISTA (Visual Impact Simulation Technical Aid).
colour/shadow/textured perspective drawing program.
(STEA83)

ii.) mapping

c) VIEW
a suite of programs used for visual analysis, and part of a larger land use planning program. The key element in the suite of programs is the Digital Terrain Model (DTM) upon which calculations are based. (AYLW82).

Both BIBLE and VISTA were developed at ABACUS.
The suite of programs known as VIEW was originally developed by Turnbull and Dwyer in the early 1970s at the University of Southern California. Since then VIEW has been further developed and modified in Scotland. Initially, through Design Innovations Research (DIR), a partnership involving the late Prof. Graeme Aylward and Mark Turnbull; currently, research and development of VIEW is undertaken in the Turnbull Jeffrey Partnership (Planners, Architects and Landscape Architects) in Edinburgh.
These computer methods and the manual techniques outlined previously are classified by the author in (G35)

The advantages of modelling building and topographic geometry by computer are numerous

i) a greater number of proposals may be assessed, encouraging experimentation in design solution searching.

ii) a host of building and topographic appraisal packages may be applied, eg. energy, layout and costing in building; and drainage, road alignment and earthworks in landscaping: these in addition to visual assessment.

iii) the scale and complexity of problems dealt with by computer methods is far superior to human capacity.

iv) objective information is provided enabling designers to make more informed decisions.

v) computers are best suited to well defined repetitive numerical tasks which typify hypothesis testing in design assessment.

Other benefits will be cited and discussed in chapter three under the comparative evaluation of visual modelling techniques.

2.5 Summary

The place of visual assessment methods and models in the design process framework is summarised in diagram (G36). The underlying structure is the Markus/Maver model and the R.I.B.A. workstage process. Special reference is made to computer-based methods and models.

CHAPTER 3

3.1 Introduction

In recent years, the development and use of a range of visual impact assessment methods has been stimulated by two main factors, made clear in chapter one:

i) the increased scale of human intervention on the landscape.

ii) the inadequacies of verbal 'expert' evidence at inquiries; objective and pictorial evidence being considered more helpful in understanding the scale of visual impact and in decision making.

At a time when there is a critical and increasingly demanding public eye on the impact of large scale building operations, it is expedient to review the techniques currently employed for visual impact assessment.

3.1.1 Chapter Objectives

The intention of this chapter is, through the use of a case study approach, to evaluate the merits and shortfalls of manual and computer-based tecnhiques for visual assessment. To date there has been no systematic effort to conduct such an appraisal,although a number of authors have written about the techniques available e.g (BURE80). Piggot's thesis (PIGG79) was the first to review the techniques under the title of visual impact assessment. However, his thesis was written from a planning viewpoint and is essentially descriptive and discursive; he effects no direct comparative evaluation of the techniques in use.

3.1.2 A Case Study approach

The comparative evaluation and validation of visual modelling techniques is a slightly easier task than that of appraising e.g. the thermal performance of a building. Most of the visual models are descriptive and, therefore, may be compared directly with the real world situation which they attempt to portray. For this reason a case study approach was adopted. The building chosen was the 'B' nuclear power station at Hunterston. A description of the surrounding area, the industrial activities and visual impact of Hunterston on the Clyde Estuary is contained in Appendix 1. The power station is in a sensitive coastal setting, visible from a range of population centres at varying distances and angles. These and other factors were conducive to a rigorous and fair evaluation.

3.1.3 Generalising from the Particular

One qualification should be made clear at this point concerning the conclusions. With the use of only one case study, there is a danger that generalising conclusions from particular findings may lead to a narrow view of what is a very wide field of application. There exists a whole variety of situations in which certain techniques are more applicable than others. However, it was felt that the power station at Hunterston presented few modelling problems to the techniques and, therefore, the conclusions drawn could be seen as typical of the techniques in general.

3.2 Techniques for Evaluation

Visual models still extant from the Hunterston power station study were collated. Although none of the techniques outlined in 2.4.5 was used as a design aid at Hunterston, most of those described are principally concerned with either visibility or visualisation. The focus of the evaluation then centred on the more traditional techniques of visualisation, and the new computer-based methods for both visualisation and visibility analysis. The computer methods were conducted in a post hoc visual appraisal of the power station by the author. Five methods were evaluated.

a) Sketch perspectives
b) Artists' impressions
c) Physical scale model
d) BIBLE (perspective drawing program). At the time of this evaluation, VISTA was not available for assessment.
e) VIEW (visibility analysis program)

The first three methods are well established techniques for visualisation, and need no detailed explanation. The two computer based methods require a brief description of their capabilities and operational procedures.

3.2.1 BIBLE

The program BIBLE is an interactive perspective drawing package, providing wire line drawings of buildings for montaging, or to act as the base drawing for an artist's impression. Based on a hidden line algorithm by Galimberti and Montanari (GALI69), the improvements and development of a friendly user interface by ABACUS during the 1970s led to its uptake by many research institutes and design practices (PARK79). The programme is written in Fortran and operates on mainframe (DEC System-10) and mini-computers (PDP 11/24)

Input geometry data files for processing in BIBLE may be entered by three methods:

i) manual digitising of plans/sections/elevations.
ii) other ABACUS programs, e.g. GOAL, use similarly constructed data files and these may be directly input to BIBLE
iii) Alpha numeric input at a terminal, of point,surface and body data to specify objects for BIBLE processing.

Pre-processing data manipulation can be effected by the program IMBISS. Repetitive building elements may be copied from primitive geometry shapes, then scaled, rotated, reflected or translated to a user defined location, e.g. within the OS grid co-ordinate system. Data files consist of the X Y Z co-ordinates of points and how these points relate to whole forms (surface specification). Initiating a run of the program produces a command menu display in the top right of the screen. The user may interact with the program during run time and may interrogate views of the geometry data, as he chooses various viewing parameters in the menu. The menu comprises:

i) general commands

HELP	displays a list of the command options available to the user
INPALL	allows user to type in parameter values,rather than use the screen cross hairs to indicate positions.
TYPALL	displays the current parameters
NEWFIL	clears memory of old data file and prompts user to specify new data file to be read
BYEBYE	ends programme run

ii) viewing commands

EYEP	the eyepoint co-ordinates (XYZ) may be specified for the observer/camera location
FOCUSP	the focuspoint co-ordinates (XYZ) may be specified for the point or direction of viewing
MIDP	the mid-point of the picture (XYZ) may be specified to select different windows on the scene

iii) display mode commands

HIDDEN	hidden lines are not drawn
DASHED	hidden lines drawn dashed
VISIBL	hidden lines drawn

iv) projection commands

1ORTHO selects orthographic parallel projection
2PERSP selects perspective projection (3 point)
3PAHOR selects oblique parallel projection on to the horizontal plane
4PAVER selects oblique parallel projection on to the vertical plane

v) photomontage commands

ANGLEV sets the viewcone angle for the observer window
LENSFL sets the focal length of a camera; used in photomontage mode. This over-rides any angle chosen in ANGLEV
ENLARG sets the enlargement factor for photomontaging: this will enlarge the computer view by the same amount as the site photograph negative was enlarged to the final print.

vi) output commands

SCREEN displays the perspective on the terminal, typically, Tektronix 4000 series vector (4010,4014) and raster (4027) terminals.
CALCOMP compiles a plot file for later plotting on a high quality remote drum plotter (CALCOMP)
PLOTL plots the perspective on a local A2 size flatbed plotter (TEKTRONIX 4663)
OUTFL compiles a plot file with geometry data and viewing parameters, and allows redisplay and reselection of the viewing window using the program BIBPLT at a future date.

The output from the program may be used to form montages with site photographs. Computer views are drawn on transparent film and then overlaid on the existing view to simulate the proposed effect of the development in the landscape. A more complete description of the montaging procedure can be found in (PURD83b).

BIBLE data may be applied to the colour perspective drawing program VISTA, developed at ABACUS by Peter Fox and Donald Stearn (FOX81) (STEA82) (STEA83).

3.2.2 VIEW

The program suite known as VIEW is part of a larger set of computer programs for land use planning, engineering, architecture and landscape architecture. VIEW is the visual analysis section of this program suite. Several questions are posed at the beginning of visual assessment studies:

from where is the development visible?

what can be seen - how much? colour and form? does it protrude above the horizon line?

In answering these questions, decisions can be made on design objectives and the probability of achieving them.

There are two methods to determine the visibility of a structure in the landscape:

a) viewing towards the site/structure

b) viewing out from the site/structure

Projects that require assessment on a large scale, typically rural landscapes, may make use of this principle of intervisibility in which 'if A can be seen by B, then A can see B'.

Traditional visual assessment is conducted on views looking towards the site: this is likely to give rise to an incomplete picture of the general impact in an area. To simplify this checking process and outline the general visibility of the structure over the immediate vicinity, the program VIEW checks data points around the site by viewing out from the point of interest. This is the fundamental difference in the way in which VIEW operates, as distinct from the more traditional methods of visual assessment (G37).

The first stage in VIEW visual analysis is topographic and land-use data capture. These data are largely based on Ordnance Survey maps and stereo pair aerial photographs of the site and surrounding area. Data preparation is a semi-automated digitizing procedure at present.

Automatic contour following processes by laser, using maps or stereo pair photographs, are possible and likely to be a more cost effective method of data capture than manual digitizing, certainly over large areas of ground. Data are recorded for a regular square grid placed over the terrain; this is known as a Digital Terrain Model (DTM).

> "A digital terrain model (DTM) is an ordered array of numbers that represents the spatial distribution of terrain characteristics. In the most usual case, the spatial distribution is represented by an XY horizontal coordinate system and the terrain characteristic which is recorded is the terrain elevation, Z .... Recent literature has referred to these distributions as Digital Elevation Models (DEM) to distinguish them from other models which describe different characteristics of the terrain.... It is important to note that characteristics other than elevation may also be included in the DTM. These characteristics may include such items as land value, ownership, soil type, depth to bed rock, land use, etc." (DOYL78) p 1481.

Different kinds of digital terrain model exist. These are classified in (G38); examples of each are shown in (G39). Applications of terrain modelling are numerous:

- # open cast surface mining operations, volumetric calculations and site management (MALL77).
- # radar visibility studies. (DOYL78)(OTTO78)(G40).
- # gravimetric analysis in connection with mineral and oil prospecting. (OTTO78).
- # correction of remote sensing data. (OTTO78).
- # terrain simulation for flight simulation systems and military applications. (G41)(DOYL78).
- # physical planning activities, eg. forest management programs and water management. (G42)(DOYL78).

In order to determine the most suitable DTM type for a particular application, three points must be considered:

a) the purpose of the DTM

b) the type of terrain

c) the equipment, time, data source and processing power available.

For the purposes of visual assessment a regular square grid is acceptable. The use of contour information creates unnecessary data storage: the use of irregular grids often does not match with land use patterns and certainly results in variable topographic accuracy in different directions across the DTM. The scale at which DTMs are constructed in visual impact studies is greatly influenced by the terrain type; the point density of the grid is normally adjusted to accommodate landscape variations. Point density will be taken up later in the Chapter. VIEW operates on topographic and land-use data gathered in a regular square format grid (G43). The elevation height at each grid intersection is input sequentially; this obviates the need to store planimetric information. Topographic data is recorded as a set of Z values in matrix format (G44); likewise, land use data for trees, buildings, etc. is stored in a formatted matrix. In addition to visual analysis, the data as they stand may be used to assess:

- # earthworks calculations
- # road alignment
- # the effect of tree growth
- # slope analysis
- # drainage analysis
- # sun/shade analysis

The variety of applications is a significant and attractive reward for investment in the compilation of a site DTM. The grid used in VIEW is based on a geographic coordinate system, with the origin in the upper left hand corner of the study area; in any such matrix there are I rows and J columns, numbered from the origin (G45).

Having selected a suitable grid size in accordance with required accuracy and terrain type, elevation and land use data matrices may be interpolated from, typically, OS maps and stored on the computer system for preprocessing error checks or further data manipulation before initiating the main processing programs VIEW1 and VIEW2. The data collection procedure is summarised in (G46). Pre-processing programs include:

INSERT : allows the insertion or concatenation of small data sets to form larger matrices; specification of matrix size and location in larger data set required.

CHECK : checks the elevation data matrix against user specified maximum slope between any two grid intersection points, and lowest and highest elevation values. The program identifies gross errors in the elevation data matrix.

DIGERR : calculates the average, minimum and maximum elevational error for a chosen set of points within the data set, e.g. actual Bench Marks and Spot Heights on O.S. maps may be compared directly with the interpolated height in the digital terrain model.

IDGEN : generates an integer matrix from an elevation matrix of real numbers.

HTADD : defines height additions, e.g. trees and buildings to be added to an elevation data set using an integer overlay data matrix.

CHANGE : allows point row or matrix alterations to be made to data sets.

INTERP : creates data sets by interpolating from existing, larger matrices according to user specified parameters.

ELGRID : plots to user specified scale a grid with existing elevation data for each grid intersection.

PART : partitions smaller data sets from a larger matrix for processing.

STRING : converts string formatted data to F or I formatted data.

VALID and COORD: validate the user defined value at each coordinate point in the matirx.

Having located the object of interest in the modelled terrain, the VIEW programs are ready to run:

VIEW1 : identifies areas of visibility from a user specified observation point. The program is based on a DTM and checks each grid cell for visibility from the viewpoint. The cells may be listed alphanumerically or plotted in binary map form (0 = invisible cell,1 = visible cell). Several viewpoints can be assessed and the resulting visibility matrices concatenated to show how often cells are visible; visibility contours may then be generated. (TURN82a).

VIEW2 : identifies areas of visibility; percentages of visibility; areas acting as backcloth; and the percentage visible above the horizon of structures from user specified observation points. The program is also based on a DTM and is a development of VIEW1. (TURN82b).

The procedure employed by VIEW1 and VIEW2 for checking visibility is summarised in (G47)(AYLW77). Corrections for earth's curvature and light refraction are accounted for in the running of the programs; these are important in large scale analysis. The VIEW programs check the visibility of each grid cell within a certain viewing cone and up to a certain distance from a user specified observer location; this 'window' on the environment is user-defined, in which an operator may choose:

: the vertical and horizontal clipping lines in the visual field of the observer.

: the radius or limit of visibility. (G48)

The concepts of % visibility and backcloth, which form part of the VIEW2 processing capability, are outlined in (G49a-c).

a) % visibility of objects.

b) % visibility of objects seen above the horizon line.

c) area acting as backcloth to the development.

There are three output programs which:

i) display the results of VIEW processing.
SYMCON
: plots a contour map to a user specified scale with the option of overlaying symbols on the map, typically, land use data or visibility map output from the VIEW processing programs.(G50). The program may plot only:

the symbols
the grid
the contour map

or any combination of the three (TURN81a). The symbol overlay may be in colour.

ii) describes visually the input landform data set.
PERSPX
: generates perspective projections of the DTM; the output is monochromatic (TURN79)(G51)(G52).

iii) interrogates the topographic and land use data.
SECT
: prints or plots cross sections through DTMs, using grid intersection points and interpolating elevations at other intersections with the grid lines (TURN81b).

All the programs in the VIEW suite are written in FORTRAN and operate on a number of computer systems, including mainframes (DEC System 10, IBM 370) and mini computers (PDP 11/23). The user may run the programs interactively or in batch.

3.3 Evaluation Criteria

In order to effect a fair and unbiased evaluation of the five chosen techniques a set of performance criteria, encompassing the important aspects and considerations in visual modelling, was determined. The criteria both highlight strongpoints and expose weaknesses in each technique.

Criteria: a) Flexibility
b) Design value
c) Data acquisition
d) Accuracy
e) Time
f) Cost
g) Communicability
h) Accessibility

Obviously, many of the groups will be inter-related, some more so than others; however, a definition and statement of purpose for each of the eight group headings follows.

3.3.1 Flexibility

Incomplete coverage in visual analysis studies results in underdeveloped design objectives and guidelines and can lead to unstructured solution searching. The term flexibility should be an essential feature of each technique; it relates strongly to the iterative solution searching procedure of the design process. In detail, flexibility refers to the adaptive capacity of each technique to

i) appraise alternative solutions quickly,
ii) from a range of viewpoints,
iii) in different climatic conditions,
iv) with changes to existing landscape, built form or topographic features,
v) and to what extent multiple use might be made of the data used in the technique

These may be referred to as:

i) Built form
ii) Coverage
iii) Environmental conditions
iv) Context
v) Multiple use.

A high degree of flexibility within each technique is required if it is to be acceptable as a robust design investigation tool.

i) <u>Builtform</u>

As a designer works through the various stages of the design process from outline proposals to detailed drawings he will require to appraise the solutions which he proposes at each stage. In order to do so as profitably as possible, even from the early stages, he will need techniques not only flexible enough to appraise the wide range of alternatives he generates, but also sufficiently objective to derive worthwhile results for decision making, giving direction to the whole design process.

This section on built form flexibility aims to assess the ease with which each technique can be used to investigate a variety of building solutions proposed.

ii) <u>Coverage</u>

Coverage relates to the area under study. Assessment will be made of how each technique may be used to investigate the visual impact of design solutions from viewpoints within the study area.

Traditional methods eg. artists' impressions usually involve only a limited number of viewing locations: there is a threefold criticism of this approach to visual assessment:

a) investment/return imbalance; in which a great deal of time and effort is expended for the return of only one view of the proposed building.
b) that a single view of a complex development is inadequate to fully explain design intentions.
c) very often view points are chosen to enhance a building's appearance, rather than highlight visual problems.

Full coverage for visual assessment must include appraisal from:

a) Population centres	:	residential/industrial/leisure/ scenic viewpoints etc. no. of people and activity patterns.
b) Transportation networks	:	roads/railways/ferries etc. size and frequency of use.

iii) Environmental Conditions

This section will assess the degree to which each technique might successfully model the effects of climatic, seasonal and diurnal changes on design proposals. This area of visual simulation is specially important in appraisal where visibility may be determined as much by the climate in an area as by the topography or vegetation. The effect of environmental conditions on visibility is extremely complex; (G53) attempts to outline this relationship.

eg. Visibility may be determined by vegetal growth which is controlled by climate through seasonal variations.

It is possible for a building to be hidden or visible through an intervening tree belt as the vegetation alternates between winter transparency and summer opacity; these seasonal variations will also bring colour changes, from lush summer greens to autumn browns, creating ever changing visual environments which the designer must be aware of in order to propose sympathetic or conspicuous solutions, whichever he desires.

In particular, the localised variations of microclimate will directly influence visibility and vegetal growth. Sea or coastal fog is one such cause of visibility reduction. In addition, the topographic configuration of an area may effect the microclimate, resulting in extended periods of vegetal opacity where the vegetation is sheltered from the autumn winds.

The climatological characteristics of the Hunterston area are summarised in Appendix 2.

iv) Context

Context refers to the adaptability of each technique for use in rural or urban situations, and attempts to assess the ease with which it is possible to simulate changes to existing landscape or topographic features,eg. could the technique be used to simulate the effect of a ten year tree planting strategy to screen a development.

Certain techniques are more suited to urban simulations than rural or coastal long range visual assessment. Therefore, distinction will be made between those techniques which assess in detail the appearance of buildings and those which attempt only to appraise general visibility in the study area.

v) Multiple use

A number of the modelling techniques to be studied may have applications outside use in visual assessment. These further capabilities will be identified under the heading 'multiple use'.

3.3.2 Design Value

This section is concerned with identifying the role of each technique as a working tool in the design process. Many traditional methods of visualisation are crammed into the final stages of the design process, eg as final presentation drawings or models. Sketch perspectives may have been the only means of visual appraisal undertaken previous to final presentation. In an urban setting this may be sufficiently accurate to give a reasonable impression; however, in a rural environment the complexity of topography, landscape and building location may lead to inaccurate, probably misleading, early sketch impressions. Ultimately, the usefulness of a technique will be reflected by how much attention is paid to its findings in suggesting alterations and improvements to the design.

3.3.3 Data Acquisition

Data acquisition refers to the collection of all the necessary information required to undertake each technique. The purpose of this heading is to investigate the ease with which this can be done, and how time and cost can militate against the use of certain techniques in the collection of detailed information. Data acquisition is very strongly related to graphical accuracy since the more information one has about a project, the more detailed the technique can be.

This section will also examine the time at which data is required for each technique; for some it may be at the very end of a project, as in the case of a final artist's impression, others may use data generated throughout the course of a project and again others may require data at the very beginning of the project in order to make some critical first level design decisions perhaps concerning location, orientation and scale. The timing of data requirements is indicative of the usefulness of the technique being employed. New methods of visual assessment must be capable of handling both crude design data as well as detailed information in order to maximise application and usefulness.

3.3.4 Accuracy

The principal test of a modelling technique must be its reliability and effectiveness as a tool for predicting future reality. Thus, the more accurate a model:

i) the better chance of achieving design intentions.
ii) more structured solution searching will accrue.
iii) better informed design decisions can be made.

Traditional methods of visual assessment have been the object of heavy criticism in recent years, notably at public inquiries where they tend to lack credibility. A typical example of this may be found in the inquiry held in 1974 for the Torness nuclear power station. (BELL74).

"Productions A7 and A8 (artist's impressions) of the South of Scotland Electricity Board tend to minimise the visual impact of the proposed station. These productions were meant to portray the layout shown on production A2. On site inspection, siting poles were placed on the foreshore to correspond with the buildings on A2. Mr Lobb (the architect) agreed with me (the reporter to the inquiry) that by error the buildings shown on the artist's impressions on A7 and A8 were sited about 100 yards further inland." (BELL74) Paragraph 20, page 60.

And again, in an urban setting:

"Richard Roger's drawings for the Coin Street scheme are 'grossly misleading' according to the Coin Street Action Group which is opposing the Greycoat scheme. On the basis of the drawings the average height of the offices appears to be between nine to 11 storeys. But, claims the action group, the real figure should be at least 13 if not 14 storeys. The drawings, it says, underestimate the bulk of the proposed buildings by 30 per cent." (ARCH79b) p628

These are not isolated cases, as explained by the Royal Fine Art Commission for Scotland.

"A most serious criticism of designers is that much of the illustrative material presented is poor, and therefore can confuse or mislead Planning Committees.....
Reference is made to an Aberdeen presentation in which a highly detailed drawing was 'grossly out of proportion'. The submission for another building, now constructed in Woodside Crescent, Glasgow, caused concern. The scheme was described as 'very ugly' and the presentation considered to be 'worthless' due to inaccurate dimensions on an elevational drawing, and a 'discrepancy in the illustrations of relative building heights'." (PROS83) p4.

This section on accuracy will examine the degree of credibility that can be associated with each technique as regards its capacity to portray a proposed building in two or three dimensions, on paper or through a physical model, in terms of its correct X, Y, Z location, perspective and scale.
Accuracy is a key aspect of visual assessment in so far as designers with no confidence in the graphical fidelity of a modelling technique cannot hope to take meaningful decisions or make clear recommendations. All methods of visual assessment will have some measure of inaccuracy; it is vital, therefore, to have some objective indication of that inaccuracy and the extent of the maximum error incurred when using each technique.

3.3.5 Time

Modelling techniques have different time scales from inception to completion. This can vary from a single day for a sketch to several weeks for a site model of the area.
The time taken for each technique will be assessed under two sections:

i) time for data collection and preparation.

ii) time for simulation eg. the act of drawing a perspective.

3.3.6 Cost

This criterion accounts for the financial investment required by each technique, and assesses the cost effectiveness of each to design practices. Four sub-sections of cost will be appraised:

i) man hours

ii) equipment

iii) materials

iv) running cost (of maintaining availability of technique in design office.)

It will be particularly important to establish the cost effectiveness of the new computer based methods in practice.

3.3.7 Communicability

The success of different visual assessment techniques may be measured by their ability to communicate design intentions to a client or lay audience without misleading or harmful distortions of information.
Often viewing methods give rise to incorrect assessment; these may -

i) incur perspective or other optical distortions.

ii) restrict the horizontal or vertical angle of view.

iii) indicate a misleading scale.

iv) focus interest unduly.

The typical rectangular format of a photograph or drawing can result in a distorted impression of the scene by:

i) emphasising the foreground disproportionately.

ii) reducing the significance of background hills, and distant objects.

The use of a television screen as a viewport for presentation has gained acceptance in recent years, being a readily identifiable format for viewing. Bearing in mind these and other communication factors, it is hoped that this section will establish the problems encountered by each technique in presenting an unbiased view to the public.

3.3.8 Accessibility

In many cases, architectural firms employ the skills of a specialist or consultancy to undertake the work of visual modelling eg. model-makers and perspective artists. This section on accessibility refers to the availability of these specialists to practice, and seeks to identify the skills and equipment necessary to execute each of the five methods in the study. It is not uncommon for practices to have in-house expertise on perspective rendering and certainly the accessibility in this case will contrast quite markedly with access to computer systems for some of the Computer Aided Design (CAD) programs studied in the evaluation.

3.4 Hypotheses

A number of hypotheses were proposed at the outset of the evaluation. These hypotheses fall into two categories, general and performance hypotheses.

3.4.1 General hypothesis

That

i) traditional manual visual modelling techniques such as artist's impressions, are not particularly suited to the current need of rigorous visual analysis, especially in the preliminary stages of design, and that

ii) a move towards computer-based techniques is inevitable to present more comprehensive and objective visual impact appraisals.

3.4.2 Performance hypotheses

That

i) The role of manual visual modelling techniques is one of final design presentation rather than of interim design analysis and appraisal.

ii) Computer-based techniques are more suited to large scale visual assessment; manual techniques are best at solving specific design problems from specific locations.

iii) Perspective drawings are always susceptible to the impressionistic hand of the artist, causing either unknown inaccuracies or, sometimes deliberately prejudiced illustrations.

iv) Investment of time and cost is not necessarily proportional to the quality or quantity of the results achieved in each technique.

v) Communication of design intentions at public inquiries may be improved through the use of more reliable and informative computer-based methods.

vi) The use of computer aided design (CAD) methods for visual impact analysis is often hindered by the uncertainty of program capabilities and application by design practices.

3.5 Sketch Perspectives

3.5.1 Flexibility

Four sketch perspectives of the proposed power station at Hunterston were drawn to indicate initial proposals (G54a)(G55a)(G56a)(G57a).

Coverage

(G58) depicts the position and angle view of each sketch, outlining the visual coverage of the technique. Coverage can be quite extensive using this method, however, this must be weighed against the accuracy and usefulness of information to the ongoing design activity. The locations for perspectives, may, however, only be guessed from the designer's own knowledge of the site and previously identified critical views. Equally, there may be other, as yet unidentified views not included for analysis; there can be no guarantee that all the important viewpoints will be found by site inspection and map reading. The degree of coverage, ie. the number of views, will be predetermined largely by population centres, transportation networks and leisure places in the vicinity. The balance of effort, time and cost to produce the perspectives is favourable; however, it is not likely that this outweighs the need for veracity in the image. The fact that a series of sketches can be produced relatively cheaply is an advantage, if a general impression is only required. The method must be considered flexible in terms of its coverage of the study area. Coverage may be restricted by the need to show landscape features in the scene which can help in the construction of the perspective.

Builtform.

Although sketch perspectives allow a relatively quick method of investigating different designs, their accuracy is suspect. This tends to outweigh the method's ability to apply rigorous appraisal to alternative solutions.

Context.

The context is best modelled using photographs in a photomontage sketch presentation. This is common in townscape studies. The four sketches of the Hunterston proposal depict the context rural landscape in a very stylised manner, likely only to have real significance to the drawer himself.

Environmental Conditions.

Manual sketching techniques can provide some feel for the effect of climate on views of a building. In the case of Hunterston this was not attempted. Clearly, the sensitive use of a drawing pencil can indicate the vagaries of climate. Photomontage sketches remain the best method of modelling environmental conditions.

Multiple use.

The sketch perspective technique cannot be used for other appraisal purposes.

3.5.2 Design value

By the very nature of its appraisal capabilities, sketch perspectives are usually only applied in the early stages of design. As a speedy method of visualisation it is normally used to:

i) give impressions of the visual impact in an area:

ii) assess first order design decisions concerning massing, position and orientation on site.

Although this is a well established technique, its utility in visual assessment is limited. This is due to the fact that sketches are essentially a personal interpretation of a design future. The idiosyncrasies of a drawing prevent objective assessment. Sketch perspectives best contribute to an understanding of the form of development from chosen viewpoints, indicating visibility, the amount of skylining and scale in the landscape. Used in a photomontage mode the technique can depict a high degree of realism.

3.5.3 Data acquisition

The information required consists of three types:

a) Maps of the area to assess impact and visibility and choose view positions.

b) Drawings - Sketch or Outline proposals for the building itself.

c) Set of Photographs from a range of viewpoints.

Very little data is required in addition to information quite likely already gathered for design work. This low level of input data to the modelling technique reflects the degree of accuracy and detail which an be achieved.

3.5.4 Accuracy

Sketch perspectives are not noted as highly accurate renderings. Their function as an early design tool very often results in their being impressions of a designer's aim rather than as part of an accurate visual assessment. Nevertheless, a fair degree of accuracy is required if design objectives are to be realised. A photomontage or sketch based on a photograph can best bring accuracy to the context environment. The success of the designer drawing his proposal in that context will be a function of his skill and understanding of perspective, knowledge of his design, and locational cues in the photographed scene for locating the building sketch properly. To evaluate the accuracy of the four sketches drawn for Hunterston, photographs were taken from similar viewpoints. (G54b)(G56b)(G57b). The view (G55b) no longer exists.

1. View from Millport (G54b)

 # Landscape features (coastline/promintory/hill profile) accurately depicted.

 # The emphasis on edge and line boundaries can be misleading, eg. the pylons to the left of the B station are only faintly visible in the photograph.

 # The location of the building and its profile against the horizon on the photograph and the sketch are in marked contrast.

2. View from Burnfoot, Fairlie. (G55b)

 # This view no longer exists. The BSC terminal obstructs views of the power station from such locations, south of Fairlie. This is a limitation on this technique in that existing views can only be drawn. Trying to predict the view, eg. after earthworks removal is possible, but susceptible to error. Digital methods, ie. computer-based techniques, are equipped to tackle this type of problem more readily than manual perspective methods.

3. View from Gull's Walk. (G56b)

This view has a good degree of accuracy in both the context and building rendering. In comparison with(G54), however, there is a 25% increase in building porportion. This type of discrepancy is certainly not helpful to the design decision process. Even as general impressions the inconsistency between sketches in building delineation, which is at the heart of worthwhile visual modelling, proves that significant degrees of error can arise in sketching techniques.

4. View from Moor Road to Dalry. (G57b)

This view appears to be the most accurate of the four. The existing landscape, and power station location are well matched.

In summary, the technique is only suited to illustrate a concept, not reality.

3.5.5 Time

The sequence of producing a series of sketch perspectives can take from two days to a full week. The time scale is dependent on a number of factors:

- building complexity
- level of detail and accuracy required in the sketches
- photographic processing (if photomontaging the sketches).

The activities time scale for the Hunterston sketches was:

i)	Familiarisation with site and design/ selection of critical views of development.	- already developed in early design stages.
ii)	Photographs/drawings taken from views.	- 1 day
iii)	Photographic processing	- 1 day (Outside office processing; colour would be longer.)
iv)	Sketches of proposed development.	- 1 day

The time taken for sketch perspectives can be considered to take two to three days, certainly no more than one week. (CART79)

3.5.6 Cost

In the main, cost will vary according to the level of sketch detail and whether photomontage presentation is undertaken. Following through the average time scale of activities outlined under the heading 'time':

2 office man days (architectural assistant)	£50
photographic costs	£25

This estimate of £75 for the four Hunterston sketches is reflected in the low quality results and performance of the drawings as a design aid. (CART79)

3.5.7 Communicability

This technique is not particularly suited to presenting proposed designs to lay audiences. Sketches are impressionistic and can only aim to depict an individual's perception of a design. In general, therefore, sketch perspectives are undertaken primarily as an aid to the architect and not necessarily as a presentation technique. How much they aid the architect in design is open to question, particularly since the accuracy obtainable is well below that required for decision making and sensitivity analysis.

3.5.8 Accessibility

Usually this method of visualisation is conducted in-house, with an assistant undertaking the photography and sketching. No specialist skills are required, and again this may reflect the low level of rigorous investigation.

3.6 Artists' Impressions.

Nowadays, most finished presentation perspectives are based on a site photograph of the existing view with the proposed development positioned in the scene. This can be achieved by two means.

Firstly, a perspective rendering of the building and its context; or, secondly, a photomontage presentation, in which a building may be drawn on to a site photograph. The second method offers more realism and accuracy and is, therefore, frequently favoured. In the case of Hunterston, two fully rendered perspectives were commissioned: these were compared with the existing views (G59)(G60).

3.6.1 Flexibility

Coverage

(G61) indicates the visual coverage of the impressions. As with sketch perspectives, this method lacks an initial procedure for locating the critical viewpoints other than on site inspection. Viewing positions are usually preselected to dispel specific objections or to enhance the visual appearance of a building in its setting. The technique is rightly considered as a presentation tool in the final stages of design, though it is often used in an investigatory role during design. Coverage is severely restricted; major demands of time and finance being required for each individual view. This may be justified for certain views regarded as important; however, in cases where there is likely to be a number of critical viewpoints for assessment the application of a perspective rendering technique would be both expensive and time consuming.

Builtform.

As a technique for presenting a final design, an artist's impression is not normally a medium for builtform solution searching and testing. The time taken to set up new perspectives of alternative designs in different site locations from various viewpoints is a laborious process and clearly demonstrates the traditional method of manual perspective drawing to be unsuited to the pressures and demands of rigorous design appraisal.

Context.

The use of photomontaging techniques can guarantee an accurate portrayal of the context or setting of a development. This will have significant savings in time and cost. Landscape alterations are difficult, though not impossible, to simulate and assess with veracity; this is particularly noticeable in open landscapes where there are likely to be few known features that might act as cues for setting up a perspective.

Environmental Conditions.

Unless using photomontaging methods, artists' impressions very rarely recapture the typical weather conditions which a site may experience. In the two views, (G59a) and(G60a), the sky has been drawn in such a manner as to heighten the drama of the building in its setting. This is a common feature in perspective rendering and can influence the way in which the building is perceived. The use of a series of site photographs taken in a range of weather conditions is critical to productive visual assessment of the effects of climate on perception.

Multiple Use.

Artists' impressions may be used for colour studies and the appraisal of detailed design features; however, it is regrettable that the vast and highly skilled resources of labour devoted to each view cannot also be tapped for other purposes.

3.6.2 Design value

Detailed artists' impressions are usually commissioned towards the end of the design process, allowing little or no feedback to the designer to effect changes on the drawingboard. This is not always true; some firms of designers can work closely with a perspective artist during the design process, modifying details and design as a result of the impressions drawn. More typically the technique is used at the tail end of the design stages and as such plays little significance as an investigative or explorative design analysis and appraisal tool.

3.6.3 Data acquisition

The data required for an artist to produce a rendering can vary from very scant outline proposals to detailed scale drawings by architects. Typically, an artist might require:

scale drawings of the design proposal.

locational site plan indicating landscape proposals.

photographs of the site from known viewpoints.

This type of information is readily accessible in the course of any project.

3.6.4 Accuracy

Many perspective illustrators seek high degrees of fidelity in their work. Nevertheless, there is always the possibility of human error occurring in view generation. This is an unquantifiable inaccuracy, and has frequently raised the suspicions and doubts of planning committees and inquiries. (BELL74)(ARCH79b)(MAYC83).

A common source of error in perspective drawing is the location of the development in the landscape, its positional accuracy. The major effort in constructing a perspective lies in the placing of the development structure in its correct relationship with the context environment. Using analogue models difficulties arise in accounting for earth's curvature and light refraction, which displace the perceived location of an object in the scene. This can be a problem with perspective drawings taken over distances of two miles. The site relationship of buildings is, therefore, often suspect and, on occasions, exacerbated by the lack of positional cues to determine the planimetric location in a scene. Equally questionable is the internal massing of the development drawn in perspective. Examples abound in which building rooflines, features or scale are misrepresented in impressions; sometimes on the order of the developer, client or architect (PROS83) p4. This interference is often the source of suspicion. Every impression, however, by definition contains a great deal of personal interpretation; what may not be translated to suit personal whims is the objective location and form of a development in its setting.

Comparing the two impressions of the 'B' station at Hunterston with the corresponding site photographs after construction, the most notable feature is the playing down of the background hill scenery to heighten the drama of the buildings in front. (G59)(G60). Neither perspective indicates the proper relationship between building and context, depicting a quite different view from that of reality and providing decision makers with a very misleading impression.

3.6.5 Time

The time required for each drawing will be determined by the size of the drawing, ie. A4 or A1, and the detail to be included. The Hunterston perspectives took about 20 hrs each to complete, and the perspective artist worked uninterrupted on the renderings. Two thirds of the time taken for each perspective is spent in setting up the correct viewpoint and view direction. Several rough set ups may have to be made to obtain the desired view. This is one notable area in which computer based perspective programs are an advantage over manual methods. Very many views of the proposed building can be generated by the computer and save time in the perspective setting up process. This saving, though, is not without its drawbacks, in that an illustrator 'coming cold' to a line perspective drawn by a computer, may not be fully aware of the interplay of the building surfaces and form; time may be lost in coming to terms with these relationships to effect an accurate rendering, which in the manual process would only constitute one third of the time spent.

3.6.6 Cost

The use of photomontage methods can result in substantial cost savings, since the environs of the building are captured photographically. Full renderings, like the Hunterston impressions, are costlier. There are a number of variables which determine the cost of perspective illustrations; these factors qualify the normal pricing system of £/square inch.

Cost variables.

a) Medium (water colour/ink/pencil)
b) Existing features or cues in the scene to facilitate the perspective construction.
c) Size of perspective. A1/A4
d) View position. (ground level or aerial view: cost increase of 50% for aerial views due to greater drawing complexity)
e) Complexity of building design
f) Level of detail required in perspective.
g) Amount of foreground/sky/building detail in the view.

In addition to the £/square inch costing mechanism, professional architectural illustrators may use an hourly rate of pricing: this is currently set at about £15. Using this system the Hunterston perspectives, at current prices, would cost £300 each. Those commissioning an artist would be buying skill and reputation, therefore, the figure of £300 may vary widely depending on the illustrator. Clearly a client's available finance will dictate whether a perspective is to be undertaken in the latter stages of design. More important matters such as the granting of planning permission may determine the early use of this technique in the design process, regardless of cost.

3.6.7 Communicability

The communication of design intentions through artists' impressions is hindered primarily by the fact that the impressions are idiosyncratic. As a personal interpretation,therefore,certain features can be highlighted or played down often distorting the real impact on a scene. Perspective drawings often emphasise the best qualities of a design and minimise those which may take away from its appearance. It is not surprising that many impressions are called into question at inquiries in which lay committees find drawings misrepresentative of design proposals. Artists' impressions must be regarded only as an individual's perception of a design in terms of the atmosphere and feeling of the scene depicted. The underlying objective location of the development in the view, so often a source of doubt and criticism at inquiries, is not open to personal interpretation.

While a perspective drawing may engender a better understanding of design intentions, several views may be required adequately to explain the proposal. Such views may have one of two common objectives; to allay fears of unsightliness or to generate enthusiasm for a design. These are emotional goals and show the application of the technique to be distinct from objective visual appraisal. Every artist, as a creator, has something inside which demands expression. It is not uncommon for this to filter through in a perspective rendering. The finished product must be accepted and interpreted, therefore, as only one personal impression of the proposal. Sometimes a strong personal interpretation can be an aid to imagining the future design reality, however, more often than not an impression can be specious.

3.6.8 Accessibility

Perspective illustrating is a highly skilled service and normally operates on a consultancy basis, though some design practices may have in-house expertise. There are around fifteen consultant architectural illustrators in Scotland and these may be readily commissioned for work. Numerous other illustrators advertise in the national building design press.

3.7 Physical Scale Models

The importance of physical scale models to the process of design is unquestionable (LANG78). In practice, model building has led to many innovative design solutions. Quite often site models, also showing the surrounding landscape, are constructed for the purpose of visualisation. This application of modelling alone is under criticism here. The site model used for the Hunterston power station project was assessed (G62). Two views of the model were compared with reality (G63) and (G64).

3.7.1 Flexibility

Coverage

The visual coverage obtained from a site model is concentrated within a small area containing the development. At Hunterston the need for detail on the model building increased the model scale in turn reducing the area which could be realistically modelled. Any view may be taken from within the model; however, it is impossible accurately to simulate views from locations outside the land area modelled. (G65) outlines the area covered by the site model at Hunterston. In general, it is extremely difficult to conduct long range (ie. over one mile) visual analysis studies with any assurance of detailed accuracy. The cost and physical inconvenience of modelling large areas of land prohibits complete coverage for visual assessment.

Builtform

In terms of built form, a physical model is ideally suited to simulating the varying effects of different designs on the site. Only the building model need be built and placed in the modelled context environment.

Environmental Conditions

To simulate the effect of climate when viewing the model a number of

methods may be employed.
variations in lighting levels.
different backcloths of sky or land forms.
the use of smoke effects eg. to model reduced visibility in fog.

Context.

The opportunity of studying various options to change the landscape or vegetation around a site is possible on a small scale; if, however, large scale earthworks removal is intended, its effect on views as simulated in the model may require further model building independent of the existing site model.

Multiple use.

There are a variety of other uses to which small scale physical models may be applied:
lighting studies
wind tunnel experiments.
landscale design.
heliodon experiments for shadow analysis.
photogrammetric plottings can be taken off models to calculate cut and fill. (CLOU76).

3.7.2 Design value

Distinction may be made between models built for presentation purposes and working models used throughout the design process. Most models used in visual analysis work will encompass a large area of land; this may be modelled early in the design process and used during design development and as a presentation model. To this may be added working models of the building or development on its own. This pattern is typical of many projects, eg. the design for a power station at Torness by the South of Scotland Eleectricity Board. In this case the same landscape model was used over a seven year design period. Using models in this manner demonstrates their potential as a flexible and highly valued design tool. In many cases, though, architectural scale models are built subsequent to design decisions. This merely assures designers that correct visual evaluations have been made and supplies the client with a prestigious model to exhibit, perhaps in the entrance foyer of his building. This cosmetic approach to model building is of little value to rigorous appraisal and design feedback.

3.7.3 Data acquisition

The data required for model building is no more complicated than that which would normally exist in the course of a project.

O.S. contour and land use maps of the study area.

landscape and building proposal drawings.

3.7.4 Accuracy

Varying degrees of accuracy can be achieved depending on the cost and scale of a model. While a small scale model would best suit the needs of coverage of a large area, the accuracy of the model would be suspect. To use such a model in visual analysis work would be inappropriate; such viewing correction factors as earth's curvature and light refraction cannot be simulated in analogue models. The accuracy of small scale models is further deteriorated by human errors in the manufacturing of model parts, eg. an error of 1mm in manual cutting at a scale of 1:5000 represents a scaled error of 5m in reality. This level of modelling accuracy is not appropriate to veracious visual assessment. In topographic model building the vertical scale is frequently increased, sometimes by a factor of two; this avoids a flat appearance of the model, and eases the task of contour building. Clearly, such activities would be foreign to model building for visual impact studies, but only at the risk of incurring extra cost (JEFF80). Small scale models for visual assessment work are often incapable of simulating landscape features to any degree of acceptable precision. For example, the two comparative views (G63) and (G64) patently demonstrate the inaccurate modelling of tree cover.

Model accuracy may, therefore, be linked directly with cost and scale of building.

3.7.5 Time

The type of model which might be used for visual assessment studies would take 4 to 6 man weeks to build. This may be constructed in-house by a firm of designers, or, more typically, sub contracted to a model making firm, many of which advertise in the architectural and building press.

The Hunterston model was constructed in 5 man weeks by a firm of professional modelmakers.

3.7.6 Cost

Using a professional modelmaking service, model prices range from £1,000 (block models) to £10,000 (detailed site and building model). On average models prices would be £3,000. In the case of models required for visual studies the cost may be as much as £6,000 (JEFF80). The cost is divided two ways; 25% for materials and 75% for labour. The Hunterston model was costed at £4,000 (current prices).

3.7.7 Communicability

Traditionally, physical scale models have been a helpful and readily accepted method of design presentation to decision makers on committees or at public inquiries. Such models attempt to indicate the appearance of the building in its setting or to explain a design concept with the hope of eliciting a critical response from both designers and lay persons. This is particularly necessary where visual design problems are complex and paper based appraisal methods are inadequate in comprehensive assessment. With a physical model, an observer may adopt any viewing angle around the interest building and in any desired sequence of movement and time. Formal spatial and temporal appraisal in this manner is a key advantage of this technique, and certainly fundamental to architectural experience and criticism. The result of such an approach will permit a realistic assessment of proposals.

In general, views of a model tend to be 'bird's eye' or aerial views, the observer being unable to imagine a view from a certain location within the model. This is frequently referred to as the 'Gulliver gap' and may be overcome by the use of a modelscope, which is a miniature lens mounted at the end of a periscope-like camera attachment (G66). The modelscope scales down the observer's field of view and may be positioned at ground level in the model to simulate more realistic terrestrial views. Simulations using a modelscope may be captured either on still photographs or on video. The most successful modelscope simulations have been carried out at the Berkeley Environmental Simulation Laboratory, California University (BURE80) p. 20; simulation of movement through a model is possible with a modelscope suspended from an overhead gantry and thereby manipulated at the command of the observer (G67). Such methods of viewing scale models increase communicability, and, if sufficient quality and accuracy can be achieved,are to be recommended as a helpful method of visual assessment.

3.7.8 Accessibility

Modelbuilding is a readily accessible professional service, ranging from small two-man businesses to large firms with, typically a team of up to twenty modelmakers.

In practice, design offices will prefer to build models in-house; however, high quality presentation models are more likely to be sub-contracted to a professional modelmaker. The task of building a scale model is very labour intensive, and the larger firms are, therefore,better equipped to compete for work.

3.8 BIBLE Perspectives

3.8.1 Flexibility

Coverage

Five views of Hunterston were generated from varying positions around the study area using BIBLE. Once the data of the interest object has been digitized into the computer's memory, there is a high degree of viewing flexibility. Almost any view may be generated. (G68) shows the coverage of the five chosen views; further perspectives could be added without significant increases in time. Indeed, CAD methods for visualisation are more applicable than manual methods when large numbers of development views are required. This is due to the fact that the main effort in the CAD procedure is data preparation, and the time-consuming task of setting up perspectives is devolved to the computer.

Builtform.

There is a high degree of flexibility in the testing of alternative builtform proposals. Many levels of building detail may be modelled to suit needs at a particular stage in design; for example, sketch models can be compiled using under ten shapes (about 30 mins. to input data) or more detailed models of up to 100 shapes (about one day to input) (G69). The use of Form Generators, primitive shapes, which can be scaled, rotated and translated to construct data files, releasing the user from the tedium of alphanumeric entry, have made data input to BIBLE an easier task. Consequently, there is more incentive to test other built form solutions, which in the past would have been too uneconomic and time consuming to attempt.

Context

The program BIBLE principally addresses the problem of builtform modelling The photomontage feature permits context modelling (land form and vegetation) which can be provided external to the program, by photography. Nevertheless,some progress has been made over the past six months to model context features. This was first attempted by the author in 1979 for quantitative studies rather than qualitative assessment, eg. to what degree do trees or earth moving operations interfere with visibility? (G70). Again the use of Form Generators for landscape elements, eg. trees, with options to investigate alternative species/growth rates/seasonal foliage cover offers high flexibility in assessing the effect of context changes on the visibility of a development proposal.

Environmental Conditions.

The monochromatic display output from BIBLE does not allow the appraisal ofclimatic effects on visibility. Indeed, in many CAD photomontages,where an object is viewed over a large distance, the hard lines of the computer image militate against reading the object in its proper location, since one would expect to see softer lines and surfaces as atmospheric perspective modifies the image. This is a draw-back to the CAD approach to visualisation. Frequently, hand crafted methods of montaging are adopted to construct an understandable simulation.

Multiple use.

One of the main features of modelling the geometry of a building by computer is that the data may be employed on a number of disparate appraisal tasks. In the case of BIBLE, the base geometry can be used by other ABACUS programs to investigate;

: energy performance (ESP)

: functional layout, cost etc. (GOAL)

: colour visualisation (VISTA)

If a CAD approach to visual assessment were intended, therefore, it would be timely to consider the other spin-offs in terms of computer-based building appraisal offered by the existence of a common building geometry data base.

3.8.2 Design value

The flexibility inherent in the CAD approach is best seen in the varied application of computer based models to all levels of the design process. There is flexibility in the level of building detail, and simulation options to allow sketch appraisal or rigorous assessment of a final design. Additionally, since the program can be operated interactively there exists a healthy interface between designer and machine as feedback stimulates interrogation and development of design ideas. The applicability of a program such as BIBLE to the ongoing process of design is a feature which can directly satisfy the requisite of comprehensive and accurate solution searching and testing in visual assessment.

3.8.3 Data acquisition

The data required to form geometry data files for computer processing is no more complex than that used in traditional methods of visual assessment. Typically, a user of the BIBLE program would base the computer model and viewing parameters on information taken from:

- : scaled orthographic projections of the building.
- : maps of the building and viewing locations, showing XYZ co-ordinates.
- : site photographs for montaging.

3.8.4 Accuracy

A detailed computer model of the 'B' power station at Hunterston was constructed and five views generated from known locations. The output plots were compared with the actual site views by means of overlays (G71) to (G75). Using this early version of the program a number of the views did not match exactly. This was due to the difficulty in establishing the correct enlargement factor; inconsistent calibration of the camera lens viewcone with that stored by the computer logic in BIBLE (similar sized lenses, eg. 50mm, manufactured by different companies have different viewcone angles); omission of algorithms to correct the perspectives at viewing distances over two miles. These points will be taken up again in section 4.4 in which a highly controlled case study using BIBLE is described. A further view, taken closer to the building and with lines in a more incised perspective, was compared and recorded on video (APPENDIX 5).

Using a computer-based method for visualisation eliminates human errors, however accidental, which occur in perspective drawing. The accuracy of the computer image is, therefore, a function of the fidelity of the survey information for the building location and viewpoint, and of the scale drawings of the development.

3.8.5 Time

By far the largest amount of time in undertaking a CAD visualisation is devoted to data preparation. This can range from as little as 30 minutes to 1 full day depending on the complexity of the object being modelled. The Hunterston data set took one day to compile; each perspective view was generated at 10 minute intervals. These times relate to an experienced user of the program operating interactively on a mainframe computer system. Further presentation time may be necessary to mount the montage on card.

3.8.6 Cost

Cost varies with building complexity and context,ie. rural or urbanscape. A costing procedure for the Hunterston perspectives is outlines;

Data preparation :	labour	£75
	computing costs	£25
View generation	labour	£5 per view
	computing costs	£1 per view
	materials	£4 per view
		£10 per view

The computing side of BIBLE montaging would cost £150 for five views. An increased number of views would capitalise on the initial data investment. To the cost of £150 must be added photographic expenses; these may result in a final figure for CAD perspective montaging of £250 for 5 views. These costs are based on a bureau service, as operated by ABACUS; in house computing facilities and overheads may significantly increase this cost to design practices.

3.8.7 Communicability

The BIBLE montage, formed by acetate overlays of the building placed on corresponding site views, allows improved visual assessment. More often than not a qualitative judgement is required at an inquiry. In such cases the use of a perspective artist to 'add some flesh' to the bones of a wire line computer perspective is essential. The communication of the design idea can be improved, without positional distortion of the image as an artist sketches up from the base computer drawing.

CAD methods which have a proven track record in applications are now being accepted by planning committees at inquiries, particularly on account of the completeness and accuracy of the visual study (TURN83). The time will shortly be coming when computer terminals will take their place at inquiries, and proponents and objectors to schemes will have the opportunity of on the spot assessment as they interact with the computer.

3.8.8 Accessibility.

At present, ABACUS operates a consultancy service with the program BIBLE to design practices. This remains the most common uptake of CAD visualisation, although the program may be bought for £2,000 to operate on a mini or mainframe computer. There are many other visualisation programs available in Britain, however, none has been used with such rigour as BIBLE in visual impact assessments.

3.9 VIEW Visibility Studies

3.9.1 Flexibility

Coverage

A digital terrain model of the Hunterston area was constructed; its coverage is indicated in (G76). Any simulated appraisal using VIEW will, naturally, assess every point in the data set as defined by the viewing window. Typically, there is 360^0 coverage from any observation point.

The establishment of terrain model boundaries is often a complex task. The ability to perceive mentally where landform will no longer affect the visibility or backcloth of a proposed development only comes with experience and even then may be suspect. One method in tackling this problem also demonstrates the flexibility of the DTM approach to visual analysis.

In the early stages of design the DTM may be used on a large area, say $200Km^2$, with a grid size of 250m. Initiating the VIEW programs on this data set, the designer may appreciate general visibility in the district, and partition off a subset of the original matrix for more detailed appraisal. This sub-matrix may cover an area of, say $40Km^2$, with a grid size of 100m. Again VIEW may give an understanding of the local area visibility, and suggest detailed means to reduce or heighten this. A further sub-division may be made to produce a site terrain model with a grid size of 25m. This may be used for drainage, earthworks, road/path alignment or the effect of landscaping (trees and earth mounding) on intra site visibility. We may conclude that boundary establishment for DTMs depends largely on its design application.

Coverage, of course, is not complete without mention of the viewpoint flexibility. VIEW may operate on any user defined viewpoint: inside or outside the data set; at ground level or at any height to simulate the top of a building, chimney or pylon. In addition, new views which may come into being after large scale earth removal can be simulated readily.

The concept of viewing out from the site rather than towards it (G37) addresses the need for a more comprehensive visual coverage of a study area, and comes closer to the heart of visual impact assessment; that designers should be concerned with the impact of a building on an area rather than the impact perceived from a chosen single viewpoint.

Builtform.

Building and other engineering structures are modelled in VIEW by a user specified height addition to a grid intersection point. The location of the building may, therefore, be around half a grid cell size out of position. From experience, this problem does not significantly interfere with the accuracy of visibility calculations. Object displacement from true location to grid cell intersection is taken up again in Chapter 4. A very wide range of building heights, breadths and site locations may be examined using VIEW and often visual objectives can be achieved as a result of rigorous assessment of building options from an early stage. In the past, limitations on time restricted wide ranging synthesis and appraisal of proposals. VIEW lifts that restriction and, additionally, feeds the designer with evaluations which are likely to cause more orderly and informed stages of design development in order to achieve creative design objectives.

Context

There is a high flexibility in VIEW with respect to the modelling of landform and vegetation. In the case of landform, two data sets are frequently compiled; an existing and a proposed model. These may be used to compare before and after views of the landscape (using PERSPX); to compute the need for, or removal of, earthworks to or from the site; and to assess the effect of landscape proposals on site visibility. Additionally, the effect of tree growth over future years may be simulated; account can be taken for various species and their growth patterns.

Environmental Conditions.

The modelling of climatic effects in VIEW is minimal. The output from the program is concerned principally with whether an object is visible or not and whether it has backcloth. The quality of that visibility as affected by climate is not under examination. There is, however, one method of modelling an aspect of climatic interference on visibility. By bounding the range of the radial searching distance from the observer location in VIEW it is possible to model the restrictive viewing which would occur in fog, mist or precipitation. Otherwise, the program has no call to simulate the qualitative effects of climate on views.

Multiple use.

Many of the other(non visual)applications of terrain modelling have been outlined in 3.2.2. These afford an attractive multiple-use feature to the designer, and may be of use in the longer term, after construction, in landscape management.

3.9.2 Design value

An early decision to use a DTM and land use appraisal package in a project is vital to cost effective use of computers and maximum efficiency in designer feedback. The way in which VIEW is structured is most applicable to gradual detailed appraisal throughout the design sequence. Large scale analysis (grid size 250m) may be undertaken to establish the critical boundaries of visibility and appreciate the scale of the visual problem, ie. how visually absorptive is the landscape context? More detailed appraisal, centred on specific sites with specific proposals can then be assessed as design proposals begin to emerge. Still further detailed evaluation can be conducted on a specific site for a specific proposal. Continued use of a program such as VIEW during design has been proven to elicit more reasoned and speedier decision making and to indicate to the designer the most rewarding line of investigation in achieving design objectives.

3.9.3 Data acquisition

There are a number of methods of acquiring data for VIEW processing. Field surveys, using theodolites, may be discounted due to the scale of the data required. Others may be classified:

i) Manual interpolation of spot heights or contours from maps. This data requires to be keyed in alphanumerically at a computer terminal as X, Y and Z co-ordinates, or as a string of Z co-ordinates at a prespecified planimetric interval.

ii) Semi-automated digitizing process for contours or spot heights. A digitizing puck or pen is manually positioned at significant points on a map. A foot-pedal control prompts the recording of the X and Y co-ordinate and the Z value is keyed into the computer's memory at a terminal.

Both these methods are labour intensive and prone to error in typing values at a keyboard. Differing map scales (metric and imperial) can further complicate the task of data capture, while outdated O.S. maps may produce inappropriate topographic or land use data for visual assessment. These problems can largely be overcome by automatic procedures of data acquisition.

iii) Raster scanning of a map by a digital camera. The resultant image requires feature encoding for contour lines and land use data (raster to vector format conversion of data).

iv) Automatic photogrammetric interpolation. Data is recorded on digital tape by photogrammetrically tracking along the contour lines or land use areas as modelled by stereo pair aerial photographs. Such a system has been devised by Prof. G. Petrie at the Univesity of Glasgow's Topographic Science Unit (PETR80). The conversion of the data captured into a format that is compatible with other applications programs has not yet been developed, though this process would clearly speed up data acquisition for VIEW.

v) Laser-Scan, FASTRAK automatic line following digitising system. Combining the best features of manual digitizing systems and raster scan methods, this interactive system uses a laser beam probe,steered at high speed and with very good resolution, to gather data from an enlarged photographic negative or an original map. Although the hardware is prohibitively expensive outside research, government and large mapping organisations, a bureau service is in operation at a reasonable cost (HOWM82).

vi) Existing digital information. In recent years the Ordnance Survey in Britain has been engaged in data capture for computing applications. Digital map data on magnetic tape is becoming increasingly available for land areas in Britain, and may, in time, provide a national topographic data base.cf Sweden (OTTO78).

vii) Remote sensing, LANDSAT. Data gathered from satellite sensors is on a scale and accuracy inappropriate to visual assessment.

Although these techniques are finding widespread application in a number of fields, the problem of converting contour digital data to gridded data, operational on the VIEW programs, has not yet been addressed. The current method for data preparation in VIEW is described in ii) above. Errors occur in map interpolation and input typing; these must be corrected to ensure the validity of subsequent analysis and appraisal based on the data set constructed.
Data requirements for VIEW processing include:

: O.S. maps of study area.
: Stereo pair aerial photographs. (for detailed land use assessment).

Clearly, there are no extra demands for information using VIEW than any other technique might require.

Two crucial decisions remain to be taken before data collection can start:

i) the boundaries of the data base

ii) the grid size interval.

These may be determined largely by the reasons for modelling, ie. the area of interest and degree of accuracy in the results. Data for Hunterston was gathered on a 100m grid size.

This resulted in:

i) considerable loss of time and effort in digitizing highly redundant points in large flat areas of ground. A variable grid size, matching terrain roughness, would be advantageous in speeding up the input process.

ii) inaccurate modelling of land use patterns (less than 100m x 100m) especially when height additions are involved, eg. trees and buildings. This will be taken up again in 4.4.2.

To speed up the process of data set construction, the author compiled a small computer program, written in Fortran, to read free format data input and convert it to a format readily processed by VIEW. The program algorithm flow chart is described in (G77).

3.9.4 Accuracy

No map is without errors. It seems reasonable, therefore, to assume that there are errors in the terrain model used in VIEW, both map based and interpolation/keyboard errors. In traditional methods of visual assessment the magnitude of the error is difficult to establish. The VIEW process, in contrast, allows the inaccuracies to be quantified. The purpose of this part of the study was to discover the veracity of the VIEW output. In the Hunterston terrain model it was felt that grid coarseness was likely to distort the visibility results.

To test this hypothesis, five viewpoints were selected within the elevation data set for comparison with actual views. The five locations, none of which fell exactly on a grid cell intersection, were checked on site for visibility of the power station. The nearest grid cell intersections in the elevation matrix to the viewpoints were tested in the program VIEW2 for corresponding visibility of the power station. The results are plotted in (G78) to (G82). The VIEW2 visibility predictions correspond exactly to the actual on site views. This study was closely followed by a similar verification of VIEW2 by Design Innovations Research for the South of Scotland Electricity Board (AYLW79). In this case the interest object was a large radio mast at Blackcastle Hill, near Torness in East Lothian. 93% of the sample observations on site matched the VIEW2 output.

Provided an appropriate grid size is chosen, there is little evidence to suggest that inaccuracies will be any higher when it appears that the grid orientation is in conflict with the landform orientation, ie. when valleys or coastlines run at 45^0 across the grid orientation the accuracy of the DTM is no less than if the valleys or coasts ran horizontally or vertically with the grid.

Localised topographic variations are often the source of discrepancies between VIEW2 calculations and actual on site observations of visibility. (G83) demonstrates the inconsistency of DTMs with real topography in such cases. Clearly grid size selection must be made with care. There are procedures to overcome this problem; highly advanced terrain modelling makes use of continuous grid size adjustment algorithms to match grid point density to terrain roughness or variability (MAKA73). This is not an option in VIEW, and it is doubtful if this extra flexibility in more accurate terrain modelling would cause significant improvements in visibility calculations: the use of a regular square grid cell has two inherent advantages; those of convenient programming and machine storage.

On site verification of visibility does not indicate the degrees of error which a user may expect from the VIEW program. A more objective appraisal of accuracy was undertaken. The study aimed to investigate the relationship between the grid size of digital terrain models and the resulting error in the calculated height of any point within the data set, whether on grid intersection points or not. The graphs produced from the results are therefore a measure of the sensitivity of digital terrain models to localised topographic variations.

The need to relate terrain accuracy to object/building accuracy is essential in visual impact studies; particularly in complex terrains where it may be difficult to form a good impression of the most suitable grid size to achieve a satisfactory level of accuracy in the object visibility results. Two hypotheses were made and tests carried out to unearth this relationship; these are described later.

Sampling

Three methods to assess terrain model fidelity were considered:

i) comparison of real and modelled point elevation values (spot heights and Bench Marks from O.S. maps).
ii) comparison of 2-d sections through land, based on modelled terrain and O.S. map contours.
iii) comparison of earthworks cut/fill calculations.

Method ii) was rejected on the grounds of contour inaccuracies (a point on a contour map may be elevationally inaccurate by up to one quarter of the contour interval (HARL75) p167), and, in any case, the DTM is largely derived from the contour map. Any discrepancies based on this method are likely to describe interpolation skills. Method iii) was also dismissed; the data sets which would have made this a feasible technique were not sufficiently varied, most occurring below a grid size of 10 metres.

Method i) was elected and 160 sample points were gathered for analysis. Four points were regarded as spurious data; these data occurred on unnatural landscape features; an environmental hill, a causeway, a railway embankment and a road/building cutting. (G84) outlines some of the problems. The breakdown of the remaining 156 points was as follows;

Points	Accuracy
109 spot height	±30cms. (HARL75) p166
13 known Bench Marks	±3 cms (HARL75) p165,(BRAN72)p14.
34 unknown Bench Marks	±1 metre

The 34 unknown Bench Marks were due to building demolition, road realignment or obliteration of mark. Although the exact plan location was known it was impossible to determine on site the height of the Bench Mark above ground level. The resulting inaccuracy was in the order of ± 1 metre. Thus it was decided to discard the 34 unknown Bench Marks in the analysis.

The remaining 122 points represented a sample of 3.0371%, 4017 data points having been interpolated manually when the 75 x 75 (5625 points) data set was created. (The remaining 1608 points occurred at sea level, ie. value 0m.) The 3% sample was widely spread over the study area, though principally restricted to roads and paths.

Program DIGERR

Use was made of the program DIGERR to analyse the real and interpolated points. DIGERR input requirements for any point include: (G85)

a) The actual elevation value of the spot height.
b) The elevation value at point A
c) The elevation value at point B
d) The elevation value at point C
e) The elevation value at point D
f) The horizontal distance, DIST1, from the left hand boundary of the grid cell to the spot height.
g) The vertical distance, DIST2, from the upper boundary of the grid cell to the spot height.

Interpolating from points A,B,C,D the program calculates, for each spot height DIST1 and DIST2 from the top left corner of each grid cell, the elevation value of the spot height in the digital terrain model. This is subsequently compared with the actual height and the difference is printed out, together with statistical analyses of all the sample points.

Data Files

Four data files were compiled to investigate accuracy at four grid size intervals, 100m, 200m, 300m and 400m (PURD80a).

Hypothesis 1

<u>The graph describing the relationship between grid size and elevational error is ogival in shape.</u>
Thus the graph contains two tail off points; one at the lower end of the graph where increasingly smaller grid sizes will not significantly reduce error; and another at the higher end of the graph where increasingly larger grid sizes will not significantly increase the error (G86).

Hypothesis 1 - Testing and Correlation

The results of the DIGERR program for each of the four data files is shown in (G87) and graphed in (G88). The bivariate data in (G88) were analysed using a least-square polynomial line equation program to establish trends in the graph. This proved unsuccessful, and a linear regression program was applied to the data to establish the best fitting straight line through the data. The correlation coefficient, a measure of line/data fit was discovered to be very high;

$$\text{correlation coefficient} = r = \frac{\sum_{1-n} X_i Y_i - n\bar{X}\bar{Y}}{\sqrt[2]{\left(\sum_{1-n}(X_i-\bar{X})^2 \sum_{1-n}(Y_i-\bar{Y})^2\right)}}$$

$$= 0{\cdot}9873$$

where X_i = grid size

y_i = average elevational error

n = no.of points graphed

$$\bar{x} = \frac{1}{n}\sum_{1-n} x_i$$

$$\bar{y} = \frac{1}{n}\sum_{1-n} y_i$$

The data is, therefore positively correlated, with a high correlation coefficient, and a regression line of equation $y = 0.0375 + 0.0133\ x$ or: Average elevational error = 0.0375 + (0.0133 grid size).

Hypothesis 1 - Conclusions.

The relationship tends to suggest a linear regression, not ogival as hypothesised. Although only four points were plotted, and this may be considered too few to draw any particular conclusions, when further points were added during hypothesis 2, the graph maintained its straight line feature.

Hypothesis 2.

The straight line graph which maps grid size to elevational error has different degrees of slope which correspond to different types of terrain.

The graph will have a steeper angle for rough highland terrain where elevational error increases more rapidly with coarser grid sizes; smooth lowland landscapes will have a shallower sloping graph angle since coarse grids will still be able to model the terrain fairly accurately. (G89) is a hypothesised graph. This hypothesis was based on the findings of Imhof (IMHO65), in which steeper terrains were discovered to have a higher average altitude error than flat ground, all other factors being equal (G90).

Some of the phrases used already to describe ground variations require the yardstick of a terrain classification system. No one parameter can measure ground surface form or relief. A host of systems for classifying landform have, therefore, been devised. Makarovic classifies them : (MAKA76) p58.

i) Qualitative. : Coastal/lower slope forms/lowland terrain/steep scree/highland terrain/summit terrain.

: flat/undulating/mountainous (AYEN76)

ii) Quantitative. : 3d slope direction

- gradient: the rate of change of altitude along a slope line, and measured at any one point as the maximum inclination to the horizontal in degrees. (EVAN72) p37.

- aspect: the horizontal direction of movement down a slope line, and measured in degrees clockwise from north in the direction of a line perpendicular to the contours away from the hillside. (EVAN72) p37.

: grain size. (Valley spacing).

: surface area/planar area of land.

and many other methods.

iii) Mixed. : The most common method in which quantitative descriptions are modified by qualitative accounts of the terrain characteristics.

For the purposes of detailed land form modelling in geomorphology several landscape characteristics may be required exclusively to address any particular area. In visual analysis the necessity for specific description is inappropriate. As a measure of land surface warpedness, and eminently suitable for computer applications, the measure of surface area/planar area was chosen as a measure of terrain 'roughness'.

Therefore,

$$\text{Terrain 'roughness'} = t = \frac{\text{planar surface area of DTM}}{\text{warped surface area of DTM}}$$

in flat terrain t = 1 and on hilly ground, t would tend towards 0.

Appendix 3 describes a computer program, devised by the author to determine the value of t for any given topographic data set.

Hypothesis 2 - Testing and Correlation.

The elevational errors of four other data sets were collected and graphed with the four points from the Hunterston data sets. The graphed points were:

Data Set	Grid Size	Average error
FOSS	500m	8.1163
TORN	500m	6.3833
HUNT	400m	5.558
HUNT	300m	3.633
HUNT	200m	2.872
HUNT	100m	1.382
BLACK	100m	1.4852
LOWCA	20m	0.4228

(G91) outlines the resulting graph, and the data was again processed through a linear regression program yielding the following best fit line equation:

$$y = -0.0277 + 0.01418x.$$

where, y = average elevational error

x = grid cell size

Similar to the graph in hypothesis 1, the calculated correlation coefficient was again very high at 0.9817.

Hypothesis 2 - Conclusions

The data used in hypothesis 2 may be said to be highly correlated, which proves that the hypothesis was incorrect. Below 500m grid sizes there appears to be no significant divergence of the graph for different terrain types. Although insufficient data restricts the conclusions that can be drawn from (G91), further points have been added to the graph since this study and only confirm the finding of non divergence. Data sets vary from coastal lowlands and steep sided sea lochs in Scotland to inland undulating sites. The author still remains sceptical of this graph, and further study (outside the timescale of this thesis) will be necessary to produce convincing evidence of divergence. At the moment, (G91) is sufficiently accurate for determining the most appropriate grid size for visual analysis studies, for all terrain types, given a tolerable/average error.

Conclusions on Accuracy.

The straight line equations derived above have proved a useful guide in practice, and may be improved as other data sets are assessed for accuracy. It is possible that the window on the relationship between grid size and error was too small to yield a proper investigation of the two hypotheses, eg. it is still unclear as to the shape of the graph over 500m. (Grid cells in excess of 500m are rarely used in landscape or architectural practice; planning applications may use such large cells; however, it is unlikely that accurate topographic modelling would be the main concern at such a large scale).
(G91) now provides users of DTMs a method of grid size selection based on accuracy.
Another criticism of VIEW is the crude modelling of land use data; whole grid cells are used. This can lead to calculation discrepancies with actual observed conditions and will be taken up again in 4.4.2

3.9.5 Time

The data preparation sequence for topographic and land use information was timed under three headings; interpolation from O.S. maps, input typing at the computer terminal and the time taken to check the data once stored in the computer.

Using the INSERT program the number of data points interpolated manually was cut down from 5625 (75 x 75) to 4017 (the remaining points were located on the sea, and assigned a default value of 0 in the INSERT program).

Topography. (4017 points)

- : interpolation time = 10 hrs.
- : keyboard time = 7 hrs (including error checking and editing)
- : checking time = 2 hrs.

Land Use. (5625 points)

- : interpolation time = 3 hrs.
- : keyboard time = 2.5 hrs (including error checking and editing)
- : checking time = 1 hr.

These times describe use by an inexperienced computer operator/typist. Additionally, they relate to a one-man process and would be significantly improved if a two-man team were working on data capture.

To these times must be added data preparation and cross checking procedures.

1. Around 2 hrs may be added due to the need to draw intermediate contour lines on O.S. maps.
2. An additional 1 hr can be added to the land use data preparation if a cross checking procedure is adopted. This would involve updating of map information by viewing stereo pair photographs to check on recent land use alterations.

In all, one might expect to spend 4 man days preparing a topographic and land use data set, 75 x 75 points in dimension. Interrogation of data by VIEW and results display are negligible, the main core of effort having been devoted to data preparation. These tasks may be performed early in the design process, having a double spin off; firstly a good understanding of the site character is built up, and secondly the resulting data matrices may be used throughout the subsequent design stages and even after completion.

3.9.6 Cost

A complete visual analysis study (alternative site locations, building heights, etc.) may be undertaken in an area comparable to Hunterston for around £4,000. The data sets would, of course, remain and may be of further benefit in other applications during design. The multiple use of the topographic and land use data bases must be borne in mind when considering the cost of visual assessment. This cost is mainly incurred in the data preparation stage; processing of different schemes, appraisal of different characteristics and output display of results constitute a small part of the overall cost. The decision to implement a DTM and land use data base must, therefore, be made after considering the likely multiple-use which could be made from that initial investment.

3.9.7 Communicability

The presentation of the results from the VIEW programs has received much just criticism. The VIEW output is in an antiquated line printer form, monochromatic, and very difficult to interpret. The program SYMCON can improve the data presentation by clearer plotting methods and coloured overlay symbols. Often, though, more than enough information is produced and this can lead to difficulties in decision taking, judging one map output with another.

Therefore, the presentation of data must relate to the aims of the study, answering specific questions on visibility and addressing other clearly defined problems. Despite claims that VIEW can offer a comprehensive project analysis and appraisal, decision makers are frequently swamped with information. Selective presentation of results is likely to afford improved communication and better understood decision making. Recently, the use of colour computer graphics to display output has resulted in more easily understood maps of visibility information (G92).

Of the two parties to which visual assessment techniques communicate results, designers and lay public,the VIEW suite is more useful to the on going decision making of the designer. A selection of output material, upon which major design decisions were taken, may be shown to the public; however VIEW's greatest value lies in the rigorous assessment which it can bring to the design process.

3.9.8 Accessibility

At present, the VIEW program suite is only available commercially through Design Innovations Research (DIR), 44 North Castle Street, Edinburgh. DIR is a planning and design consultancy and has undertaken a wide range of projects.

PROJECTS COMPLETED BY DIR

CLIENTS	PROJECTS
Midlothian District Council	Torness Lines Midlothian
South of Scotland Electricity Board	Torness Lines East Lothian Torness Lines Lammermuir Hills
Palmerston Northumberland Partnership	Morvan Quarry Planning Application
Use of DIR Computer Programs by W.J. Cairns and Partners	Flotta Oil Handling Terminal
	Foss Mining Project
	Cowdenbeath Phase 2 Environmental Improvement Project
	Pilton Environmental Improvement Project
	Lowca Land Reclamation Project
	Dewshill Land Reclamation Project
	Meikle Earnock bing Land Reclamation Project

	Summerlee bing Land Reclamation Project
Use of DIR Computer Program by Turnbull Jeffrey Partnership	Midmar Drive Housing Development Galashiels Walkway Reclamation Project A71 Road Junction Earthworks Linkswood Bulk Fuel Installation Visual Analysis

3.10 Conclusions.

What is clear from the foregoing evaluation is that all manual and computer-based methods have a place and a particular role to fulfil in the design process. There is an interdependence about the methods. The degree to which each is emphasised in application will vary from project to project, having established;

i) the purpose of the assessment:
- what decisions will be taken on the basis of the findings?
- what data are required to make the decisions?

ii) the development of information:
- defining constraints
- assessing opportunities

iii) the methods of assessment:
- manual
- computer based.

Hypothesis conclusions.

a) General hypothesis (3.4.1) : Verified; however, a complete rejection of traditional methods is unjustified.

b) Performance hypothesis (3.4.2) :
i) Untrue; manual methods of assessment are used frequently throughout design, although with varying degrees of accuracy.
ii) True

iii) True.

iv) True; especially in the case of computer-based methods.

v) True.

vi) True.

Three of the evaluation criteria were discovered to be of prime importance to designers:

i) Flexibility

ii) Design Value.

iii) Accuracy.

Communicability and accessibility were noted as being of secondary importance.

None of the techniques was prohibitive on the grounds of data acquisition. Cost and time were not regarded as major factors in deciding to use the techniques, if visual assessment was required; although they may put restrictions on the availability of certain techniques.

Designers are now beginning to see the role of CAD methods in rapid analysis and appraisal to unravel the major issues and components of initially indeterminate design problems. Thus CAD methods score highly on the criteria of flexibility (G93) to (G97), design value (G98) and accuracy (G99). Traditional methods are valued best at providing good means of communication (G100) and offering readily accessible services (G101).

Patently, a mix of techniques is the best approach, dependent on the type of project and the problem of visual analysis.

CHAPTER 4

Introduction - Case Study Projects

Throughout the course of this research work repeated application of the computer programs BIBLE, VIEW, and VISTA has been made in live design projects. This has been considered an important aspect of the work in maintaining its relevance, and monitoring the needs of design practices in the field of visual assessment. The value of case study material may also be seen in:

i) indicating new directions for program improvements, eg. user interface and output features.

ii) stimulating continuous revision and reappraisal of program capabilities.

iii) testing program robustness and suitability for visual assessment.

4.1 Wire Line Perspective Drawings.

The program BIBLE has been used in the modelling of a wide range of building types and design applications.

4.1.1 Proposed Public Housing, London Road., Calton, Glasgow. 1983.

A proposal for housing development, which came before the Planning Department of Glasgow District Council, was assessed using the program BIBLE. The main issues concerned were housing privacy and the'corridor effect' created along the street frontage. Several perspectives were drawn from specific window and pavement locations to appraise the privacy of housing courts. A series of perspectives taken from successive locations along an existing main road gave an impression of the spatial quality driving or walking through the development. (G102) (SUSS83).

4.1.2 Proposed Hospital for the Dutch Government. 1982.

Designed by the Dutch firm of architects, Eijkelenboom, Gerritse and Middelhoek using ABACUS software, including BIBLE for visualisation (G103). In this case, the geometry was digitized initially for the program GOAL to assess the functional layout, thermal performance and services installations; it was a simple matter to produce a visual appraisal of the geometry data base using BIBLE.

4.1.3 Shipbuilding Factory, Glasgow. 1976.

This student project used a set of BIBLE generated perspectives as the basis for presentation drawings in the final year Architecture course at Strathclyde University.

4.1.4 International Conference Centre (ICC), Berlin 1979.

BIBLE may also be used in graphic design exercises. This project used BIBLE to generate a logo for the PARC '79 Conference held in the ICC building. (G104)

4.1.5 Hilton Hotel, Edinburgh. 1980

Visual modelling by computer in an urban context may include representation of the surrounding townscape in addition to the study building. (G105) demonstrates such a case; it is the winning entry to a competition for a Hilton Hotel (unbuilt) in Edinburgh. The townscape model was constructed photogrammetrically by digitizing points from aerial stereo pair photographs; while the geometry data describing the study building was input alphanumerically. Using BIBLE,views were generated to simulate its impact on the urban environment. Digitizing the context environment, whether urban or rural can be a laborious and frequently unnecessary focus of effort, especially if it is to remain unaltered. Well established photomontage procedures exist which capture the context view on photographic film; computer generated perspectives may then be drawn or overlaid on the photographs. These are now described by various case studies in 4.2.

4.2 Photomontaging.

4.2.1 Scottish Exhibition Centre, Queens Dock, Glasgow. 1980.

Early proposals for the Scottish Exhibition Centre were modelled by computer using BIBLE. The work, commissioned by the Project Planning Division of the Scottish Development Agency, involved the visualisation of the proposed building from viewpoints on the north and south banks of the river Clyde. Site photographs were taken from five positions and together with matching BIBLE views, these formed the basis of a set of artist's impressions (G106). This is a particularly good example of the new and traditional methods working hand-in-hand.

4.2.2 Waverley Market, Edinburgh. 1981.

The proposed Waverley Market by Building Design Partnership was recommended for visual appraisal by the Scottish Royal Fine Arts Commission SRFAC. The building was thought to cause some degree of visual obstruction of the High Street and the Castle from Princes Street. The scheme as proposed was modelled using BIBLE then montaged with site photographs. Several passes through the program allowed alternative building heights to be considered rapidly. Iteratively, a recommended height was resolved and suggested to the architects. (G107) Incorporating this revised height in the scheme a reduction in the floor to ceiling height of the development was inevitable. Concern arose as to the quality of these interior spaces, and, quite independently of the SRFAC, the architects commissioned a series of interior perspectives of the shopping arcades. (G108).

4.2.3 Strathclyde University, Campus. 1981

Over a two year period from 1981 ABACUS has built up a detailed geometric model of the campus at Strathclyde University. This has been tackled principally by undergraduate students taking an optional course in visual impact analysis. A block model and a detailed model exist. Typically, students may use these models and photomontaging procedures in the project time during the option to simulate the visual effects of studio-based design projects. (G109).

4.2.4 Castle Peak Power Station, Hong Kong. 1982.

It is imperative to know the viewpoint location in the course of constructing a photomontage. In this case, a second power station on the Hong Kong mainland at Castle Peak by the architects Robert Matthew, Johnson-Marshall, a number of the viewpoints of the site photographs were unknown, having been taken from a ferry and a helicopter. The building geometry was assembled and prepared for viewing by the program BIBLE (G110). The onshore photomontages were drawn (G111). To locate the XYZ viewpoint co-ordinates of the offshore and aerial photographs a program was devised to iteratively search back to the correct observer position. This procedure was based on a triangulation method with two known objects in the photographs and the computer views, and the viewpoint acting as the variable. Finally, the accurate wire line perspectives and the colour site photographs formed the basis of a set of finished colour montages by a perspective artist.

4.2.5 Midmar Housing Development, Edinburgh. 1983.

As part of a submission for outline planning permission by CALA Homes for a housing development in Midmar Drive, the architects Turnbull Jeffrey Partnership requested a set of BIBLE perspectives. These were produced from sketch drawings of the house types and site layout (G112). Black and white montages were compiled, and a perspective artist used these as the context and building images underlying a set of colour rendered perspectives. (ARCH83b)

During the study an important aspect of perspective drawing arose. The artist chose a view to sketch the entrance road to the development, quite independent of the CAD views. This view was then simulated retrospectively by BIBLE. The resulting perspective was sufficiently inconsistent with the artist's original drawing as to cause concern for the perspective drawing procedures adopted by the artist and the program (G113). The discrepancy was found to be due to two factors:

i) incorrect eye point location for the program BIBLE: this demonstrated the importance of data accuracy when working on a small scale project.

ii) two point perspective drawing by the artist. Although it is perfectly possible to construct three point perspectives by hand, it is normal to use only a two point set up, assuming that the montage photograph was taken with a horizontal line of site. In this case, the artist drew a two point perspective to match with a three point photographic view of the scene. Thus the camera viewpoint and focus point were not at the same level, ie. the camera was tilted. BIBLE will draw with three point perspective which, in this case, resulted in a dissimilar perspective drawing.

The artist involved was, however, very keen to use CAD methods. Perspective set-up time was eliminated and full effort was concentrated on the accuracy of the colour renderings.

4.2.6 Norit Clydesdale Factory, Glasgow. 1980.

With the advancement of computer and video technology towards the end of the 1970s, this study marked the beginning of an era of colour montaging and computer graphics simulation (ARCH82b). The potential for colour visualisation and montaging had been established with the acquisition of a Tektronix 4027 Colour Graphics terminal, and the early experimental video montaging by Gardner and Purdie at ABACUS in 1979. The merging of monochrome video and computer graphics was demonstrated using the system configuration outlined in (G114). Further experimentation during the course of this project resulted in the specification of a colour montaging system (G115).

The project was financed by the Scottish Development Agency and Glasgow District Council, and involved the colour visualisation of a £6m activated carbon processing plant in Cambuslang, Glasgow for Norit Clydesdale, an international chemical company. Two factors concerning the building design were under examination; the height of the chimney and the colour of the external materials as seen from a number of locations in the vicinity. The study consisted of three distinct phases:

: computer modelling of the factory complex.
: site photography.
: final montage production.

The methodology is described in (G116). A detailed account of the project may be read in (GARD80a). The standard procedure for geometry modelling using BIBLE was implemented; from architect's scale drawings, a model of the building geometries on the site was constructed and specific views generated (G117). Three of the monochrome BIBLE views were coloured using a polygon colour-fill routine on the Tektronix 4027 screen, and stored as a display file on tape. These views were replayed on the video montage system outlined in (G115) and by changing the building surface colours on the Tektronix screen a number of material and colour options were appraised for the external cladding of the building. A video tape lasting 30 mins captured the investigation procedure and options. Hard copy montages were also constructed (G118) showing a high degree of realism in the visualisation.

4.2.7 Architecture Building, Strathclyde University. 1982.

The acquisition of an Advanced Electronics Design (AED)512 raster scan colour computer graphics terminal at ABACUS brought greater resolution of image generation and a vastly increased palette of colours to choose from (256 colours on the screen at any one time from a palette of over 16 million). This terminal, together with the photographic screen copying unit (Image Resource Video Print 500), brought the possibility of serious colour visualisation and research into colour computer graphics generation. To assess the capability of the hardware (AED512) and the software (VISTA), this study looked at the visual realism which modelling procedures at ABACUS could achieve.

This retrospective visual appraisal of the Architecture Building at Strathclyde University provided a useful comparison of actual and VISTA generated views (G119). The time of day and sun position were recorded for correct shadow generation on the surface in addition to the regular viewing parameters. BIBLE geometry data describing the building were converted to a VISTA data base and surface colour specifications compiled. The resulting view generated by VISTA appears inaccurate, owing to an error in the viewpoint elevation height. Nevertheless, the project demonstrated the potential of realistic visualisation by VISTA on the AED512.

Some of the problems encountered in the work included:

i) the modelling of foreground landscape.
ii) the simulation of window glass and other reflective materials.
iii) the weather staining of building surface materials.
iv) the need to model facade detail at different levels depending on viewing distance.
v) the need for shadow intensity variations -
  a) across surfaces, caused by diffuse light.
  b) dependent on climate, eg. sunny or overcast days.

These and other matters continue to be solved and integrated in the operation of VISTA. Notwithstanding these difficulties in displaying the scene, the level of realism achieved in visualisation is eminently acceptable to architects in the course of design.

4.2.8 Hitchin Priory Development, Hertfordshire, England. 1983.

The presentation of visual evidence at a planning inquiry can win or lose aesthetic decisions. In this case, the client, a life assurance company, was proposing an office development in a sensitive semi-rural landscape and required high quality visual material to put before a local planning committee. The programs BIBLE and VISTA were employed to address two problems:

i) the building scale in relation to adjacent housing. (BIBLE).
ii) the building colour in relation to existing brickwork colours. (VISTA).

This project has its significance in the fact that it was the first occasion that the AED512 colour terminal was used in earnest in a consultancy study.

Photographs from a number of vantage points around the site were recorded on black and white, and colour print film; a selection of seventeen views was made therefrom for computer montaging. These views were chosen in agreement with the Local Authority Planning Officer, the architects and planning consultant.

The geometry data files for computer processing were compiled from 1:200 scale architect's drawings of the proposed building and an existing wall, surrounding and intersecting the site. Control point information, known site features and surveying poles, were included for each view and surveyed in reference to the O.S. grid to the nearest 100mm. Control points or bodies were originally used in video mixing work by ABACUS two years ago. They were used to key the computer perspective on to the corresponding site photograph because the enlargement factor was not fixed, there being a zoom facility in the video mixing equipment. The control points were seen as a useful way of obtaining accurate montages, and subsequently all montage work, whether video based or using photographs and acetate overlays, employed a number of control points in each view. The BIBLE wire line plots were drawn on acetate and overlaid on the black and white site photographs (G120). The program VISTA was then applied to the data to generate colour views of the proposals in their setting (G121) and (G122). A more detailed description of the study and procedures adopted for photography and computer modelling is contained in (TURN83).

In certain cases, the foreground tracery of trees or shrubs partly obscured views of the building. The difficulty of achieving a montage in such cases is, in effect, the problem of how to slip the computer view in behind relevant foreground, yet in front of background objects. To overcome this problem colour transparencies of the site photographs were overlaid on the VISTA colour output; background objects which were hidden by the building required to be edited out of the transparency. The two images combined were then rephotographed on a light table for subsequent presentation. Colour control was extremely difficult to achieve due to lack of control in the colour printing process.

In addition to the computer-based montages, a series of artist's impressions were drawn for presentation purposes (G123). The most time consuming part of this work involves the construction of the two point perspective such that the drawn building matches the position of other site objects in the photographs. This setting up procedure for the perspectives was obviated by the use of the computer wire line drawings. More attention could then be directed towards the rendering of the final perspectives, knowing that the building location and scale were accurately drawn already.

Three main areas of concern resulted from this study:

i) Data inaccuracies. Incorrect reportage of survey data identifying viewpoint and control point information caused lost time in rechecking and reprocessing the computer views. As a result, two specifications are currently being drafted; one for surveying procedures and another for photography on site.

ii) Overlaying. The difficulty in effecting a realistic colour montage when views of the development are interrupted by foreground features still remains unresolved unless time consuming hand crafted methods are used. This runs against the idea of speedy computer based visualisation. An automated solution to colour montaging is being sought in which image handling and mixing, through the use of a "frame grabbing" device will allow a higher quality merging of site and computer images. This will be taken up again in chapter six.

iii) Colour copying and reproduction. Maintaining the correct colour balance and quality of hardcopy reproduction from graphics terminals has consistently proved to be a stumbling block in the presentation of accurate visual evidence, especially when building surface colours and textures are under examination. In the same manner, research dissemination in this field is fraught with reproduction difficulties; even within this thesis, uncertainty exists as to the fidelity of the colour graphics reproduced. Significant improvements in the copying and reproduction of colour computer graphics for visualisation in architectural design are required if the benefits of building detailed simulation models are to be properly harvested.

4.3 Composite Visual Analysis

4.3.1 Transmission Line Routing, Torness, East Lothian.

Over the past three years Design Innovations Research(DIR) and ABACUS have been involved in the visual assessment of transmission line routing in the Torness area of East Lothian. The proposed pylons were to link the output generated by the Torness Nuclear Power Station to the National Grid.

Before this consultancy work commenced DIR were required to prove the utility and fidelity of their programs for visual assessment. This was carried out on a significant man made feature in the Torness area, the Blackcastle Hill Radio Mast (AYLW79). Following the success of this study DIR were commissioned by the South of Scotland Electricity Board to aid in the visual appraisal of two alternative pylon lines in a proposed routing south towards Eccles from Torness. This was known as the Thornton Bridge study and included visibility analysis (VIEW) and visualisation (BIBLE). In all, three lines were under assessment. The first stage of the Torness to Dalkeith connection, and the two alternative routes south to Eccles, known as the Direct and Circuitous Routes. The visibility analysis was particularly concerned with the visual intrusion of the pylons as seen from the A1 road to the east of the site and following the coastline. Maps of pylon visibility for each route were produced eg. (G124) revealing that the two routes (Circuitous and Direct) were equally intrusive, and the supposed hypothesis that the Circuitous route would be screened by higher ground proved unfounded. From this investigation a number of critical viewing points were identified for visualisation using the program BIBLE. The study report is contained in Appendix 4. This was accompanied by monochrome photographs and overlays showing the impact of the pylons from the chosen locations.

A second phase of the work involved colour montaging from another five viewpoints. An example of this part of the study may be seen in (G125) and (G126), in which the circuitous and direct routes are compared from a known viewpoint (PURD80b). In the end, the 'direct route' was adopted since there appeared to be no significant visual advantage of rerouting the pylons round the 'circuitous route'. Improvements to the programs VIEW and BIBLE were outlined, as a result of this project in (PURD80c). In general, these urged the inclusion of correction factors for earth's curvature and light refraction, and the calculation of % visibility statistics based on actual pylon dimensions rather than averaged heights. The generalisations of VIEW were, therefore, found to be to inaccurate for BIBLE.

Later that year, 1980, a further study was commissioned to appraise the visual intrusion of part of the proposed transmission line west from Torness to Dalkeith. The section under study was in the vicinity of Nunraw Abbey near Garvald in East Lothian. As with the previous study topographic and land use data bases were compiled for VIEW with the help of semi- automated digitising routines developed at the Topographic Science Unit in Glasgow University's Geography Department. Two possible routings of the line passed Nunraw Abbey were considered; these were known as the north and south routes. From a number of selected viewpoints, including the abbey and positions at regular intervals along a nearby road, the visibility and the degree to which the pylons were backclothed were calculated using VIEW. These data are summarised in (PURD82c) and allow a direct comparison to be made between the routes. Locations for BIBLE photomontage work were identified, numbering 10 in all. The pylon element library, as described in Appendix 4, was used to construct the geometry files for each line. The BIBLE views were drawn on acetate and overlaid with control point registration on colour site photographs. Comparative views were examined, eg. (G127) and (G128).

Ultimately, there is a degree of personal subjectivity in deciding which alternative is less intrusive; however, the accuracy, quality and objectivity of the data upon which judgement is made cannot be called into question.

Following these studies, the SSEB were engaged in a Public Local Inquiry regarding the routing of transmission lines from Torness. The inquiry took place in Haddington, East Lothian during April/May 1982. The main issues under debate were engineering and planning aspects, health and safety. Visual assessment fell into the planning category and played a prominent role in decision making, though it was generally agreed that the techniques employed were never free from some measure of subjective judgement. The DIR and ABACUS reports were not produced at the inquiry. Full consent was granted by the inquiry Reporter to the transmission line route between Torness and Eccles, while the SSEB were invited to reconsider routing the Torness/Dalkeith line higher up in the Lammermuir Hills along a suggested route by the East Lothian District Council, referred to as the Dipslope route. The original submission by the SSEB had presented the case for a line lower down the Lammermuir Hills known as the Hillfoot Route. This was refused on the grounds of its impact on amenity, agriculture and human interests.

This project is not seen as typical of drawing on the best resources and facilities of the program VIEW. The focus of the investigation by VIEW centred on the comparison of two alternative pylon routes, already predetermined. VIEW would have been better used in establishing the least intrusive route through the landscape, although other forces such as engineering and structural requirements, access and maintenance would have had to be borne in mind. The concept of route planning and optimisation on a number of economic, environmental and social criteria is taken up in chapter 7.

4.4 VIEW and BIBLE : a verification case study for the South of Scotland Electricity Board.

4.4.1 Introduction

Case study projects as described thus far in this chapter have repeatedly pointed to one increasingly important aspect of computer-aided visual analysis, that of the need to quantify calculation inaccuracies. The objective of this study was, therefore, to gain a greater understanding of the sources and types of errors which affect computer-based methods of visual analysis. In turn this was intended to provide suggestions as to how these inaccuracies could be overcome for future use, and to qualify BIBLE and VIEW with known levels of fidelity.

The South of Scotland Electricity Board kindly offered to be involved in the study and provided data regarding an existing pylon line near Innerwick at East Lothian to act as the object of interest in verifying the computer programs. Maps, pylon data and aerial photographs were obtained for the area under analysis (G129)

In many ways electricity transmission towers are a stringent test of a visual assessment technique: they are

i) a series of very small targets, in planar dimensions, eg. 5m x 5m
ii) usually sited in open undulating landscapes with large viewing distances
iii) strung out across the landscape over distances of 5 miles and more.

These factors place considerable stress on a technique faithfully to predict a visual impact, particularly with regard to the positional relationship of the objects which may be described over a two mile length.

The study comprised four stages:

i) Modelling of the pylon line by computer techniques, VIEW and BIBLE, to generate results on visibility and perspective drawings respectively. The possible sources of error are outlined.
ii) Photographic survey of the study area. The sources of error known to exist in the photographic processes are outlined.
iii) A comparison between the C.A.D. results and the existing pylon line is effected to establish the nature and scale of discrepancies, and to account for these errors.
iv) Resolution of inaccuracies as far as possible; suggest hardware and software improvements; quantifying the remaining errors for future applications.

Definitions.

Accuracy may be defined in a number of ways. For the purposes of this study (G130) was devised in which the various types and effects of errors in computer and photographic imaging may be identified.

Positional or Aesthetic.

Inaccuracies in the quality of image reproduction can be classified under two headings:

i) Positional: variations in the location of objects reproduced on the computer or photographic image.

ii) Aesthetic: variations in colour, tone and sharpness of the computer or photographic image.

While both aesthetic and positional image variations are important in visual analysis, this study is primarily concerned with positional aberrations. The problem of aesthetic variations may well be by-passed in the future with the use of digital cameras and advanced colour computer graphics.

Some definitons are required to clarify the measurement and characteristics of Positional Variation or Distortion:

Measurement of Positional Distortion:

The difference Δd between the theoretical position D_T and the actual position D_A of an image point may be expressed either as:

a) angular deviation from centre of photograph/scene e.g. 20 seconds of arc
b) linear deviation eg. +0.02mm
c) percentage deviation eg. 0.1% - 0.2mm over a 200mm field (G131)

Direction of Positional Distortion:

The direction of positional distortions may either be radial or tangential. (G132) Radial distortion, as implied by its name, causes imaged points to be distorted along radial lines from the optical axis. Outward radial distortion is considered positive and inward radial distortion is considered negative. Tangential distortion occurs at right angles to radial lines from the optical axis. Tangential distortion is generally of much less consequence than radial distortion and can often be disregarded. (WOLF74) p36.

Direct or Oblique.

Direct errors affect the image over the whole field of view. Oblique errors only affect the image at the edges, increasing in severity the further from the lens axis (G133). In the process of measuring any quantity, factors such as human limitations, instrument imperfections, and instabilities in nature render the measured values inexact. Due to these factors no matter how carefully a measurement is performed, or a technique is applied, it will always contain some error. There are two classes of error:

a) Systematic : an error in a measurement which follows some mathematical or physical law. If the conditions causing the error are measured, a correction can be calculated and the systematic error eliminated.

b) Random : after the systematic errors have been eliminated, the errors that remain are called random errors. Random errors are generally small, but they can never be avoided entirely in measurements (WOLF74) p. 501.

It is clear that discrepancies in compounding a montage arise from two sources:

a) Computer output results; both visibility calculations and perspectives.
b) Photographs

These two inputs to the montage production stage are subject to a number of factors which will cause some degree of variation of the image from reality:

a) Computer : quality of input data
: generalisation to grid squares for visibility calculations

b) Photography : Optical distortions
: Process distortions

The variations in the computer generated images will be positional, whereas the photographic image variations will be both positional and aesthetic.

4.4.2 VIEW

The VIEW program features and routines have been outlined in Chapter 3. The purpose of this study was to check the validity of the VIEW results with on-site information, in greater detail than time permitted in the Hunterston study. The topographic and land use data sets used were partitioned 50 x 50 matrices from the main Torness data set (80 x 74) used in 4.3.1 (G134) and (G135). This partitioning reduced computing costs and did not limit a full analysis of the effects of the surrounding topography particularly with regard to % visibility calculations above horizon lines. Six pylons were chosen to be viewed from ten viewpoints (G136) (G137) and (G138).

The program VIEW2 calculated % visibility and % visibility above horizon for each of the 60 combinations of pylons and viewpoints. These results were compared directly with on-site observations (G139) to (G148).

The calculations for % visibility are based on two changes to the original topographic data base:

i) the elevation values of the grid intersections from which views are calculated correspond to the actual viewpoint heights.

ii) the elevation value of the grid intersection for each pylon location corresponds to the actual height at the base of the pylon. Therefore, the specific height addition used in VIEW2 for each pylon will be the same as each pylon height (and not an averaged height, which caused problems in the pylon study at Torness 4.3.1. These were summarised in (PURD80c)).

Notes on (G139) to (G148).

Data base

The discrepancies between the results of VIEW2 and the actual visibility of the pylons are primarily due to the inaccuracies of the topographic and land use data bases. These inaccuracies are:

topography	:	elevation height only (interpolated from OS maps)
land use	:	XY location (since land uses must be generalised to grid squares). elevation height (since tree heights will vary from the categories in the data set).

Visual Acuity

On site observation of pylon visibility is difficult, especially in determining exact percentages of visibility. In the case of a 25m high pylon, a mistake of only 1.5m in judging visibility can lead to a 6% - 7% discrepancy with the real percentage visibility. These slight inaccuracies in on-site observations have resulted in the observed values being rounded to increments of 5%.

Observations.

Most of the differences between the VIEW2 results and actual visibility are positive, ie. VIEW2 more often than not states that more is visible than in reality. This accords with the amount of land use data used by VIEW2 in calculating visibility, which is less than in reality, giving slightly increased values of visibility in VIEW2 results.

Error differences between VIEW2 and reality are slightly higher for % visibility calculations than for % visibility above horizon calculations.

Sources of Error.

(G149) and (G150) show the spread of errors in % visibility and % visibility above horizon respectively, between VIEW2 calculated results and on-site observed values. The graphs indicate that some two thirds of the results are within the expected tolerance range, due to the inaccuracy of the digital terrain model. The inaccuracies of VIEW2 are caused by the generalisation of topographical and land use data to a regular grid pattern. Grid coarseness affects four areas of the visibility calculation procedure which in turn influence the overall accuracy of the VIEW2 results.

a) Terrain and Land Use Modelling
b) Visibility Ray
   : length of ray
   : angle of ray
c) Object Displacement
d) Object/Grid size Proportions

A number of hypotheses were formed regarding the influence of these factors on the accuracy of VIEW2 calculations. The investigation and results of these hypotheses are now dealt with.

a) Terrain and Land Use Modelling

The generalisation of topographical and land use data to grid cells in a digital terrain model affects the accuracy of visibility calculations.

Land Use

In this study the main source of error arose from the land use features. Small copses and individual buildings such as farmhouses, which may significantly affect visibility from some viewpoints, were not realistically modelled in the 100m x 100m land use cells. Sub-division of a larger grid cell to smaller squares is therefore desirable, and possible with VIEW. Time did not allow subdivision of land use cells in this study,although it should be used if visibility accuracy is a high priority. Comparative figures of increased accuracy with smaller land use cell sizes are not yet available.

Topography

Topographical modelling is never fully accurate. Experience has yeilded the graph in (G91). Thus, any point within the bounds of a 100 metre grid digital terrain model, whether on a grid intersection or not, will have an expected elevational error of 1.5 metres. Referring to (G151) and (G152), there is an expected error in calculating % visibility and % visibility above horizon of $\pm 15\%$ and $\pm 20\%$ respectively for a 30 metre high pylon, typical in this study. These limits of expected error can be seen in the graphs of (G149) and (G150). In addition to this average elevational error, localised topographical variations within grid cells can cause more severe discrepancies between actual and VIEW2 calculated visibility results. There are two types of topographical variations which grid cells will not model accurately, hill tops and valleys (G83). In this study, topographic errors show up most noticeably when dealing, from most viewpoints, with pylons 123 and 124. These two pylons are near a hill top and their calculated visibility by VIEW2 is affected by the inaccurate modelling of the hill top topography.

b) Visibility Ray Characteristics

Two features of the visual rays used by VIEW2 to calculate visibility between grid intersections were thought to contribute to the discrepancies in the final results.

i) length

ii) angle

i) Length of Ray

Hypothesis : The longer the visual ray, then the more accurate the visibility results. (Since the ray would have to zig zag through more grid intersections between viewpoint and object of interest). (G153)

The visibility results are graphed against the length of ray in (G154) and (G155). The data appear to be uncorrelated, with short and long visual rays having equal magnitudes of error between actual and VIEW2 visibility results.

ii) Angle of Ray

Hypothesis : The nearer the angle of the visual ray is to 0, 45 or 90 degrees then the more accurate the visibility results. (Since the grid intersections which the ray zig zags through will more accurately define the intervening topography between the viewpoint and the object of interest.) (G156).

The visibility results are graphed against the angle of ray in (G157) and (G158). The data appear to be uncorrelated; though there are a number of more accurate calculations over 20 degrees. The sample of data points in this case may be too small to yield any positive conclusions as to the effect of ray angle.

c) Object Displacement.

In most cases, grid coarseness will not allow pylons or viewpoints to be matched exactly on to a grid intersection that is also their true OS location. Pylons and viewpoints are therefore displaced on to grid intersections for VIEW2 processing. The true height of the pylons and their elevation heights to the base are observed. The maximum displacement occurs when the pylon or viewpoint is located at the centre of the grid cell. (G159)

X displacement = 50m

Y displacement = 50m

Max. positonal displacement = 70.7m

The displacement of the pylons and viewpoints in this study are outlined in (G160) and (G161).

Hypothesis : The greater the X,Y displacement of pylons or viewpoints, then the greater the error in VIEW2 visibility calculations.

This hypothesis was tested by six graphs comparing:

1. pylon displacement: (G162) and (G163).
2. viewpoint displacement: (G164) and (G165).
3. pylon and viewpoint displacement (compound displacement) (G166) and (G167).

with errors in visibility calculations. All six graphs show a positive correlation between displacement and error.

d) Object/Grid Size Proportion

This area has not been fully dealt with in this study. However, there appears to be some degree of evidence to support the hypothesis that:
the ratio of object height and width to the grid cell of the digital terrain model is related to the accuracy of the visibility results. It is a generally held opinion that objects such as pylons, typically modelled by case i) in (G168) will yield less accurate visibility results than large buildings such as power stations which could be modelled using case vi), ie. whole grid cell height addition. The relationship of accuracy to object/grid size proportion is not yet known, though it might be expected to be a straight line graph.

Conclusions

Most of the VIEW2 modelling problems outlined in this study have been identified in previous reports as likely sources of error in visibility calculations. This section outlines their significance, although the sample of viewpoints and pylons chosen may not be sufficiently large to yield a complete picture.

The study has revealed a number of points worthy of further investigation:

1. more detailed land use modelling
2. significance of object displacement
3. definition of objects in the DTM.

Current work involves:

1. Testing a more accurate version of VIEW2; which interpolates visibility on a straight line between viewer and object, rather than zig zag through the data set.
2. Testing land use modelling on smaller grid sizes eg. 25m. to assess any significant rises in accuracy.
3. The comparison of section/sight lines drawn from the viewer to the object:
   a) from O..S. maps
   b) old version of VIEW2
      (zig zag through data points)
   c) new version of VIEW2 (interpolates between grid intersections to make a straight line of sight).

4.4.3 BIBLE

In 3.2.1 it was noted that BIBLE was based on a hidden line elimination algorithm (GALI69) and that the resulting perspectives or wire line drawings could be used in conjunction with site photographs to form a photomontage of a proposed development. In order to generate these drawings, however, geometry data describing the proposal need to be keyed into the computer. Immediately it can be seen that there are two possible sources of error in causing aberrant results:

i) Input data.
ii) Program algorithm.

Input data

There are three steps in creating the geometry data which describes the object of interest or proposed development.

i) Data collection.
ii) Data preparation.
iii) Data manipulation.

i) Data collection

The input data required for the modelling process comes from two sources:
a) drawn information about the object itself.
Pylon dimensions were supplied by the SSEB and control point data was interpolated manually from OS maps (G169). The computer models of the pylons are not detailed to every strut and tie; however, the outline form and overall dimensions are accurately portrayed. The control points were input as vertical cuboids to mark corners of buildings etc. It may be assumed that there is negligible error in the description of the interest objects. The accuracy of the control points will depend on the accuracy of the O S maps from which they were interpolated.

b) map co-ordinates for the location of the object in space, and the viewing parameters.
Map coordinates for object locations and viewing parameters were obtained by manual interpolation of O S maps. Here is a fundamental source of error, since "maps are deliberate generalizations of reality" (HARL75). Therefore, interpolating data from O S maps necessarily implies inaccuracies in the location of

: control points
: objects of interest
: viewing parameters (eg. viewpoint location and focus point)

1:1250 scale maps were used in the study and any error which might arise from inaccurate O S maps and the manual interpolation procedure will be $\pm$ 5 metres in X and Y and $\pm$ 3.8 metres in Z ($\frac{1}{4}$ the contour interval of 50 feet.)

One method of overcoming the problems of using inaccurate maps is to undertake a photogrammetric survey of the area. Aerial photographs were available and the Photogrammetric Unit at Glasgow University were asked to interpolate the elevational heights of a number of points in the study area:

a) Objects of Interest (pylons) base heights
b) Control Points
c) View Points

Three aerial photographs cover the area at Innerwick, from which two stereo models were constructed. Information obtained from a photogrammetric survey is not error free; there are five possible sources of error (WOLF74):

a) Lens distortions
b) Shrinkage and expansion of film and paper
c) Tilted photographs
d) Errors in ground control
e) machine accuracy/skill of operator

a) The metric cameras used in aerial photography are almost distortion free. The maximum displacement error of a point imaged in the corner of the photograph is usually no more than 0.01mm from its ideal distance from the main lens axis.

b) Shrinkage and expansion of photographic paper when printing aerial photographs varies from negligible amounts to 0.2 per cent, depending on a number of factors:

Type of film and thickness
Storage temperature and humidity
Paper type and thickness

c) Since it is impossible to maintain a straight or level flight path there are usually small tilts in the camera position when taking aerial photographs. These tilts can be eliminated when using the stereo plotting machine by setting up the photographs with identical tilts as existed during the survey. Any error in the subsequent interpolation is negligible.

d) Photogrammetric measurements are only as accurate as the ground control points on which the stereo model used for interpolation is set up. Ground control points are points of known elevational height (Bench Marks or Spot Heights on O S maps) which also appear on the photogrammetric stereo model. These points are used to set up the stereo model in which interpolations can be made. At least three control points per stereo model are required, and they should be as far apart as possible. Bench marks are accurate to within ±3cms and spot heights to ±30cms. Therefore, the errors which may be incurred in setting up the ground control for a stereo model are:

The accuracy of the Bench Marks or Spot Heights used.
The skill of the photogrammetrist in locating the ground control points on the aerial photographs.

e) Machine accuracy refers to the condition of the stereoplotter machine, the scale of the aerial photography and the expertise of the operator. The machine used in the study had been recently serviced, the scale of the photography was sufficiently detailed to pick out the interest objects and the operator was a regular user of the machine. Machine errors were, therefore, limited to the manufacturer's specifications which indicated a possible inaccuracy of 0.79 - 1.37 metres on any interpolation.

The errors induced by the photogrammetric survey can therefore be quantified as ±2m. This accuracy is an improvement on the O S information accuracy and the control points and viewpoints for the computer views are based on data obtained by this photogrammetric study.

ii) Data preparation.

The BIBLE geometry files may, in the case of pylons, be constructed from a library of pylon elements or parts, already extant in the computer's memory. This saves a large amount of data preparation time. Control points should also be prepared at this stage: (G170) lists the four control point details and accuracy.

Check procedures for input data

Data entered in the computer may be checked in two ways:

a) visually

b) manual check of numbers

In the first instance, BIBLE data should be checked visually, by running the computer program with the newly created geometry files. This activity can be done interactively on a graphics terminal. The order of the input data is checked by this method, since the program BIBLE will not draw incorrectly structured input data. If the input is correct, this visual check will allow the user to assess the broad form of the object he has described and entered in the computer. The second method of checking is more laborious. It involves the manual check of individual numbers which describe the pylons or parts of pylons entered in the computer. This activity may be done interactively or at the drawing board with computer printout of the geometry files. In both check procedures the user should be verifying correct input data for:

: the geometry description of the object

: the placement parameters of the object ie. X,Y and Z location in the model coordinate system and its orientation (degrees from north).

iii) Data manipulation.

The manipulation of data may be achieved through the program IMBISS, described in 3.2.1. Rotation and positioning of the geometry data may be effected in relation to a local model co-ordinate system (G171).

Having completed the steps of data collection, preparation and manipulation the program BIBLE may be used to generate any number of views of the interest object described, with given viewing conditions such as camera type and view direction. One point is worth noting here. During the early visualisation of the pylon line it was felt that when compared with site views the pylon data were inaccurate. This suggestion was put to the SSEB, who had supplied the data originally. It was found that the initial data had an error of some 4.7m in the Northing value (the author had suggested and error of 5.0m). The accuracy of the program was beginning to highlight human errors in the supply of data, and brought to mind the first law of computer science, "garbage in, garbage out".

Program algorithm

It might reasonably be expected that errors in constructing a computer perspective may arise from the procedure adopted by the program in calculating the projection. The program BIBLE uses a number of user-defined parameters and routines in perspective drawing. These may be summarised as follows:

i) Perspective projection

ii) Lens size/viewangle and the enlargement factor of the print from the negative

iii) Earth's curvature and refraction of light

i) Perspective Projection

When straight lines are drawn from a viewpoint or centre of projection to all the points of a group of objects and then extended to pass through a plane or surface of projection behind the group of objects, the image recorded on the plane is the perspective projection of the group of objects. Alternatively, the projection plane may be between the viewpoint and the group of objects, forward projection. The program BIBLE uses the first method mentioned, back projection. The projection plane must be at right angles to the direction of view.

The parameters required to generate a perspective projection are, therefore:

user defined	:	viewpoint
	:	focus point
	:	objects of interest
BIBLE generated	:	projection plane

The objects of interest are defined in the model coordinate system. The viewpoint and focus point are chosen and specified in the same coordinate system (G172).

Perspective drawing in computer graphics is based on a number of matrix transformations, converting the three-dimensional world co-ordinates describing the object to screen co-ordinates for viewing on a terminal. Conversion matrices may be found in a number of references, eg. (NEWM82) p341 and (CARL78) p465. The method used in BIBLE may be described:

A simply defined projection or picture plane is established by effecting a translation and rotation of the interest objects and view direction in three dimensional space. The focus point is translated to the origin, while the viewpoint is rotated about the origin on to the X axis. This results in the view direction being co-incidental with the X axis (G173). The co-ordinates of the interest objects are similarly translated and rotated. A projection plane upon which the perspective may be constructed is defined by the Y and Z axes (G174). A fully three-dimensional perspective projection can then be made on to the back plane formed by the Y Z axes. All the significant points defined in the interest objects are now mapped on to this two-dimensional surface or plane and may be associated values (Y,Z) with respect to the origin which is the focus point and centre of the view. The matrices computing this perspective transformation were examined and compared with the standard matrix procedures for graphical projection found in most good computer graphics texts. The projected picture on the YZ axes plane may be treated for hidden line removal. With pylons this routine is unnecessary and all visible lines defining the pylons are drawn. Similarly, if one pylon is directly behind another with respect to the viewpoint, then both pylons will be drawn, as if the nearer pylon were "see through", which, in fact, it is.

ii) Lens size/viewangle and enlargement factor.

Once the screen co-ordinates of the perspective projection have been computed, the user may specify two parameters:

a) The size of the objects on the film negative. This is defined by the lens size or viewangle. Although human vision is fractionally greater than 180^0 in a horizontal arc, perspective drawings are seldom greater than 60^0. This is due to the fact that objects drawn outside a 60^0 cone of vision are distorted. Defining either the lens size or the view angle has the same effect on the view generated since the focal length of a lens also determines the angle of view. (G175) graphs camera lens sizes (focal length) against viewangle. The program BIBLE has a viewangle calibration similar to the lens calibration of the Nikon series lenses used in this study. Thus specifying either lens size or viewangle defines a certain amount of the perspective projection generated by BIBLE for viewing; this is called the window on the scene. The proportion of the interest objects to the size of the window matches the proportion of objects on the film negative to the dimensions of the negative.

b) The size of the objects on the final photographic print (to effect a montage).This is defined by the enlargement factor from the film negative to the print. A perspective artist will set his picture plane on the drawing board according to the scale of the perspective drawing he requires. The program BIBLE, however, always sets the picture plane at the YZ axes through the origin which is also the focus point of any view. In order to vary the size of the drawing a scaling factor is required; this is known as the enlargement factor in BIBLE. Thus while the lens size informs the program what size the object is on the film negative, the enlargement factor indicates the scaling required for the program to draw the correct size of the objects to fit the enlarged photographic print.

There are two possible sources of error which may arise in defining and scaling the window

a) The viewangle of lenses varies with manufacturers. Thus, while a Nikkor 50mm lens may have a viewangle of 46^{0}, and Olympus 50mm lens may have a viewangle of 48^{0}. This results in small differences of the image size on the negative, when different types of camera lenses of the same focal length are used. It can be seen, therefore, that to eliminate viewangle errors in defining the window, the lens calibration of the equipment being used should be known.

b) Due to the small size of 35mm film negatives the enlargment factor is sometimes difficult to determine. The problem was initially tackled by modelling existing features in the landscape as control points to match the computer view with the photograph (G176). This method is still valid; however, as before, inaccuracies are likely to arise when measuring the chosen buildings or features on the film negative to calculate the enlargement factor.

Another method was devised whereby surveying rods or poles were placed in the foreground at either side of the camera view (G177). The distance between the marker poles was more easily measured on the film negative, allowing the enlargement factor to be more accurately calculated. These scaling factors and procedures in BIBLE were examined and found to be error free.

iii) Earth's curvature and refraction of light.

The algorithm for adjusting the elevation values of objects to account for earth's curvature and light refraction is derived from (LOVE73) p45-47. This text contains printing errors, and the original derivation of the formulae was calculated. There are three errors in the Lovejoy reference:

a) earth's curvature formula
b) light refraction formula
c) combined formula.

a) Earth's curvature.

(G178) outlines the geometry of the earth's curvature calculation. It is exaggerated at this scale, and (G179) shows the curvature in more detail, with AB = AB' more obvious than in (G178).

Now, let distance OA = R = Radius of the earth. (3958 miles)
and AB = AB' = C = viewing distance.

Then in triangle AB'O;

$$[B'O]^2 = [AO]^2 + [AB']^2 \quad \text{PYTHAGORAS.}$$

$$[R + BB']^2 = [R]^2 + [C]^2$$

$$R^2 + 2[BB'] + [BB']^2 = R^2 + C^2$$

Now we must assume that $[BB']^2$ is neglible.
$[BB']$ = h = reduction in height of earth's curvature.

$$2\left[BB'\right]R = R^2 - R^2 + C^2$$

$$BB' = \frac{C^2}{2R}$$

$$\text{or} \quad h = \frac{C^2}{2R}$$

The Lovejoy text cites the formula incorrectly as $h = \frac{C2}{2R}$

b) Light refraction.

The correction factor for the refraction of light is not a linear function of the viewing distance C, because refraction is dependent on : air temperature

: atmospheric pressure

: angle of ray through the atmosphere and other parameters.

The formula given in Lovejoy's text suggests that the relationship is linear, ie.

$$h_1 = \frac{kC}{R}$$

where k and R are constants

k = coefficient of refraction 0.075.

R = radius of the earth 3958 miles.

and h_1 = addition in height for refraction of light.

C = viewing distance.

This formula is erroneous and should read:

$$h_1 = \frac{kC^2}{R}$$

Proof 1 According to the text formula in Lovejoy:

if k is a constant and dimensionless

and if C is a linear distance

and if R is a linear distance

then $h_1 = \frac{kC}{R}$ gives the result that

h_1 is dimensionless, when in fact it should be a linear distance.

Proof 2 Proof that $h_1 = \frac{kC^2}{R}$

The coefficient of refraction is defined as $k = \frac{\tan r_B}{\tan \alpha}$

where:

r_B = angle of refraction

α = angle subtended by S_B at the centre of the earth.

(G180) is not drawn to scale, and it may be difficult to see that the angle α is subtended by S_B at the centre of the earth.

Explanation : CX = CO = 3958 miles.

XZ = S_B = 3 miles (for example)

Therefore since XZ = 3 miles then XY or OZ (the height correction) = 1ft.

Therefore since OZ = 1ft and XZ = 3 miles
and XC = 3958 miles

we can assume that XZ is more or less equal to XO which allows us to say that the angle α is subtended by S_B at the centre of the earth and that:

$$k = \frac{\tan r_B}{\tan \alpha}$$

$$\tan r_B = \frac{XY}{OY} = \frac{XY}{S_B} = \frac{\text{correction factor}}{\text{viewing distance}}$$

$$\tan \alpha = \frac{XZ}{CZ} = \frac{S_B}{L} = \frac{\text{viewing distance}}{\text{radius of the earth}}$$

Replacing in the formula $k = \dfrac{\tan r_B}{\tan \alpha}$

then: $\tan r_B = k \tan \alpha$

and

$$\frac{XY}{S_B} = k\,\frac{S_B}{L}$$

$$XY = \frac{k\,(S_B)^2}{L}$$

where XY = correction factor = h_1

K = coefficient of refraction normally 0.075

S_B = viewing distance = C

L = radius of earth = R

Therefore, $XY = \frac{K(S_B)^2}{L}$

may be written as:

$$h_1 = \frac{kC^2}{R}$$

c) Combined formula.

The correct combined formula is therefore:

$$h - h_1 = \frac{C^2}{2R} - \frac{kC^2}{R}$$

$$= \frac{C^2}{2R} - \frac{2kC^2}{2R}$$

$$= \frac{C^2 - 2kC^2}{2R}$$

$$= \frac{C^2(1 - 2k)}{2R}$$

Again the Lovejoy text appears to have an error in the printing of this formula. C2 is used instead of C^2.

Correction factors for the refraction of light in visual assessment deal only with horizontal refraction through the atmosphere. Although limited in number, there are cases where the refraction of light vertically through layers of the atmosphere must also be accounted for. This is particularly noticeable in mountainous regions, eg. the Cairngorms in Scotland, where the visibility and visualisation of objects at lower altitudes can be distorted. The mathematical formulae describing this relationship can be found in (TRIC70) p11 and (GHOS71) p92. This is not considered a critical feature of visual assessment work and the inclusion of such formulae in the computer-based visualisation models is outside the remit of this thesis.

Subroutine correction in BIBLE.

The subroutine used in BIBLE to correct the calculated co-ordinates of points in a scene for earth's curvature and light refraction was examined and found to be accurate (PURD82d).

A comparative test was used to validate the algorithm. Five objects were placed at 5 kilometre intervals along the X axis, the furthest object being 25 kilometres distant from the origin. Views were generated with and without the curvature and refraction algorithm in BIBLE. The results are shown in (G181) where an accurate manual calculation was used as a cross check.

Summary of errors in BIBLE.

The main source of error in generating the computer perspectives is the accuracy of the input data. Most of the data used in the study are derived from O.S. maps, which do not claim high degrees of accuracy. Therefore, when modelling pylons and control points by computer, the accuracy of the output will be largely determined by the quality of the input data. The input data for this study may be summarised:

Positional error	± 5m in X and Y (pylons and control points)
Elevational error	± 1m in Z (pylons)
Elevational error	± 2m in Z (control points)
Orientation	$\pm 2^{0}$

4.4.4 Site Photography.

Four viewpoints were selected for detailed examination by the program BIBLE. The viewpoints selected were intended to investigate two important aspects of visual impact modelling.

1) the range of viewpoint locations from the interest objects; close-up or distant.
2) The internal and external locational consistency of the interest objects: the internal locational consistency refers to the positional accuracy of the pylons in relation to each other. External consistency refers to the positional accuracy of the pylons in relation to existing features also modelled by the computer as control points.

Each of the four views chosen represents one of the four possible combinations of these two factors.

VIEW 1: Distant:
External locational consistency
5 pylons; 2 control points.

VIEW 2: Close-up ;
External locational consistency
2 pylons: 2 control points.

VIEW 3: Close-up ;
Internal locational consistency
3 pylons; 1 control point.

VIEW 4: Distant;
Internal locational consistency
5 pylons

Experience has yielded the following checklist of photographic equipment necessary on site.

Site plan of area or map, at least 1:10,560. Preferably 1:12500 or 1:1250.
Xerox copies of maps for marking on information for each view:

viewpoint

control points

focus points

Drawn information of object of interest.

Camera: 35m cameras provide sufficient accuracy

: metric cameras/ 5" x 4" plate cameras/ 3½" x 2¼" or 2¼" x 2¼" cameras will offer higher quality prints and only marginal degrees of accuracy improvement.

Tripod and levelling device to ensure view through the lens is horizontal. Polaroid camera and film for on site recording of chosen control points and focus point in the scene. Gridded focussing screen to locate midpoint of the scene.

Range of camera lenses: 28mm/35mm/50mm/85mm

Black and white 35mm print film

Colour print film

Colour slide film

Site procedure

i) Select viewpoint at known location. (G182)

ii) Ensure sufficient control points in the view. (G183)

iii) Set and note camera viewing parameters. (G184)

eg. lens size

focus point

control points in the view.

Photographic Prints

A4 black and white prints are adequate as working photographs during the study; these may be produced before the computer model is ready. For final presentation purposes A3 prints may be obtained and mounted on card. The acetate overlays may be loose (with registration marks at the corner of the photographs to ensure a proper match) or hinged by tape on the card.

Sources of Photographic Errors.

The process of photographing and printing a scene consists of a number of stages where discrepancies may arise with the corresponding computer generated views. These inaccuracies can be summarised under four headings:

a) Optical Distortions
b) Geometrical Distortions
c) Perspective Distortions
d) Process Distortions

Optical distortions occur because of slight imperfections in the camera lens; geometrical and perspective distortions are due to the limitations of lenses when photographing in awkward circumstances; process distortions arise during the printing of the photographs.

a) Optical Distortions

Photographic lenses cannot produce a perfect image; variations from the ideal image are called lens errors or aberrations. There are three main reasons for lens aberrations:

i) The refractive index of glass varies with wavelengths; causing CHROMATIC ERRORS.
ii) Lens surfaces can only readily be polished if they are spherical, and spherical surfaces do not bring light to a focus; causing SPHERICAL ERRORS.
III) Light consists of waves, the visible spectrum. As in acoustics, waves are prone to bend; causing DIFFRACTION ERRORS.

In detail there are seven chromatic and spherical errors, each of which is either direct or oblique: (JAC078)

i) CHROMATIC ERRORS :

Lateral colour	Oblique
Chromatic aberration	Direct

ii) SPHERICAL ERRORS :

Spherical aberration	Direct
Coma	Oblique
Curvilinear distortion	"
Astigmatism	"
Curvature of field	"

iii) DIFFRACTION ERRORS :

Diffraction	Direct

Lens aberrations cannot be completely eliminated; however, they can be partially corrected by careful lens design. As a general rule, the more expensive a lens, the more correction characteristics it has. Only two of the lens aberrations listed above gives rise to variations in positional accuracy. These are curvilinear distortion and diffraction.

i) Curvilinear Distortion

Curvilinear distortion is the inability of a lens (due to spherical aberration) to maintain the same magnification across the image plane. Aberrations are particularly noticeable at the extremities of the image field ie. the corners. A grid consisting of vertical and horizontal lines when imaged by a lens suffering curvilinear distortion will appear barrel shaped (if the aperture stop is in front of the lens) or pin cushion shaped (stop behind lens). This aberration is usual in that only shape, not sharpness is affected. (LANG74)(G185). In current lens design, curvilinear distortion can be more or less eliminated by the position of the aperture stop in the lens. Any remaining distortions will be found only at the very edge boundaries of the image and may be fully eliminated by printing only the inner 95% of the negative. This is normal studio practice.

ii) Diffraction

Even when all the chromatic and spherical errors in a lens have been reduced to a minimum, errors still remain due to the diffraction of light in the lens (G186). The ray of light XX^1 should be a straight line, but the lens causes the ray to be bent so that it meets the film plane at Y^1 (DALL80). The errors incurred by diffraction are small and increase towards the edge of the view, ie. radial. Further diffraction errors are introduced during the printing of the photograph (see Process Distortions). Since diffraction distortions and the enlargement factor of the computer perspectives act radially the use of control points in the computer view, which also appear in the photograph, can aid the accurate fit of the montage. This should eliminate the errors incurred by diffraction.

b) Geometrical Distortion.

Geometrical distortion is very often referred to as wide angle distortion. The distortion effect created is due to the large viewangle of wide angle camera lenses, ie. when the viewangle is greater than 60^0. When such lenses are used too near a subject (0 - 10 metres) they cause distortion of foreground objects near the edges of the field of view. (G187). Although the computer program BIBLE takes account of geometrical distortion (G188) it is advisable to observe an upper limit of 60^0 for the viewangle measure. This implies that only camera lenses of 35mm or larger should be used in site photography for montage. In most cases this limitation is acceptable since views are likely to be taken over distances of 100 metres.

c) Perspective Distortion

Perspective distortion is characterised by converging upright lines on the photographic image. It is caused by incorrect camera viewing conditions, ie. the camera tilted forward or backward,vertical tilt. (G189) Perspective distortion is caused by the combination of three factors:

a) viewpoint
b) focus point
c) position of the object in relation to the viewpoint and the focus point.

Since the computer program BIBLE constructs these parameters from user defined input, the computer views will be drawn with perspective distortion, if this type of view is requested.(G190) In addition to the forward and backward camera tilt which causes perspective distortion, there is another type of camera tilt - horizontal tilt. Unlike vertical tilt, horizontal tilt does not distort the position of the object or scene being viewed. The effect of horizontal tilt is to cause an awkward match between the photograph and the computer view. (G191) The control points which are common to both the photograph and the computer perspective will match the two views to the correct positions; however, the photograph will not be level. Obviously, the effect of horizontal tilt is to be avoided, if only for convenience and a pleasing presentation of the montage.

d) Process Distortions

When printing a photograph, there are two factors which will cause positional variations in the image:

a) Shrinkage and Expansion of the photographic paper.

b) Diffraction of light through the enlarger lens.

Under normal studio conditions paper shrinkages of expansions of up to 1 percent are not uncommon. Distortion in the x direction is often markedly different from distortion in y. It is impossible fully to overcome the random errors induced by paper shrinkage; however, the use of control points in the computer view to match control points in the photograph will help to eliminate some of the discrepancies, though not all. The maximum error that might reasonably be assumed due to paper shrinkage or expansion is 0.5 per cent, which is a possible positional error of an image point of up to $\pm$2.5mm in an A3 size photograph. The positional distortions of the image incurred by b) act radially. These distortions are small (0.1mm) and extremely difficult to quantify. Nevertheless, since the distortions are radial, the possible inaccuracies of the montage match can be compensated for by keying the computer control points on to the corresponding control points on the photograph.

Summary of Photographic Errors.

<u>Optical Distortions</u>					
Curvilinear Distortion	:	positional	tangential/ radial	systematic	oblique
Diffraction	:	positional	radial	systematic	direct
<u>Geometrical Distortions</u>	:	positional	radial	systematic	oblique
<u>Perspective Distortions</u>	:	positional	radial	systematic	direct
<u>Process Distortions</u>					
Shrinkage and Expansion of Photographic Paper	:	positional	radial/ tangential	random	direct
Diffraction	:	positional	radial	systematic	direct

4.4.5 Comparison of CAD perspectives and site photographs.

In the final submission, three acetate overlays accompanied each of the four views chosen. The first overlay, (a), demonstrated the most accurate montage obtained using BIBLE. The second overlay, (b), showed the effect of changing some of the viewing parameters, such as lens size or viewpoint position. The third overlay, (c), showed the extent of the error expected in the montage due to the inaccuracy of the input data. (G192) summarises the extent of error discrepancies. (G193) to (G196) indicate the four views with overlay c) in each case; the rectangle round each pylon represents the maximum predictable locational error in X, Y and Z. Full pylons are shown on all the overlays. In effecting realistic montage, the pylons are normally cropped to fit into the curves of the landscape. This may be achieved in two ways. Firstly, a good knowledge of the site and the proposed pylon route may be sufficient to enable the designer to see how much of each pylon will be visible in the scene; he may then crop the full pylons to their correct percentage visibility. Secondly, and more commonly, the designer may crop the pylons according to the percentage visibility data obtained from the program VIEW2.

Appraisal of overlays.

N.B. Overlays (a) and (b) are not shown for each view.

VIEW 1

Overlay a) The predicted pylon view has a good match with the site photograph, with the exception of pylon 124. The X, Y input location data of this pylon, as interpolated from OS maps, appears to be erroneous.

b) The importance of the X, Y locations of viewpoints and objects is demonstrated in this overlay. Marginal changes in viewpoint position can very easily produce misleading computer views. Great emphasis must be placed on obtaining accurate X, Y co-ordinates for the viewpoint and focus point in any view.

c) The boundaries of predicted error account for the small X, Y positional discrepancies of pylon locations, arising from inaccurate map interpolation. Although pylon 124 is within the error boundary, it is likely that its X, Y location is more erroneous that the locations of the other pylons. (G193)

VIEW 2

Overlay a) The position of pylon 123 is slightly out. However, this is based on two control points which have a similar inaccuracy due to OS map interpolation. Pylon 124 is also noticeably out of proper location and is likely due to insufficiently accurate input data.

b) Minor changes, such as a 3% increase in the enlargement factor have significant effects on the final view obtained.

c) The predicted pylon locations are within the boundaries of maximum expected error. (G194)

VIEW 3

Overlay a) There is an accurate fit on pylons 123, 125 and the Blackcastle Hill Mast. The input location data of pylon 124 is suspect.

b) The effect of reducing the eyepoint elevation by 21.36 metres has quite a significant effect on foreground objects. Distant objects eg. Blackcastle Hill Mast appear to be little affected.

c) The boundary of predicted error does not quite encompass pylon 124. There appears to be sufficient evidence to state that there is erroneous X, Y location data for this pylon. (G195)

VIEW 4

Overlay a) There is a very good match from distant to close-up pylons. Assuming that the best fitting pylons are positioned accurately, then it appears that the input location parameters of pylon 124 are incorrect. An accurate survey of the X, Y co-ordinates from aerial photographs will determine this.

b) Very small changes, such as an increase of 10mm in lens size have significant effects on the views obtained. The four overlays, one for each view, which demonstrate the effects of error in the viewing parameters, emphasise the need for a close control of the site photograph, the photographic processing and the computer work.

c) The pylons are all within the boundaries of the maximum predicted error due to OS map interpolation. (G196)

One of the most interesting aspects of the montage results concerns the accuracy obtained in the elevational positions of both the pylons and the control points. In all cases, the objects modelled have a high degree of accuracy in their elevation value. This fact reflects on the need for good quality input data for X, Y location of objects. The input data for the base heights of the pylons was within $\pm$ 1m, and $\pm$2m for the control points. In contrast, the accuracy of the X, Y values was $\pm$5m. Thus it can be seen that the most significant source of error in effecting a computer montage will be the quality of the input data describing the position of the objects being modelled. In addition it is important to maintain a close control on the viewing parameters, since minor changes in viewpoint locations etc. can significantly distort the final perspective.

4.4.6 Conclusions and Recommendations.

i) Computer

The study has revealed that the main source of error causing discrepancies in the computer aided montage work is the quality of the input data upon which the program draws the perspectives. Obviously, the degree of accuracy to which a designer may wish to work will be determined largely by the viewing distance to the object, its size and the level of design detail reached. For the purposes of this pylon study, the accuracy achieved is of a sufficient level. Marginal increases in accuracy are possible through the use of photogrammetric techniques; however, this would incur unjustifiable costs. Two recommendations are stressed. Firstly, the use of a model co-ordinate system as explained in 4.4.3 will increase the accuracy of the program calculations. Secondly, if the quality of the X,Y input location data must be improved, then photogrammetric techniques should be employed. Thus, in addition to calculating the Z value of various points in the stereo model, it should be possible to obtain all the required X, Y and Z co-ordinate data of the interest objects and the control points from the stereo model. The accuracy of such interpolation would be in the order of $\pm$2 metres.

ii) Photogrammetric Interpolation

At least three widely spaced spot heights are needed to set up each stereo model for interpolation. Outdated photographs may show eg. altered terrain and road patterns; similarly, trees may have been planted or removed. Avoid choosing control points or viewpoints under trees; these locations cannot be determined from stereo photographs. Shadows also prevent accurate interpolation of ground points.

iii) Photography

a) Camera type

35mm cameras are sufficiently accurate for this type of visualisation work. However, larger format cameras, such as 5"x4" plate cameras or metric cameras with distortion free lenses used in photogrammetry, will provide greater accuracy if required. Only in extreme cases will it be necessary to use such cameras.

b) Lens calibration

The lens and other photographic equipment being used must be calibrated.

c) Control points

There should be at least two known control points in any view. They must be fixed objects in the scene eg. buildings. Natural features such as hill tops or trees are too vague to act as control points. The points chosen should be in the middle distance and preferably at either side of the scene.

d) Studio printing

The usual studio cropping of negatives when printing is acceptable, provided there remains in the printed photograph sufficient objects with which to determine the enlargement factor.

e) Conversion mounts

Avoid the use of conversion mounts to couple lenses and camera bodies made by different manufacturers.

iv) Land Survey Specification

Case studies using BIBLE have drawn attention to the need for accurate land survey data. Minor discrepancies in elevation or planimetric dimensions can result in problems of montaging. A land survey specification for measuring viewpoint, control point and focus point data on site, as input parameters to BIBLE and VISTA, is in the process of preparation.

v) Photographic Specification

Guidelines as to the photographic procedure and data recording on site were also thought to be a necessary control. A detailed specification, dealing with the instructions to the photographer and the limits of acceptable accuracy, is also under preparation.

CHAPTER 5

5.1 Introduction

At this stage it is perhaps worthwhile to summarise briefly the main points which the thesis has established thus far:

i) there is continued pressure on land resources for urban and rural development purposes.

ii) existing procedures for visual assessment are frequently being called into question on the grounds of inaccuracy, inflexibility, incompleteness and a lack of rigorous examination of alternatives.

iii) the demands of planning juries and landscape conservationists are placing a heavy responsibility on the part of building designers in sensitive environments to demonstrate that careful consideration has been given to the existing visual character of an area. The previous chapter identified some of the practical areas in which computer-based methods might assist and undergird a traditional approach to visual assessment, and help to allay the fears of those concerned with preserving an acceptable visual environment.

To date, visual analysis techniques have dealt with such concepts as:

i) subjective landscape evaluation

ii) visibility determination

iii) visualisation.

While i) is seen very much as a personal evaluation process, ii) and iii) have been amenable to computer application. This is due to the fact that ii) and iii) operate with well-defined visual analysis components:

i) observer locations

ii) topography and land use elevation values.

iii) object locations

iv) object geometrical descriptions.

producing specific results, eg. the degree of visibility and perspective drawings. Patently, these are two of the most straightforward concepts to appreciate in visual analysis.

From real world observations, though, the root of visual design problems is not, 'how much is visible?' etc., but the clash between natural and man-made forms. The resolution of this visual conflict, whether it be to highlight or minimise the formal or aesthetic contrast of the building in its context, is an intuitive design act, little aided by seductive pencil sketches or maps of visibility. In recognising the need for more sophisticated visual design tools this chapter will argue for a new approach to visual analysis, based on the quantification of certain visual attributes in the observer/object relationship. In section 5.6 a specification will be outlined for a computer program to manage and measure the different visual attributes involved.

5.2 Visual impact analysis - a state of the art review.

5.2.1 A Central Issue in Design.

The term visual impact is relatively new. It was first coined by Kevin Lynch in his book 'The Image of the City' in 1960 (LYNC60). Since then it has been taken up by a number of authors, notably Gordon Cullen in his book Townscape (COLL81), first published in 1961. Initially, 'visual impact' was defined within the urban design context, and only during the 1970s has it come to have reference in rural landscape applications. This co-incided with the expanding threat on the countryside already described in chapter 1.

The fact that society nowadays describes buildings as having some degree of visual impact is telling of standards and attitudes towards environmental issues. Contrast the reception given by an English country village to that of a village in a 'Third World' developing nation at the prospect of a petro-chemical plant being located nearby; to one an unwelcome visual intrusion, to the other an opportunity for economic growth. The growing importance of visual impact is, therefore, a recognition of the valuable visual resources in countries such as Britain, particularly where scenery would be irretrievably lost in the face of development pressures.

While "visual impact" is relatively recent terminology, large scale development projects in the landscape have been undertaken for many centuries, eg. Stonehenge, the Pyramids, Roman road and water management schemes, landscaping projects such as at Blenheim Palace, and factory/mill developments during the industrial revolution. Unquestionably, such structures have a visual impact on the landscape; but it is acceptable. There are a number of reasons why:

i) land was not as important an issue as it is nowadays.

ii) developments were largely located in uncontroversial landscapes, whereas today threatened sites are often unique and visually sensitive environments.

iii) Age softens an impact. Phrases such as 'get used to', 'always been there' or 'never known it without' often mellow an observer's reaction to an otherwise major visual intrusion in the landscape.

iv) The classical grandeur or style of a structure in the landscape often reduces its visual intrusiveness. Frequently the proportion and elegance of a structure can help carry off a bold statement in the landscape.

v) The structures were very often a symbol of economic, political, religious or social achievement. For example, in the industrial age, large scale developments reflected both a nation's wealth and prosperity, and man's ingenuity and engineering achievement. Not to build was seen to hinder progress.

The reasons that visual impact has become a central issue in design today are five fold:

i) land is recognised as an important resource.

ii) development is impinging on senstive rural areas.

iii) developments are more often formally unsympathetic with the host landscape.

iv) increased personal access to the countryside has resulted in greater concern and stronger pressure on the task of planners and architects to manage and preserve the landscape more diligently.

v) the expansion of the industrial age has passed and society is now fully engaged in a resource management age, of which visual resource management is one element.

The changing role and attitude of planning inquiries towards visual assessment procedures is also clear. In the past, aesthetics was considered a rogue or misfit evaluation process in comparison to more objective assessments such as economics, and health and safety matters; visual assessment based on whimsical or idiosyncratic sketch presentations was readily dismissed as having too high an element of subjectivity involved. Currently, decision makers at inquiries are requesting more objective presentations, and listening with increasing scepticism to expert qualitative judgements.

Considering these matters, it is necessary to conclude, for the moment, that there is little evidence to suggest that the designers of our environment are confident in the decision making processes which deal with likely intrusions on the existing visual environment. What steps might be taken to rectify this state of affairs? First, a review of the significant literature on visual impact analysis must be considered.

5.2.2 Significant research and literature in recent years.

One of the most striking features of literature on visual impact analysis is the scarcity of references. The most notable authors in recent years have been the late Prof. Graeme Aylward and Mark Turnbull. Their interest in this field was stimulated in the 1970s when they were associated with W. J. Cairns and Partners, Environmental

Consultants, during design development work on the Oil Handling Terminal for Occidental at Flotta in Orkney. Perhaps the most significant advances in visual impact analysis research were made at this time, and the findings were published in a number of journals during the mid to late 1970s (CAIR77) (CAIR78) (AYLW75) (AYLW77) and (AYLW78). These publications set out the procedures adopted in the visual assessment of the oil terminal and described a number of visual characteristics of building design, termed 'visual descriptors', which were used to merge the terminal components unobtrusively into the flat Orkney landscape. The most detailed and developed paper of the list above appeared in the journal Design Methods and Theories Volume 12 No. 2, 1978 (AYLW78). Undoubtedly this paper was a watershed in the field of visual assessment, opening up a whole new area for research and investigation. To date, the author is unaware of research work which has tried to promote the ideas and arguments presented in that paper.

Aylward and Turnbull's Paper.

The initial proposition of their paper states that:

> "decisions about the visual appearance of a building or structure cannot be taken in isolation from the existing landscape in which it is to be sited. If this is so, then the visual character of this landscape must be described in the same terms as the visual character of the proposed developments. In this way a description can identify change and facilitate the statement of visual objectives. The elements of a description will be called 'Descriptors'." (AYLW78) p72

Other authors, particularly in the field of semiotics, have reported findings which bear out this postulate. For example, Appleyard, in addressing the question 'why are buildings known?' suggests, inter alia, that the distinctiveness of its physical form causes recognition of a building or place (BROA80) p138. Lynch refers to this notion as 'imageability' (LYNC60) p9. Appleyard lists the component attributes of buildings which constitute imageability as: movement around the building (human activity)

contour
size
shape
surface
architectural design quality
symbolism in the design.

His investigation revealed size, shape and contour (specific physical attributes of building form) to be highly correlated with building identification. This evidence substantiates Aylward and Turnbull's contention that visual descriptors may be used in the process of visual assessment. Aylward and Turnbull define their descriptors as:

a) the surfaces that give an object form:
  i) shape
  ii) size
  iii) edge — Formal descriptors

b) the relationship of the surfaces to each other and to the viewer:
  i) overlap
  ii) position
  iii) rotation — Relational descriptors.

c) the effect of light on surfaces:
  i) colour
  ii) reflectivity
  iii) shadow — Luminance descriptors.

The authors do not claim the list to be exhaustive of all the aspects of perceptual psychology; however, "they have proved effective in practice, and have been found to be communicable and not particularly idiosyncratic." (AYLW78) p73 Following a short discursive account of each descriptor, the authors draw on practical experience from the Flotta design project and outline the use of the descriptors in practice.

5.2.3 Pointers to future development

New developments in visual analysis require to be generated by taking a momentary step backwards from the current pursuits of visibility determination and visualisation. The reason for this retrogressive step is to clarify the terminology and reformulate a broader approach to visual impact analysis. Only by addressing these two factors will visual impact studies be geared to match the requirements of future detailed scrutiny by planning assessors, and aid designers reach satisfactory design conclusions. How can this be achieved? To promote new ideas the author believes it is necessary to reflect on three fundamental aspects of visual impact analysis.

i) The development of visual perception theories.

ii) The definition of terms employed.

iii) The needs of architectural practice in the future.

5.3 The sources of future development in visual impact analysis.

5.3.1 Visual perception theories

A great deal of literature has been written on the subject of visual perception as it affects a variety of disciplines, not least architecture. This is hardly surprising since the perception of visual form is the most important process by which man can begin to understand and manipulate his environment. Many theories, ideas and explanations have been proposed and discussed; however, there is little agreement and unity among researchers in this field, reflecting the diverse views of research methods, definitions and factors for consideration. Each theory proposed, and there are many (PAST71), has its merits and succeeds in achieving its uniquely defined aims and objectives for one particular understanding of visual perception. Thus, there is no definitive theory of visual perception; each merely emphasises certain points in explanation of observed physical, psychological or physiological phenomena.

Visual Perception - Pre-20th Century

The theoretical discussion of visual perception began when the Greeks discovered errors of sight in their temple columns (FLET75) p194. These illusions demonstrated that the sense of sight was untrustworthy in providing information about objects and in determining our actions in response to them (PAST71) p4.

There was an inordinate gap in contributions to theories of visual perception until the seventeenth century when Descartes proposed the first major theory on visual perception. Following Descartes, a flush of thinking and writing brought two main stream theories of visual perception into the debating arena; the nativist and empiricist theories. These two theories were to last until the early 1900s and the advent of Gestalt Psychology. Ittelson helpfully refers to the nativist/empiricist dichotomy as 'built in or built up.' (ITTE60) p30.

In 1649 Descartes' book 'Passions of the Soul' contained the first expression of a nativist theory of perception; that man has certain innate physiological mechanisms for perception. Descartes' ideas were substantiated by Malebranche in his book 'The Search after Truth' 1674. Contrasting the nativist theory, Locke (An Essay concerning Human Understanding in 1690) and Berkeley (Essay Towards a New Theory of Vision, in 1709) developed an empiricist theory of visual perception which dominated thinking in this field until the beginning of the twentieth century. The empiricists held the view that man learns to see, and that all knowledge derives from experience. Condillac (Origin of Human Knowledge, 1746) and Bailey (Review of Berkeley's Theory of Visison, 1842) advanced the nativist standpoint while Helmholtz developed the empiricist argument further in 1871 through his report on 'Recent Progress in the Theory of Vision'. (PAST71) The nativist/empiricist conflict was resolved in the next most significant event in visual perception theory, the Gestalt Movement.

Visual Perception - in the 20th Century.

The four main approaches to visual perception developed during this century are:

i) The Gestalt Movement
ii) Experimental/Behaviourist Theory
iii) Functionalism
iv) Psychophysics.

Their differences lie in the nature of the perceived object or stimulus, and the process of perceiving. In formulating a new approach to visual analysis these theories must be assessed, and one or a combination of them used as a baseline for understanding how man perceives objects in the visual scene.

i) The Gestalt Movement.

Gestalt Psychology began in 1912 through the work of Wertheimer, though Kohler and Koffka, more articulate in setting out the principles of the theory, are well known as early proponents of the movement (KOHL47). Gestalt theory represented a reaction against extreme empiricism and nativism, and opened the way for other theories of perception in the twentieth century. The phenomenological approach to visual perception propounded by Gestalt theory concentrated on the detailed description of conscious direct experience to whole visual stimuli as a means of how man perceives form in the environment. The Gestaltists believed, therefore, that perception could not be understood simply by reference to individual physical characteristics of the stimulating visual environment. Thus, complex patterns, eg. our everyday visual world, were perceptually organised in large and simple forms.

Although spatial vision was much researched before this century, the Gestalt Movement is significant in that it brought to focus the importance of form perception as distinct from spatial perception. The Gestalt concepts of; Figure and Ground; Segregation and

Differentiation; Closure; and Good Gestalt are helpful in understanding the perception of the visual environment (PRAK77) p18. Nevertheless these ideas have a high element of subjectivity and this phenomenological approach is not considered helpful to new procedures in visual analysis.

ii) The Behaviourist Approach.

The 1920s saw the emergence of a Behaviourist theory in psychology through the work of Pavlov and Watson. This was taken up in the field of visual perceptual psychology by Hull (HULL43) and Hebb (HEBB49) who developed the Behaviourist viewpoint that the link between stimulus and response was through the nervous system. There are little, if any relevant findings in this line of research work to influence thinking today for visual analysis.

During and immediately after the second World War significant advances in theories of visual form perception were achieved. There were two main reasons:

a) Needs of the armed forces, in judging distances, recognising features and flight reaction times, etc., caused a great deal of financial and political support to be given to research in the field of visual perception.

b) The emergence of Information Theory through the work of Weiner (WEIN48) and Shannon (SHAN48), and its application in perceptual psychology demonstrated that some of the Gestalt ideas in perceptual organisation were measurable (MILL49). Until then Gestalt psychologists believed that visual organisation and patterning were subjective, unquantifiable concepts. Since 1945 a wide range of measures of visual form has been defined (ALLU60), and this area of research activity has become an important development in visual form perception (ZUSN70) p13-14. Indeed Zusne and other authors have rightly seen the need to reduce the plethora of physical form measures by relating them to broader theories of visual perception (ZUSN70) p176 (MICH65) p74.

Returning to the two final approaches to visual perception theory, Functionalism and Psychophysics, it is to be noted that these theories dominated post-World War Two research.

iii) Functionalism.

The main proponents of the Functionalist approach to visual perception were Ames and Ittelson (ITTE60) p6. Their theory laid emphasis on such functional factors as needs, values and personality in influencing perceptual organisation. Brunswik further developed these ideas with his Probabilistic Functionalism theory in the 1950s. He believed that laboratory experiments and tests removed the probabilistic nature of visual information as experienced in the real world, and established a radically new method of research in perception theory, that of representative design (WEIN66). Through this means Brunswik obtained a more representative understanding of perception by studying a subject's everyday environment and behaviour, 'live' on site. Again such an approach is highly subjective, based on individual personality and preferences, and inappropriate as the basis for an objective assessment of form in the visual environment.

iv) Psychophysics.

The fourth and final approach is that of Sensory or Perceptual Psychophysics. J. J. Gibson was the first of a number of authors to outline a psychophysical approach to visual perception theory (GIBS50). "Psychophysics assumes that there are lawful relationships between properties of the physical world and the human's behavioural response. It further assumes that these relationships may be determined without recourse to introspection by applying, within a carefully controlled environment, a set of known, independent stimuli, and recording in a quantitative fashion the variations in selected indicators of response." (LIPK70) p3.

For the purposes of objective visual impact studies, we may discount the relationship between the objects perceived and the behavioural response. What is of particular interest is that the elements of the physical world have distinguishable visual attributes. In his 'Ground Theory' of visual space perception Gibson suggests that in order to make sense of the visual world, distal stimuli must be related to the ground, which acts as a fixed continuous reference surface. His theory is distinct from all previous theories of visual perception, notably because past theories concentrate attention on what is seen in the visual field, whereas Gibson argues that this attitude offers insufficient scope in understanding the visual environment. He suggests that the real problem in perception is the visual world, and that a fundamental condition of seeing is that there are physical surfaces related in space by the ground texture, reflecting light and projected on to the retina. Such a simplistic view of visual perception can be misleading from a psychological, behaviourist or phenomenological viewpoint; however, for the purposes of objective visual appraisal it is helpful and adequate to accept that the "elementary impressions of a visual world are those of surface and edge". (GIBS50) p8. It is clear that the psychophysical approach to visual perception offers the greatest help in formulating a new understanding of the measurement of objects which man perceives in his environment.

The application of information theory and the advent of a psychophysical theory in form perception led other researchers to work on the quantification of form during the 1950s and 1960s. Throughout the 1960s in particular the search continued to define an acceptable metric system for visual form. Perceptual psychologists such as Gibson, Zusne, Arnoult, Michels and Vanderplas were prominent in the field of psychophysical research; however, there was rarely a conjunction of opinion or theory. This was due to the abstract nature of much of the research, and it is notable that the most significant contributor to the quantification of visual form in the post-war period, Fred Attneave, related much of his work to practical experimentation. Attneave is frequently referred to in current visual perception research.

Two applications dominate research in visual perception nowadays, military defence and computing.

i) Defence. Aircraft/warship simulation for a wide variety of training exercises.
- low attitude flight simulation
- take off/landing exercises.
- reconnaissance missions
- inflight refueling
- aerial combat
- harbour manoeuvring
- docking procedures, etc.

Visual recognition studies involving soldiers abandoned in unknown, but not featureless terrain, provide observers with first hand evidence of the means by which man recognises his environment and acts accordingly. A large proportion of this research work is classified and unavailable to lay researchers.

ii) Computing.

The advent of high resolution advanced colour computer graphics has stimulated research work in visual perception in order to maximise the realism of objects viewed on the screen. A great deal of this work is stimulated by the intellectual challenge to match real observable situations with computer generated views. Many practical applications are known, but the data quantities and storage, computing time and costs, and hardware facility access hinder active and regular use. Nevertheless, a great deal of the effort involved in computing and visual perception has opened new avenues for investigation, in particular that of Psychopictorics which was developed for pattern recognition studies and automatic picture processing. Psychopictorics is the process of object detection, "characterisable or definable by a significant ordering of a set of psychophysical properties" (LIPK70) p34.

Visual perception is a process involving four factors; the reception, selection, organisation and understanding of a physical stimulus in creating an experience or response. This process will be different to everyone, producing a variety of responses, since it is determined largely by culture, background, values, past experience and aspirations. It is not the intention of this thesis to explore the psychology of perception, but rather it is to measure the objective attributes of visual form which elicit a subjective value judgement from the observer. A psychophysical approach to visual perception is adopted, in so far as it offers the means by which the visual attributes of form such as edge, shape, surface pattern etc. may be quantified.

5.3.2 Definitions

Debate and controversy on visual impact issues at inquiries is often heightened by a confusion in terminology, and the varying degrees of importance attached by individuals to such concepts as the visual absoptivity of the landscape. Few authors agree on specific definitions, and there is an obvious need to clarify the language used in visual assessment. More precise visual terms, simple and well defined, must be seen as advantageous to both designers and lay persons alike in

- describing the visual effects of decisions during the design process.
- promoting commonly accepted definitions in debate.
- eliciting more informed responses.
- communicating meaning at inquiry presentations.

<u>Visual Impact</u>

The notion of 'impact' can be understood in a wide variety of contexts; socio-cultural, economic or environmental. Such impacts are described in terms of the degree of change, whether beneficial or detrimental, brought by an event or events to an existing set of conditions or circumstances. This thesis is principally concerned with a sub section of environmental impact, that of visual impact.

In this context, "an impact can be stated in terms of changes to the functioning of ecosystems and in terms of changes to the visual character of the area " (AYLW82) p228. This necessarily implies that in order to assess impacts, "a fairly detailed knowledge of the capabilities and limitations of the environmental setting is required" (HALL76). In the end, the judgement as to whether an impact is adverse or beneficial is subjective. In the case of visual impact, though, there is scope for improving the objectivity of the grounds upon which subjective judgements are made.

Turning to the definition of the full term 'visual impact', the author believes this phrase to be the most widely abused in the field of environmental design. Earlier it was shown that the notion of 'visual impact' originated in townscape urban studies through such authors as Lynch and Cullen. Both authors refer to the visual impact which a city has on those who live in or visit it. Lynch best defines the visual impact of a building by its 'imageability' (LYNC60) p9. However, this is in an urban context. More recently, 'visual impact' has been used in the rural context. It is important to establish the usage of the term in these two situations.

The need to distinguish between urban and rural visual impact is due to the nature of the urban and rural contexts. On the one hand, the urban environment contains hard, sharp, man made edges, surfaces, textures and shapes; on the other, the rural environment consists of soft, ill-perceived natural edges, textures and shapes. Designing in these environments is fundamentally different from a visual impact viewpoint.

i) Viewing conditions;

The distance over which buildings are viewed in the rural context is frequently one mile or more; whereas in urban environments the viewing distances typically may be restricted by street frontages. The viewing of developments in the landscape is often direct and focussed, with the target building only occupying a particular section of the visual field. In contrast, urban settings demand that the observer perceives the target building dynamically, ie. he moves his head and takes in several views which provide him with a complete and sufficient panoramic picture of the building and context in order to make a judgement. The visual proximity of buildings in a street scape requires dynamic viewing in order to appreciate the complex relationships and arrangement of design which afford a building its 'imageability' or visual impact in an urbanscape.

ii) Form and detail

The scale of perceptible form and detail varies from urban to rural environments. Since viewing distances are greater in rural settings, important urban scale details such as fenestration and surface textures will be largely imperceptible when considering rural visual impact. In most cases, only the colour and overall massing and form of a development would be considered in a rural visual impact study.

How do these two factors influence an understanding of visual impact in urban and rural environments?

Firstly, visual impact will be defined as:

> a measure of the degree of visual contrast between a building or structure and its context environment. A null visual impact will be the result of a low-key harmonious blending of building and environment, while a high degree of visual impact will be associated with conspicuous and highlighted forms distinguishable and conflicting with background colours, textures, shapes and scales.

This definition does not rule out the possibility of designs with high visual impact being wholly valid and acceptable solutions to design problems. In urban situations, visual impact will be concerned principally with proportion, scale and style, testing an architect's designability in a man-made aesthetic. In rural landscapes, visual impact measures will be derived from the larger scale massing and formal problems of design in a more subtle and dynamic natural aesthetic.

Perception

A perception occurs when we experience something through our sense organs and is the process by which we learn about the world and the necessary responses to be made in it. This process may be visual, aural, tactile or olfactory; in this thesis we are purely concerned with the visual perceptual process. (G197) summarises the percentual process.

Percept

An impression of an object obtained solely through the use of the senses.

Response

Behaviour or reaction to a percept.

Distal stimulus

The object perceived.

Proximal stimulus

The retinal image.

Visual descriptors

A set of attributes which describe the visual character of a percept, eg. size, edge and shape. The term was coined by Aylward and Turnbull (AYLW78) p72, where a more detailed thesis presenting the idea of visual descriptors may be found.

Visual modelling

The modelling of man-made structures and their environment in 2d or 3d, eg. artists' impressions or physical scale models.

Visual field

The extent of our vision which we see at any one instant in time.

Visual world

Panoramic and continuous in character, it is the complete perceivable visual environment; 360^0 around an observer at any one instant in time.

Visual absorptivity

Visual absorption is the capacity of an environment to accommodate a potentially visual intrusive element. The extent to which this is possible without a marked visible change is a measure of the visual absorptivity of that environment. Visual absorptivity is highest in rural settings when there is undulating topography, and varied and thick vegetation; in urban contexts, visual absorptivity is dependent on the scale, texture, size shape and material finishes of the existing developments.

Visual transparency

Defined in (JACO70) by the degree of vegetal density and the amount of topographic closure which may contribute to hiding a proposed development. In urban settings the surrounding built environment will add to the determination of visual transparency.

Visual complexity

Defined in (JACO70) as the amount and clarity of visual information that the observer must sort and evaluate in understanding a scene.

Visual range

The maximum distance at which a building or structure may be discriminated from its background setting.

Viewshed

The area in a terrain which is visible from a selected viewpoint.

Visibility

To the meteorologist, 'visibility' is measured by a distance, "that at which it is just possible to distinguish a dark object against the sky" (MIDD68) p4. This definition of visibility is better understood in the visual impact analysis context as visual range. To designers of the environment, visibility has for some time now been commonly accepted as a measure of whether an object can be seen or not, due to intervening vegetation, topographic and built forms, and regardless of distance. It is possible to broaden the concept of visibility by redefining the initial question. Rather than ask 'can the development be seen?', if the question 'what is visible?' were posed, more than just a measure of the observable part of the development would be required in the answer. Thus, a complete answer would necessarily involve reference to the visual characteristics or attributes of the development in relation to its setting. These are defined as visual descriptors and appear in greater detail in section 5.6.

Form

Almost all the notable researchers in visual form perception deal with the definition of form in different ways. Some readily dismiss form as shape, while others have proposed various classifications of the general concept of form. The main difference between definitions seems to be whether form refers to the object itself, eg. an interesting form; or an attribute of the object, eg. its shape or pattern.

In defining form, Gibson identifies three broad classifications (GIBS51) p403 :

a) Solid or Surface Forms which are realities. The substantial shape of an object in three dimensions.
b) Pictorial Forms which are representations which the perceiver takes to stand for realities. The projection of an object on a flat surface, eg. an artist's impression.
c) Geometrical Forms are abstracts, specified by symbols, eg. plans, sections and elevations.

The first classification of form is best in keeping with the conventional architectural meaning of form, which is usually seen as a 3d volume uniquely defined by:

points or vertices - where several planes come together
lines or edges - where two planes meet
planes or surfaces - the limits or boundaries of a volume.
(CHIN79) p18.

Gibson makes a fundamental distinction between two common views of the term form, projected form or silhouetted shape, and the invariant shape of an object in depth. He argues that the former is not a primitive spatial impression, but believes that form must be considered as one of the variables of an object, like colour, size etc. Patently such a definition of form is variant, ie. the silhouette shape or profile of an object will alter with changes in the observer or object location. In contrast, more recent authors have argued for a view of form in visual perception theory according to Gibson's second definition, that form is the invariant shape of an object in depth. Indeed, Hake, and Attneave and Arnoult contend that form cannot be properly defined unless its relation to shape invariance is clear.

"Form is invariant under rotation". (HAKE66) p151 "whenever we speak of form, we are referring to a somewhat vague set of properties which are invariant under transformations of colour and brightness, size, place and orientation." (ATTN56) p463.

Although Aylward and Turnbull do not define form, by implication they follow the form invariance convention. "Multiple views of an object give more meaning to its form than static views" (AYLW78)p77. This implication is further supported by the fact that, in agreement with other authors, Aylward and Turnbull helpfully define Gibson's projected form or silhouette as the variant, shape. Thus the key to a proper definition of form is to distinguish between projected shape and depth shape. The former is referred to as shape and the latter as form. The visual attributes of form, eg. shape, size, edge etc. will be defined and discussed more fully in 5.6.

Spatial perception

One of the drawbacks of analogue modelling systems is the restriction of such methods to an Euclidean geometry. As a consequence discrepancies are bound to arise between observed reality and the modelled image since objects are perceived differently from their physical location. The visual perception of three dimensional space, therefore, requires the clear understanding of an appropriate geometrical or spatial structure.

Various geometrical systems have been developed and are described, in relation to visual perception, in numerous texts, (CARR35) (WATS78) (BLAN78) (FISH69) (REDE68) (CAEL81) (BLAN57). From these texts, it is clear that Euclidean or Affine geometry, which preserves parallelism, is unsuitable as a spatial framework for visual perception. Non-Euclidean or Riemann geometries (elliptical or hyperbolic) are necessary to explain the vagaries of visual space. Blank is the most convincing of the authors in this field, and sets forward a conclusive argument that the metric for visual space is a hyperbolic function in the same manner of Bolyai and Lobachevski's definition of a hyperbolic geometrical system (BLAN61). Visual space is, therefore defined as having a constant negative or downward curvature. This hyperbolic function can and is incorporated in most computer based systems, since it is possible to adjust digitally for such factors as earth's curvature.

Depth perception

Objects may be perceived as occupying a particular location in three dimensional space by a number of depth cues.

Primary depth cues.

i) Binocular image disparity. The marginal discrepancy between the two retinal images when perceiving an object; stereoscopic vision.

ii) Convergence. The movement of the eyes to fix on an object, depending on whether it is near or far in the visual scene.

iii) Accommodation. The degree to which the curvature of the lens of the eye adjusts in order to bring an object into focus.

Secondary depth cues.

i) Linear perspective. The convergence of parallel lines in the field of view.

ii) Size. The apparent size of objects in the visual field can aid depth perception, if the real size of the objects is known.

iii) Motion parallax. The relative apparent motion of objects at right angles to the line of vision. Two unequally distant objects will appear to move at different speeds, eg. foreground trees and background hills observed from a moving train.

iv) Overlap. The covering of a far object by a near one. Also termed eclipsing or interposition.

v) Aerial perspective. The blueness/blurredness of distant objects. This is caused by the progressive reduction in the luminance range of increasingly distant objects on account of light from the object being scattered by water vapour, smoke and dust suspended in the atmosphere. Thus aerial perspective is a simple gradient of hue running toward the violet end of the spectrum with increasing distance.

vi) Position. The position of objects relative to each other on the picture plane conveys a sense of depth. Normally, more distant objects appear higher than closer objects.

vii) Brightness. The brightness of objects as seen in daylight can aid depth perception; all things being equal bright objects will appear nearer.

viii) Light and shadow. The relationship of lit and shaded areas around objects is a strong cue to depth perception. In particular, the shadow length can help to locate objects properly in the scene, since this is created from a single base reference source, the sun.

ix) Texture gradients. The relative distance of objects from an observer can be judged by their relationship to each other on a ground texture or patterned surface eg. the land. This aspect of depth perception derives from the work of Gibson (GIBS50).

5.3.3 Needs in architectural practice.

Reviewing the future needs of architectural practice in the field of visual impact analysis it is possible to identify three specific areas for which techniques might be developed and applied.

i) Formulating design strategies and objectives. The visual objectives of a project emerge at an early stage in the design process (AYLW82), and are commonly described as blending/masking/or highlighting. Determining the capability of structures to be masked or blended into the forms of a background setting is not an easy task; the main difficulty is, of course, the terrain of the study area which is frequently large and undulating. Thus the process of forming strategies and objectives is dependent on a thorough understanding of the complex and dynamic relationship that exists between the observer locations/terrain/and building location. Clearly, this is best investigated by the designer with computer assisted methods, and frequently on a trial and error basis.

Soon after project inception, such procedures may indicate the feasibility of, eg.

- hiding or exposing the development in the existing landscape,
- minimising or maximising the skyline protrusion,
- tree planting or earth mounding to screen the development, from critical viewpoints.

These tasks may be given a quantitative value, eg. the depth of a particular location within which it is possible to site a structure without the structure being visible or protruding above the horizon can, from a given viewpoint or set of viewpoints, readily indicate the nature and scale of the design problem at an early stage. In such cases there is more likelihood of the design process guaranteeing that physical change in the landscape, brought by design strategies for building layout and form will meet initial visual objectives. The importance placed on setting objectives and proposing design strategies soon after the project has commenced is seen as addressing the real issue in visual impact analysis:- that of appreciating the topographic constraints and limitations delineating an acceptable design solution space to meet visual aims.

ii) Assessing alternatives

The ability to reach decisions and subscribe to a particular design choice with any measure of confidence is partly dependent on the variety and scope of alternatives assessed. In the course of design the techniques employed for visual assessment must therefore be fast and flexible, able to cope with a range of hypothesised design solutions. With the possibility of future legislation on environmental impact analysis and more scrupulous planning inquiries, there is patently a need to outline the rationale for certain design decisions and choice from alternatives.

iii) Sensitivity analysis.

Having arrived at a tentative solution, a designer may wish to examine the effects of marginal changes in order to tune the solution to a better fit. This investigation of the thresholds of sensitivity may involve the mapping of those areas in which there is a significant variation in the visual impact of the proposal; or boundary markers delimiting areas of skyline protrusion from areas that provide complete backcloth to developments.

Such procedures would require computer assistance to handle the large and complex calculations. The results would give the designer a feel for the changing visual relationship between the object and observer, and direct the designer in producing higher quality solutions, in the sense that his objectives are more likely to be met.

A computer-based approach to visual impact analysis is being recognised by a number of design practices in Scotland as the most appropriate means of responding to the challenges outlined above. Until fairly recently visual assessment has been conducted with the help of spatial and mechanical model types; to a large extent these models are tried and tested. However, improvements therein are likely to centre on the skills of artists and modelmakers. Traditional methods of assessment are unable to incorporate any further developments in assessing the visual impact of buildings. The new generation of computer-based visual assessment models will certainly be better equipped and prepared to meeting the rigorous demands of increasingly detailed appraisal and evaluation procedures.

5.4 Foundations for the Assessment of Builtform in Visual Impact Studies.

5.4.1 Introduction

The objective measurement of builtform in architecture is, traditionally an area fraught with pitfalls and dangerous assumptions; however it is the contention of this thesis that the abstraction of both topography and builtform by computer models can yield helpful measures as to the degree of visual impact buildings possess. The approach adopted to advance new thinking in visual assessment takes Aylward and Turnbull's 'visual descriptors' (AYLW78) as a start reference point.

Such an approach to assessing the impact of builtform in the landscape presupposes an ability to isolate form from its context, in order to measure it independently from the landscape. The proposed method will draw upon the programs:

VIEW for visibility analysis
and
BIBLE for object visualisation (and VISTA for polygon set operations)

The program VISTA may also be used in appraising the colour tone and texture of object surfaces. However, the development of such procedures using VISTA is outside the timescale of this thesis. The accuracy of both VIEW and BIBLE is known and therefore any erroneous calculations may be more fully related to the methods of measurement proposed.

In proposing a new method of computer-aided visual impact analysis the following hypothesis is stated.

> There exist a number of formal, relational and luminance characteristics of man-made structures which can be both defined and measured. These 'visual descriptors' adequately describe the form of building developments, allowing designers to assess the degree of visual intrusion man-made structures exert on the surrounding countryside.

5.4.2 Visual descriptors.

To attempt to measure all the descriptors as listed by Aylward and Turnbull would involve many years of research and development work. Within the timescale of this thesis it was decided to concentrate efforts in developing the ideas behind the formal and relational descriptors rather than the luminance descriptors. This ordering is due primarily to the fact that:

i) design is a direct specification of space and form (CHIN79) p49.

ii) spatial and formal dimensions are reinforced by light, colour, texture and detail.

Thus the geometrical properties of a form and its physical relationship to the observer must be established before the attributes of colour, texture etc. can be assessed. The luminance descriptors of colour, reflectivity and shadow are more difficult to measure, not least because of the variety and subjectivity of each individual's perception. Additionally, the unfaithful reproduction of colour, tones and texture in photographic work frequently results in such chromatic studies being set up 'live' on site with large colour display boards placed in the scene for building colour choice. Only with the advent of advanced colour computer graphics with screen resolution akin to (1024 x 1024 pixels) and image processing can serious research into accurate scene and colour matching in visual analysis commence.

Formal and relational descriptors may be assessed purely on three factors: i) a geometrical description of the interest object

ii) a set of observer locations

iii) the topographical and land use description of the study area.

The design attributes of proportion, scale, rhythm and symmetry are not under assessment in this thesis. These are more complex aspects of design, the compositional unity and variety or overall aesthetic of which may only be properly and fully assessed by including a measure of subjective judgement based on the observer's own experience.

The aim of the thesis is not to quantify the whole visual scene by some metric of beauty, but to quantify those 'descriptors' or elements of form in the scene which may contrast or harmonise with the form of the setting.

The classical heuristic and intuitive approach to design problem solving will remain pre-eminent in any use of the approach. However, it is argued that a more informed and perhaps more productive design process will accrue from the implementation of rational computer based design methods in visual assessment. The main advantages and reasons for a computing approach were set out in chapter 2.

Recent comments in the architectural press, regarding the design of the Sizewell 'B' Nuclear Power Station, have centred on the lack of debate and discussion on the unsympathetic formal aspects of such large scale constructions in sensitive coastlines and landscapes. In this respect it would appear that in 1983, the architectural profession is no further ahead than 1979 when the Watt Committee on Energy made vague reference to the subject of visual impact:

> "However, by use of careful building and structure grouping techniques and design and large scale landscape design the visual intrusion in the environment can be reduced." (WATT79)

While the sentiment expressed is agreeable, the means by which it might be obtained are lacking. This has been brought into sharp focus by the Sizewell inquiry. The Sizewell project clearly demonstrates that there is a gap in the ability of designers to articulate form at such large scales and in such sensitive and demanding settings.

> "In other words when we speak of design, the real object of discussion is not the form alone, but the ensemble comprising the form and its context." (ALEX64) p17.

The visual attributes of building form cannot be seriously considered unless related to the shapes and contours of the natural landscape. On a small scale this analysis may be achieved intuitively; however, on a larger scale with greater viewing distances involved, and many more points of potential impact, the problem of understanding the complex relationship between the builtform and the context cannot be satisfactorily dealt with by intuitive means.
In developing computer-based techniques for visual analysis the need for a formal design vocabulary and a context-dependent grammar is, therefore, recognised. The intention is to develop a better understanding of the visual interaction between the man-made and natural environments by describing the effect of design changes in terms of the vocabulary and grammar. The formal design vocabulary is based on Aylward and Turnbull's 'visual descriptors'; the syntax will vary according to the visual characteristics of the host landscape or context for the development, and the visual objectives (highlighting/blending/or masking). Time has restricted the work at present to the development of the vocabulary, and this is described in more detail in 5.6.

5.5. Criticisms of an Objective Approach to Visual Assessment.

5.5.1 Introduction

Including some of the more intangible factors bearing on visual assessment, the visual impact of a building may be determined from:

i) the features of an environment: scale, proportion, shape size etc. of the constituent elements.
ii) the perceptual capabilities of the observer.
iii) the values and aspirations of the observer.
iv) the context of the development: rural/industrial, economic/social setting.
v) the context of the observer: economic/political/ and social background.

The questions of how we perceive, and what we perceive, therefore, cannot, in the final analysis, be dealt with as separate entities and still expect useful conclusions. The two are intrinsically related. This is a fact frequently referred to by designers on the suggestion of some objective measurement of architectural aesthetics. Nevertheless, quantitative information can be helpful to designers because it is data in a very explicit mode. On the other hand it can sometimes be dangerous and misleading to quantify phenomena, such as occur in visual perception, since they are frequently elusive and subtle in structure and nature. This attitude has resulted in an impasse in following new directions in visual analysis. In order to make headway, it is necessary to discard temporarily the question of how we perceive, and concentrate on the problem of what we perceive. In so doing a greater understanding of the how process in perception may be gained.

An approach based on the need to quantify what it is that we perceive is bound to suffer criticism from a number of sources; in this case, three moot points will be discussed.

i) Personality in Perception.
: objects are perceived differently by individuals on account of various background factors.

ii) Meaning in the built environment.

: objects possess meaning in the environment for a number of historical, social reasons etc. This is unquantifiable and may influence individuals' perceptions.

iii) The objective/subjective debate.

: Whether a choice is made to distinguish between the objective and subjective aspects of perception will determine the way in which individuals understand the perceptual process.

5.5.2 Personality in Perception

The influence of cultural, social, economic and political backgrounds to visual perception is well documented; (SEGA66) (PICK72) (HABE80). Any individual's perception of the environment will be tempered by these variations, with the result that no two persons will perceive a scene in the same way. Judgements are always subconsciously imposed in forming a perception; they may be based on -

- source and type of stimulus.
- ability of a person to use the available informaiton.
- past experience.
- personal values, moods and expectations.

Thereby, an observer "with great adaptability and in the light of his own purposes, selects, organises and endows with meaning what he sees". (LYNC64) p6. The most basic question, therefore, is whether one can measure a highly subjective personal experience like visual perception.

The inadequacies of objective appraisal techniques in accounting for the complex cultural and social framework through which individual judgements are made are valid grounds for criticism. Nevertheless, although visual perception is a highly idiosyncratic process there is some structure to it. Lynch suggests three components; identity, structure and meaning.

> "It is useful to abstract these for analysis, if it is remembered that in reality they always appear together. A workable image requires first the identification of an object, which implies its distinction from other things, its recognition as a separable entity. This is called identity, not in the sense of equality with something else, but with the meaning of individuality or oneness. Second, the image must include the spatial or pattern relation of the object to the observer and to other objects. Finally, this object must have some meaning for the observer, whether practical or emotional. Meaning is also a relation, but quite a different one from spatial or pattern relation." (LYNC64) p8.

The third component, meaning , is that element which is unique to each observer and will always remain unquantifiable. The remainder, identity and structure, may be quantifiable and could provide some start point for the way in which form might be assessed numerically in visual impact studies. Certainly Lynch argues in favour of some sort of distinction between form and meaning. Thus, while total perception is regarded as immeasurable, there is a structure to it, parts of which are quantifiable, and of direct use in visual studies.

5.5.3 Meaning in the Built Environment.

The separation of meaning from form in visual perception is subject to criticism. Any distinction made, therefore, must be seen as a temporary measure to facilitate the quantification of form, and never wholly exclusive of reassessment in the light of some underlying symbolism or personal interpretation. Returning to Lynch's tri-partition of visual perception, the approach adopted in this thesis recognises, in agreement with Lynch, that it is possible to "separate meaning from form, at least, in the early stages of analysis" (LYNC64) p9.

Thus, while meaning is regarded as a vital component in visual perception, the identity and structure of form will be investigated as the preliminary stages of this perceptual process. This sequence of identity and structure, then meaning, corresponds to the notion that formal legibility (identity and structure) is the common perceptible base upon which individuals construct their own meaningful structures and interpretations.

What is understood by the term, 'meaning in architecture'?

> "As in language, however, architectural forms and spaces also have connotative meanings - associative values and symbolic content that is subject to personal and cultural interpretation, and can change with time. The spires of a Gothic cathedral can stand for the realm, values or goals of Christianity. The Greek column can convey the notion of democracy, or, as in America in the early 19th century, the presence of civilisation in a new world." (CHIN79) p386.

> "The environment should be perceived as meaningful, its visible parts not only related to each other in time and space but related to other aspects of life: functional activity, social structure, economic and political patterns, human values and aspirations, even individual idiosyncrasies and character. The environment is an enormous communications device..." (LYNC71) p226.

> "When we refer to the 'meaning' of buildings therefore, we refer to all those things which relate those buildings, beyond the 'face value' of their physical properties, to all those other things in life which people attach significance and value - including their purposes, their conceptions, their ideas and beliefs." (BROA80) intro.

Semiotics, the study of connotative meaning, was a subject poorly documented, though not necessarily unresearched, in the field of architectural and urban design until the work of Krampen within the last five years. Architectural semiology was born in the early 1950s with the emergent belief that architecture was a complex system of signs and meanings, composed according to a set of rules or grammar. Krampen traces this early development in semiotics in his text, 'Meaning in the Urban Environment' (KRAM79), concentrating on thinking and research in Italy, particularly at the Florence School of Architecture.

Theories identifying the components of architecture, "analogous to constitutive linguistic elements" (KRAM79) p22, and grammars or syntaxes operating on these elements attempted to explain the meaning of buildings, past, present and future. It is not the remit of this thesis to review this area in depth; Krampen's book offers a satisfactory summary if required. What is significant about this area of research is that it led to a number of objective indices of architectural design. Keimle, Buttlar and Wetzig, and Bortz are notable in this field. A common thread running through their research was that of developing an objective measurement of facades by details and elements, eg. windows balconies or columns.

These types of approach to the measurement of the built environment are not recognised by the author as relevant or helpful in the determination of form measurement for visual analysis applications. The classification and measurement of detail and facade texture is inappropriate to typical visual assessment, and certainly will not aid the process of formal design at a large scale.

5.5.4 The Objective/Subjective Debate.

Although it is not fully understood how we perceive objects, it does not follow that we cannot attempt to understand more objectively what we perceive. Such a distinction between how we perceive - perception, and what we perceive - the percept, is a moot point in architectural psychology. These may be seen as the subjective and objective components of visual perception.

Using psychological terminology, "subjective refers to phenomena appertaining to mental life, while objective refers to phenomena occurring in the physical environment." (HESS72) p14. Thus, 'how we perceive' objects may be regarded as subjective, while 'what we perceive' can be interpreted as the objective elements of the physical environment.

For the purposes of this thesis it is necessary to make this distinction since designers are primarily, though not exclusively, concerned with the characteristics and attributes of what is perceived rather than with the mechanisms and variables of how one perceives. This approach may be criticised as naive; however, it is the author's contention that there are common descriptors of form that are quantifiable for the purposes of design, eg. the amount of skylining edge: such factors will not necessarily have the same importance in individual preferences, but this is immaterial to the designer in achieving his design objectives. This idea was seen by Aylward as critical in developing a new approach to visual assessment.

> "It may be said that the subjective heart of visual analysis is emotional rather than rational; the rational presentation of subjective judgement is therefore very important if visual impacts are to be given the same attention as would be given to physical pollution." (AYLW75) p467

In his book 'Managing the Sense of a Region' Lynch makes reference to this distinction; "what one can see" as a separate issue from "how one sees it" (LYNC76) p8. The reason for separating the two questions is that, while the latter cannot be dismissed altogether, it must not hinder an analysis of the former problem, 'what we perceive'. In essence, the answer to 'how we perceive' is variety itself; the answer to 'what we perceive' is beheld by, and therefore common to, all.

One of the purest sources of what we perceive as important in the urban environment is children's drawings. Although such drawings are often the result of what children want to see rather than what is actually there, it is interesting to note the elementary components of form and space which children use to describe their primitive understanding of the environment. (G198) shows a child's attempt to depict his home urban environment. The most striking feature is the emphasis on well defined shapes and hard edged contours. The more subtle components such as relative size or scale of objects, overlap, object orientation and position in relation to the observer are weakly executed in the drawing.

Thus, object shape and edge may be the starting point in tackling the problem of 'what we perceive', following which overlap, size and object orientation may further build up an understanding of the essential formal components of a scene. This is subject to personal qualification, according to background, experience, intuition and preference, but it may provide a sufficient basis for making more rational subjective judgements in visual impact studies.

5.5.5 Summary

It is clear that the next stage of research endeavour in visual analysis must tackle the question of 'what is seen?' Not in terms of the overall image of a building which may be depicted by an artist's impression, but the geometric characteristics which tell an observer about the form and shape of the building and its setting. A better understanding of how these characteristics interrelate and the role each plays in contributing to the visual impact of developments will lead to greater sensitivity both in the quality of the building design and in its relation to the context environment.

5.6 The Program Suite VIDERE

5.6.1 Introduction

The structure of a suite of computer programs, collectively known as VIDERE (VIsual DEscriptor RoutinEs) is described in this section.

The intention of the program suite is to allow a designer to assess the visual impact of structures in the landscape in terms of observer and object attributes.

VIDERE draws upon the output and data bases of the programs BIBLE, VISTA and VIEW1. These provide the VIDERE suite with accurate builtform and topographic appraisal in the form of perspective images of the building and visibility assessment. The program software already extant in VIDERE and the flow chart algorithms outlined are based on the Fortran language (Fortran: version 66). The program suite is intended to be used on 32-bit minicomputers or mainframe machines. At present the programs are written or specified for batch processing, with an interactive input data preparation facility.

Program application

The program is first and foremost a design tool for architects in practice concerned with difficulties in assessing the visual implications of certain design decisions and options. A selection of the appraisal work undertaken at each stage in the design process may be summarised to give a succinct presentation at client meetings or planning inquiries. It is important to state that VIDERE does not obviate the need for impressions of a design proposal, either manual or computer generated; it may be used most effectively in conjunction with these techniques.

The main purpose of the program is to make clear the formal and tonal conflicts which exist between a proposed development and its host landscape; in addition, the means by which these may be overcome, through form modification and siting, are indicated in the output information. Three levels of program application in the design process may be identified:

a) goal formulation
b) problem scoping
c) target setting

a) Goal formulation

General goal formulation in visual impact analysis may take one of four visual strategies, as outlined by Aylward and Turnbull: (AYLW78) p80.

i) Blend	:	the modification of objects or buildings to merge with context. This action may also be termed 'blurring'.
ii) Mask	:	the camouflaging or hiding of developments by, applied patterning or texture, and landform or vegetal screens respectively.
iii) Emphasise	:	the highlighting of building surfaces or elements. Building treatment in the sense of an art object in context.
iv) Combination of i) ii), iii)	:	applied to individual building elements

The program VIDERE may be used to effect any one of the above strategies in design, as chosen by the architect. There is no compulsion to choose the blending strategy consistently, however, it is without doubt the most frequent goal in sensitive design environments. Consideration of visual goals ought to be made in the light of the long term future of the context environment, eg. forest planting or felling, environmental reinstatement and road realignment may significantly alter the visual character of an area within a short period of time. Such activities may result in the original visual goals becoming inappropriate and the structures taking on an unintended appearance.

b) Problem scoping.

Often the scale and scope of the visual impact problem in design is unclear for the first few weeks of design development, certainly until some feedback on early hypothesised solutions is obtained. VIDERE would, therefore, seek to inform the designer as early as possible of the main visual difficulties and the prospect of resolving them successfully or otherwise. One of the fundamental questions in a visual assessment study, where the objective is to blend or mask the structure, is to establish the feasibility of hiding the development in the landscape; either completely hidden, or seen against a low contrast background. The specification of a skyline design space may help in determining whether or not blending or masking is a serious option open to the designer. The term 'skyline design space' refers to the height above ground level at each possible development location in the study area at which skylining of the proposal would commence, given a certain observer location (G199). Thus the skyline design space may be seen as a measure of the visual absorptivity of the host landscape.

At present, only the program to calculate 'dead ground' exists (TURN82c). This program and others, which determine design solution spaces, are likely to make significant advances in the objectivity of early problem scoping in visual assessment studies. The planimetric boundaries within which acceptable solutions may occur can help focus design effort more rapidly. Additionally, the capability of knowing to what extent a building may be hidden in the landscape, before synthesis, is certain to make the process of design more rewarding and structured.

c) Target setting

Above all, visual assessment techniques must be procedures which bring a designer to a satisfactory solution. The setting of specific targets for the formal and aesthetic features of a development can be a forlorn hope if a designer is not guided and aided throughout the design process by vigorous appraisal tools which amongst other capabilities can show him the directions to pursue in improving the solution towards specific visual aims. Sensitivity analysis, therefore, must not only inform the designer about the current status and impact of a proposal, but it must also reveal critical design thresholds, such as skylining, and indicate the means of resolving any conflict which may arise that is undesired.

The features of the program suite VIDERE are intended to facilitate sensitivity analysis during design, initially as alternatives are assessed, and latterly as a specific solution is refined.

At various stages throughout the design process VIDERE may be implemented to appraise specific visual tasks, eg. detectability and recognition. At any one time an observer may be involved in one of eight visual tasks in looking at or attempting to perceive an object. These tasks in visual perception may be described as the process of selecting and extracting significant information describing the main features of an object.

a) Visibility task : firstly it must be determined whether or not it is physically possible to see an object; this will be dependent on intervening topography and vegetation, and the earth's curvature.

b) Detectability task: if the visibility task produces a positive response, ie. there is no obstruction along the line of sight between the observer and the object, then the subject has to judge whether or not any stimulus pattern from the object is present in his field of view. This is a task based on detecting a change in the expected visual scene.

c) Discrimination task : any discernible stimulus must next be discriminated from its background or adjacent surfaces. In so doing an observer will seek to view the object stimulus in terms of its brightness or figural unity as distinct from its background.

d) <u>Legibility task</u> : Having discriminated an object from its context, an observer must next decide whether the stimulus pattern can be read and understood. The resolution of detail, giving rise to a differentiated figure, may be deliberately hindered by such devices as camouflage and illusions. These visual tricks may either prevent detection, step b), or hinder an understanding of the stimulus object. The legibility task, therefore, requires the observer to seek some meaning in the stimulus.

e) <u>Identification task</u> : if an object is perceived as legible, the subject ought then to identify the critical features and attributes of the stimulus, eg. shape, contrast, edge sharpness or patterns.

f) <u>Recognition task</u> : in this case the observer must judge whether or not a stimulus is familiar, ie. whether he recognises it from past experience or whether he must interpret the stimulus from the given visual information. Recognition from experience plays a large part in the speed and accuracy with which objects are perceived in the visual environment.

g) <u>Judgemental task</u> : having recognised or understood an object the observer is required to exercise some critical assessment of its visual qualities and character in the environment. In so doing an observer may assign scaled values or objective measures to specific attributes of the object.

h) Manipulation task: in the instance of architectural design the task of manipulation or modification is possible. By this means a design in the context environment may be altered or manipulated in the scene to effect one of many visual objectives, eg. blurring the edges to hinder identification or blending the visual surfaces to prevent detection. The task of manipulation and modification has the aim of problem solving in design.

These tasks are sequential in the process of visual perception and to a great extent depend on the duration of visual exposure of the stimulus. For the purposes of visual assessment it should be assumed that, within reason, there are no restrictions to the length of time an observer may chose to discern and object/building in the landscape.

Model building in computing - VIDERE

In building a computer model for use in visual analysis work it must first be decided which variables are important enough to merit inclusion in the simulation. The significant components in visual assessment would appear to be

i) the building or object of interest.

ii) the observer locations.

iii) The context environment.

How these elements interact is at the root of visual assessment, and consequently, in formulating an accurate computer model for prediction. This relationship may be described in system modelling terms (G200).. The physical scope of the model is limited by the study area digitised; the accuracy by the topographic and builtform data bases as input to the model; and the quality of the output is a function of the context variables' ability to simulate reality. Next, the structure and components of the VIDERE suite will be described.

5.6.2 VIDERE model structure and elements.

(G201) outlines the procedure within the VIDERE suite of programs for measuring the visual descriptors of a chosen study building and context environment.

Input

The input data is structured in two ways : (G202)

a) data bases for topography and land use common to the VIEW programs; and the geometry data base for the building as used in BIBLE and VISTA.

b) output display files:

i) from VIEW in the form of visibility maps produced by the processing program VIEW1 (1 = visible 0 = invisible cells). These locate the points of visibility within the topographic data set and may be further modified in VIDERE by the determination of visual range and visual acuity. Thus a more realistic answer may be given to the question 'from where is the development visible?', giving consideration to observer viewing limitations and the climatic conditions prevailing.

ii) from BIBLE and VISTA in the form of perspective images. These images may be stored in a display file either in the computer memory or on a video disc, depending upon the number of views required. Video disc storage is certainly the cheaper method. This output data may be used to appraise in greater detail 'what is actually seen by an observer', in terms of the formal and aesthetic properties of the artefact in its context. BIBLE output provides the visual descriptor routines SHAPE, SIZE, EDGE, etc. within VIDERE, with the formal attributes of an artefact seen in perspective; and VISTA supplies the tonal and colour surface specification of the object.

The tonal descriptors of shadow and colour have not been dealt with in detail due to the timescale of the thesis and the need for accurate and controlled colour modelling studies. To a very great extent, though, these attributes are best assessed visually, in terms of a manual or computer-generated perspective drawing. Shadow and colour may be quantified; however, such measures would be too abstract to permit any worthwhile judgement for visual assessment. Tonal attributes of building form are discussed in Appendix 6 and will be taken up again some time in the future, when image processing devices are available for visual assessment tasks.

Processing

The main processing programs and parameter specifications in VIDERE relate to three central aspects of visual assessment :

a) observer characteristics

: visual field specification, defining a viewing window.

: visual acuity; a program called ACUITY investigates the limits of visual perception of the study object based on the visual acuity of the observer.

b) observer/object relationship.

: visibility of the object; in this case the program VIEW1 is used to determine the visible cells in a topographic data base.

: visual range; a program called VRANGE maps out those locations in a study area that fall inside the visual range of an object/building given certain climatic conditions, the time of day, the time of year and the building surface specification.

: view distance; the planar and three dimensional physical distance between the object and the observer may be calculated using the program DISTAN.

: view direction; the planar and sectional angles between the object and the observer may be measured using the programs PLANAR and SECTAN respectively.

c) object characteristics.

: shape; the measurement of the silhouette outline of a building may be measured using the program SHAPE.

: size; the size of a building, as measured in millisteradians and expressed as a fraction of the visual field, may be computed in the program SIZE.

: edge; building edge measurement may be addressed using the program EDGE, for both internal and external edges of a projected shape.

: overlap; the quantification of building overlap may be calculated in the program OVRLAP.

: position; the relative position of an object or building in the visual field may be measured in the program POSIT.

: backcloth; use is made of the program VIEW2 to calculate the percentage backcloth of buildings.

The formal descriptors may be used to assess the detailed visual attributes of a design proposal and may be represented and compared on either an interval or ordinal scale of measurement. Next it is necessary to describe the background theory and program structure for each of the three headings defined earlier:

a) observer characteristics

b) observer/object relationship

c) object characteristics.

a) Observer Characteristics

i) Visual field.

In any attempt to study the visual impact of buildings it is necessary to define the visual framework or window through which observers view the environment; typically this is the visual field, though it may be restricted by camera or binocular viewing frames. Defining a visual field will allow the quantification of certain aspects of viewing, eg. the size of an object may be measured as occupying a certain percentage of the visual field.

There are a great many features in the visual world to which an observer could pay attention; our viewing is therefore selective, and the most important object at any one time will be the focus of visual attention. For the purposes of visual assessment it is reasonable, and necessary for ease of calculation, to assume that an observer will view an object directly, ie. the object will occupy the central fovea of the retina. This assumption is further backed up by the fact that visual acuity drops off at a fast rate outside the central fovea, making serious visual assessment impossible when viewing objects indirectly. Thus most of the visual detection and discrimination tasks are done in the central part of the retina. In focussing attention on an object, an observer delimits a viewing area or cone

i) in space - by paying attention to only part of a scene.

ii) in depth - by paying attention to only some details.

"The visual field is that area of one's surroundings which is visible at one time. It is limited by the facial contours and the size of the sentient retina." (REED 72) p25. It is possible to delineate the visual field of individual observers using a perimeter. The instrument charts the outer limits of the visual field by presenting a stimulus at various points around a subject's field of view. Thus the boundary of the visual field can be traced and defects within it mapped out on a visual field chart. A typical chart is shown in (G203). The monocular visual field is a slanting irregular oval; the binocular visual field is a combination of the overlapping right and left monocular visual fields (G204).

In the past, visual assessment procedures have employed two approaches to defining the visual field. Firstly, a simple horizontal format rectangular visual field specified by eg. a 140^0 horizontal angle of view and a 75^0 vertical angle of view. Secondly, a method developed over ten years ago, the use of steradians, to place values on the extent of the visual field. The first method, which generalises the visual field to a rectangular viewport, is dismissed as too inaccurate.

The second procedure for specifying the visual field is described in greater detail in (HOPK71) and (LASS76). In this case, the visual field is partitioned into concentric circles (G205), and each annulus may be measured quantitatively, in terms of stéradians.

> "The basic idea underlying the quantification of visual intrusion is that its extent depends on how much of the field of view is taken up by the intruding element. To express this, a unit of field of view is required. This is known as the solid angle. It is defined as the angle subtended at the centre of a sphere of unit radius, by a unit area on its surface. This unit is called a stéradian. Since the area of a sphere of unit radius is 4π , there are 4π (13.56) stéradians of solid angle about a point. A unit steradian is a relatively large solid angle, and in practical applications the unit used is the millisteradian (1000 millisteradians = 1 steradian)." (LASS76) p73.

Since an object in the 20^0 - 50^0 zone of vision would be less intrusive than an object in the central 6^0 cone (G205), a position factor is also defined by Lassière.

Zone	Position factor
$0^0 - 6^0$	10
$6^0 - 20^0$	3
$20^0 - 50^0$	1
$50^0 - 90^0$	0.1

Therefore one steradian in the $0^0 - 6^0$ cone has the same intrusiveness as 10 steradians in the $20^0 - 50^0$ cone. The importance of the position factor weighting can be seen in (G206) where three shapes of similar size are considered. Shape compaction results in higher values at the central cones of vision.

The formula for calculating the number of steradians which an object occupies in the visual field is defined in (LASS76) p73 as :

$$\Omega_\theta = \frac{H}{d_p} \left(\cos \theta_1 - \cos \theta_2 \right) \times 1000 \qquad (5.1)$$

where Ω_θ = the number of millisteradians in the horizontal angle of view θ

H = the height of the object.

d_p = the distance of the object

$\cos \theta_1$ = the first boundary angle of the intrusive element as measured from a line at right angles to the direction of view.

$\cos \theta_2$ = $\cos \theta_1$ + the angle over which the object intrudes.

$\times 1000$ to convert to millisteradians.

This formula may be used to calculate certain areas of the visual field, typically those delineated by an object or building in the scene. Three assumptions are made regarding the observer's visual field.

i) it is static, ie. the observer does not move his head.

ii) the eyes are focussed on the object of interest.

iii) the observer's vision is unimpaired.

Within the processing of the program suite VIDERE there is opportunity for the user/designer to specify the limits of the visual field that he wishes to base his assessment on. This may be achieved in step 4 of (G201); the default setting remains at

: 60^0 upwards

: 75^0 downwards

: 100^0 to either side of the central line of vision.

ii) Visual acuity

One of the most significant factors in determining whether an object is discernible is the visual acuity of the observer. Visual acuity is commonly defined as the ability of the human eye to distinguish details in a scene and in particular to detect an object as distinct from its background. Thus the different types of perceptual tasks that an observer is given to perform, eg. discrimination, detection and recognition are to a very great extent dependent on an observer's visual acuity or the resolving power of the eye. The most critical factors limiting visual acuity are the sharpness or contrast of the study object as seen against its background; eye defectiveness; and the brightness level of the object. A number of authors describe experiments to measure visual acuity, eg. (FALK56) and (PIRE67).

i) ".... the numerical value of visual acuity is the reciprocal 1/a of the visual angle a, in minutes of arc." (PIRE67) p139.

ii) "For clinical purposes acuity is stated as the ratio between the distance at which a detail can be discriminated and that at which a 'normal' observer can discriminate it. Thus 20/20 or normal vision means that an individual can distinguish a detail at 20 feet, the same distance that it is discriminable by a normal eye. In clinical terms 20/10 is better and 20/40 worse than normal." (DAY 69) p44.

Normal vision is defined in i) as the discrimination of a detail subtending an angle of 1 minute of arc, ie. a = 1. Thus 20/40 visual acuity would be defined in i) as 0.5, and 20/10 as 2.0.

Given ideal conditions, with a uniformly bright background, the minimum perceptible object subtends a value of 0.5 minutes of arc at the eye. This is comparable to 20/10 vision.

The integration of a measure of observer visual acuity in visual assessment studies is achieved by the program ACUITY (G207) The program appears early on in the application of VIDERE and is intended to define the maximum distance at which an object can still register a stimulus change on an observer's retina, as seen against the context background. A user of the program ACUITY would be required to specify an acceptable level of visual acuity; the default setting is specified at normal vision, 20/20, ie. for normal daylight illumination, a limit of one minute of arc for an object seen against its background.

Although visual acuity drops off noticeably across the visual field from the central fovea, this variation will be dismissed. Again it is necessary to assume that the observer will view the interest object directly, and where the visual acuity is critical in just perceiving an object it is likely that the object would be largely confined to the central 6^0 cone of vision. There are three means by which visual acuity can be reduced in order to minimise the impact of an object/building in the visual scene.

i) Camouflage which involves the reduction and elimination of those factors such as contours and patterns which distinguish figures from background. The act of camouflaging objects in their context is achieved by introducing "noise" in the colour, texture or pattern of the visible form in order to weaken its perception. This visual noise limits the acuity of the observer in discriminating or recognising an object.

ii) Illusions which may be created to disrupt identification or deceive an observer, eg. by scale or juxtaposing.

iii) Blending the perceived shape of a building with its context background. This may be achieved iteratively through successive stages of designs as a building may be modified formally or manipulated in plan to blend in with the existing lines and tones of the host setting.

b) Object/Observer Relationship

i) Visibility

The primary task in any visual assessment concerns the mapping of the area from which the site or interest object is visible. This calculation is based purely on the physical line of sight connecting the observer and the object; factors which may affect visibility, such as the observer's ability to perceive objects, are dealt with elsewhere in this section under visual acuity and visual range. The term 'viewshed' refers to the mapped area from which a development is physically visible; the visual range is defined as the maximum distance at which an object is discernible. Thus the extent of the visual range will always be equal to or less than the limits of the viewshed.

As the boundary delimiting the extent of visibility, the viewshed may be mapped as a binary matrix, where 0 = invisible cell and 1 = visible cell. This task may be accomplished using the VIEW1 program (G201). In some cases, distant objects normally invisible beyond the horizon, can appear visible due to light rays being bent upwards in warmer air temperatures; this phenomenon is dealt with in the VIEW processing logic and ensures the mapping of true as opposed to apparent visibility.

Normally visibility is mapped as a measure of visual intrusion; however, the technique may be employed for several other tasks where highlighting or prominence is the objective. For example in locating :

: lighthouses with maximum visibility.

: wind generators with maximum exposure to wind.

: solar collectors with maximum exposure to sun.

: TV and radio masts, and communications systems for optimum range and series linking.

ii) Visual Range

Having established that there is an uninterrupted line of sight between the observer and the object, it is necessary to determine how far one can see through the atmosphere along the sight-line, ie. the visual range. Measurements of visual range very rarely appear in visual assessment studies, and this can mean that design decisions are taken purely on the grounds of visibility and not on whether the object can be detected at all.

Unless conditions of clear visibility prevail, the visual range ought to modify the viewshed. This is dependent on four principal factors;

a) the observer's visual acuity. This has been dealt with above.

b) the amount and distribution of light, natural and artificial, falling on the interest object.

c) the characteristics of the objects at which, or for which, an observer is to look:
   : object size
   : the contrast of the object with its background.

d) the atmospheric conditions prevailing between the observer and the object.

These factors are dealt with in (MIDD68) and (TRIC70), and predominate in determining whether or not an object can be perceived. The problem, then, is to establish a usable mathematical relationship between the target, the atmosphere, the light and the mechanism of the eye, that will generate the mapping of the visual range at any time.

The calculation of visual range.

Notation.

σ = extinction coefficient (also called attenuation coefficient).
V = visual range
R = viewing distance between observer and object.
V_2 = meterological range
ϵ = liminal threshold of brightness/contrast.
C = contrast
C_0 = inherent contrast
C_R = apparent contrast
b = scattering coefficient of light
k = absorption coefficient of light
Υ = transmissivity of light through a medium, eg. air.
B = brightness or luminance (candelas/m^2 or apostilbs)
B_0 = inherent brightness
B_R = apparent brightness
N = Number of particles per unit volume.
ρ = density of water (10^6 grams/ m^3)
F = Luminous flux (lumen)
I = Luminous intensity (candela)
E = Illuminance (lumens/m^2 or lux)

First, it is necessary to determine the contrast between the object and its background. This may be defined as :

$$C = \frac{B - B'}{B'} \qquad (5.2)$$

where the luminance of the object is B and that of the background B'. Thus if an object is less luminous than its background, then the contrast value tends towards -1, for an ideal black surface; while if an object is brighter than its background, C will be positive.

The calculation of the surface luminance of an object is dependent on the surface's reflectivity characteristics, and may only be discussed after defining four photometric concepts:

Photometric Concept	Symbol	Metric Units
Luminous flux	F	lumen
Luminous intensity	I	candela
Illuminance	E	lumens/m^2 (lux)
Luminance	B	candelas/m^2 (apostilb)

Illuminance is the flux received on a unit area of a surface (typically a square metre) and measured in lumens/m^2 or lux. Standard illuminance values for the sun normal to a surface throughout the year are given in (G208); these assume a BRE (Building Research Establishment) average sky. However, these values need further modification to adjust for the altitude of the sun and the illuminance coming from the rest of the sky in the form of diffuse light. To calculate the modified or horizontal illuminance due to the sun, the following expression is defined.

horizontal sun illuminance = normal sun illuminance x cos α (5.3)

where α = the altitude angle of the sun.
The illuminance coming from the rest of the sky has been measured throughout the year yielding the values in (G209). Therefore, for any time of year and of day,

total illuminance on a surface = horizontal sun illuminance + sky illuminance (5.4)

Luminance is a measure of surface brightness.

"the luminance of a source in a given direction is equal to the illuminance produced on an elementary surface normal to this direction, divided by the solid angle subtended by the source at this surface. If the illuminance is measured in lumens/m^2, for example, and the solid angle in steradians, the luminance will come out in candelas/m^2. Note that the distance from the source to the surface does not matter, since for a given area of source the solid angle varies inversely as the square of the distance. This is in agreement with the experimental fact that an extended source has the same luminance at any distance, provided the intervening medium is perfectly transparent." (MIDD68) p11.

We require to form a link between illuminance and luminance.

"This problem has no general answer, because of the many ways in which surfaces absorb, transmit and reflect light falling upon them, and in particular the many distributions of reflected light that may occur. But there is one particular type of surface of special theoretical importance, called a perfect diffuser, which has the property that its luminance is the same in all directions over an entire hemisphere." (MIDD68) p11.

Middleton pursues the notion of a perfectly diffusing white surface in his text, concluding with the illuminance/luminance relationship.

"Thus a perfectly diffusing white surface receiving an illuminance of π lumens per unit area will have a luminance of one candela per unit area in any direction. It follows that a surface of luminous reflectance R (but still perfectly diffusing) receiving π lumens per unit area will have a luminance of R candelas per unit area. Or if a perfectly diffusing white surface receives an illuminance E, its luminance will be $B = E/\pi$". (MIDD68) p11.

Thus, we may state:

$$\text{luminance (candelas/m}^2\text{)} = \text{illuminance (lumens/m}^2\text{)}/\pi \qquad (5.5)$$

The link between illuminance and luminance is clear, however, characteristics of surface reflectivity need to be taken into account in obtaining a final value for surface luminance.

> "The surfaces of the material world differ with respect to their structure and composition both physically and chemically. Depending on how the object is put together (cells, crystals etc.) and what it is made of (its chemical substance), it will reflect more or less of the light falling on it and it will also reflect relatively more of one wavelength or more of another. This differential reflection is the physical fact referred to when we speak of surfaces as having brightness and colour." (GIBS50) p45

The term 'surface reflectivity' is defined as the percentage of light reflected by a surface, to the amount of light received at the surface from the light source. This reflected component of light is made up of three parts :

i) Ambient light : caused by interreflections. Always present unless there is no light source.

ii) Diffuse light : light reflected usually from a matte or textured surface from a light source.

iii) Specular light : light reflected directly from a mirrored or polished surface.

The program VISTA distinguishes between these three components of reflected light and measures surface reflectivity, like most classic reflectance models (BLIN82) p21 (BLIN77) p192 (COOK81) p307 (COOK82) p7, as a function of the angle between the light source, the surface and the observer (G210). In measuring surface luminance, the reflectivity of a surface will be defined for two situations:

i) when the angle of incidence equals the angle of reflection and $\gamma = 0^\circ$, ie. there is high specular light reflectance, causing glare.

ii) when the angle of incidence and of reflection are equal but $\gamma \neq 0^\circ$, ie. there is principally ambient and diffuse light reflectance seen by the observer.

In case i) we may assume that the luminance of a surface will be equal to the illuminance of the light source divided by π. The resulting value will be high, as we might expect, since the sun will be reflected off the surface towards the observer when $\gamma = 0$ (G210).

In case ii) we may discount the specular component of light reflectance. This is assumed since the specular light reflectance value, $\cos^n \gamma$ (G210), falls off rapidly from $\gamma = 0^\circ$. (The Specular Exponent n varies from 1 to 200, depending on the surface; for a dull, or textured surface n is small, for a shiny or smooth surface n is large; for a perfect reflector n would be infinite (STEA83)). In order to calculate the luminance value of a surface when specular reflection does not occur it is necessary to modify the figure obtained in (5.5) by a surface reflectance factor, SR. Values of surface reflectivity for common building materials and landscape surfaces appear in (G211).

Therefore,

$$\text{Surface luminance} = \text{illuminance} / \pi \qquad (5.6)$$

when $\gamma = 0^\circ$, and where illuminance is derived from (5.4) according to the time of year and day.

and,

surface luminance = illuminance $/\pi \times$ SR (5.7)

when $\gamma \neq 0^{\circ}$, and where SR values are found in (G211) for most common surfaces.

Thus surface luminance is defined. In order to calculate the contrast between object luminance and background luminance, when an object appears against the sky, values of sky luminance for certain times of the day, weather conditions and the time of year may be found in (G212).

Returning to formula (5.2) we shall now define the inherent contrast, C_o, between object and background as seen close at hand; and the apparent contrast, C_R, as seen over a viewing distance, R, thus:

$$C_o = \frac{B_o - B_o'}{B_o'} \qquad (5.8)$$

and

$$C_R = \frac{B_R - B_R'}{B_R'} \qquad (5.9)$$

This is due to the fact that the contrast of a building in its setting against the landscape or sky varies exponentially with distance; thus:

$$\left(B_R - B_R'\right) = \left(B_o - B_o'\right) e^{-\sigma_o R} \qquad (5.10)$$

where $e^{-\sigma_0 R}$ accounts for the difference perceptible between C_0 and C_R over the viewing distance R, and with the inherent extinction co-efficient of light, ie. the atmospheric interference on the passage of light, equal to σ_0. We shall now deal briefly with the reason why the extinction coefficient is expressed as $e^{-\sigma_0}$ in (5.10).

The extinction or attenuation coefficient is made up of two components of the behaviour of light through the atmosphere; the scattering coefficient, b, and the absorption coefficient, k. σ_0 may also be defined in terms of the transmissivity of the atmosphere, thus:

$$e^{-\sigma_0} = T$$

where transmissivity "is the fraction of the incident flux which remains in the beam (of light) after passing through unit thickness of the medium" (MIDD68) p14.

Thus (5.10) deals with the extinction coefficient by expressing it as the transmissivity of the atmosphere over distance R, resulting in the expression $e^{-\sigma_0 R}$.

We shall now look in more detail at the calculation of σ. The extinction coefficient, σ, is a function of the quantity of solid matter and water content in the air. Bennett has referred to these as "suspensoids" (BENN30) p20.

Suspensoids are

a) liquids : concentration of condensation nuclei - fog, mist, rain etc.

b) dry solids : concentration of solid particles - dust, soot etc.

The effect of suspensoids can be shown in that visibility is frequently improved :

a) when winds blow from rural and particularly mountainous areas (few dust particles) than from populated areas (many dust/soot particles).

b) in the afternoon compared with the morning because air currents have carried dust particles from lower layers to higher layers of the atmosphere.

c) when there is a high pressure, between two low pressures, bringing fresh dust-free air. If a high pressure lasts, visibility can drop off as the dust nuclei settle in the lower layers of the atmosphere.

d) after long periods of rain or snow, dust nuclei may be entirely precipitated.

The effect of climate on visual range is yet another aspect of visual assessment requiring further examination outwith the time scale of this thesis. It is suggested that the data gathered for Hunterston in Appendix 2 and the mathematical relationships derived in this chapter can form the basis of some validation and calibration exercises.

Returning to the calculation of σ it is purely a physical problem involving the number of droplets or particles per m^3 and their size, thus

$$\sigma = \pi N a^2 \qquad (5.11)$$

where there are N droplets per m^3, each of radius a (metres). These two factors will enable the full specification of σ, by allowing the calculation of the volume of water per m^3 of air, where :

$$v = N\left(\frac{4}{3}\right)\pi a^3 \qquad (5.12)$$

v = the volume of water per m^3 of air.

In many cases, while the value of v is similar, the visual range may vary. This is due to the fact that the size of the droplets can range from 0.01 mm for a mist to 0.5 mm in rain, causing variations in the opacity of the atmosphere. Indeed a heavy thunderstorm will be more transparent than a drizzle, given that v is similar in both situations.

(5.12) must be modified to account for what is known as the "scattering area ratio" (LaME43). This is the ratio of the area of the light-wave-front acted on by the particle to the area of the particle itself. Drawing on LaMer and Sinclair's work, the scatter area ratio (K = luminosity of radiation or luminous efficiency) tends towards the value 2. Therefore in normal conditions, the particles in the air scatter twice the expected amount of light. Thus (5.11) may be re-written as

$$\sigma = K\pi N a^2 \quad (m^{-1}) \qquad (5.13)$$

where K is typically 2.

The number of drops/m^3 can range from 50 to 500 x 10^6 for cloud, and from 1 to 10 x 10^6 for fog. (HOUG38). The diameter of a rain drop may be 0.5mm, and that of a droplet in fog or mist 0.01mm (MINN59).

Returning to the definition of contrast, using (5.8) and (5.9), (5.10) may be rewritten :

$$C_R B_R' = C_0 B_0' e^{-\sigma_0 R}$$

or

$$C_R = C_0 \left(B_0' / B_R' \right) e^{-\sigma_0 R} \qquad (5.14)$$

Now B_0' and B_R' may be assumed for the purposes of visual assessment to be equal. Thus, the simplest expression of contrast reduction over horizontal lines of sight may be described as:

$$C_R = C_0 e^{-\sigma_0 R} \qquad (5.15)$$

At this stage, only object contrast has been specified; it now follows to determine the meteorological range, V_z : In this case $V_z = R$ and referring to equation (5.15) we may write.

$$C_R / C_0 = e^{-\sigma_0 V_z} \qquad (5.16)$$

Now, the meteorological range is defined as "that distance for which the contrast transmission of the atmosphere is two per cent" (DUNT48) p238.

Therefore, we may say

$$e^{-\sigma_0 V_z} = 0{\cdot}02 \qquad (5.17)$$

Using natural logarithms,

$$2 \times 10^{-2} = e^{-\sigma_0 V_2}$$

$$\ln 2 + \ln 10^{-2} = \ln e^{-\sigma_0 V_2}$$

$$0{\cdot}6931 + (-4{\cdot}6052) = -\sigma_0 V_2$$

$$-3{\cdot}9121 = -\sigma_0 V_2$$

$$V_2 = \frac{3{\cdot}9121}{\sigma_0} \qquad (5.18)$$

where σ is the extinction coefficient of the atmosphere, and V_2 is the meteorological range, the one an inverse function of the other in a linear relationship.

Now we are able to define and specify the formula for calculating the visual range. The further an observer is from an object of inherent contrast, C_0 the less will be the apparent contrast, C_R , until at some distance, R, the apparent contrast becomes equal to the minimal perceptible contrast, ϵ. This liminal threshold, ϵ , was earlier seen to be 0.02 given reasonable conditions of viewing. Therefore substituting the appropriate notation in (5.15) we obtain

$$\epsilon = C_0 e^{-\sigma_0 V} \qquad (5.19)$$

where V is the visual range, and the absolute value of C_0 will always be greater than ϵ. If $C_0 < \epsilon$ then the object is invisible at any range and no calculation is necessary. Simplifying and using natural logarithms,

(5.19) becomes:

$$\epsilon = \frac{C_o}{e^{\sigma_o V}}$$

$$e^{\sigma_o V} = \frac{C_o}{\epsilon}$$

$$\ln e^{\sigma_o V} = \ln \left| \frac{C_o}{\epsilon} \right|$$

$$\sigma_o V = \ln \left| \frac{C_o}{\epsilon} \right|$$

and

$$V = \text{visual range} = \left(\frac{1}{\sigma_o}\right) \ln \left| \frac{C_o}{\epsilon} \right| \tag{5.20}$$

where,

σ_o = extinction coefficient.
C_o = inherent contrast of an object against its background.
ϵ = liminal threshold of contrast.

A graphical solution has also been devised to determine visual range. Duntley has produced a series of nomograms for the visual range of objects as seen against various backgrounds (DUNT48); one is shown in (G213). These may be used manually in the following procedure. The inherent contrast of the object is marked off on the right hand scale; the meteorological range, derived from (5.18), is located on the left hand scale and a line drawn to connect it with the contrast scale mark. The visual range may be read off on the horizontal scale of sighting range for any desired size of object at the point where the meteorological range/contrast straight-edge intersects with any desired object size curve.

The flow chart specification for a computer program subroutine, VRANGE, is shown in (G214).

iii) View Distance

The concept of distance, ie. the physical 3d straight line distance between an observer and an object or building, is an important and fundamental measure in visual assessment studies. It is central to the specification of visibility (viewshed), the visual range, visual acuity view direction, and the size and position of the object. A number of authors, most recently Johnson, have shown that the visual impact of a building decreases exponentially with distance (JOHN83) (G215). In its own right, then, distance is a significant measure for assessing visual intrusion. Despite this, almost all calculations based on distance use the planar distance between object and observer, represented in the traditional form of concentric circles on a plan drawing of the study area (G216). The main problem in using the concentric circles approach is that no account is taken of topographic variations.

In many cases, and especially at large viewing distances, planar distance is a sufficiently accurate measure of observer/object distance. However, in certain steep sloping terrains, eg. Scottish glens, the planar distance measure is inappropriate and could be misleading. Landscapes with severe topographic undulations must use the physical or 3 dimensional distance between the observer and object to calculate an accurate viewing distance. Although the distinction between planar and physical distance may seem insignificant to consider in certain landscapes, for other types of landscapes it could mean a critical reduction in the visual range, ie. the difference between seeing the building or not. (G217)

a) Planar distance

The calculation of the planar distance is dependent on the I, J co-ordinate values of the observer (IOBS, JOBS) and the object (IOBJ,JOBJ) and may be expressed thus:

planar distance = $\sqrt[2]{((IOBS-IOBJ)^2 + (JOBS-JOBJ)^2)}$

b) Physical distance

The measurement of the physical distance is dependent on the planar distance and the elevational values of the observer and object locations, (G218). The expression:

$$\sqrt[2]{((IOBS-IOBJ)^2 + (JOBS-JOBJ)^2 + (ZOBS-ZOBJ)^2)}$$

uniquely defines the physical distance. One assumption is made in the value of the object location; that the distance, whether planar or physical, is measured to the nearest point on the object from the observer.

The algorithm flow chart for a general distance measuring computer program DISTAN is shown in (G219). Within the program structure there is an option for the user to chose either planar distance calculation for lowland rolling terrain, PLAND; or to use the physical distance in cases of highland or rough terrain, PHYSD.

In the case of PLAND, the input requirements would constitute the dimensions of the study area and the I, J location of the object. PHYSD would require, in addition, the elevation matrix of the study area. In order to reduce the number of calculations, the program DISTAN is primed to check the visibility status of each observer point in the data set. This process uses the viewshed matrix of visibility results from VIEW1 interrogation of the study area, and if a point therein is registered as invisible then no attempt is made to calculate the distance. The output from DISTAN may be in the form of alphanumeric print-out of distance values, or more readily understood contour maps, using the display program SYMCON from the VIEW program suite. DISTAN is currently being validated and used to assess the significance of the physical distance in certain landforms, as hypothesised in (G220).

iv) View Direction

Together with view distance, view direction uniquely defines the physical relationship between the observer and the object. View direction may be fully specified by both the planar angle α, and the sectional angle θ. In order to effect the calculation of these angles, the planar location and elevational height of the observer and the interest object ought to be given. These are:

	location	elevation
observer	I_1 J_1	Z_1
object	I_2 J_2	Z_2

An assumption is made in calculating the view direction; that the viewing angles are measured from the observer to the geometric centre of the interest object. Note that this is different from that assumed in calculating the view distance. In that case the nearest point of the object to the observer was used.

a) Planar angle

The planar angle, α, is measured in degrees clockwise from North (G221), such that

$$\tan \alpha = \frac{|I_1 - I_2|}{|J_1 - J_2|} = \frac{\Delta I}{\Delta J}$$

Now the calculation of α will vary depending upon which quadrant the angle is in (G222). Therefore the procedure for calculating all values of α, ready for computer programming is as follows:

IF $I_1 < I_2$ (object to right of observer)

and IF $J_1 - J_2 = 0$ then $\alpha = 90^0$

or IF $J_1 > J_2$ then $\alpha = \arctan\left(\frac{\Delta I}{\Delta J}\right)$, quadrant I

or IF $J_1 < J_2$ then $\alpha = 90^0 + \arctan\left(\frac{\Delta J}{\Delta I}\right)$, quadrant II

OR IF, $I_1 > I_2$ (object to left of observer)

and IF $J_1 - J_2 = 0$ then $\alpha = 270^0$

or IF $J_1 < J_2$ then $\alpha = 180^0 + \arctan\left(\frac{\Delta I}{\Delta J}\right)$, quadrant III

or IF $J_1 > J_2$ then $\alpha = 270^0 + \arctan\left(\frac{\Delta J}{\Delta I}\right)$, quadrant IV

OR IF $I_1 = I_2$

and $J_1 > J_2$ then $\alpha = 0^0$

or $J_1 < J_2$ then $\alpha = 180^0$

The flow chart algorithm, outlining the subroutine, PLANAR, is shown in (G223). PLANAR calculates the planar angle, clockwise from north, between any given object and observer locations.

b) Sectional angle.

The view angle in section between the observer and the object is termed the sectional angle. As with view distance, when calculating the sectional angle, account must be taken of the earth's curvature and light refraction, since we are dealing with the perceived locations of objects. The section angle, θ, is measured in degrees from a horizontal line of sight, where θ is negative if the object is below the observer height. (G224). The observer and object locations are as in the planar angle calculation, with the elevation heights Z_1 and Z_2 respectively. The computing procedure and calculation of θ is as follows:

IF $Z_1 = Z_2$ then $\theta = 0$
(object and observer at same height)

IF $Z_1 \neq Z_2$ then $\theta = \arctan \frac{|Z_1 - Z_2|}{\text{planar distance}}$

and θ is negative if $Z_1 > Z_2$
(observer above object)

or θ is positive if $Z_1 < Z_2$
(observer below object)

The subroutine, SECTAN, which measures the sectional angle for any given object and observer locations is described in (G225). The input to the subroutine consists of the IJZ values of the object and observer points; the output is the value of θ.

c) <u>Object characteristics</u>

i) Shape

Our primary perception of objects is based upon the contrast which a surface has, seen against the background. This contrast area is termed the shape of an object and is delineated by areas of contrast change or edges; these define the overall profile or enclosing contours of the shape. (BAIR74) p61. Thus the exterior edges or bounding limits of a surface or object as projected on to a plane define its shape (G226). Gibson has defined this projected shape as

> "the shape which an object possesses when projected on to a plane; its silhouette, defined by its outline or contour. The projected shape of an object changes as the direction of view changes. The visual field contains projected shapes."
> (GIBS50) p34

Projected shape is clearly distinct from depth shape or form; Gibson defines depth shape as

> "the shape which an object possesses in three dimensions and which is defined by its surfaces. Depth shape of an object remains constant from whatever direction it is viewed. The visual world contains depth shapes." (GIBS50) p34.

These definitions are in accordance with Zusne, who writes concerning shape as a term describing the specific instance of a visual configuration; one cuts out shapes, constructs random shapes, recognises and identifies them. (ZUSN70) p2.

The notation 'shape constancy' must be clarified at this point. To be fully correct it should read depth shape constancy, ie. an object will retain the same form in three dimensions despite changes in the observer location causing the projected shape to vary (G227).

Form discrimination.

The observation and recognition of a form involves three clear components; shape, size and edge. These combine to define a specific form as in (G228), and may be seen to have importance in the process of visual perception at various viewing distances (G229). Shape is, therefore, a first order descriptor of form; though by itself, it may not define the unique form of an object. Size and edge are normally required to complete full recognition of a form. The inadequacy or ambiguity of shape in form discrimination is demonstrated in (G230), where different forms or viewing angles can be assumed from the same projected shape. In combination with edge, however, shape may uniquely define object form, since all the visible surfaces of the object will be defined. In fact, projected shape and the number of surfaces visible is a reasonable approximation of the complexity of the object being viewed.

Shape recognition

A number of authors have dealt with the fundamental factors which allow shape recognition. These may shed light on the most suitable means of measuring shape in visual assessment, and are summarised below:

a) Deutsch(DEUT55) p30.

i) Shape recognition is independent of the location of the shape in the visual field. It is not necessary to fixate the centre of a figure in order to recognise it nor need the eyes be moved around the contours of a figure. Attneave and other authors would disagree with this view, especially when the shape is unfamiliar (ATTN50). In any case, it will be assumed that shapes will occupy the central cone of vision of an observer.

ii) Recognition can be effected independently of the angle of inclination of a figure in the visual field. (By this is not meant tilt of the figure in depth such as occurs in shape constancy experiments, but the tilt of an image in two dimensions.)

iii) The size of a figure does not interfere with the identity of its shape. The area of a shape may, therefore, be less significant in developing measures of shape.

b) During the early 1950s Attneave and Arnoult applied information theory to form perception and established some important factors in the way in which shapes are recognised and discriminated from their backgrounds (ATTN54) p183.

i) The information about shape is concentrated at the edges or contours, where contrasting surfaces of colour or texture meet. The study of shape will, therefore, be necessarily close to that of edge since contours are places of high informational content in discerning the shape of an object or form.

ii) Shape information is further concentrated at those points on a contour at which its direction changes most rapidly, ie. at angles or peaks of curvature. This was further substantiated by experiments reported by Attneave in (ATTN57) and by Brown et al in (BROW62) p526. In both references the authors identified that the number of sides or independent turns (angles or curves) along the shape contour was a critial stimulus parameter to effect proper shape recognition.

iii) Redundant visual stimuli in shape recognition occurs in three ways:

1. areas of homogeneous colour/texture/contrast.
2. contours of homogeneous direction or shape.
3. symmetry

The notion of visual redundancy is described in (G231)

Shape measurement in Visual Impact Assessment.

The calculation of the projected shape of an object or building will depend on a number of parameters:

: observer location
: object location
: geometrical description of the object.
: in some cases it may also be necessary to indicate the % visibility of the object, as modified by topography or trees. This may significantly alter the visible shape of the object as opposed to its theoretical projected shape from a given viewpoint.
: the definition of the edges allowing the object to stand out against its background. These may be termed edge contrast ratings; a low rating will indicate either a blurred edge or low contrast of the object with its background.

: the direction of view will be centred on the geometric centre of the object.

Three aspects of shape quantification in visual assessment require a little more detailed explanation; the abstraction of the visible shape contour, the percentage visibility of the shape, and the means of dealing with curved contours.

i) Shape abstraction.
In order to measure a shape, first it will be isolated from its context, shape abstraction. In the case of complex groupings of buildings the shape abstracted will take the profile as indicated in (G232).

ii) Percentage visibility.
Rural and urban environments pose a tricky problem in the measurement of shape. Buildings are frequently screened by intervening trees or ground, affecting the perceived shape. (G233) demonstrates how it is possible for the perceived shape to vary quite dramatically across this single parameter of percentage visibility. The Gestalt grouping principles of closure and good continuation of shapes are certain to influence the way in which objects or buildings are viewed in these cases, especially if the screen is in any way transparent, eg. the mesh of tree trunks, branches and leaves.
"In a visual world of the sort provided by rooms, streets and countryside, the actual fact is that we see one object behind another. Koffka once argued convincingly that there was truth in the statement that he could see his desk-top extending uninterrupted beneath the book which lay upon it." (GIBS50) p40.
We shall make an assumption though that the effect of percentage visibility will be manifested as in (G233b) from the base of the building upwards, and that only the visible projected shape will be measured.

iii) Curved contours.

Although a number of buildings are characterised by curved elements, by far the majority are planar, not sectional. When curved elements do occur in section they are often on a small scale and frequently indiscernible at the viewing distances typical in visual assessment. Indeed, only large domes or spheres, as at Dounreay Power Station on the north coast of Scotland, will require a system of measurement for curved contours. This may be defined by specifying the centre point, arc angle and radius of the curved shape.

Morphometrics - the measurement of shape.

Although many methods of shape quantification have been devised, no single acceptable measure has been established. (DODW66) p185. Attneave and Arnoult have suggested three reasons why projected shape is not easily calculated: (ATTN56) p452.

i) Shape is a multidimensional variable, though it is often carelessly referred to as a 'dimension', along with brightness, hue, area and the like.

ii) The number of dimensions necessary to describe a shape is not fixed or constant, but increases with the complexity of the shape.

iii) Even if we know how many dimensions are necessary in a given case, the choice of particular descriptive terms remains a problem; presumably some such terms have more psychological meaning than others.

In reviewing the various procedures for measuring shape, distinction must be made between two types of description variables, analytical and Gestalt.

a) analytical variables: which describe the formal properties of shapes eg. shape area, length of perimeter contour.

b) Gestalt variables: which do not provide a description from which the shape can be reconstructed, but which abstract important properties of the shape as a whole, eg. the number of sides of a shape. Shape information is, therefore, collapsed to a few parameters.

Several researchers have attempted to list the significant variables of shape.

i) Physical factor structure. (STEN66) p303.
In this case, Stenson related the perceived complexity of 20 random shapes to 24 physical measures of shape. Four measures were found to account for most of the shapes presented to subjects for assessment.
a) the number of turns in the form
b) the length of the perimeter.
c) the perimeter squared to area ratio
d) the variance of the internal angles.

ii) Form Characteristics (HAKE66) p142.

Hake summarised the most frequently used measures of shape from a variety of applications.

a) Area, perimeter and maximum dimensions of geometric forms.
b) Number of elements in dot patterns.
c) Number of angles and line segments.
d) Number of indefinitely extended straight lines.
e) Texture.
f) Perimeter to area ratio
g) Regular-irregular. Simple-complex.

iii) The Metrics of Visual Form (BROW67) p243.

Brown and Owen assessed 1000 shapes, 200 each of 4, 8,12, 16 and 20 sides, against 80 measures of shape. Their objective was to graph the number of shape measures against shape accountibility for each of the 4, 8, 12, 16 and 20 sided shape classifications. Their results proved that relatively few independent measures are needed to account for differences amongst shapes. (G234) indicates the graph of Brown and Owen's work for the first 12 factors or measures of shapes. It can be seen that for 4-sided figures, up to 87% may be accounted for by 12 factors of shape. In this case, the 80 measures used correlated highly with five factors

a) compactness
b) jaggedness
c) skewness of contours relative to x axis
d) skewness of contours relative to y axis
e) dominant axis

iv) Statistical Moments (ZUSN70) p67.

Zusne suggested the use of statistical moments as measures of shape,

a) The 1st moment of area is the centre of gravity, specified by two co-ordinates.
b) The 2nd moment of area is compactness, and this measures the overall dispersion of the shape.
c) The 3rd moment of area measures the symmetry of the shape about a given axis.
d) The 4th moment of area measures shape elongation in terms of some height to length ratio.

Zusne points out that the measures are a little insensitive to small but perceptually conscious protrusions of shape, and this may be of significance in visual assessment over large viewing distances.

Reviewing these methods of measuring shape, it is necessary to identify those which are best suited to helping in the visual assessment of building shape. We have established that there is no single parameter value for shape (ZUSN62) p154; we wish then to select a number which may be used in describing building shape for a number of visual reasons, eg. a horizontal emphasis in flat terrain. Many of the methods described above tend to be based on randomly generated polygons, and often are concerned with shape description to allow later independent reconstruction. It is clear then that some of the methods will be inappropriate to visual assessment in architecture where shapes are a little more regular, and others will be too detailed since we are not concerned about reproducing the shape.

Three measures of shape are defined as appropriate in visual assessment; compactness, angularity and directionality. These factors may be seen to relate to the:

i) visual integrity of a building
ii) visual irregularity of the structure profile
iii) visual emphasis of the structure, horizontal vertical or balanced.

It is strange that only one of the factors, angularity, takes edge into account, and even then as a minor parameter. Earlier it was seen that edge played a major part in shape recognition (ATTN57)(BROW62) and, therefore, it is surprising not to see edge act out a more significant role in shape measurement. Some of the reasons why edge is an inappropriate measure in shape assessment for visual impact studies are outlined in (G235); however, the topic of edge will be returned to later in its own right. We shall next return to the three shape measures defined above.

i) Compactness

Compactness is a Gestalt variable of shape, and our authority for using it in visual impact assessment is derived from some research work by Hochberg, Gleitman and Macbride at the University of California in 1948. (HOCH48) They found that on exposing observers to views of a circle, a square and a cross of equal area, in accordance with predictions, the threshold of shape perception was found to increase with the criterion of simplicity chosen, ie. with compactness. The circle had the lowest threshold of perception, the square next, then the cross. In the case of visual assessment we may relate the compactness of a shape to the threshold of perception, mostly over large viewing distances.

Four methods have been devised to quantify shape compactness. The first two are size variant, and the latter two size invariant.

a) The minimum bounding rectangle.
The smallest and largest X and Y coordinate values of the shape will define the enclosing boundaries for shape compaction. A further step may be taken to calculate the percentage coverage of the enclosing box by the shape. This would yield a measure of shape complexity. (G236)

b) Spikes to edge nodes.
The average distance between the geometric centre of a shape and its edge nodes may be used to quantify compactness.

c) Perimeter/Area ratio.
A very common method for measuring compactness is the relationship between shape perimeter and area. Attneave and Arnoult argued that the measures perimeter and area were sufficient to order shapes along a compaction/dispersion continuum, though not as a quotient, but as the perimeter squared over the area. (ATTN56) p468 Although this measure is size invariant there is a tendency for it to breakdown at the high and low ends of the continuum. This is significant when considering large viewing distances to buildings which will appear small. The basic relationship

$$P^2/A \quad (5.21)$$

may be modified to express a measure known as dispersion.

$$1 - \frac{2\sqrt{\pi A}}{P} \quad (5.22)$$

This variation on P^2/A describes the compactness of a shape as a number between zero and one, with the circle having the value 0, the most compact figure.

d) Shape/Circle compactness ratio.
The compactness of projected shape may be measured by the size invariant expression

$$P_s \,/\, P_c \quad (5.23)$$

where P_s is the perimeter contour length of the shape, and P_c the perimeter contour length of a circle with the same area.

We must choose a size invariant measure for compactness in visual assessment work; for minimum computing load, we will choose the dispersion expression (5.22) above.

ii) Angularity.

The angularity of a shape may be measured by the sum of its internal angles at each edge node (G237). Edge nodes, where the shape contour changes direction, have always been seen as places of high informational content in discerning shape. In the instance of visual assessment they describe the irregularity of the building profile.

iii) Directionality.

One of the most striking features of a building shape in the landscape is a vertical emphasis, often contrasting with the context landform, eg. a power station chimney. The directionality, horizontal or vertical emphasis of a building, ought then to be considered as a dimension of shape in visual assessment. At a simple level it is possible to indicate one of three states, given an object form and an observer location:

i) horizontal axis dominant, ie low profile.

ii) vertical axis dominant, ie tall building element.

iii) balanced : a perfect square, circle.

A more complex dominant axis factor may be obtained by using Zusne's formula for the fourth moment of area, which measures shape elongation in terms of a height to length ratio, thus:

$$U = \int_A (x - \bar{x})^4 \, dA \qquad (5.24)$$

where U = 4th moment of area

A = shape area

X = the value of X (horizontal dimension) for each Y in the integration.

$\bar{X}$ = X value of the centroid.

This general formula may be used on very complex shapes. A simplified version, for use on regular rectangular shapes may be described by integrating (5.24), thus:

$$U = \int_A (x - \bar{x})^4 \, dA$$

$$U = \int_0^X \int_0^Y (x - \bar{x})^4 \, dx \, dy$$

$$U = \int_0^X (x - \bar{x})^4 \, dx \int_0^Y dy$$

$$U = \left[\frac{(x - \bar{x})^5}{5} \right]_0^X \left[y \right]_0^Y$$

$$U = \left[\frac{(x - \bar{x})^5}{5} + \frac{(\bar{x})^5}{5} \right] \cdot Y \qquad (5.25)$$

where Y = the vertical dimension of the shape.

Some shapes and the values of the fourth moment of area are shown in (G238). A simple horizontal to vertical ratio may be used; however, this is an insufficiently robust measure for minor shape deviations from regular figures. In many cases buildings do not appear as rectangles when viewed from the side at an angle, or when the building grouping is complex and a number of shapes are overlapped. On such occasions the shape perceived is too complex to apply a height/breadth ratio, and (5.24) may be implemented.

The idea behind the measure for shape directionality or dominant axis, is to aid the designer in appreciating the horizontal or vertical proportion or emphasis of the building as perceived in the landscape. Whether this is acceptable to the designer or not is a matter of his own personal judgement.

Program SHAPE

The flow chart algorithm describing the operation of the program SHAPE is outlined in (G239). Three options are on offer to the user; to measure compactness, angularity or directionality. These may be initiated to assess the building shape from a single viewpoint or from a matrix of observation points at some user defined interval. An ordinal scale of measurement is used on the output presentation of the results. It is proposed that contours, based on the values for compactness etc., are drawn using the program SYMCON for overlaying on OS maps. A designer/user may then appreciate the variation of the perceived shape configuration as seen from the surrounding landscape. Boundaries defining significant changes in the perceived shape may be interpolated manually from the contour plots, and sensitivity analyses may be conducted on minor modifications to the building form or orientation.

ii) Size

Definitions

As with shape, the term 'size' invites a variety of definitions. A host of authors in the area of psychology have dealt with the definition of size by distinguishing a number of aspects, eg.

a) physical or objective size : describing the size of the distal stimulus in the physical world, expressed in metres.

b) retinal or physiological stimulus size : defining the size of the proximal stimulus on the retina.

c) relative size : defining the size of an object in relation to one of three references :

i) its surrounds.

ii) similar shaped objects also visible.

iii) the past experience of the observer.

Such definitions tend to be a jumble of subjective and objective terms which have little bearing in visual assessment. Joynson was the first author to define size in terms of the visual field :

> "Apparent angular size : the proportion of the visual field an object appears to fill." (JOYN49) p120

Ittelson helpfully terms this definition of size as projective size (ITTE51) p62. We shall assume the term, projective size, and Joynson's definition as the meaning of size in this section. It can be clearly seen that projective size is an important measure in visual impact assessment.

Perceived Size

Visual tricks or illusions may be employed by designers to lessen the size of a building in the landscape. The placement of other objects in front of or near a building may affect its perceived size; and again a building sited in open countryside with few visual cues, eg. trees, may appear to be smaller than it actually is (HOLW41) (G240). Such factors cannot be accounted for in computer application, and our inability to perceive the correct size of a building in the landscape may be used as a deliberate policy to increase or reduce the visual impact, wholly outwith any computing appraisal of size.

Geometry of Vision.

Projective size is principally determined by the observer and object locations, the object dimensions and the geometry of the eye. The terminology and description of viewing parameters is outlined in (G241) where

$$\frac{S}{D} = \frac{R}{17} \quad (5.26)$$

$$\tan \alpha = \frac{S}{D} \quad (5.27)$$

$$\alpha = \arctan\left(\frac{S}{D}\right) \quad (5.28)$$

S = physical object size

D = physical viewing distance

R = retinal size

α = visual angle of object subtended at the eye,

and $\tan \alpha = \frac{S}{D}$.

tan of 1 minute of arc = 0.00029 and

tan of 1 second of arc = 0.0000048, and

for very small angles, the tangent varies linearly with the size of the angle, thus:

tan 10 minutes of arc = 10 x tan of 1 minute.

Measuring Projective Size.

In order to measure projective size it is necessary to refer to the earlier definition of the visual field and the unit, steradian. From (G241) it is clear that the steradian value of projective size is directly related to the physical dimensions of the building and the viewing distance. The relationship though is not linear. Since an object reduces its apparent size by one quarter when the viewing distance is doubled, we may write :

$$B = \frac{a}{D^2} \quad (5.29)$$

where B = the area of the retinal image.

D = the viewing distance.

a = a constant.

This is the inverse square law of projective size. Using (5.1) it can be seen that the proportion of the retina occupied by the building, measured in steradians, is :

$$S_\sigma = \frac{H}{d_P}\left(\cos\theta_1 - \cos\theta_2\right) \times 1000 \qquad (5.1)$$

where, H = the vertical dimension of the building and accounts for the vertical angle subtended by the building at the eye.

d_P = the viewing distance, which is defined as D

$(\cos\theta_1 - \cos\theta_2)$ = the horizontal angle of vision subtended by the building at the eye.

(5.1) therefore accounts for all the variables in the inverse square law of projective size. The millisteradian value, S_σ, may be assumed an accurate measure of projective size. The program SIZE, intended to calculate the projective size of an object from an observer location, is specified in the flow chart algorithm of (G242).

iii) Edge

Any instantaneous impression of the visual world in our minds is composed of surfaces which have boundaries of varying clarity. The sharpness of these boundaries or edges varies with brightness or colour contrast and determines, to a large extent, the degree of attention paid to each part of a scene. The edges and shapes of a scene are closely related, in that a shape is delimited and characterised by its edge or bounding profile, indeed :

> "shape cannot exist without an edge. A surface without edge is background, with an edge shape is given to a surface." (ATTN54) p184.

Thus, while the measurement of building shape may provide an important understanding of the visual impact when natural landscape features and curves are stopped abruptly by artefacts, the contrast of particular edges of the shape, seen against the background, may allow a designer to identify the key aspects of the building shape which may be causing high visual attention, eg. skylining. In dealing with the term 'edge' in visual assessment, two means of measurement can be described :

i) clarity
ii) direction.

We shall return to these two methods later. First, it is necessary to address the problem of defining the term 'edge'.

Definitions.

Attneave's definition, above, refers to edge as a bounding contour or perimeter, the external edge of an object. In the case of architectural design, this definition is incomplete, especially if determined by contrast, since no account is given for edges of high contrast formed by shadows falling across building surfaces. These may be termed internal edges, ie. internal to the projected shape of the building. Aylward and Turnbull are in agreement with Attneave's definition (AYLW78) p75, which differs from the accepted psychological understanding of edge. The psychological viewpoint would argue for edges to occur within the boundary or limit of the surface. Aylward and Turnbull argue their point on two grounds :

a) most buildings in rural contexts are seen over large distances, therefore internal edge is not as critical as external edge.

b) the problems in visual analysis centre on the conflict between man-made and natural form giving edges; ie the external edge or boundary of the object, where building meets nature.

Zusne makes clear the psychological standpoint by discriminating between, on the one hand, contour and outline, and on the other, edge.

a) Contour and outline relate to the description of two dimensional forms or objects; such as silhouette.

b) Edges define the three dimensional form of an object. An edge delimits a sudden change in colour, texture or direction of lines, signifying the end of a surface, passage to another surface or simply the end of an object. (ZUSN70) p17.

One of the main reasons for Zusne's discrimination is derived from the age-old disagreement between psychologists when reversible figure/ground configurations are considered. Both Forgus (FORG66) p20-23 and Hochberg (HOCH64) p83-94 support Zusne's distinction, "that while both a contour and an edge can delineate only one or two adjacent areas to which they are common, a contour may shift its allegiance quite easily, delineating one, then the other area, if conditions favour both areas as figure; an edge does not do this". (ZUSN70) p17. In adopting Zusne's understanding of the term 'edge', a hierarchical definition of edges occurring in the visual world is classified in (G243), with special reference to architecture and builtform visual analysis studies.

The measurement of edge.

Gibson has attempted to measure edge in terms of the course that an edge follows in space by specifying

a) edge length
b) edge direction (left/right/zero slant)
c) edge curvature (convex/concave/straight) (GIBS50) p195.

Such a specification is principally concerned with the reproduction of edge, eg. in pattern recognition studies, although some of these basic concepts may be employed in edge assessment for visual impact studies. Dudani and Luk have described a technique for extracting the edges from a digital picture of a scene by the other classic measure of edge, ordered pairs of coordinates defining the edge nodes of a polygon. (DUDA78) p145. Unfortunatley no subsequent operations or calculations are conducted on the edge node data, except image reproduction.

Returning to the two methods of edge measurement in visual assessment identified earlier, edge clarity and edge direction, these may be best seen to relate to Attneave's claim that edges are fundamental elements in form perception:

a) that information about object shape is concentrated along contours.
b) that information is further concentrated at those points on a contour at which its direction changes most rapidly; peaks or angles. (ATTN54) p183.

a) will depend largely on edge clarity and b) may be described as edge direction.

Edge Clarity.

One of the most subtle components of visual aesthetics is the contrast of juxtaposed surfaces. At one extreme there is camouflaging where there is low contrast between the object and its background; and at the other there is skylining where high contrast ratings occur between the sky and any object seen against it. We shall define the contrast rating of an edge as :

$$C = \frac{B}{B'} - 1 \qquad (5.30)$$

where C = contrast rating
B = luminance of the object side of the edge.
B' = luminance of the context side of the edge.

such that when $C = 0$ there is zero contrast between the object and its background; when $C = -1$ the object is highlighted or skylined against a bright background; and when $C > 0$ the object will stand out against a darkened context background.

The edge contrast rating of a shape may, therefore, be defined as :

$$C = \frac{(\sum B_o / N_o)}{(\sum B_c / N_o)} - 1 \qquad (5.31)$$

where B_o = the luminance of the object side of the edge.
N_o = the number of edges.
B_c = the luminance of the context side of the edge.

(5.31) may be used to measure the edge clarity of a shape, and (5.30) to measure the edge clarity of a particular edge section. It is most likely that (5.30) would be used in appraising the skylining problem of buildings in the landscape, where (G211) and (G212) may be referred to for luminance values. Since the horizon line is the most prominent contour in the rural visual scene, building forms breaking the natural flow of this line can cause significant visual intrusion and ought to be assessed in terms of the total length of silhouetted edge, expressed as a fraction of the total external building edge, thus

$$SF = \frac{\sum E_s}{\sum E_o}$$

where SF = Skyline factor. SF = 1 when the building is seen fully against the background sky and SF = 0 when skyline protrusion does not occur.
E_s = length of silhoutted edge.
E_o = length of external object edge.

The quantification of edge clarity and skylining is incorporated in the specification for a computer program EDGE, the flow chart algorithm of which is indicated in (G244).

Edge Direction

The visual emphasis of a building structure in the landscape is a function of its visible contrasting edge, and is commonly of two types - horizontal or vertical. Notice that edge direction is different from the directionality of shape, since edge direction may also account for high contrast internal edges which may yield a different visual emphasis as an observer looks at a building.

Internal and external edges of contrast ratings $-0.3>C>0.3$ may be selected for direction assessment using the program EDGE. In this case surface and background luminance values must be input to the program. Having identified those edges causing greatest contrast, and therefore most prominent visually, a direction value for each is calculated either as horizontal or vertical according to the limits:

$$45^{0} \leqslant V \leqslant 135^{0}$$

$$0^{0} \leqslant H < 45^{0} \quad \text{and} \quad 135^{0} < H \leqslant 180^{0}$$

where V = vertical angle

H = horizontal angle measured anticlockwise from a horizontal baseline at 0^{0}.

The sum of the lengths of the vertical edge angles may be expressed as a fraction over the sum of the horizontal edge angles to yield a figure of edge direction. When edge direction equals 1 the edges would be balanced; edge direction greater than 1, there is vertical emphasis, and edge direction less than 1, there is horizontal edge emphasis. Use may be made of the program SYMCON to display contours of edge direction in project presentation, to see the changing edge emphasis as an observer moves around the study area. The flow chart algorithm for the program EDGE and the quantification of edge direction is outlined in (G244).

iv) Overlap

Definition

Overlap or interposition as it is referred to in visual perception, is one of the principal cues for depth perception and judging the distance of objects relative to each other. The phenomenon occurs when one object or surface partly obscures or overlaps the bounding contour or profile of another object or surface. The obscuring object is seen as nearer the observer, while the obscured object lies further away.

In the case of familiar contours, overlap may be determined by the interruption of expected profiles. Dealing with unfamiliar objects, an observer must base his understanding of the object relationships on the significant edge nodes of the shapes concerned. Some edge nodes will appear to be inside projected shapes, others outside, and yet others common to two adjacent surfaces. This last category consists of edge nodes of high information content regarding overlap; these points are known as junction points. (G245)

Measurement of Overlap.

In computer graphics, perspective drawing packages make use of algorithms to calculate the portion of the modelled scene that is invisible from a selected viewposition. Two methods are used, hidden surface and line algorithms. The program VISTA makes use of a hidden surface algorithm, and this will form the basis of the quantification of overlap in the program VIDERE. In VISTA the junction points of overlapping polygons are known as augmented points meaning that they augment the edge node information in uniquely defining the visible portion of a projected shape in a scene. Four polygon relationships may be defined :

polygons are : disjoint
: conjoint
: subjoint
: co-incident

and four polygon set operations, thus :

: union A u B
: intersection A n B
: difference A - B
: difference B - A

Any two polygons, the overlap of which is to be determined, may be referred to as :

: A - the dominant polygon (nearest the observer).

: B - the subordinate polygon (furthest from the observer).

The complete 4 x 4 solution space for polygon set operations on any two polygons is described in (G246).

The procedural specification for the program OVRLAP is outlined in the flow chart of (G247). The visible projected shape input would be adjusted prior to initiating OVRLAP, by data from percentage visibility studies taking account of landform and land use obscuration. Each pair of polygons is assessed for the area of overlap, which may be expressed as a fraction of the total object surface area visible. The resulting value OVAREA can be assumed to be a measure of the percentage overlap of any two or more polygons; OVAREA may be calculated for a number of observer locations to map the variation of percentage overlap with observer movement using the program SYMCON.

v) Position

Definition

The term 'position' defines "the location of an object in an observer's field of vision in relation to the foreground and the background". (AYLW78) p77. Its relevance to visual assessment lies in the fact that it can determine those objects or buildings which are near the observer and backclothed, and those which are distant and possibly causing a skylining problem.

> "On flat terrain objects on the line of sight parallel to the terrain whose bases are in the lower part of the viewed scene appear nearer, and further away the closer the base of the object is to the line of sight. This does become distorted when the terrain is not flat or the line of sight is not parallel to the terrain." (AYLW78) p77. (G248)

Thus the significance of position in understanding the visual world increases with distance. Ogle's work substantiates this finding (OGLE64), since it is possible to understand the positional relationship of objects with each other, with a greater depth of field in viewing. This fact favours visual assessment work since viewing distances tend to be large.

Measurement of position.

Given reasonably flat terrain the position of a building in an observer's field of view may be found using the program POSTIN. (G249) indicates the calculation procedure within the program POSTIN. First, the sectional angle between the observer and the object/building is calculated; this angle is then classified into one of ten states (0-9) which may be plotted as contours of position using the presentation program SYMCON. Each of the ten classes of position value relate to nine vertical angle sections and the horizontal state, which has a null value (G250). The vertical angle of vision adopted is very closely related to the physiological boundaries of the normal human visual field, ie. 60^{o} upwards and 75^{o} downwards.

Examples.

a) A building viewed at the same height as the observer is standing ie a horizontel line of sight, will have a position factor, PF, of 0. (G250).

b) A building situated below the observer eye height is almost certain to be backclothed. In this case, where $1 \leqslant PF \leqslant 5$, the areas of 100% building backcloth due to position, may be mapped. In undulating terrain a great many more occasions may arise when a building is fully backclothed despite having a PF value greater than 5. In such cases, the program VIEW2 may be initiated to investigate the extent of backcloth.

vi) Backcloth.

The percentage backcloth of a building is simply a measure of the extent to which terrain is 'seen' behind the building, reducing its profile contrast against the horizon skyline. Aylward and Turnbull incorporated a backcloth assessment package in the program VIEW2 in 1980; this was based on the geometrical relationship between the landform, the building and the observer as indicated in (G251). Since its implementation the program routine has been verified in a number of planning and design projects dealing with skylining problems and forms a key feature of the VIEW program suite capability.

Output

At this point, only one of the visual descriptors of form as outlined by Aylward and Turnbull has not been dealt with; that is rotation. The descriptor 'reflectivity' was covered under visual range, earlier in this section. "Rotation defines the apparent changing shape of an object viewed from different viewpoints, establishing its three dimensional form." (AYLW78) p77. Thus rotation is concerned with observer movement around an interest object, locating boundaries of change, eg. in shape or in skyline protrusion. The fact that the programs in VIDERE deal with a set of observer locations and not a static viewpoint allows a user to identify change boundaries in the study area for each formal descriptor and thereby address the variable 'rotation'. Rotation may be seen as a function of the rate of change of the visual descriptors of form as seen from the surrounding area. This may be interpolated from the output of each descriptor program.

The worth of computer-based simulation in visual analysis is concerned with the quality of the output data presentation. Increasingly, the successful application of visual assessment programs is dependent on the legibility of output data :

a) for the architect in order to take decisions.
b) for the client to appreciate the implications of his project.
c) for the inquiry reporter in assessment.
d) and for the lay public to be aware of the local impact, should any arise.

Such needs cannot be met by choosing a single observer location. Only as the changing formal characteristics of a building and its relationship to the context environment are mapped out around the study area can a complete and worthwhile assessment be effected.

Since we experience architectural space and form through movement, proper visual assessment must be based on a two dimensional mapping output,upon which a designer may appreciate the varying visual attributes of a building in relation to the landscape. The output from the appraisal programs within VIDERE may be charted out by the display program SYMCON, defining boundaries of change, eg. from 100% backcloth to skylining; zones of transition where the perceived building shape may change; and limitations of visibility, eg. due to an observer's visual acuity.

Such maps can be overlaid on Ordnance Survey maps of the study area to determine the visual appearance of the development as seen from a variety of locations chosen by the observer. The design activity loop may be closed by feedback, from the evaluation of the output results to reanalysis and resynthesis (G18) until a satisfactory solution is achieved.

5.7 Summary.

This chapter has presented the background theory and specification for a set of visual descriptors for use in visual assessment studies. The routines described may be used in conjunction with the more traditional methods of visualisation to increase an architect's understanding of the visual implications of one or a number of design proposals, as seen from a selection of viewpoints around the design site. The intention of the program VIDERE is to improve goal formulation, objectives and target setting, assessment of alternative development strategies and design sensitivity analysis throughout the full course of the design process.

Continued software development and hardware acquisition are seen as the two main areas of future research endeavour in computer-aided visual impact analysis. While the former is a matter of programming ability, the latter topic, hardware acquisition, ought to be dealt with in more detail than simply specifying a shopping list of computing machinery. For this reason chapter six deals with the overall framework of the software and hardware systems currently being assembled at ABACUS to allow a fully integrated appraisal package for visual impact assessment.

CHAPTER 6

6.1 Introduction

This chapter is intended to form an outline specification for a computer-based visual assessment system. The software and hardware components in the system specification are described in detail, in so far as experience in this field has taught the author about program features and deficiencies, and hardware capabilities.

Two environments are identified, research and practice. The research system would be located within a suitable academic establishment and perhaps maintain a commercial contact with industry through, eg. a bureau service at a Science Park. The system outlined for architectural practice is a great deal smaller in scale, though not necessarily proportionally less sophisticated. The processing core of both the research and practice systems is the new breed of 32-bit mini computers which will undoubtedly bring the most significant advances in architectural computing over the next three to five years. Both system specifications permit monochrome and colour perspective visualisation, and the mapping of object characteristics, eg. visibility and shape, as symbol or statistical overlays on OS contour maps.

a) The research system.

Two features of the research system proposed are a direct result of the findings from the earlier chapters, notably chapter 3 :

i) integrated approach : the system as outlined relies heavily on shared data bases, processing power and output devices. The assessment procedures of each part combine to give the user/designer a complete understanding of the visual impact of a simulated development. Although the elements are well integrated, there is opportunity, should the user so desire, to make use of one section in visual assessment, eg. monochromatic visualisation using the program BIBLE.
The system is integrated in another sense, that it makes no attempt to usurp well tried and tested methods of visual assessment. Rather, as a more rigorous and accurate base

in providing high quality information about the visual characteristics of a development, the procedure outlined can stand side by side the traditional techniques and further improve their reliability, eg. artists' impressions.

ii) structured procedure: one of the main drawbacks of the traditional approaches to visual impact assessment is the fact that such techniques tend not to be evenly spaced out throughout the various stages of the design process. This is especially so in the early formative stages of design where there is a clear need to establish realistic visual goals and objectives as quickly as possible. The system proposed then incorporates a high degree of flexibility such that a user/designer may simulate either sketch design proposals of alternative schemes or a more detailed scheme in the final stages of design. Specific parts of the system may be implemented to solve particular design problems, eg. building skylining or the external colour and appearance of the material finishes, at any point in the design process.

During the system construction, it is proposed that the operational elements would be offered on a bureau service for consultancy work in visual impact assessment; this would validate the ongoing research effort and review its appropriateness to architectural practices involved in visual impact problems. Although, at present, ABACUS and DIR operate such a consultancy service there are a number of significant software and hardware gaps in the system, preventing ease of use and administration of data relevant to any one project job. In describing the various elements of the system, section 6.2 identifies the key missing components at present and discusses the possible solutions.

b) The practice system.

The specification of a system for practice cannot be realistically focused on the single design task of visual assessment. If architectural practices are to invest in computing it is crucial that the processing capability can support a range of automated design and management tasks to eliminate redundancy in daily machine usage. Visual assessment by computer will not occupy 24 hour processing. To obtain the greatest benefit from computing investment by practices in visual assessment, it is necessary to describe briefly the broader context of applications to which computing power may be applied in the design office. These and other aspects of the practice system are taken up in section 6.3. The integrated and structured features of the research system are incorporated, with increased relevance, in the practice specification. Clearly, a practice system gives special advantages over the consultancy research system in day-to-day usage by designers. 'In house' processing results in faster decision making and assessment at the drawing board for an architect, who may be considering other non-visual variables in the design proposal; additionally, shared data bases, eg. topography, can permit computer appraisal of many more practical design issues, eg. earthworks and drainage calculations, since they may be readily accessed and computed on a personal practice computer system.

6.2 Research System Specification.

6.2.1 Introduction

(G252) outlines in detail the elements and connections of a proposed computer based system for visual impact analysis. The reader will discern four discrete processing programs at the heart of the appraisal system; VIEW, VIDERE, BIBLE and VISTA. One of the main features of the system as proposed, however, will be the interchange of input data and output display files between the programs and their display processes respectively.

Three independent bodies from research and practice would be involved in contributing expertise and facilities within the system:

i) Topographic Science section of the Department of Geography at Glasgow University, under the directorship of Prof. Gordon Petrie; providing photogrammetric data capture facilities.

ii) ABACUS at the Department of Architecture, Strathclyde University, under the directorship of Prof.Tom Maver; providing development and use of BIBLE and VISTA.

iii) Design Innovations Research, Edinburgh, a design and planning consultancy managed by Mark Turnbull; providing development and use of the VIEW suite of programs.

Existing elements of software and hardware are indicated by a full line box, whereas components yet to be written or purchased are outlined in a dotted line (G252). At first sight, the system may appear over ambitious; however, much of it already exists. The incompleteness centres on areas such as;

i) more efficient means of data capture, eliminating error prone manual procedures.
ii) more effective use of data for processing, avoiding duplication of data preparation for each program.
iii) better quality presentation of results.

In describing (G252) in detail, three horizontal sections may be defined; pre-processing, processing and post-processing. These will be discussed in turn rather than describing the system by its vertical structure since the horizontal transfer of data is more important to the success of the system operation than the vertical program processes which have to a great extent been established in practice to date. Individual elements of each horizontal section will be discussed from top down and left to right.

6.2.2 Preprocessing.

i) Photogrammetric input.

Data capture continues to prove one of the most critical problem areas in visual assessment. A number of methods will be discussed in succeeding sections, however, here emphasis is given to photogrammetric procedures. Over the past four years the Topographic Science section of the Department of Geography at Glasgow University has been involved with ABACUS and DIR in data capture from stereo pair aerial photographs. There, procedures exist for the automatic digitising of building and landform data using a GalileoStereosimplex stereo plotting machine equipped with an X/Y/Z (3D) digitising system.

A building data base for use in the program BIBLE may be recorded on digital tape from the digitising system and transferred to the BIBLE host computer. This procedure addresses the specific problem of acquiring existing builtform data. Subsequent data input is required describing the proposed development.

The acquisition of landform and landuse data by photogrammetric plotting is thought to be most applicable when large areas are under study, typically, 40km^2 and more. The facility exists to store contour data in X, Y co-ordinate pairs for successive Z contour elevation intervals. These may subsequently be interpolated to form a regular square grid matrix of points across the study area for VIEW processing. One of the main areas of development in this section of the system is the setting up of a land use data capturing facility. The recording of X, Y co-ordinate pairs along the bounding edge of land use areas remains the only automated alternative to labour intensive manual interpolation and alphanumeric input. In particular, the control and accuracy offered by photogrammetric digitising makes this approach to data capture of crucial importance to the veracity and utility of output results. However, it can be an expensive method of data acquisition, since trained operators are required for the photogrammetric plotting, and the study area may not be covered by sufficiently detailed aerial photographs.

This often results in plotting being restricted to fairly large scale studies.

ii) Landform data capture.

Four other methods of topographic data acquisition are seen as feasible procedures within the system, distinct from photogrammetric processes; some were dealt with in 3.9.3

a) Manual interpolation from O.S. contour maps.
Although this method is highly prone to error it is the most frequently used data preparation method; error checking programs in the VIEW suite can identify gross errors very quickly before moving on to the processing phase. In many ways this method is only a stopgap measure until a semi-automated contour digitising procedure becomes readily available to practice (when photogrammetry is inappropriate).

b) Semi-automated contour digitising.
This work is under development at the Department of Architecture Plymouth Polytechnic. Topographic data may be recorded digitally on tape or directly into the computer's memory by a user tracing out the contours of an OS map placed over a digitising tablet. An early prototype of this process is currently operational; however, it is far from applicable as a validated and robust method of data capture until the planimetric accuracy of the contour can be increased.

c) Laserscan Fastrack System
This procedure attempts to capitalise on the wealth of existing map documentation; the laser scanning process along each contour line is described in detail in 3.9.3. Undoubtedly, this is the most efficient method of topographic data capture, and is particularly suited to VIEW processing, following the completion of an interpolation program which converts the contour data read from OS maps

into grid cell points at user defined intervals. The cost of obtaining topographic data through the bureau service operated by Laserscan is around £100 per $25km^2$ at 1;10,000 scale, and contour interval of 25ft. Conversion to grid data is extra, although still an economically feasible procedure for design practices. Unfortunately, the Laserscan service is currently dedicated to mapping work for the Ministry of Defence and unavailable for commissioning project work.

d) Form generators.
The use of topographic form generators in data preparation is principally connected with landform modelling in reclamation studies at quarries or mining spoil tips. The specification of ridge heights and direction, slope gradients etc. can form possible landform solutions quite rapidly in the case of remodelling derelict and scarred landscapes. This particular section of the system remains to be tackled, though with less priority than other elements.

Land form data generation is still, therefore, very much an ad hoc process for each project, depending on the scale of the study area, the required dimensions of accuracy and the availability of mapping facilities to generate digital data. The hardware requirements for methods a) and b) exist; method c) is used on a consultancy basis and requires only the facility of digital tape reading; method d) when fully developed would make use of the digitising tablet facility used in method b).

iii) Land use data capture.

Land use data capture is currently a manual interpolation process based on OS maps. Two other techniques are being developed to speed up this process:

a) land use boundary plotting at Plymouth Polytechnic by a (2D) digitising tablet input.

b) photogrammetric plotting of land use areas, as described earlier.

Hardware exists for these two lines of development; however, a significant amount of time needs to be devoted to software programming to gather the land use data as it is traced out. Land use is an extremely important issue in visual assessment as was seen in 4.4, and the development of an automated land use data capturing method must be a high priority in future system development.

iv) Error checking and data management.

Typically, three data bases would be produced before VIEW processing; an existing and proposed landform data base, and an existing land use data base. Fairly rigorous error checking and data management routines exist in VIEW which allow detailed interrogation of these data bases.

Error checking	Data management
: CHECK	: INSERT
: VALID	: IDGEN
: COORD	: HTADD
: DIGERR	: CHANGE
: ELGRID	: INTERP
	: PART
	: STRING

as described in 3.2.2. With the exception of ELGRID, which plots a grid of elevation values, these programs may be operated interactively on any vector or raster terminal screen, or on a printer with an alphanumeric keyboard. Software and hardware requirements are extant.

v) VIEW data bases.

The VIEW data bases are stored in memory according to the user specified grid interval. While grid squares have proved sufficiently accurate in studies to date, future development of the system proposed ought to consider the storage of contour data for VIEW processing rather than gridded data. Not only will data storage requirements be reduced with such an approach, but any subsequent visibility calculations would be based on source data from OS maps, and not, as presently, on grid interpolated data. Land use modelling would also be free of the very restrictive grid cell format; it is envisaged that land use data in the system would be supplied either from automated digitising sources or from the BIBLE program geometry data, through a VIEW/BIBLE data translation program.

vi) VIEW/BIBLE translator.

The ability to transfer input data between the programs VIEW and BIBLE is regarded as a high priority in the system development, and central to the integrated concept. This task is purely a matter of software programming, although clearly a significant amount of man power and resources is required, together with necessary expertise.

vii) VIEW data file preparation.

Since the main processing programs in VIEW are operated in batch, input data files with user defined parameters are required in addition to the data bases described in v) above. Standard parameter files exist for each of the processing programs in VIEW, though in any future system developed it is proposed to construct an interactive front-end to these programs and remove the need for formatted parameter files. Again this only involves a commitment to software development.

viii) Builtform data capture - BIBLE.

As in the case of landform, four other methods of data capture, distinct from photogrammetric plotting, are identified as input sources to the program BIBLE.

a) Existing data files. Geometry data files from other ABACUS programs, eg. ESP and GOAL, may provide data for BIBLE processing. The transfer of data in this way is frequently used at present. In certain specialist visualisation problems a library of standard elements or parts may be constructed. The pylon studies described in 4.3 are a case in point; existing data files for pylon types are stored in the computer memory for referencing when pylon visualisation problems occur. A detailed description of the pylon element library is contained in Appendix 4.

b) Manual keyboard input. This is a relatively slow process and highly prone to errors. Indeed the typing of alphanumeric characters at a keyboard is largely foreign practice to architects and designers who would be better suited to input methods using a digitising tablet and stylus. This means of building data generation is fast being overtaken by form generators and digitising, and may only be seen in the final system development as a stand-by method of data preparation for non standard or complex geometries.

c) Digitising at a tablet.
This is probably the most conventional means of architectural data preparation for computing. Such a procedure exists within the program GOAL, and this is intended to form the basis of a digitising input routine for BIBLE. Hardware requirements for this task exist at ABACUS; the main commitment of resources would be devoted to software writing and the specification of a graphical interface within the digitising procedure.

d) Form generator.

Development work on a form generator input system has already commenced at ABACUS. The program BIBMAK allows a user to construct or manipulate geometry data for BIBLE processing. Three option levels within BIBMAK are identified as:

i) INPUT - RECT : construct a rectangular prism
EXTR : construct extruded shape
REV : construct rotated shape
MAN : input data manually
BIB : input BIBLE file

ii) MANIPULATION - MOVE : move object to XYZ location
COPY : copy object
ROT : rotate object by degrees
SCALE : scale/reflect object
EDIT : edit the object description
DEL : delete the object.

iii) CONTROL - GROUP : group/ungroup objects
GRID : objects adjusted to a grid
LIST : list the database
DUMP : dump the database in a file
DRAW : draw the object.

Further development in the area of a form generator input procedure will involve the specification of building, engineering and landscape elements, described in standard data files and ready for manipulation through the BIBMAK program.

Building elements : /roofs/doors/windows/stairs/columns/walls/etc.
Engineering elements : /pylons/wind turbines/road embankments and surfaces/etc.
Landscape elements : /trees: deciduous, coniferous/ etc.

These objects may be selected at a graphic tablet or through a menu and cursor/pointer on a graphics terminal. The hardware exists for either process, and it is seen as a highly desirable facility in the proposed system configuration; the principal need in this area is for software development.

The ideal set up for building data capture in the system structure would be a combination of methods c) and d) outlined above, with infrequent resort to method b) and limited specialist use of method a).

ix) BIBLE data base.

The current method of storing geometry information in a BIBLE data file is unnecessarily large. Detailed surface and edge specifications for each object element are required, greatly increasing the data storage requirements. These specifications are frequently repetitive and could be removed altogether by the use of form generators. Until now BIBLE data bases have been relatively small; however, it is expected that with increasing demand for detail in modelling and more complex buildings being appraised the current data file structure will be inappropriate. The solution lies wholly within the construction of a form generator data preparation and storage facility. In this case surface and edge specifications would be stored outside the main data base; these standard forms need then only be identified within the BIBLE data base and assigned scale, location, elevation and orientation values.

x) BIBLE/VISTA translator.

The transfer of geometrical data between BIBLE and VISTA has been a useful feature of the visualisaiton section of the system to date. The program BIBVIS, which effects the data conversion, incorporates data file editing, appending and creation options for the user. This element of the system is, therefore, complete, but may require modification at a later date to handle BIBLE data files constructed by a form generator.

xi) Builtform and colour data input - VISTA.

The data input management module of the program VISTA is the routine VISIMP, which allows a user to create and edit a geometry data base; create a colour specification file in RGB values for each surface;

create tiles on surfaces which may act as brickwork patterns or windows etc.; and set up a control file to run the viewing module of VISTA. These data may be hand keyed at the terminal with the help of a screen menu and cursor/pointer. Alternatively, and more commonly, the geometry data are transferred from BIBLE through BIBVIS. VISIMP is a fully operational component of the system configuration.

xii) VISTA data base.

Similar to the BIBLE data base, the storage requirements could be significantly reduced with form generators. It is envisaged that at some future date the data bases for BIBLE and VISTA will be generated from a common form generator/digitising input procedure at the head of the visualisation side of the system configuration.

6.2.3 Processing.

i) VIEW1

VIEW1 may be operated on existing teletype or Visual Display Unit terminals, typically Tektronix 4000 series machines, local to a processor or remotely, connected by telephone lines and an acoustic coupler. The hardware devices exist as does the VIEW1 software which addresses the specific problem of visibility from one or a number of observer locations. The output may be in the form of a map of visibility or contours of visibility for multiple viewpoints; these are stored as alphanumeric symbols and may be plotted as 2d maps or printed in statistical tables by the display programs described in the first section of 6.2.4.

ii) VIEW2

As with VIEW1 both the hardware operating system and the software for VIEW2 exist. In addition to mapping visibility VIEW2 tackles questions of :

: the % visibility of an object.

: the % visibility above horizon.

: the areas acting as backcloth.

: the areas acting as 'dead ground' and their depth.

Both VIEW1 and VIEW2 are well tried and tested programs, and perform a key role in the rigorous and accurate visual assessment of building proposals from a very early stage in design.

iii) Landscape design programs.

In addition to the VIEW suite of programs, several landscape design programs may operate on the topographic data base.

: cut and fill earthworks calculations

: drainage analysis

: road alignment

: steps/path design for landscaping.

The relevance of these programs to visual assessment can be seen in that:

i) cut and fill calculations can determine available earth for screening a development.

ii) drainage patterns may determine the location, species and growth rate of trees planted on site; in turn these will afford specific colours and patterns at different seasons and offer transparent or opaque screens to development.

iii) certain road alignments may involve tree felling and could disrupt the visual appearance of an area.

Such relationships are not easily assessed manually and these programs may give a great advantage to a designer in forecasting some of the more detailed visual impact problems in landscaping. Like the VIEW programs, software is complete and the hardware requirements exist.

iv) VIDERE.

The program suite is described in detail in section 5.6, and forms part of the author's ongoing research involvement in the system specification. The theory and algorithm structure behind each of the sub-programs within VIDERE has been set out, and programming has commenced on a number of the routines. The output results are statistical in form and may be charted out in 2d map drawings by the program SYMCON. The significance of the program VIDERE in the system proposed lies in the fact that it bridges the gap between the 2d mapping of the visual implications of a development in the landscape, and the 3d visualisation of its form.

v) BIBLE

Section 3.2.1 describes in detail the program BIBLE which has existed for close on ten years. Consequently a number of algorithms, particularly the hidden line algorithm, have become outdated; their replacement in any system development work would reduce the computing requirements of the program, though this is not considered a high priority. It is suggested that an image space algorithm for hidden line elimination be used instead of the current object space algorithm. This will reduce the number of sorting steps (and the computation time) from an exponential to a linear relationship with the number of objects in the scene. Further programming effort ought also to be devoted to extending the range of drawing projection options, from simple parallel and perspective projections to metric projections (isometric, axonometric oblique etc.). The hardware requirements for operating the program BIBLE are, typically, the Tektronix 4000 series vector terminals, of which four exist at ABACUS operating from a mainframe DEC System 10 and 16-bit minicomputer PDP11/24. In the system proposed the central processing unit, a 32-bit minicomputer, would require a modest investment of time to transfer the BIBLE program to operate on the new processor.

vi) VISTA

VISTA has only been extant since the summer of 1982 and like BIBLE would require to be converted to operate on the 32-bit system processor as proposed. Two colour graphics terminals at ABACUS (Tektronix 4027 and AED 512) may be used to operate VISTA. The main area of development need is, therefore, seen as software programming to simulate:

i) the grading of shadow across a surface.
ii) the effect of climate on perceived colour over large viewing distances; and depth cueing.
iii) the relationship of British Standard colours to RGB values for the terminal.
iv) the modelling of reflective and transparent surfaces, eg. windows.

These features will serve only to increase the realism of VISTA output and continue to attract widespread interest in colour visualisation for designers.

6.2.4 Post processing.

i) VIEW display programs.

The program SYMCON is the most heavily used of the four VIEW display routines, though the monochromatic output is often difficult to read. For this reason the development of a colour graphics display module within SYMCON is seen as relevant to improving the legibility and communicability of the output maps and overlay symbols. Access to a colour graphics device is possible, leaving only the software programming to be undertaken. The programs SECT and PERSPX, described in 3.2.2, are complete packages with monochromatic output. Software development is required in the program SPHINX which generates 3d views of landform, buildings and landscape elements. Investment is principally required in the data preparation sequence, which will to a large extent be overcome by the establishment of a form generator input program.

ii) VIEW output -hardware requirements.

The VIEW output is primarily monochromatic, and for this reason may be printed or plotted on a dot matrix printer (upwards of £400) or a drum/flat bed plotter; an electrostatic plotter is considered inappropriately expensive. Sufficient for the plotting requirements of VIEW, a 36" width drum plotter (upwards of £10,000) is recommended, providing greater accuracy than a comparable sized flat bed plotter. Neither the dot matrix printer nor the drum plotter have been acquired as yet for local use within the system, although these devices are available for output printing and plotting at the Edinburgh Regional Computing Centre (ERCC) which houses and maintains the DEC System 10 processor used by the VIEW programs. A high quality daisy wheel printer, for use in statistical presentation is available locally, as are a series of vector terminals (Tektronix 4010 series) for previewing plot files and controlling the post processing output and display routines. Although colour presentation is dependent on the development of a colour display routine in SYMCON, the display terminal hardware requirement may be met by the use of the AED512 raster device.

iii) Program BIBPLT

The display program BIBPLT is a useful and recent addition to the output sequence of the program BIBLE. BIBLE view files may be replotted using BIBPLT with different scaling factors and user defined windows on the scene. The software is complete and operates on existing vector terminals at ABACUS.

iv) BIBLE output - hardware requirements.

For some time now three standard means of displaying BIBLE output files have been established and used successfully in practice:

a) local Tektronic 4010 series direct view storage tube terminals. These are normally used when an operator is running the BIBLE program interactively and requires to display the study object on the screen. Subsequent hard copies from the screen may be obtained by a thermal copying device.

b) local A2 flat bed Tektronix 4663 plotter. The acetate overlays for montaging are plotted on this device.

c) remote (ERCC), high quality Calcomp drum plotter. In cases where high quality documents and drawings are required the Calcomp plotter gives a finer line quality than the local flat bed plotter.

The output hardware requirements for BIBLE are fully extant and operational.

v) Monochromatic video mixing.

The system configuration outlined in (G114) for monochrome video montaging of images may be mounted at ABACUS when occasion demands. The scan conversion process reads the conventional geometric representation from a vector terminal and converts it to raster format in order to be mixed with the raster camera image, and displayed on the monitor and recorder. Within the scan convertor the features of image zoom, fade, pan and line change black/white are available to the user.

vi) Program BIBDIS.

BIBLE view files may be linked directly to the AED 512 terminal and colour rendered using the program BIBDIS. The software is operational and the hardware extant.

vii) Program PAINT

Minor errors can occur in the viewing module of VISTA which manifest themselves as incorrectly coloured polygons or pixels when displayed on the colour terminal screen. The program PAINT has been devised to allow a user to 'clean up' a perspective view by addressing polygons or pixels in turn and altering their colour.

viii) VISTA display module.

Software development in this section is complete permitting the display of VISTA output files on a range of vector and raster terminals, typically;

a) TEKDIS for display on Tektronix 4010 series vector terminals (wire line perspective).

b) DISPLY for display on a Tektronix 4027 colour raster device. (Full colour and shaded perspectives may be drawn but on a limited colour palette; only 8 colours on the screen at any one time from a choice of 64.) (STEA83)

c) AEDDIS for display on an Advanced Electronics Design (AED) 512 colour raster terminal. (In this case the colour range is greatly extended to 256 colours on the screen at any one time from a palette of 16.8 million.) (STEA83).

ix) VISTA output - hardware requirements.

Three types of output device exist at ABACUS and are described in the previous section

i) Tektronix vector terminals. TEK 4010 series
ii) low colour choice raster terminals TEK 4027
iii) high colour choice raster terminals. AED 512

Since the mid 1970s the falling cost of memory and processing power has resulted in an ever expanding market for raster scan computer graphics systems. These are fast replacing the more expensive storage tube terminals, and offer significantly increased visual realism through colour raster scan displays. Although raster systems are accepted as standard graphics technology for the future, these systems pose a number of problems regarding line image quality which are likely to be of considerable importance to architects and designers.

a) low display resolution. A raster scan image is generated by plotting the individual intensity of each picture element (pixel) in a series of horizontal lines across the screen forming a 2d raster or matrix of pixels. This array of pixel intensity values is known as a bit map, and may be held in a frame buffer (a large digital random access memory store). The resolution of the screen will determine the size of the bit map; maximum screen resolution is around 1024 x 1024 pixels at present. This dimension of screen resolution is probably sufficient for design purposes; however, smaller screens are more typical and often graphical images on 512 x 256 pixel screens appear fragmented, particularly diagonal lines. This phenomenon is known as 'staircasing' or 'the jaggies', and is wholly due to the low screen resolution. Two approaches are possible to eliminate 'staircasing'; by software programming, or built in with the hardware system (CATM78) p6. In the system configuration proposed it is intended to upgrade the existing AED512 raster colour terminal at ABACUS to a higher resolution device, the AED1024, which has built-in hardware anti-aliasing to smooth out the visual appearance of 'the jaggies'.

b) One disadvantage of increasing the screen resolution though, is that the scanning rate of the raster image decreases. In some cases, if the rate is too slow then the image will appear to fade slightly before being refreshed, causing the picture to flicker.

The trade-off between screen resolution and flicker appears to be best compromised in the AED1024 device (£8,000) which is recommended as an essential element of hardware in the colour modelling capability of the system.

x) Video disc storage.

Clearly the need to store a large number of images is an essential feature of any visual impact system, particularly one on the scale proposed. It is suggested that this problem be tackled by acquiring a laser video-disc system. Image storage is achieved using custom pressed discs; a 12 inch disc may store as many as 10,000 to 25,000 A4 size pictures. Reproduction far exceeds that of a standard television screen, and storage requirements are reduced to at least one tenth of conventional computing storage on floppy discs or magnetic tape.

Candidate video disc hardware would include the Philips Laservision system, which boasts a two way communications interface (RS-232-C) connection for computing applications. An external computing facility may drive the video system and reference images at will by over 10 frame search and play command facilities. (PHIL83). At just under £500 for a top loading Philips video disc machine this is considered a high priority for handware acquisition in the system.

xi) Colour video mixing.

The colour video mixing configuration described in (G115) remains available at ABACUS for video montaging. Image storage may be effected on the video disc system, although this configuration is likely to be superseded in the near future by image handling or digital frame grabbing technology (see xiii).

xii) Colour hard copy devices.

The problem of colour hard copying and reproduction was first discussed in 4.2.8 where achieving the correct colour balance was identified as the main difficulty. A two level solution to this problem is proposed in the system configuration.

At a low quality reproduction level: - a 35mm print or slide film copying device attached to the colour graphics terminal, eg. Image Resource Video Print 500; such a device exists at ABACUS.

At a high quality level:- an ink jet plotter, with three continuous flow ink guns of magenta, yellow and cyan; the resolution pixel size is 0.2mm x 0.2mm, with an operational speed of 55 cm^2 per minute. Even at the cheap end of the market a suitable A3 size dot matrix ink jet plotter would cost £4,000.

xiii) Image handling.

The difficulties of image montaging encoutered in the Hitchin Priory project (4.2.8) confirmed the need to access automatic montaging facilities in the form of an advanced frame grabbing device or image handling system. Image processing and its attendant objectives of enhancement, restoration or reconstruction may be thought appropriate here; however, as (G252) indicates in the VISTA post processing section, the need for capability in image handling is at a fairly low level. The system merely requires the user to capture a background image - the scene - and edit out the intervening foreground section which would obscure a future view of the proposed development. These two images would be stored separately. It would then be possible to construct a montage automatically on the terminal screen by a series of overlays:

1. the main background context image, overlaid by
2. the VISTA generated perspective, overlaid by
3. the edited foreground portion in the original scene.

Interim storage of images would be possible using the video disc system. A range of image capturing systems is available in the computing/video market; however, none as yet has been capable of meeting the performance requirements of the proposed configuration. Digital cameras and frame grabbing devices, which scan photographs and convert the visual data into a bit map for raster display, do provide the user with the facility to:

i) address individual or groups of pixels in the image.

ii) and effect image editing to store on tape or disc partitioned areas of the scene.

However, the major difficulty with digital camera and frame grabbing technology at present is the limitation on colour choice; most systems operate on a coding of 16 colours on the screen from a 64 colour palette, which is wholly inadequate for the purposes of detailed visual assessment. Unless a wider colour palette becomes available in digital camera systems it would appear that the only alternative route to image handling would be to adopt a relatively more expensive solution in the form of an image processing system. The current prices of digital cameras or frame grabbing devices range from under £4000 to £10000 for advanced systems, whereas an image processing kit for handling the type of visualisation projects envisaged would cost upwards of £20000 (including terminal hardware, which quite often must be bought complete with the system as a workstation).

6.2.5 System Costing.

The preceding sections indicate that many parts of the system are extant. A costing exercise on the labour and hardware requirements to fill those gaps identified in the configuration has been undertaken as part of a grant application made recently to a range of research councils, government funded bodies, national and regional utilities, and private industry. Around £120,000 is thought to be required for labour resources in setting up the system and programming; and around £120,000 has been earmarked for hardware investment, over a three year period.

At the time of writing, the commitment of a number of utilities (electricity, gas, etc) and other interested parties is still being sought, despite support from the National Research and Development Council through the British Technology Group, who are prepared to underwrite half the financial requirement. It is believed that four main benefits would arise from the setting up of a centre for visual impact analysis (perhaps based in a Science Park), and a system such as the one proposed for research, development and consultancy project work:

> "educational: the centre would be the natural focus for training, education and research in visual impact analysis; its existence would raise awareness in Europe of the relevance of the whole new generation of computer graphics techniques to architecture and planning.
>
> professional: architects and planners availing themselves of the service would, in turn, provide to public and private sector clients, a substantially improved design service; client bodies - local and central government, nationalised and private industry - could themselves use the service directly as an aid to the management of the natural and man-made environment..
>
> political: the evidence generated by the Visual Impact Analysis technique would assure the effectiveness and objectivity of public planning inquiries; the need for some planning inquiries - those in which debate centred on the degree of visual intrusion - may be obviated with consequent saving of public money.
>
> environmental: most important of all, the quality of our remaining areas of relatively unspoilt natural landscape may be preserved for the benefit of future generations." (MAVE82).

6.3 Practice System Specification

6.3.1 Introduction

In architectural practice the decision to invest in computing facilities is often a matter of developing a long term strategy for office automation. Such an approach will inevitably require some structured or rational assessment of office procedures in order to:

i) identify what it is possible to automate.
ii) select what requires to be automated now and in the future.

This potential for an orderly system expansion from an initial computing investment is of crucial importance in specifying a configuration for practice. In addition the subject area of visual assessment ought not to dominate or limit the choice of hardware purchase. Typically, an architect's office investing in a computing facility would seek to derive benefit from the system under a number of broad headings:

i) office and project administration.
ii) word processing.
iii) technical design calculations.
iv) draughting.

The practice system configuration outlined in (G253) is intended both to meet the need for system expansion and to support the range of automated tasks in an design office, in addition to the underlying function of providing a computer-based capability in visual impact analysis.

6.3.2 System hardware and software.

Recent advances in the development of 32-bit mini and micro computing systems have resulted in these machines becoming the likely future standard for computing power in design offices over the next three to five years. The decision as to whether a micro or mini computing system best suits a particular office will depend on the project work load and the level of automation desired. For the purposes of this specification, a design staff of some 10 to 15 persons will be assumed. The work load in this case would quite easily justify investment in a 32-bit minicomputer system for a wide range of office and design tasks. Such processing machines as the VAX 11/750 or 11/730, or the Apollo DN300 would constitute the central processing unit in the system. In particular, the Apollo system may be extended to allow multi-user access to the central processor from terminals used locally in different sections of a design office, eg. for word processing by secretaries and design calculations in the drawing office. Multi-user systems will unquestionably be the future standard in computer aided design applications, with up to 8 users and 15 tasks running concurrently from the new 32-bit mini computer machines.

The peripheral input/output devices indicated in (G253) are readily available from a range of manufacturers:

Device	Cost
i) A0 digitising tablet	£1000
ii) low resolution raster terminal for alphanumeric data preparation and system user interface	£1000
iii) high resolution colour graphics raster terminal (AED767).	£4000
iv) low quality dot matrix printer	£500
v) high quality daisywheel printer	£2500
vi) 36" width drum plotter	£10000
vii) ink jet matrix copier.	£4000

At around £25000 for the central processing unit, the total system hardware cost would be £48000, although a cheaper monochromatic version may be realised for around £35000, using a flat bed plotter.

Applications software would incur further cost, if in-house software development is not envisaged. While BIBLE and VISTA may be purchased for £2000 and £5000 respectively, the VIEW software is only available for use on a consultancy basis. Other applications software for design calculations, word processing and financial management etc. are freely available in the computing market, although poor quality software at cheap prices ought to be avoided. Around £5000 may purchase reasonable quality software for general design and office tasks. At these suggested software additions, the system outlined in

(G253) would total around £60000. This need not be assembled as a minimum starting configuration, and in many cases would act as a target configuration to be formed over a three year period.

6.3.3 Summary.

Many architectural practices are now beginning to appreciate the availability of low cost computing resources with the current trend emphasising the undoubted worth of 16 and 32 bit microcomputers. However, those practices wishing to enter the field of computer-based visual impact assessment must consider a higher level entry to the purchase of equipment and software. The system outlined in (G253) may be seen as typical of the commitment required. In this case, the multi-user feature, large memory capacity, increased processing power and range of peripheral input/output devices operating from 32 bit minicomputers are significant advantages over the microcomputer approach, and are considered essential features of a computer based approach to visual assessment, integrated with other design and office management tasks.

CHAPTER 7

7.1 Thesis conclusions

The thesis has covered a great deal of ground from identifying the problem of visual intrusion, to specifying a computer-based system for visual impact assessment. In many ways this only serves to underline the lack of ongoing research and development work in visual impact analysis in the UK today. It is hoped that this will bring the subject area up to date, and, more importantly, point the way forward for further research endeavour. The main thesis conclusions and implications may be described as

i) there is a growing recognition of the value of our visual landscape heritage and the need for its preservation; this is typified by increasingly scrupulous public inquiries deliberating on the visual consequences of development proposals.

ii) future man-made intrusions on the countryside are inevitable, particularly energy-related developments, and almost certainly in sensitive visual environments.

iii) there is serious doubt as to whether traditional methods of visual assessment can cope with the rigorous appraisal demands of impending EEC recommendations on Environmental Impact Analysis.

iv) notably the accuracy, flexibility and adaptability of traditional methods of visual assessment during the design process leave a great deal to be desired, and certainly appear out of keeping with likely future demands for comprehensive and veracious visual appraisal.

Computer-based procedures and models are regarded as best able to satisfy these demands and present objective information for decision making by planning juries and committees. Three computer programs were discussed in the text; BIBLE, VISTA and VIEW. The background theory and specification for a fourth program, VIDERE, was presented in chapter five. As a radical new direction in visual assessment, VIDERE is a design tool for architects involved in the amelioration of the formal aspects of a design with its host landscape setting. The act of amelioration may encompass one of a number of visual design objectives, eg. highlighting or blending a structure in its context.

Taken as a whole, the computer-based programs provide a total capability in visual assessment. The hardware and system configuration for their operation was outlined in chapter six, and may be considered as the author's main conclusion as to the future direction of visual assessment in landscape and architectural design. The system described in (G252) is also intended to establish the physical framework for visual resource management which is almost certain to represent any future approach to planned development or longterm intrusion in a visually sensitive area.

7.2 Main recommendations

From the conclusions derived in 7.1 it is possible to make a number of recommendations to specific groups and organisations in some way involved or influencing the subject area of visual impact analysis.

a) Governmental

The continuing threat of industrial development on the landscape requires methods of environmental assessment sufficiently capable of measuring relevant, and predicting future impacts, both accurately and comprehensively. In this respect, an obvious framework for these methods would arise from the integration of EEC Environmental Impact recommendations in the UK planning system. The pros and cons of adopting EEC legislation have been dealt with in chapter one; it is the author's contention that, ultimately, such environmental law would provide a natural and sharp focus for the debate of sensitive environmental issues at public planning inquiries. The adoption of EEC legislation is urged.

b) Professional

In the future, planners, architects and landscape architects will more than likely be required to make use of computer-based visual appraisal programs if both client and public groups are to be convinced that sufficient care has been taken to preserve an acceptable visual environment. The growing mistrust and incompleteness of purely manual techniques for visual assessment is likely to result in increased uptake and development of a computer based approach by those practices engaged in environmental design. The design professions are urged to support and encourage these new directions.

c) Funding bodies

Increasingly, design practices are having to resort to computer assisted methods of visual appraisal, especially in large scale landscaping or development projects impacting on a wide area. Quite clearly there is a need for accurate and comprehensive appraisal procedures in visual assessment; their relevance to practice is unquestionable and has been reflected by recent interest in a number of journals and magazines; (RIBA83) (ARCH83b) (BUIL83) (COMP83). Funding bodies, in particular the Research Councils, are urged to undergird the financial commitment to the continuing research and development work in this field.

d) Research

It would be wrong to leave the subject of visual impact assessment without reference to its place within the broader context of environmental impact assessment, and the concerns of land use and landscape planning. The techniques outlined in the thesis are to some extent being used by practices involved in visual assessment, and it is hoped that this may help develop commonly accepted standards and procedures for visual assessment in Environmental Impact Studies. However, visual impact assessment is only one component of environmental planning and design. Other factors equally relevant to the siting of developments, include soil characteristics, depth to bed rock, land acquisition and the water table. The combination of these engineering, geological and design criteria into a computer-based environmental planning system for optimum siting and route location is considered a desirable future extension of this work within the broader field of planning.

At an even higher level though, social, political and economic decision making are to the fore in selecting development locations; therefore, any such computer-based approach to site and route planning ought to be structured in such a way as to match four commonly accepted levels of decision making regarding development (G254). At a national level, the social, political and economic consequences for the nation may be considered in conjunction with the environmental and recreational importance of possible development locations. Regionally, more specific environmental consequences, transport implications and land use alterations may be added to the decision making process. Locally and on site, environmental issues ought to have pre-eminence. Thus, there are four distinct levels at which it is possible to form a computer-based analysis system for optimum site and route planning. At each level any number of relevant and quantifiable criteria may be assessed, with the problem of weighting in such multi-criteria planning problems being addressed by pareto optimisation techniques. (GERO82) p633. Regional and local planning research groups are urged to develop the suitable framework for such a computer-based approach in environmental design.

At a more specific level in visual analysis research, the development and implementation of software remains the main focus of effort in the foreseeable future. Chapter six has outlined the detailed needs in this development work; broadly they constitute data capturing methods, data transfer routines between programs, and data presentation.

One final recommendation for practices, concerning the quantity of information which may be produced from computer assisted methods, ought to be covered. The virtue, so often extolled in computer-aided design, of being able to investigate many more design options and appraise data that 'one might not otherwise have known' using manual techniques, is sometimes an inappropriate aspect of design. Too much data can mean long interpretation times and make succinct presentation an impossible target. In the case of visual assessment it is all too easy to interrogate visibility for a range of given conditions and design hypotheses, resulting in a large volume of presentation data. Use of computer-aided methods in visual assessment ought then to demand that the user/designer:

i) interrogates the computer model with specific questions.

ii) imposes standards on the quantity and quality of information produced, such that he can cope with it, collate it, understand it and draw conclusions from it.

Computers have a significant role to act out in design offices; however, they must be employed for specific reasons in design, dovetailing with established and efficient methods, developed with understanding and used with clear objectives in mind, knowing what the hardware and software limitations are, not necessarily their capabilities.

7.3 Analogies

There are a number of interesting analogies which can be drawn between the way in which certain aspects of architectural design and technology have advanced in recent years, and the prediction of future trends and development in computer-based visual impact analysis.

Firstly, it is possible to see a parallel between the topic of energy and visual assessment. Ever since the first oil crisis in 1973, a recognition of the world's depleting energy resources and the notion of energy conservation have taken on an increasingly important role in planning and design. Nowadays quite sophisticated computer models for energy simulation in buildings exist providing designers with an accurate capability for predicting a building's energy performance.

After the same manner, it is feasible to predict that the current growth in concern for landscape preservation may well result in advanced appraisal techniques continuing to be developed to afford architects and other designers the facility of accurate visual prediction.

Secondly, the development of the typewriter to current word processing provides an interesting analogy between the way in which techniques have been invented to deal with text production and what the future might hold for the way in which images and graphics are processed in visual assessment studies. Significant steps in typewriter development may be noted as; first manual invented in 1868; electric golfball typewriters appeared around the early 1960s; electronic typewriters became available in the mid to late 1970s; and word processors, as a separate workstation in offices, have been on the market since the late 1970s. The way in which the text is dealt with developed from a heavy manual process on paper to a sophisticated screen editing and manipulation procedure on a word processor. In the same way, it is possible to draw a parallel with the way in which graphics in visual assessment are and might be handled. While the traditional manual methods of visualisation still have a place, automatic digital techniques are tending to dominate graphic image generation nowadays, and there is every likelihood that fully automatic image handling in visual assessment, akin to word processing in text generation, will be feasible by the end of this decade. The foremost development towards this goal is undoubtedly the computerised design facility of the U.S. Forest Service; the landscape architects involved in the resource management and design of forested areas in America are able to access shared data bases, dealing with eg. topography and plant species, on a network of Hewlett Packard Series 9800 desktop computers (and plotting facilities), replacing the need for manual drawing.

In proposing a fairly high technology solution to the problem of visual assessment, it is extremely difficult to foresee the likely advances in hardware and software capabilities any further than the next year or two. We may resort to several computing analogies to speculate on the significant developments which may affect visual assessment:

i) Availability

In a relatively short period of time, fairly powerful computing resources have become available to users of microcomputers. We might extrapolate a similar powerful capability to become available for specific design tasks, eg. visual assessment, from existing mini and mainframe computing facilities.

ii) Size

The reduction in the physical size of computers from large valve mainframe machines in the 1950s to the small, even briefcase size, computers of the present day is due to microchip technology. Ultra Large Scale Integrated (ULSI) chips are likely to bring even more dramatic size reductions, and we might imagine a total visual assessment system operating on a drawing board/desktop computer sometime by the end of this century.

iii) Data bases

In recent years information services such as CEEFAX, PRESTEL, CONTEL and VIEWDATA, and electronic mailing have pioneered the way in the sharing of common data bases and the flow of information. We might see a parallel here with the way in which drawn information may be passed electronically from a design office to a site; this may be initiated from an office computing resource, storing data and information also available for modelling the visual impact of proposals. In the case of forest management the effects of planting and felling strategies may be assessed 'in house' by a designer and any chosen policy sent electronically to a local forestry centre with the necessary locational and procedural details for action.

iv) Cost

Within the last ten years computing costs have fallen by more than a factor of 1000 for comparable machine power. Thus, while many would see the price of hardware for visual assessment prohibitively expensive at present, within the next five years, we may see a growing uptake in computer systems for visual assessment as hardware costs continue to fall.

In general we may conclude that the rate of change in computing technology is likely to increase towards the end of the century, providing a high level of automation in design offices. Preparatory research and development of application software, such as visual assessment, requires to be undertaken now.

7.4 Personal criticism

As with most ongoing research subjects it has proved difficult to determine the best place to cease certain lines of investigation and document the findings. In this case, whatever decisions were made, the broad objectives of the thesis, as outlined in the introduction, have been achieved:

a) it summarises the current problem of visual intrusion and predicts the future sources of conflict between the landscape and man-made developments.

b) it reviews current procedures in visual assessment and proposes a computer-based approach to future methods.

c) it establishes the practice needs and background arguments for a new approach to visual assessment.

d) it proposes a computer program suite, VIDERE, to measure some of the formal and locational characteristics of development as seen by an observer, and outlines a tentative specification for an integrated system in computer-aided visual impact analysis.

With the possibility of EEC legislation on the environment, the thesis is seen as a timely overview of the current state of visual impact analysis. In addition the thesis has sought to draw together the diverse subjects and topics related to visual impact analysis.

In so doing the author considers the thesis to act as a framework within which other research work and development can be placed with the aim of promoting a total capability in visual assessment.

APPENDIX 1

1. Hunterston and Surrounding Area

The Hunterston peninsula, situated on the west coast of Scotland and protruding into the Firth of Clyde, is approximately 26 miles south west of Glasgow. The west coast of Southern Scotland has very few areas of lowland between the sea and the moorland hills of Ayrshire and therefore Hunterston is both exceptional and noticeable. (G255)(G256)

In topographic terms, the peninsula consists of an area of land, 458' in height known as Goldenberry Hill, separated from the steeply rising western bank of the Ayrshire moorland hills by a stretch of flat land, some two kilometres wide at the southern end, narrowing to one kilometre towards the north. Goldenberry Hill and a smaller feature, Campbelton Hill, to the north east are formed from Old Red Sandstone and, in places, intruded by volcanic rocks. At lower levels, the steeply dipping Red Sandstone deposits are overlain by sand and gravel deposits and in some areas clay and peat occur. The peninsula coastline contrasts sharply.In the north, Hunterston and Southannan Sands are host to considerable industrial activity, while in the rockier west and south west coastline of the peninsula, raised beach deposits occur,forming a narrow shelf between the sea and the high ground of Goldenberry Hill. In most places along the coast, however, there is sufficient room between sea and hills for communication routes and small settlements such as Largs and Wemyss Bay. The location of road and rail systems in the Hunterston area, connecting West Kilbride north to Fairlie and Largs have been affected by the physical features of the terrain. The main North Ayrshire coast road, A78, and the Glasgow-Largs railway line both run along the eastern extent of the peninsula, below the coastal hills. Two miles north west of Hunterston, the island of Great Cumbrae is a traditional holiday centre for Glasgow, with development focused on the southern bay of the island at Millport. Farmland covers the greater part of the island, and the main coastal road (A860) once offered fine views across the Clyde Estuary to Bute and towards the mainland, Ayrshire. Although the island is itself unsuitable for major industrial development, it suffers visually from the recent industrial activity at Hunterston on the mainland coast.

Interestingly, this fact has reduced the value of certain properties situated on the west side of Millport Bay overlooking the industrial foreshore at Hunterston. Thus while, most of the island is regarded as an area of great landscape value and a large part of Millport has been designated as a Conservation Area, the prospect from the east coast towards the mainland is one of large scale human intervention. In contrast with Great Cumbrae, the island of Little Cumbrae, with the exception of the lighthouse is undeveloped,and is not accessible to the public. The deep water off its east coast is, however, likely to be exploited with the expected increase in shipping traffic related to the Iron Ore Terminal.

2. The Scale of Industrial Activity at Hunterston

At Hunterston, once described as the finest virgin industrial site in North West Europe, the coastline bulges out into the Firth, providing attractive natural features to industrial developers, limited elsewhere along the coastline. The British Steel Corporation, North Sea oil developers and the South of Scotland Electricity Board have taken advantage of these features, and as an area previously noted for its landscape beauty, Hunterston is very much the victim of its own topographical characteristics, unique in the Clyde Estuary. The main factors which have allowed industrial developemnt are:

a) extensive areas of lowland between the Firth of Clyde and Ayrshire hills;

b) extensive stretches of sands at Hunterston and Southannan on the north of the peninsula;

c) economic deepwater berthing facilities for large tankers up to about 350,000 tons. (Also in a sheltered anchorage.)

This combination of characteristics brought an unprecedented industrial influx during the 1960s and 70s, completely altering the ethos of the Hunterston area. The developments have been on a gargantuan scale, creating their own industrial environment and imposing their presence over quite a substantial stretch of the coastline. (G257)

Initially, the South of Scotland Electricity Board purchased 140 acres of land to the north of the peninsula with the intention of building a nuclear power station. After the station had been built the Hunterston area came under increasing pressure from industrial developers who wished to construct major oil related developments and establish a massive ore handling and steel production complex. Fortunately, these grand schemes have not and likely will never be realised, though what has taken place, has without doubt dramatically and permanently disfigured the landscape and seascape of Hunterston. Visually, the 'A' power station has saturated the peninsula; nestling neatly below the towering Goldenberry Hill, all the visual objectives have been achieved, culminating in a satisfactory human addition to the landscape scenery. In contrast, the 'B' station obtrudes upon the skyline and appears adrift from the strong and solid background of coastal high ground which the 'A' station enjoys. Despite this the 'B' station is aided in merging with the coastal scenery by an excellent colour choice, which makes specific detailed features and edges difficult to determine, even in reasonable weather conditions.

On quite a different scale altogether, the British Steel Corporation's Iron Ore Terminal and Stockyard on the old Southannan Sands, south of Fairlie, cannot fail to attract attention from anywhere in the vicinity. Clearly marked by the two massive cranes at the end of the jetty, reputed to be one of the longest in the world the whole scheme, including the ore direct reduction plant to the south of the site, links a deep water access for tankers to a rail terminus for ore distribution in west central Scotland. The ore stockyard area has been screened from the motoring public by a £4.5m award-winning environmental hill, affording aural as well as visual protection along the A78, for more than a mile south of Fairlie.

The third industrial presence at Hunterston is one of the many North Sea Oil developments around the Scottish coast. Situated on the Hunterston Sands immediately north of the peninsula, the Ayrshire Marine Constructors Ltd. opened an offshore steel structures yard several years ago in anticipation of the boom in oil rig construction. The gently sloping sands towards a deep water channel between the mainland and Great Cumbrae made this an ideal site for rig construction, though, as a preliminary impact study by the

Jack Holmes Planning Group indentified the rig will certainly be a very visible feature in the Clyde Estuary.(G258) A great deal of land reclaimation was undertaken to provide the construction yard, and consequently there is a detailed monitoring program in operation noting the resulting ecological and environmental impacts. The developments at Hunterston throw up a number of different aspects of visual impact; from large areas of reclaimation and landscaping at the ore terminal and oil rig yard to the artefacts themselves such as the rig, the power stations, the jetty cranes and ore reduction plant. To this variety can be added the temporal nature of the visual impact of the oil rig itself.

The industrial activity at Hunterston may not yet have reached its limit. There is still the possibility of a third nuclear power station, and expansion plans for the BSC operations at Hunterston. (G259) Perhaps the most pertinent question currently posed concerns the possibility and success of landscape reinstatement when the sites have finally outlived their use.

3. Hunterston 'A' Nuclear Power Station (G260)

"A monstrous bulbous bunion" was the description given in 1956 by the Earl of Glasgow (Kelburn House, Largs) to the South of Scotland Electricity Board's proposal for a nuclear power station at Hunterston. Initially, following the decision to build the station in December 1955,what little local opposition there was, was lead by the Earl of Glasgow. However local gossip about large cooling towers on Goldenberry Hill, railway sidings, coal dumps and stacks eventually drummed up enough feeling to force a public inquiry, which was held at the end of January 1957 in the Barfields Pavilion, Largs. The main aim of the inquiry was to grant or refuse a compulsory purchase order for the site at Hunterston, 36 objectors contested their case on two distinct points. Firstly, the unsightliness of the station as an eyesore in coastal vistas from Clydeside resorts in the vicinity, and secondly on the taking away of good arable land on the Hunterston peninsula. Another, but less important concern was that of radiation. Thus, it is interesting to note that, even over twenty years ago the likely visual impact should play such a significant role in a public inquiry for a large scale coastal development. Obviously the attractive coastline and hills south of Fairlie towards Hunterston gave tremendous weight to the case for great care and thought in the design of the visual appearance of the 'A' station.

At the inquiry, extensive use was made of a model of the Hunterston area to "quell fears of unsightliness" (Largs and Millport Weekly News: January 1957) particularly expressed by the residents of Millport. In addition much evidence was submitted by the architect Howard Lobb, a summary of which follows, as quotes from the Largs and Millport Weekly News during the month of January 1957.

"It would be a building that could tie-in to its natural surroundings in such a way as not at all to spoil the attractions of the site from the scenic point of view."

"A piece of evidence which had a ready impact at the inquiry was the information given as to the height of the proposed power station: at 202 ft, it was eight times the height of Barrfields Pavilion, and gave an on the spot idea of the immensity of the structure".

"On the question of fitting into the background of Goldenberry Hill, Mr Lobb stated that the station would be clad with transparent and translucent glass rising for 150' above a plinth of silver grey brick. The roofs of the buildings will be green and the whole group will merge with the Firth of Clyde landscape. A project of this kind and on this scale required for its proper siting a really dominating landscape and seascape; and to ensure that such a large group of buildings would be separated from any town by a considerable area of land in order to avoid a dwarfing effect of one upon the other. The siting of the 'A' station achieves this by reason of the surrounding natural features."

"Views from Largs and Millport: looking from Millport, and to a lesser extent from Largs, the long line of the 70ft high turbine hall would follow the general configuration and pattern of the ground. The glass material used to clad the exteriors would have the effect of reducing the bulk of the reactors in particular, and the play of the light and shade reflections from the glass would reflect the changing patterns of the water and clouds. That would give a lightness and quality to the buildings which had to be seen to be believed. It had been used in similar large buildings in America. The roofs would be flat and finished in a mineralised film of green colour (sic), so that looking down from Goldenberry Hill nearby, the roofs would merge in tone and colour with the landscape. Goldenberry Hill would still command the situation. Nature would still be in command."

In the event, the South of Scotland Electricity Board and Howard Lobb demonstrated their proposals, apparently to everyone's satisfaction, and the inquiry found in favour of the compulsory purchase of the land at Hunterston by the Board. Surprisingly there was no similar public inquiry when the 'B' station at Hunterston was proposed. The reason appears to stem from the fact that since the 'A' station was already there, then there was very little to lose by building another power station. In fact, this was probably a mistake. A public inquiry had forced good design in the 'A' station, and an inquiry for the 'B' station may well have helped to establish more specific visual design objectives and goals. Thus the siting of the 'B' station was determined by virtue of a) the avoidance of underground cables from 'A' station; b) its proximity to 'A' station facilities; c) its setting below Campbelton Hill.

4. Hunterston 'B' Nuclear Power Station (G261)

Late June 1967 saw three construction groups submit tenders for a second nuclear power station on the Hunterston Peninsula. Of the three groups involved, the Atomic Power Constructions Ltd., the Nuclear Design and Construction Ltd. and the Nuclear Power Group Ltd., the latter eventually secured the contract worth £87.5m for the design, construction and commissioning of the new power station. Expected to be operational by 1973, an outstanding feature of the 1240 megawatt station was to be its compactness, a result of continuing research and development implemented in the design of nuclear power stations during the 1960s and 70s.

The decision to build a second power station at Hunterston was influenced by a number of factors prevalent during the mid to late 60s, not least of which was a growing awareness of the preponderance of power stations in the east of Scotland. Other contributing factors included the necessary coastal siting of power stations for large supplies of cold water for cooling and the use of existing transmission lines and laboratory services already constructed at

Hunterston for the 'A' station.
At the time, no objections were raised to the siting of the proposed 'B' station, and the Statutory Amenity Committee and the Royal Fine Arts Commission for Scotland both expressed satisfaction with the scheme. Hunterston 'B', an advanced gas cooled reactor, is the first of its kind to be built in Scotland: although Torness will also be of the same type, the future in nuclear power station design appears at present to be leaning towards the cheaper and less reliable pressurised water reactor type.
Hunterston 'B' was expected to be operational by early 1973, however, a series of delays in construction and commissioning resulted in the first of its reactors feeding electricity to the Scottish grid in February 1976, with the second reactor supplementing the supply in March 1977. Over the past two decades, Hunterston has been a focus of attention for power station development, and there has been much speculation about further stations being built in the vicinity.
For example, in September 1975, after scrapping proposals for a nuclear power station at Chapeldonan on the Ayrshire coast near Chapeldonan on the Ayrshire coast near Girvan, a sketch plan was unveiled for a third nuclear power station at Hunterston. The new plant, comprising 4 steam generating heavy water reactors each with an output of 660 megawatts, was to be operational by the mid 1980s at an estimated cost in excess of £7000m. One problem which this proposal encountered was the proximity of the British Steel Corporation's developments at Hunterston; and like intentions for a fourth power station on reclaimed land near the 'A' station, all future extentions by the S.S.E.B. at Hunterston appear to have been shelved.
The ongoing visual appraisal and design of Hunterston 'B' was divided under the two headings of landscape design and architectural design. Technological advancements of plant design in nuclear power stations have been quite deliberately expressed in their exterior form over the last twenty years, and thus it is possible to identify the type and age of a reactor from the formal consequences which it imposes on the architectural design. Hunterston desplays two quite different types of stations, in terms of both reactor and architectural design. The 'S' station comprises three widely spaced, quite distinct blocks, characteristic of the early Magnox type reactor station in the early

sixties; two tall glass reactor buildings and a low turbine house in front.

Reactor design and development has resulted in a remarkable resuction in the volume of the stations, and the 'B' station at Hunterston is typical of many recently built advanced gas-cooled reactors, increasing output capacity by four times to 1250 magawatts yet occupying less site area than the older magnox type. The 'B' station, a compact integrated unit contains two reactors and two turbo-alternator sets, clearly expressing their function on the external appearance of the building. Thus the form of the building is as simple as possible, following functional requirements. (G262)(G263)

The main building falls naturally into two major elements: the reactor block or charge hall and the turbine house with its associated de-aerator tower; these two elements are separated by a linking block containing equipment and control rooms. Function dictates height and span in each of the blocks, and the building envelope, trimmed down to its functional minimum, quite clearly expresses each stage of the generation process. Engineering requirements and the speed of erection have also contributed to the design decisions concerning the structure of the station which is, in the main, steel framed.

5. <u>Visual Impact on the Clyde Estuary</u>

Previously regarded as a zone with rural characteristics by the now defunct Ayr County Council, there are a considerable number of urban communities within five miles of the developments at Hunterston. The main settlements are:

Largs	:	pop 8500	:	5 miles from Hunterston B
Fairlie	:	pop 1500	:	2.5 miles from Hunterston B
Millport	:	pop 1500	:	2.5 miles from Hunterston B
West Kilbride:		pop 4500	:	2.5 miles from Hunterston B (G264)(G265)

Immediately it is obvious that any visual impact analysis on these settlements must include correction factors for the earth's currature, since over 2 miles this is significant. This is a reasonably typical situation of distance to settlements and draws attention to the importance of accounting for the earth's curra ture in order to derive sensible and accurate results from analyses.

Two factors are important in identifying the likely visual impact of developments. Firstly, the areas where there is likely to be intrusion and, secondly, the type and duration of the activity taking place in those areas. The main settlements in the area have been identified. Other areas of visual intrusion will include: road and rail networks, places of general public access and leisure/recreation areas.
During the summer months, the roads near Hunterston are often congested with tourists travelling through some of the finest landscape on the Clyde coast. Travelling north from West Kilbride the top 10 metres of the 'B' station at Hunterston is visible even though the siting and design had hoped to use the small Campbelton Hill as a screen from views south. It may be, of course, that sometime in the future the growth of vegetation will further screen the station from the southern approaches, however, one cannot help feeling that a proper understanding of the likely visibility of the scheme could have led to a more successful achievement of worthy objectives. Further north, the view west towards the station is totally screened by heavy tree growth around Hunterston House and castle. For much of the access coastal road to the station complex these same trees screen the building and a full view can only be achieved in the final approach to the station. Travelling north to Fairlie, any view of the station is blocked by the landscape mounding or environmental hill constructed for the Ore Terminal.

The general view from Fairlie southwards is of the ore terminal, a massive industrial complex with structures cutting the skyline of the hills beyond, and dwarfing Fairlie itself. Only after leaving Fairlie and approaching Largs does the station come back into view, though by this time the impact is insignificant in comparison with the other industrial structures in the Hunterston area. Most of the developments at Hunterston, including the 'B' station are visible from the moor roads which climb up the coastal hills and into such towns as Dalry. These roads, in particular, are open to the full impact of the industrial activity of the "ore terminal," which tends to draw attention rather than the S.S.E.B. power station complex.

The vista from Largs, some 5 miles from Hunterston takes in the mass of the ore terminal and jetty, with the cranes and oil rig prominent features piercing the skyline. Through all this industrial clutter it is difficult to see the 'B' station and even in reasonable weather conditions it is difficult to perceive the outline or edges of the station against the landscape background. Further north on the Clyde coast the station is not visible, and the chimney at Inverkip power station becomes the dominant man made feature.

Both ferry routes from Largs to Great Cumbrae afford views of developments at Hunterston. In particular, the route to Millport pier passes within a mile of all the foreshore developments; the more northerly route to the Cumbrae Slip provides only long distance views. The east coast road on the island and the town of Millport in the south are the main areas for visual impact assessment on Great Cumbrae. The south eastern corner of the island is particularly open to views across Fairlie Roads to the developments though any views of the ore terminal or rig are restricted from some parts of Millport, where Ninian Brae limits the views east towards the mainland. Especially to residents on the western side of Millport Bay, the main view is of the power station development, somewhat more acceptable than the industrial complex of the ore terminal and rig construction yard.

The main recreational activity in the Hunterston area is sailing and Largs, Fairlie, Millport and the National Water Sports Training Centre on Cumbrae provide the main sailing centres.

The view from Fairlie Roads towards Hunterston is again largely dominated by industry, however, the other works of man are largely dominated by the background of rolling hills along the Ayrshire coast. In the outer stretches of the Clyde Estuary west of the Cumbraes, views towards Hunterston are limited by the islands themselves. Thus, the visual impact of the developments at Hunterston is contained within a small range off the Ayrshire coast, though, certainly it is quite intensively habited. The configuration of the land, the pattern of urban settlements and the ferry routes in the area all focus attention on the coastal landscape feature of Goldenberry Hill and its associated industrial activity.

APPENDIX 2

The climatological data were derived from (PLAN71), and other local data gathered at Hunterston. The following sections outline the detailed relationship of climate to visual assessment.

1. Rainfall and Thunderstorms.

With comparatively less rainfall per annum than other areas in the West of Scotland, the Ayrshire coast is noted for its mild weather, especially in winter. Precipitation, when it occurs, is usually accompanied by a reduction in light, as passing clouds obscure the sun. Thus, the rain itself and reduced lighting conditions can effect visibility, and in the particular case of Hunterston it was found from observation that these two factors, in conjunction with the grey colour of the B power station, contributed to the station being visually lost in rainfall and merged into the background hill in reduced light. In the Hunterston area, which suffers more from constant drizzle than heavy falls of rain very few thunderstorms are experienced per annum in comparison with other regions in Britain. Consequently, while a constant drizzle will quite markedly reduce general visibility, during May to August when a thunderstorm is more likely to occur, it will coincide with intense falls of driving rain, reducing visibility to a very poor level.

Table 1

Average No. of days per month with Thunderstorms during the 20 year period 1950 - 1969

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
0.3	0.1	0.3	0.3	1.0	0.9	1.1	1.3	0.7	0.7	0.5	0.5

Ave.year total 7.7 days

Table 2

Average no. of days per month with rain falling at a rate of 0.5mm or more per hour between 07.00 and 17.00 (Greenwich Mean Time) during the 10 year period 1960 - 1969

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
10.4	8.5	10.2	10.4	10.9	9.1	8.4	10.4	12.1	12.2	11.5	12.5

Ave. year total 126.6 days

Table 3

Monthly average rainfall (mm) at Hunterston 1941 - 70

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
112	76	73	74	72	74	95	105	125	126	108	118

Aver. year total 1158mm. (G266)

Reading these three tables in conjunction, we can see that on average, one in three days per annum will experience quite a constant drizzle, reducing visibility of the B station at Hunterston. It should be noted, however, that the one in three figure will vary throughout the year from winter to summer and should be altered to allow accuracy if any one part of the year is under investigation.

2. Snow

The Ayrshire coast is a relatively snow-free region, and at Hunterston, the high ground rising immediately from the coast to the east acts as protection from the main snow bearing north to north easterly winds. Snow is a particularly interesting aspect of climate in that it can change, quite dramatically, the colour of the landscape scene by virtue of its white ground coverage. Although visibility during snowfall will be reduced similar to conditions experienced with rainfall, the more important factor of the number of snow lying days emerges as crucial in determining the visual intrusion of a construction. Unfortunately, however, in common with the remainder of the British Isles, the incidence of snow fall and the persistence of snow cover in the region are two of the most variable of all the meteorological elements. Despite this, from observation, it is still possible to predict the likely instance of snow or sleet in the area.

Table 4

Aver. no. of days per month with snow or sleet falling over 28 year period 1942 - 1969

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
6.3	6.7	3.8	1.1	0.3	0.0	0.0	0.0	0.0	0.1	2.0	3.7

Aver. no. of days per annum 24.0 (G267)

Table 5

Aver. no. of mornings per month with snow lying on the ground at 0900 (GMT) covering ½ or more of the ground during the 20 year period 1950-1969

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1.5	1.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.7

Aver. no. of days per year 4.5

It is possible to deduce from these figures that during the months of Nov. to Apr when snow is most likely to occur, on average, one day per week will experience some fall of snow, although it is highly unlikely to lie for any length of time, even in the most likely months of January and February. Thus, it would be true to say that Hunterston does not suffer from the highlighting of buildings in a snow covered landscape, since snow very rarely lies, however there is a suficiently notable reduction in visibility when snowfall does occur on about 24 days per annum.

3. Sunshine

By Scottish standards, the Ayrshire coast is comparatively sunny, however, in the case of Hunterston, the desire to reduce the visual impact on the estuary by nestling the A and B power stations in against Goldenberry and Campbelton Hills respectively, has resulted in both stations being, for a significant part of the year, in the shade of their respective hills. This shading is particularly noticeable with the A station, in the shade of the larger of the two hills, Goldenberry. (G268) depicts the solar chart applicable to Hunterston for latitude 56^{o} North, showing the path of the sun across the sky in terms of altitude and azimuth at various time of the day, for the solstices, equinoxes and other intermediate dates.

From this, it is possible to determine the shadow on the 'B' station at any time during the day, taking into account the surrounding features of the topography and plotting them as obstructions on the solar chart in order to evaluate the effect in cutting off the suns direct light and subsequent appearance of the building. Direct sunlight can change, quite noticeably, the external colour and appearance of a building, and in the case of a visual impact study it would be necessary for a full and complete examination to appreciate the different lighting conditions and subsequent colour changes which the building experiences. (G269) outlines the average daily duration of bright sunshine in hours per month, suggesting the times of year when we could expect changes in the appearance of the B station at Hunterston. The graph of (G269) is consistent with the annual trend in temperature of (G270) with marked increases in April and May and a slow drop off through the autumn.

Table 6

Average daily duration of bright sunshine (hours) during the 30 year period 1941 - 1970

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1.5	2.5	3.2	5.1	6.2	6.3	5.1	4.7	3.6	2.6	1.6	1.1

(G 269)

4. Temperature

Temperature is an important aspect of climate to be considered in visual appraisal, since it is possible to identify the probable growing season for vegetation and thus the visual changes that can be expected in the landscape. (G270) outlines the mean daily temperatures per month in ^{O}C for the Hunterston area, although temperature itself is quite a variable factor, especially with regard to variations in topography.

Table 7

Mean Daily Temperatures per month in ^{O}C over the 30 year period 1941 - 1970

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
4.1	4.1	6.0	8.3	10.8	13.5	14.5	14.6	13.0	;0.2	7.0	5.6

(G270)

The most generally accepted threshold temperature for initiating growth is $42^{O}F$ ($5.6^{O}C$), and in the Hunterston region, mean daily temperatures normally attain this value around the middle of March and continue above this value until about the last week in November. Accumulated temperature in Degree Days above the $5.6^{O}C$ datum are often used as a measure of growth, and values based on 29 years of observation for the Ayrshire region are given in Table 8.

Table 8

Average Values of Accumulated Temperature in Degree Days above 5.6°C

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
62	51	107	137	267	417	511	499	387	229	95	65

The sharp increase in May and June contrasts quite notably with the slower decline in autumn; in terms of visual analysis, we can expect a quick growth of vegetation in May and June, bringing about a related colour change and increase in foliage density. In autumn there is a very slow, but gradual colour change in the vegetation and some vegetal opacity remains into November. Consequently, if time permits a thorough preliminary study of climatological variations, it is possible to derive an insight into the seasonal variations of the landscape scenery in terms of vegetal colour and density, aiding design colour matching or contrasting and visibility studies.

5. Relative Humidity

High values of relative humidity affect the perception of colour when viewing artefacts in the landscape. The tendency of air moisture to distort the perceived colour towards the shorter wavelengths of the spectrum, demands a check on the monthly average values of relative humidity in the Hunterston area. Although values vary from 30% to 100%, a substantial number fall between 70% and 95%.

Table 9

Average monthly values of relative humidity

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
85	84	83	82	80	82	84	85	85	86	87	87	(G271)

Particularly in visual impact studies, in which views are likely to be taken over several miles, there is a need to be aware of the effects of relative humidity, tending to distort the perceived colour of artefacts and landscape towards blue.

6. Wind

The high frequency of gales and strong winds is one of the main features of the climate of the coastal areas of West Scotland. In this particular case, however, the topography of the area under consideration at Hunterston is such that the B station is somewhat sheltered by the two hills to the south of the site, Goldenberry and Campbelton.

Thus, the frequency of gales is comparatively low with respect to some of the more open or exposed surrounding areas. The sheltered nature of the site also contributes to the relatively slow lose of vegetal opacity in the autumn and the tendency for sea fog to persist longer than in other more exposed sections of the coastline. The wind rose on (G 272) outlines the expected annual % frequency of wind speed and direction for Hunterston averaged over the 9 year period 1970 - 78.

7 Sea Fog

In visual impact studies on coastal sites, visibility is often affected by sea fog. At Hunterston, sea fog can form in the Firth of Clyde when warm moist air, carried by light southerly winds, spreads over the area in summer; this fog can be carried inland when the wind veers to south west or west and sea breezes or on shore winds set in towards midday. Wind speed and direction are associated with visibility and sea fog, and the wind rose in (G272) should be studied in conjunction with instance of sea fog in order to appreciate whether fog is likely to be blown on shore or linger along the coastal strip.

Table 10

Average no. of days with "Fog" - Visibility less than 1000 metres.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1.2	1.1	0.7	0.5	0.7	0.8	0.3	0.6	0.9	1.0	0.9	1.1

year total 9.8 days.

Table 11

Average no.of days with "Thick Fog" - Visibility less than 200 metres.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
0.6	0.4	0.0	0.1	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.2

year total 2.2 days.

Table 12

Average no. of days with "Dense Fog" - Visibility less than 50 metres

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1

year total 0.3 days.

These tables and (G 273) show the visibility of the B station to be quite strongly influenced by the instance of sea fog. Although the readings are only up to 1000 metres, personal observation in the area found the station to be very difficult to perceive, even in reasonable weather conditions at any distance upwards of two and a half miles.

APPENDIX 3

Introduction

The program SURFAC calculates a measure of terrain roughness for any given topographic data set. The Fortran software and comments for the program are included in the appendix in the following pages. (G274) describes the structure of the program which contains two 'CALL' commands to subroutines. These subroutines, SQUAR and RECT, calculate the surface area of each grid cell of the data set; the naming conventions and algorithm flow charts for SQUAR and RECT are contained in (G275) (G276), and (G277) (G278) respectively.

```
C       Program  SURFAC
C       Program created 1st December 1982.
C       Program SURFAC calculates the surface area of whole
C       or part of a digital terrain model, and outputs the
C       ratio of planar/surface area.
C
C       The program may be used to measure the degree of
C       warpedness of a terrain model, and classify the data
C       set landform into anyone of the following categories:
C
C       |            |            |            |
C       |  lowland   |  regional  |  coastal   |
C       |  highland  |  local     |  inland    |
C       |            |  site      |            |
C       |            |            |            |
C .
C       Certain values of the surface area to planar area ratio
C       may be determined for each category.  Given a specific
C       landform area, the optimum grid size suitable for
C       modelling that terrain type to a required degree of
C       accuracy may then be interpolated.
C
C       The program may handle regular square or rectangular
C       grid cells.  Triangular gridded digital terrain
C       models are excluded.
C
C       Whole or part of any data set may be analysed.
C       The subdivision of the original data set must be
C       rectangular in shape; and is specified by the IMIN,
C       IMAX,JMIN,JMAX values.
C
C       The unit of measurement is feet; both for grid size
C       values IGSIZE and JGSIZE, and for the elevation values
C       in the matrix ELEV.
C
C       In calculating the surface area of each grid cell in turn,
C       the program makes a fundamental generalisation:
C
C          The centre point of each grid cell, I5, is calculated
C          as  I5 = (I1+I2+I3+I4)/4. Where I1,I2,I3,I4 are the
C          four corner points of each grid cell.  The surface
C          area of each grid cell is then calculated as the sum of
C          the area of the four triangles whose common apex
C          is the point I5 and whose bases are the four sides of
C          the grid cell.
C
C          It may have been possible to divide the cell into
C          two triangles by either of the two main diagonals,
C          I1-I3 or I2-I4.  In most cases the value of I5 for
C          each of those two diagonals would have been different:
C
```

```
C          EG        150                 140
C                     -----------------
C                    | I1           I2 |
C                    |                 |
C                    |                 |
C                    |                 |
C                    |                 |
C                    |       I5        |
C                    |                 |
C                    |                 |
C                    |                 |
C                    | I4           I3 |
C                     -----------------
C                    150                 160
C
C          for diagonal I1-I3, I5 = 155
C          for diagonal I2-I4, I5 = 145
C
C          A priority diagonal could have been set to overcome
C          this problem.  The first method described was adopted.
C
C
C       Structure of input data file.
C
C Card 1 TITLE
C        The title of the elevation data set.
C        Format (14A5)
C
C Card 2 NCOL,NROW,NCOLM,NROWM,IGSIZE,JGSIZE,ICELL
C        NCOL is the number of columns in the elevation
C             matrix.  Maximum value of NCOL is 100.
C        NROW is the number of columns in the elevation
C             matrix.  Maximum value of NROW is 100.
C        NCOLM is the number of columns in the formatted
C              input elevation data file.
C              NCOL is a multiple of NCOLM.
C        NROWM is the number of columns in the formatted
C              input elevation data file.
C              NROWM is a multiple of NROW.
C              NROW X NCOL = NROWM X NCOLM
C        IGSIZE is the vertical or I direction size of
C               a grid cell, in feet.
C        JGSIZE is the horizontal or J direction size of
C               a grid cell, in feet.
C        ICELL  is the grid cell shape parameter.
C               ICELL = 1 for square grid cell.
C               ICELL = 2 for rectangular grid cell.
C        Free Format (delimiters are comma, space bar or
C                     carriage return).
C
C Card 3 ELEV
C        ELEV is the elevation data matrix. (NR COLM X NROWM)
C        Values are in feet.
C        Free Format.
```

```
C
C
C
      COMMON/GRID/IGSIZE,JGSIZE
      DIMENSION TITLE(14),ELEV(100,100)
      DATA IUOUT,IUIN,IFIL/5,5,10/
C
C
C       Open file.
C
C
50    CONTINUE
      WRITE (IUOUT,5000)
5000  FORMAT (' INPUT FILENAME ',/,' >',$)
C
C
C       Reference subroutine RPFILE in UTIL library
C       to check input file status.  The file is
C       expected to exist, an error message is sent
C       if it does not.  If the file is successfully
C       opened, then it is read and opened on FORTRAN
C       logical unit number 10 (IFIL).
C
C
      CALL RPFILE(IFIL,ISTAT)
C
C
C       Read file.
C
C
      READ (IFIL,5100) (TITLE(J),J=1,14)
5100  FORMAT (14A5)
      READ (IFIL,*) (NCOL,NROW,NCOLM,NROWM,IGSIZE,JGSIZE,ICELL)
      NLINES = NCOL/NCOLM
      DO 100 I=1,NROW
      DO 105 J=1,NLINES
      IST = (J-1)*NCOLM+1
      IEN = IST + (NCOLM-1)
      READ (IFIL,*) (ELEV(I,K),K=IST,IEN)
105   CONTINUE
100   CONTINUE
C
C
C       Set values for IMIN,IMAX,JMIN,JMAX.
C
C
120   CONTINUE
      WRITE (IUOUT,5150)
5150  FORMAT (' INPUT VALUES FOR IMIN,IMAX,JMIN,JMAX.  FREE FORMAT '
     &,/,' >',$)
      READ (IUIN,*) (IMIN,IMAX,JMIN,JMAX)
C
C
C       Set initial value for surface area (SAREA)
C       to zero, and calculate the planar area (PAREA).
C
C
```

```
      SAREA = 0.0
      PAREA = (((JMAX-JMIN)*JGSIZE)*((IMAX-IMIN)*IGSIZE)*1.0)
C
C
C      Iterate through the area under study for
C      each grid cell:
C        a) picking out the values of the four
C           corners of each grid square processed
C           from IMIN to IMAX-1, and from JMIN
C           to JMAX-1.
C        b) calling subroutine SQUAR or RECT,
C           depending on status of ICELL, to
C           calculate the surface area of each
C           grid cell.
C        c) adding the returned value, AREA, from
C           SQUAR or RECT to the current value
C           of SAREA.
C
C
      DO 200 I = IMIN,IMAX-1
      DO 300 J = JMIN,JMAX-1
      I1 = ELEV(I,J)
      I2 = ELEV(I,J+1)
      I3 = ELEV(I+1,J+1)
      I4 = ELEV(I+1,J)
      IF (ICELL . EQ . 1) CALL SQUAR(I1,I2,I3,I4,AREA)
      IF (ICELL . EQ . 2) CALL RECT(I1,I2,I3,I4,AREA)
      SAREA = SAREA + AREA
300   CONTINUE
200   CONTINUE
C
C
C      Calculation of planar area/surface area ratio.
C
C      RATIO = PAREA/SAREA
C      RATIO always greater than zero.
C      RATIO always less than or equal to one.
C      If RATIO = 1, then area under study is flat.
C
C
      RATIO = PAREA/SAREA
C
C
C      Structure of program output
C
C      Value of : SAREA       Format    F15.2
C               : PAREA       Format    F15.2
C               : RATIO       Format    F15.10
C               : IMIN        Format    I5
C               : IMAX        Format    I5
C               : JMIN        Format    I5
C               : JMAX        Format    I5
C               : IGSIZE      Format    I5
C               : JGSIZE      Format    I5
C
C
```

```
      WRITE(IUOUT,5200) SAREA
      WRITE(IUOUT,5300) PAREA
      WRITE(IUOUT,5400) RATIO
      WRITE(IUOUT,5800) IMIN,IMAX,JMIN,JMAX,IGSIZE,JGSIZE
5200  FORMAT(' SURFACE AREA IN SQUARE FEET = ' ,F15.2)
5300  FORMAT('  PLANAR AREA IN SQUARE FEET = ' ,F15.2)
5400  FORMAT('  RATIO OF PLANAR/SURFACE AREA = ' ,F15.10)
5800  FORMAT('    IMIN = ',I5,/,'    IMAX = ',I5,/,'    JMIN = ',I5
     &,/,'    JMAX = ',I5,/,' IGSIZE = ',I5,/,' JGSIZE = ',I5)
C
C
C        Do you wish to continue statements for
C             a) new IMIN,IMAX,JMIN,JMAX.
C             b) new data set.
C
C
      WRITE(IUOUT,5900)
5900  FORMAT(' DO YOU WISH TO INVESTIGATE ANOTHER AREA ? ',
     &/,' TYPE 1 FOR YES OR 2 FOR NO ',/,' > ',$)
      READ(IUIN,*) ICON
      GO TO (120,1000) ICON
1000  CONTINUE
      WRITE (IUOUT,6000)
6000  FORMAT (' DO YOU WISH TO INVESTIGATE ANOTHER DATA SET ? '
     &,/,' TYPE 1 FOR YES OR 2 FOR NO ',/,' > ',$)
      READ (IUIN,*) IDAT
      GO TO (50,2000) IDAT
2000  STOP
      END
C
C
C        Subroutine RECT.
C
C
      SUBROUTINE RECT(I1,I2,I3,I4,AREA)
      I5 = (I1+I2+I3+I4)/4
      RMID12 = (I1+I2)/2.0
      RMID23 = (I2+I3)/2.0
      RMID34 = (I3+I4)/2.0
      RMID41 = (I4+I1)/2.0
      S12 = SQRT(((IABS(I1-I2))**2)+(JGSIZE**2)*1.0)
      S23 = SQRT(((IABS(I2-I3))**2)+(IGSIZE**2)*1.0)
      S34 = SQRT(((IABS(I3-I4))**2)+(JGSIZE**2)*1.0)
      S41 = SQRT(((IABS(I4-I1))**2)+(IGSIZE**2)*1.0)
      MP12 = SQRT(((ABS(I5-RMID12))**2)+((IGSIZE/2)**2))
      MP23 = SQRT(((ABS(I5-RMID23))**2)+((JGSIZE/2)**2))
      MP34 = SQRT(((ABS(I5-RMID34))**2)+((IGSIZE/2)**2))
      MP41 = SQRT(((ABS(I5-RMID41))**2)+((JGSIZE/2)**2))
      A1 = MP12*(S12/2)
      A2 = MP23*(S23/2)
      A3 = MP34*(S34/2)
      A4 = MP41*(S41/2)
      AREA = A1+A2+A3+A4
      RETURN
      END
```

```
C
C
C       Subroutine SQUAR.
C
C
      SUBROUTINE SQUAR(I1,I2,I3,I4,AREA)
      COMMON/GRID/IGSIZE,JGSIZE
      I5=(I1+I2+I3+I4)/4
      PLEN=((SQRT((IGSIZE**2.0)*2.0))/2.0)**2.0
      D1 = SQRT(PLEN+(IABS(I1-I5))**2.0)
      D2 = SQRT(PLEN+(IABS(I2-I5))**2.0)
      D3 = SQRT(PLEN+(IABS(I3-I5))**2.0)
      D4 = SQRT(PLEN+(IABS(I4-I5))**2.0)
      A1 = 0.5*D1*D2
      A2 = 0.5*D2*D3
      A3 = 0.5*D3*D4
      A4 = 0.5*D4*D1
      AREA = A1+A2+A3+A4
      RETURN
      END
```

APPENDIX 4

1. Introduction

This report describes the methods employed during a special visualisation study of a series of proposed transmission lines in the vicinity of the Torness Nuclear Power Station site.

This work was undertaken by William Gardner and Cameron Purdie at the request of Graeme Aylward of Design Innovations Research, who had been required by the South of Scotland Electricity Board to identify key viewpoints relating to the positioning of these lines. The task was divided into four main phases, as follows:

a) The construction of a Tower Library.
b) Modelling of particular Tower Lines.
c) Production of Montages.
d) Interpretation and Conclusions of results.

During the study, the computer perspective drawing program, BIBLE was used. Some of the video techniques employed in the visualisation work are relatively new and stem from discussions between W Gardner and C Purdie. However, the feasibility of the video mixing technique was initially proved using data and photographs of Hunterston 'B' Nuclear Power Station gathered by C Purdie and demonstrated at the Centre for Educational Practice. Further valuable experience was gained using colour graphics and photography during a similar exercise mounted for Glasgow District Council regarding the siting and visualisation of a new factory complex at Cambuslang.

2. Tower Library

An initial analysis of the four transmission tower types employed in this study, D, D30^{0}, D60^{0}, DJT, revealed considerable scope for establishing a hierarchy of pylon building components, from which it would then be possible to pick various elements and construct each individual pylon type. Having completed the library of towers, it was hoped that this would give greater flexibility and speed in constructing the proposed routes, which could then be subsequently viewed from a variety of station points specified by interested parties.

The first stage of this task involved identifying and describing the most primitive elements of each pylon type. Five such pylon building components were identified, thus:

a) The primitive tetrahedron representing of the K-unit in the pylon base. Various sizes were required for the different pylon types. (G279)

b) The full K-unit of the pylon base. Various sizes were required for the different pylon types. (G280)

c) The middle section of the pylons, represented by a truncated pyramid. Various sizes were required for the different pylon types. (G281)

d) The upper section of the pylons, represented by a truncated pyramid. Various sizes were required for the different pylon types. (G282)

e) The pylon branch types, squared and tapered, and various sizes for the different pylon types. (G283)

Following this, three intermediate pylon construction files were created for each pylon type, describing the complete base (G284), middle and upper sections (G285). The next phase of the modelling sequence involved the final construction of each individual pylon type. These were rapidly generated from the variety of building components already in the library, and(G286) to (G296) show the eleven pylon types employed in the Torness study.
For convenience, the computer geometry file naming system for each pylon is reasonably compatible with that of the SSEB, outlined as follows:

File name conventions:	SSEB	Computer
Tower types:	D	D
	DJT	DJT
	$D30^{o}$	D3
	$D60^{o}$	D6
Variations:	M3	M3
	M6	M6
	E3	E3
	E6	E6
	E9	E9
	E12	E12

Each of the eleven pylon types in the library is based on a local 3 dimensional co-ordinate system, whose origin is 0,0,0 in metres, located at the centre of the base of each tower.

In most cases, computer perspectives of objects or scenes are normally only undertaken where a considerable number of views are likely to be taken, as quite often the effort required to build the computer model can outweigh the advantages of its final use. However, in this particular case, apart from the requirement to produce a series of views in the vicinity of Torness, the major effort involved in compiling the Tower Library can only become more cost effective since it is a 'once and for all' task and may be used in the construction of any other future lines demanding visual appraisal. Thus the completed Tower Library of types and components provided a basis upon which to generate the various alternative pylon routes, described in the next section, Tower Line Modelling.

3. Tower Line Modelling

Having completed the Tower Library, the route modelling phase could begin, identifying the type, position and orientation of the towers on each of the three routes. Each selected tower from the library was named uniquely, placed into the Ordnance Survey grid co-ordinate system and angled properly using the program IMBISS. This procedure was repeated in turn for all the towers in each of the three routes, according to the following data:

Tower Library Type	Unique Name	SHIFT metres X	Y	Z	BIBROT degrees
DJTSTD	TA1	3821	3189	74.5	90
D3M3	TA2	3558	3316	95	90
D3M3	TA3	3189	3242	99.8	97
DSTD	TA4	2979	3211	112	97
DE12	TA5	2553	3168	125.8	97
D3E9	TA6	2200	3137	124.8	97

TA represents the Torness to Dalkeith Line, containing six towers. (G297)gives a typical view of this line.

Tower Library Type	Unique Name	SHIFT metres X	Y	Z	BIBROT degrees
DJTSTD	TC1	3821	3126	76	90
D3D3	TC2	3621	3126	93.6	102
D6STD	TC3	3463	3000	114.6	135
D3E3	TC4	3368	2705	138.6	0
D6STD	TC5	3405	2495	131.6	32
D3E9	TC6	3642	2358	129.8	60
DSTD	TC7	4110	2095	130.5	60
DSTD	TC8	4321	1958	127.6	60
DSTD	TC9	4600	1800	127.2	60
D6STD	TC10	4905	1621	173.5	32

TC represents the Torness to Eccles circuitous route, containing ten towers. (G298) gives a typical view of this line.

Tower Library Type	Unique Name	SHIFT metres X	Y	Z	BIBROT degrees
DJTSTD	TD1	3979	3105	74	32
DE9	TD2	4116	2884	73.4	32
DM6	TD3	4305	2579	117	32
DM6	TD4	4453	2337	120	32
DM3	TD5	4611	1095	110.4	32
DM6	TD6	4779	1926	120.5	32
D3STD	TD7	4905	1621	173.5	32

TD represents the Torness to Eccles direct route, containing seven towers. (G299) gives a typical view of this line.

At this stage, BIBLE was used to check the alignment of the towers and a few test plots were undertaken to establish the scale of photographs which would be appropriate to this study; after some deliberation, A3 size was adopted.

4. Montage Production

Use was made of two differentmethods in the production of the photographic montages. The first, and relatively conventional method was to use acetate overlays of the pylons drawn using the BIBLE program on a Calcomp pen plotter, after previewing the perspective on an interactive Tektronix 4014 terminal. Secondly, the relatively new photographic/video technique, combining two vision sources, one from a camera directed at a photograph of an existing scene and the other from the computer graphics generated on the Textronix 4014 terminal.

Much of the success in matching the two sources relies upon the accurate recording of the various perspective drawing parameters required by the BIBLE program. Consequently, care must be taken to record these parameters during on site photography and in particular control points must be included in the photograph; the control points are a necessary feature of the video mixing technique, in order to establish the correct scaling and positioning of the computer generated perspective on the photograph. The other parameters that should be noted for the accurate reproduction of the BIBLE perspective include:

Eye Point or View Point
Focus Point (centre of the camera view)
Mid Point (centre of the camera view)
Camera lens size
Magnification factor between the negative
and the final print.

Part of the current research work in the field of visual analysis is concerned with establishing the degrees of refinement and adaptability of the various techniques to suit different settings and objects modelled. Only through rigorous live studies can the real problems of implementation of these techniques be revealed and subsequently solved. In this particular case, one such problem, which had been identified some months ago in the use of BIBLE, was encountered and overcome to a previously unexpected high degree of accuracy.

Due to the rural nature of the landscape, intervening landform, buildings and trees tend to mask out parts of some transmission towers, and herein lies the problem, since BIBLE draws the complete object from any specified view, regardless of the fact that some part of its base may be hidden by a hill crest or wood. This problem is only pertinent to the video mixing technique, since in that method, we cannot erase or restrict the drawing of the pylons to suit the intervening screening forms as could be done in the composition of the conventional photomontage. Various means of tackling this problem were proposed, however, in the event, a solution was derived in keeping with the inherent modular nature of the tower construction modelling sequence. Since each pylon had been built using sub-sections, it was proposed to 'unbuild' the pylon from the base upwards until the remaining part of the tower matched the % visibility given in the VIEW 2 output. The first stage of this task involved determining the possible % breakdown of the various building components for each tower type, table 1 :

Percentage breakdown of pylons TABLE 1

Pylon	Base sections				Middle section	Upper section
DJTSTD			6m 11.7%	6m 11.7%	8.2m 16%	30.98m 60.6%
D60°STD				12m 23%	8.1m 16%	31.5m 61%
D30°M3				9m 20%	8.11m 18%	28.4m 62%
D30°E3			6m 12%	9m 18%	8.11m 16%	28.4m 54%
D30°E9		6m 10.5%	6m 10.5%	9m 16%	8.11m 14%	28.4m 49%
D30°STD			6m 12%	6m 12%	8.11m 17%	28.4m 59%
DM3				9m 19%	13.6m 29%	25m 52%
DM6				6m 13.5%	13.6m 30.5%	25m 56%
DE9		6m 10%	6m 10%	9m 15%	13.6m 23%	25m 42%
DE12	6m 9.5%	6m 9.5%	6m 9.5%	6m 9.5%	13.6m 22%	25m 40%

Having adjusted each tower from the average height of 169ft used in the VIEW 2 program to their actual heights, a table of % visibility of all pylons from the three chosen view points was completed, table 2.

TABLE 2

Photograph 1

	Pylons visible	Percentage visible
Torness - Dalkeith line		
	5	67%
	6	38%
Torness - Eccles line circuitous		
	B	68%
	C	92.5%
	D	98%
	F	57%
Torness - Eccles line direct		
	1	40%
	2	59%
	3	100%
	4	87%

Photograph 3

Torness - Dalkeith line	none	-

It was decided to pursue this view as a test of the accuracy of the VIEW 2 output.

A comparison was subsequently made between the percentage visibility results from VIEW 2 and the percentage breakdown of each tower, see table 3:

TABLE 3

Photograph	Pylons Visible	Library Type	% visible VIEW 2	nearest & breakdown in BIBLE	% Difference
1	5	DE12	67%	71.5%	+4.5%
	6	D3E9	38%	49%	+11%
2 (circ)	B	D3E3	68%	70%	+2%
	C	D6STD	92.5%	100%	+7.5%
	D	D3E3	98%	100%	+2%
	F	D3E9	57%	63%	+6%
2 (direct)	1	DJTSTD	40%	*40%	0%
	2	DE9	59%	65%	+6%
	3	DM6	100%	100%	0%
	4	DM6	87%	86.5%	-0.5%
3	-	-	-	-	-

*This pylon received particular attention in the alternation of its size since the nearest % breakdown would have meant a difference of 20.6%, significant in this type of study.

As mentioned before, these results proved to have a remarkably high correlation, and work proceeded in editing out those pylons or parts of pylons which would not be visible in the three photographs. The final perspectives corresponding to the chosen views were drawn on the Calcomp pen plotter and used in the creation of the four photomontages submitted with this report.

Montage Production: a) photographic/plotting techniques

Photograph 1

	X	Y	Z
View point (m)	2100	6000	28
Focus point (m)	1730	2150	292.68
Mid point (m)	1730	2150	292.68
Lens size	55mm		
Enlargement factor	12.5		

Photograph 2

	X	Y	Z
View point (m)	6000	2900	42.68
Focus point (m)	1730	2150	292.68
Mid point (m)	1730	2150	292.68
Lens size	55mm		
Enlargement factor	12.5		

Photograph 3

	X	Y	Z
View point (m)	1900	4700	61.89
Focus point (m)	1930	2150	292.68
Mid point (m)	1730	2150	292.68
Lens size	55mm		
Enlargement factor	12.5		

Montage production: b) photographic/video technique

The video mixing technique made use of the same views generated for the photomontages, with the inclusion of a number of control points to ensure the accurate matching of the two vision sources. The control points relating to each photograph are outlined below:

Photograph 1: Since the whole of the mast at Blackcastle Hill is visible from this viewpoint, it was felt that this would act as a sufficient control point to obtain the correct positioning and magnification of the computer generated perspective in the video mixing phase.

Photograph 2: Part of the mast is obscured in this photograph, and therefore it was necessary to include another control point. The gable wall of Lawfield farmhouse was chosen and entered into the computer view.

Photograph 3: Although the whole mast is visible, the gable wall of the house on entry to the village of Innerwick was chosen as another control point.

This montage method relies principally on a device called a Scan Convertor to generate a video representation of a vector drawing on a Direct View Storage Tube Graphics Terminal (Tektronix 4014). The vision signal from this source is then mixed, using a vision mixer, on to a background scene, input as vision via a black and white camera looking at a photograph of an appropriate scene. The complete system set-up and equipment used is outlined in (G114). The correct registration of the two images can be controlled either by adjustments to the camera lens or manipulation of the zoom and position control features of the Scan Convertor. The final result can be displayed on a black and white TV monitor in the recording studio or recorded on videotape, a cassette of which was submitted in conjunction with this report on the Torness lines.

5. Interpretation and Conclusions.

The interpretation and conclusions to be drawn from this study are pending further investigation and identification of the most critical viewpoints in the Torness area.

APPENDIX 5

Introduction

Appendix 5 is a short video tape summarising the work in computer aided visual impact analysis. The tape, which lasts for around 10 minutes describes the procedures, program operations and output display methods discussed in the thesis.

APPENDIX 6

Shadow

"Shadow is caused by the interception of illumination by an opaque body and is generally experienced as a darker figure on a lighter ground. The shape of the shadow is characteristic of the intercepting object, the type of illuminant, and their positional relationship. Thus shadow serves to characterise the shape of form". (THEI70) p593

Like colour, shadow conveys a more realistic impression of an object when the formal and locational descriptors are not sufficient to allow object identification. This is achieved by shading giving an object solidity (ITTE60) p101, depth (WEIN66) p25 and surface texture (AYLW78) p79.

When discussing the descriptor EDGE in 5.6.2, consideration was given to internal edges of high contrast where shadows fell across visible building surfaces. The contrast measurement of these building shadows accounts for the useful and quantifiable attributes of shadow in visual impact studies, although these are best appraised through visualisation and an assessment of how shadow distorts or changes the perceptible shape of a building.

The measurement of shadow.

Shadow studies may be effected using the hidden surface algorithm in the program VISTA. An assumption is made that the observer point is at the sun and VVIEW,a program module within VISTA calculates the areas of building surfaces invisible to the observer, ie. in shadow This shadow data may be stored in a file for later use in modifying surface colour and tone of the study building, as seen from an observer location other than the sun. To quantify building shadow, as seen in perspective, is not thought a helpful measure in visual assessment. It may only be best appraised when seen in the context of the whole building form, and even then against the context background, since "the articulation and modelling of form in architecture relies heavily on shadow." (CAIR78) p130.

Colour

What an observer sees as colour may be defined as a certain wavelength of light reflected from the surface of an object. Each colour has a unique wavelength, though this will vary according to the prevailing conditions, eg. time of day (available light), climate (attenuation and scatter of light waves) and the viewing distance (atmospheric perspective may occur, causing distant objects to appear blue). Although colour may be given a numerical value it is not intended that colour ought to be some objective measure of a building surface upon which visual assessment can be made. In fact the complex psychological issues of personal colour preference; colour constancy, in which the perceived colour of a surface is seen as constant across the whole area, regardless of the level of surface illumination; and distance blueness play havoc with any objective attempt to assess the colour of building surfaces as seen in the open air. Distance blueness is often referred to as atmospheric or aerial perspective, in which greater viewing distances result in a degradation of colour clarity and tone, and a greater distortion of hue towards the blue end of the electromagnetic spectrum.

"Changes of colour with distance are due to the varying capacity of light of different wavelengths to penetrate moisture and atmospheric dust without being absorbed or reflected out of the line of vision. For instance, the blue colour of the sky is due to the fact that most of the longer lightwaves (red, orange and yellow) have disappeared into space and only the short waves have been reflected back from the sun into our eyes by the dust in the earth's atmosphere." (PICK72) p38.

Only when these fundamental relationships in outdoor colour perception are resolved and simulated successfully by computer models can serious colour assessment in visual impact studies be feasible by automatic procedures, eg. image processing and montaging.

Objective Colour

Although colour is frequently referred to as hue, this is an incomplete specification and may only be properly identified by stating three variables. These are commonly called hue, lightness and saturation, although colour standards vary widely in the precise terminology:

Scientific descriptions of colour

Tektronix Colour Standard	hue	lightness	saturation
Munsell Colour System	hue	value	chroma
Young-Helmholty Trichromatic Theory	Red	Green	Blue
British Standard 5252	hue	weight	greyness
W.J. Cairns and Partners (CAIR77)	colour quality	Tone	colour intensity

At present there is no colour standard common to both the building industry and computer graphics. BS5252 (BRIT76) is standard in colour specifications for building materials, and the most popular colour model in computer graphics is the Young Helmholtz Theory. The importance of BS5252 lies in the fact that it aims to be a reference point for all other building colour standards and the mechanism for their co-ordination:

" i) it anticipates basic colour requirements for all opaque pigmented materials and finishes used in buildings.

ii) it provides colours, in harmony with natural and self coloured materials such as stones, brick and woods.

iii) it does not handle colours of translucent materials eg. window glass." (GLOA78)

From an architect's viewpoint, BS5252 is the starting point in colour specification for colour computer graphics in design. There is a tenuous link between BS5252 and the Young Helmholtz Theory through

Tektronix Colour Standard, although this has not yet been fully achieved in practice. Research work at ABACUS continues in this field to allow an automatic conversion from BS5252 colours, as specified on architects' drawings, to RGB values.

The RGB Young Helmholtz Trichromatic Theory is regarded as crucial in computer graphics because it best offers an understanding of the visual processing of colour by the human eye. (PORT76). The RGB theory states that only three primary colour sensations are required to describe different colours; red, green and blue. This is due to the fact that the human eye has only three types of narrow-band light receptors, called cones, with peak sensitivities at three different wavelengths on the electromagnetic spectrum; these correspond roughly to red, green and blue (MONT79) p 123. Thus any colour, C, may be described in terms of $C = \alpha \text{ Red} + \beta \text{ Green} + \gamma \text{ Blue}$, where α, β and γ are variables between 0 and 255, such that: eg.

0 Red + 0 Green + 0 Blue = Black
255 Red + 255 Green + 255 Blue = White
255 Red + 0 Green + 0 Blue = Red
255 Red + 255 Green + 0 Blue 0 Yellow

The diagram (G300) shows the complete RGB (Red Green Blue) colour model box.

Clearly, colour computer graphics can best be utilised in design when the link between BS5252 is established, and proper colour specifications can be visualised on colour terminals.

BIBLIOGRAPHY

(ALEX64) C. Alexander, Notes on the Synthesis of Form. Harvard University Press, Massachusetts, USA. 1964.

(ALLA68) P. Allan, J. Hollwey and H. Maynes, Practical Field Surveying and Computations, Heinemann, London. 1968. p.400-402.

(ALLU60) E. A. Alluisi, On the Use of Information Measures in Studies of Form Perception. Perceptual and Motor Skills (Journal) Vol. 11 p. 195-203, 1960.

(AMER78) American Society of Photogrammetrists. Proceedings of DTM Symposium: St. Louis, Missouri. May 9-11, 1978. On loan from Topographic Science Dept. at Glasgow University.

(ANDE81) Anderson Semens Houston Environment Design Partnership. Environmental Impact Analysis : Proposed Expansion of Downhill Ski-ing Facilities at Coire an t'Sneachda, Coire an Lochain and Lurcher's Gully, Cairngorm. Anderson Semens Houston. Glasgow, April 1981.

(APPL74) D. Appleyard. The Berkeley Environmental Simulation Project. University of California. 1974. From a video tape on Modelling Techniques held at Dept. of Architecture, Strathclyde University.

(ARCH69) B. Archer, The Structure of the Design Process, p. 76 of (BROA69).

(ARCH72) McIntosh School of Architecture - Modelscope. Architects' Journal. 6 December 1972, p.1325.

(ARCH77) Towns in the North West. Architects' Journal, 23 February, 1977, p348

(ARCH78) The Garden City : Ebenezer Howard, Architectural Review. June 1978 p321.

(ARCH79a) B. Archer, Whatever became of Design Methodology? Design Studies, Vol. 1 No. 1 July 1979. p17-18.

(ARCH79b) Rodger's drawings 'grossly misleading', Architects' Journal 26 September 1979, p628.

(ARCH80a) Land Decade 1980-1990, Architects' Journal, 2 January 1980, p. 12.

(ARCH80b) Power to the People - Prospects for the Land, Architects' Journal, p171-209, 23 January 1980.

(ARCH81) Environmental Tests - Opposition Continues. Architects' Journal, 17 June 1981, p53.

(ARCH82a) EEC legislation on environment? Architects' Journal, 10 February 1982, p37.

(ARCH82b) CAD'82 : pointers to the future. Architects' Journal, 7 April 1982, p41.

(ARCH83a) Nuclear Designs, Architects' Journal, 23 February 1983, p36,37.

(ARCH83b) Developments in Computing : CAD perspectives. Architects' Journal, 1 June 1983, p68.

(ARVI78) Robert Arvill, Man and Environment. Penguin Book 1978, (Harmondsworth) Middlesex.

(ASHW54) W. Ashworth, The Genesis of Modern British Town Planning. Routledge, London 1954.

(ATTN50) F. Attneave, Dimensions of Similarity. American Journal of Psychology, vol. 63 p516-556. 1950.

(ATTN54) F. Attneave, Some Informational Aspects of Visual Perception. Psychological Review. Vol. 61 No. 3 1954, p183.

(ATTN56) F. Attneave and M. Arnoult, The Quantitative Study of Shape and Pattern Perception. Psychological Bulletin, Vol. 53, No. 6, 1956, p452.

(ATTN57) F. Attneave, Physical Determinants of the Judged Complexity of Shapes. Journal of Experimental Psychology, Vol. 53 No. 4, April 1957, p221-227.

(AYEN76) O. Ayeni, Optimum Sampling for DTMs - A Trend Towards Automation. Journal of the International Institute for Aerial Survey and Earth Sciences (ITC). July 1976.

(AYLW75) G. M. Aylward, Flotta Oil Handling Terminal : The Visual Impact of Oil Developments. Petroleum Review : July 1975, Volume 4, p467-472.

(AYLW77) G. M. Aylward and M. Turnbull, Visual Analysis : a computer aided approach to determine visibility. Computer Aided Design, Vol. 9 No. 2, April 1977, pp103-108.

(AYLW78) G. M. Aylward and M. Turnbull, Visual Analysis : the development and use of "descriptors". Design Methods and Theories Journal, Vol. 12 No. 2, April-June 1978, pp72-88.

(AYLW79) G. Aylward and M. Turnbull, Predicted Visibility of a Radio Mast in East Lothian. Unpublished paper for the South of Scotland Electricity Board. December 1979.

(AYLW82) G. M. Aylward and M. Turnbull, Visual Impact Analysis. CAD82 Conference Proceedings.Butterworths Press, Guildford, England. 1982. p228.

(BAIR70) J. C. Baird, Psychological Analysis of Visual Space. Pergammon Press, Oxford. 1970.

(BAIR74) M. Baird and M. Kelly, A Paradigm for Semantic Picture Recognition. Pattern Recognition, Vol. 6 p61-74, 1974.

(BARR71) R. Barras, T. A.Broadbent, M. Cordey-Hayes, D. B. Massey, K. Robinson, J. Willis. An Operational Urban Development Model of Cheshire. Environment and Planning. Vol. 3 pp115-234, 1971.

(BARR80) G. Barrow (Editor), Environmental Impact Studies - Less Haste - More Speed. Symposium Proceedings. Anderson Semens Houston, Environmental Design Partnership, Glasgow 1980.

(BATT72) M. Batty, Recent developments in land-use modelling : a review of British research. Urban Studies Vol. 9, p151.

(BELL74) A. G. Bell, Report to the Secretary of State for Scotland on the proposal for a nuclear power station at Torness, East Lothian, by the South of Scotland Electricity Board. Copy held in the National Library, Edinburgh, 1974.

(BENN30) M. Bennett, The Physical Conditions Controlling Visibility through the Atmosphere. Quarterly Journal of the Royal Meteorological Society. Volume 56, 1930, pp1-29.

(BENS77) S. Bensasson, Computer Programs for Building Perspectives. Design Office Consortium, Cambridge, England. 1977.

(BIJL83) A. Bijl, Computer Aided Design and Practice Paper presented at Landscape Institute's conference on Computers in Landscape Architecture; at Strathclyde University, March 25-26. 1983.

(BISS80) R. Bisset, Methods for Environmental Impact Analysis : recent trends and future prospects. Journal of Environmental Management. Volume 11 No. 1 pp27-43.

(BLAN57) A. A. Blank, Geometry of Vision. British Journal of Physiological Optics. Vol. 14 1957, p154-169.

(BLAN61) A. A. Blank, Curvature of Binocular Visual Space. Journal of the Optical Society of America, Vol. 51 No. 3 pp335-339 (1961).

(BLAN78) A. A. Blank, Metric Geometry in Human Binocular Perception : Theory and Fact. Part 1, chapter 4 in (LEEU78) page 83. 1978.

(BLIN77) J. Blinn, Models of Light Reflection for Computer Synthesised Pictures. Computer Graphics Vol. 11 No. 2 1977, p192-198.

(BLIN82) J. Blinn, Light Reflection Functions for Simulation of Clouds and Dusty Surfaces. Computer Graphics Vol. 16 No. 3 July 82, p21-29.

(BOOK78) F. L. Bookstein, The Measurement of Biological Shape and Shape Change. Springer-Verlag, Berlin. 1978.

(BRAC81) I. Bracken, Urban Planning Methods : Research and Policy Analysis. Methuen & Co. Ltd. London 1981.

(BRAN72) A. J. Brandenberger, Organising Photogrammetric Surveying at Large Scales. Paper published by Ohio State University, Columbus, Ohio, USA. 1972.

(BRIT76) British Standard 5252. Framework for Colour Co-ordination for Building Purposes. HMSO publications, 1976.

(BROA69) G. Broadbent and A. Ward, Editors. Design Methods in Architecture. Lund Humphries, London, 1969.

(BROA73) G. Broadbent, Design in Architecture. John Wiley and Sons. London 1973.

(BROA80) G. Broadbent, R. Bunt, and T. Llorens (eds.) Meaning and Behaviour in the Built Environment. John Wiley and Sons. New York. 1980.

(BROW62) D. R. Brown, L. Hitchcock and K. M. Michels, Quantitative Studies in Form Perception : An Evaluation of the Role of Selected Stimulus Parameters in the Visual Discrimination Performance of Human Subjects. Perceptual and Motor Skills (Journal) Vol. 14 pp519-529, 1962.

(BROW67) D. Brown and D. Owen, The Metrics of Visual Form. Psychological Bulletin, Vol. 68 No.4 1967 pp243-259.

(BUIL78) Environmental Impact Analysis. Built Environment, Vol. 4 No. 2, June 1978.

(BUIL80) EEC to Demand Impact Assessments. Building Design. 8 April, 1980. p3.

(BUIL83) Visualisation using Computer Graphics. Building (magazine) 27 May 1983, No. 21.

(BURE80) Bureau of Land Management. Visual Simulation Techniques. US Government Printing Office, Washington, DC 1980.

(CAEL81) T. Caelli, Visual Perception : Theory and Practice. Pergammon Press Ltd. Oxford, 1981.

(CAIR77) W. J. Cairns, Flotta Marine Terminal, Orkney. Landscape Design, May 1977, p12-16.

(CAIR78) W. J. Cairns, The Flotta EIA Study. Built Environment Volume 4 No. 2, June 1978, p129.

(CAMP82) W. D. Campbell, Local Public Inquiry concerning the extention of ski-ing facilities at Coire na Ciste and Coire Cas into Coire an t'Sneachda, Coire an Lochain and Lurcher's Gully. Published 1982. Scottish Development Department, Edinburgh. Copy held in National Library of Scotland, Edinburgh.

(CARL78) I. Carlbom and J. Paciorek, Planar Geometric Projections and Viewing Transformations. Association of Computing Machinery (ACM) Journal. Computing Surveys Vol. 10 No. 4 December 1978, p465-502.

(CARR35) H. Carr, An Introduction to Space Perception. Longmans, New York, 1935.

(CART79) Personal communications with Mr. C. Carter, Job Architect for Hunterston 'B' Power Station. (Architects : Robert Matthew Johnson Marshall) Edinburgh. September 1979.

(CATL76) J. Catlow and G. Thirlwall, Environmental Impact Analysis Department of the Environment, Research Report No. 11, HMSO London 1976.

(CATM76) E. Catmull, A Hidden Surface Algorithm with Anti Aliasing. Computer Graphics Vol. 12. No. 3, 1978, p6.

(CHAD78) G. Chadwick, A Systems View of Planning. Pergammon Press, Guildford, Surrey. 1978.

(CHAP53) A Chapanis and R. A. McCleary, Interposition as a cue for the perception of relative distance. Journal of General Psychology Vol. 48 p113-132, 1953.

(CHER77) P. Cheremisinoff and A. Morresi, Environmental Assessment and Impact Statement Handbook. Ann Arbor Science Publishers Inc. Michigan, US, 1977.

(CHER80) G. Cherry, editor. Shaping an Urban World. Mansell Ltd., London 1980.

(CHIN79) F. Ching, Architecture : Form Space and Order. Van Nostrand Reinhold Company. New York, 1979.

(CLAR76) B. D. Clark et al. (Project Appraisal for Development Control, Aberdeen University.) Assessment of Major Industrial Applications : a manual. Department of Environment Research Report No. 13. 1976. Superseded by HMSO publication : Assessment of Major Developments, 1981.

(CLAR78) Clark, B.D. Chapman, K., Bisset, R. and Wathern,P. US Environmental Impact Assessment : A Critical Review, 1978. Department of the Environment Research Report No. 26 London.

(CLAR79) B. Clark, K. Chapman, R. Bisset, P. Wathern. Environmental Impact Analysis. Chapter 3 of (LOVE79) pp53-87.

(CLAR80a) B.D. Clark, Bisset, R., and Wathern, P. Environmental Impact Assessment : a bibliography with abstracts. 1980, Mansell Publishing Co. Ltd. London.

(CLAR80b) B. Clark, The Role of Environmental Appraisal in Forward Planning. From the proceedings of a symposium at the Scottish Development Agency on Environmental Impact Studies. Edited by G. Barrow, of Anderson Semens Houston Partnership, Glasgow. November, 1980.

(CLAR82) J. A. Clarke, ESP(Multi-zone System) User Manual. ABACUS : user manual series M30. 1982.

(CLAR83) J. A. Clarke, ESP Documentation : section 3. ABACUS Department of Architecture, Strathclyde University, 1983.

(CLOU76) B. Clouston and R. Cass, Land Reclamation - Combining model building and photogrammetry as a design tool. Landscape Design. August 1976 p28-30.

(COLL71) P. Collins, Architectural Judgement. Faber and Faber, London, 1971.

(COMP83) Visual Impact Computer Bulletin, June 1983, p13.

(COOK81) R. Cook and K. Torrance, A Reflectance Model for Computer Graphics Computer Graphics Vol. 15 No. 3, 1981 p307-316.

(COOK82) R. Cook and K. Torrance, A Reflectance Model for Computer Graphics, ACM Transactions on Graphics Vol. 1 No. 1 January 1982, pp7-24.

(COUN79) Countryside Commission for Scotland. Scotland's Scenic Heritage. Published by the Countryside Commission for Scotland, Perth, 1979.

(COWA68) J. Cowan, J. Gero, H. Ding and N. Muncy, Models in Architecture. Elsevier Publishing Co., Amsterdam, Holland. 1968.

(COWA70) P. Cowan, Developing Patterns of Urbanisation Oliver & Boyd. Edinburgh 1970.

(CROS77) N. Cross, The Automated Architect, Pion Ltd. London 1977.

(CROW72) S. Crowe, The Landscape of Power. Architectural Press, London. 1972.

(CROW77) F. Crow, Shadow Algorithms for Computer Graphics. Computer Graphics, Vol. 11 No. 2. 1977, p242.

(DALE82) J. Daley, Design Creativity and the Understanding of Objects. Design Studies, Vol. 3 No. 3, July 1982.

(DALL80) R. Dallas, Surveying With a Camera : Photogrammetry and Rectified Photography. Architects' Journal 30 January and 20 February 1980.

(DANB63) M. Danby, Grammar of Architectural Design. Oxford University Press, England. 1963.

(DARK79) J. Darke, The Primary Generator and the Design Process. Design Studies, Vol.1.No.1 July 1979, p36-44.

(DAVI78) R. Davies and P. Hall (editors) Issues in Urban Society. Penguin Books Ltd. Harmondsworth, England 1978.

(DAVS63) H. Davson, The Physiology of the Eye. Churchill Ltd. 1963 London.

(DAY 66) R. H. Day, Perception. W. C. Brown Company Publishers, Iowa, USA. 1966.

(DAY 69) R. H. Day, Human Perception. John Wiley & Sons, Australasia Pty. Ltd. Sydney. 1969.

(DEMB61) W. N. Dember, The Psychology of Perception. Holt, Rinehart, and Winston. New York. 1961.

(DEUT55) J. Deutsch, A Theory of Shape Recognition. British Journal of Psychology, Vol. 46 1955 p30.

(DOBR75) G. Dobry, Review of the Development Control System. (Final Report) Department of the Environment. HMSO. 1975.

(DODW66) P. C. Dodwell, Coding and Learning in Shape Discrimination. in (UHR 66) p185-194.

(DOYL78) F. Doyle, Digital Terrain Models : An Overview. Photogrammetric Engineering and Remote Sensing, the Journal of The American Society of Photogrammetry. Vol. 44 No. 12. December 1978 pp1481-1485.

(DUDA78) E. Dudani and M. Luk, Locating Straight Line Edge Segments on Outdoor Scenes. Pattern Recognition, Vol. 10 p145-157 1978.

(DUEL82) J. Duell, Design Decisions. Architects' Journal, 15 December, 1982 p23.

(DUNT48) S. Q. Duntley, The Visibility of Distant Objects. Journal of the Optical Society of America Vol. 38. p. 237-249.

(ECKB69) G. Eckbo, The Landscape We See. McGraw Hill. New York. 1969.

(ENVI73) Department of the Environment. Using Predictive Models for Structure Plans. HMSO publication. 1973.

(ERVI82) S. Ervin, Towards a Paperless Landscape Architecture. Harvard Computer Graphics Week. Harvard University Graduate School of Design, USA. 1982.

(EVAN72) I. Evans, General Geomorphometry Derivatives of Altitude, and Descriptive Statistics. From 'Spatial Analysis in Geomorphology' (ed. R. J. Chorley). Methuen Co., London p17. 1972.

(FAIR72) N. Fairbrother, New Lives, New Landscapes. Penguin Books, London. 1972. pp58,107-123.

(FALK56) J. L. Falk, Theories of Visual Acuity and their Physiological Bases. Psychological Bulletin Vol. 53 No. 2 March 1956. p109.

(FALK70) B. Falk, Hunterston - Portencross Report. - Land Allocation for a general deep water port, steelworks, oil terminal and refinery. Covell Matthews and Partners, London. 1970.

(FIRS72) O. Firschein and M.Fischler, A Study in Descriptive Representation of Pictorial Data. Pattern Recognition. Vol. 4 p361, 1972.

(FISH69) W. T. Fishback, Projective and Euclidean Geometry John Wiley & Sons Inc. New York 1969.

(FLET75) Sir B. Fletcher (Revised by J. C. Palmes) History of Architecture. (18th edition) Athlone Press, London. 1975.

(FOIN76) T. C. Foin, Jnr. Ecological Systems and the Environment. Houghton Mifflin Company; Boston, US. 1976.

(FOLE78) G. Foley, The Energy Question. Penguin Books, Harmondsworth, Middlesex, England. 1978 chapters 17 and 18.

(FOLE82) J. Foley and A. Van Dam, Fundamentals of Interactive Computer Graphics. Addison-Wesley Publishing Company. Reading, Massachusetts, US. 1982.

(FORG66) R.H. Forgus, Perception: The basic process in cognitive development. McGraw-Hill Book co. New York. 1966.

(FORG76) R.H. Forgus, L.E. Melamed, Perception: A cognitive-stage approach. McGraw-Hill Book Co. New York. 1976.

(FOST79) J. Foster, Leisure Provision and Landscape Planning. chapter 6 of (LOVE79). Leonard Hill, Glasgow. 1979.

(FOX 81) P. Fox, VISTA: Visual Impact Simulation Technical Aid. PhD Thesis. Strathclyde University, Glasgow, UK. 1981.

(FREE75) J.C. Free, A Model of the Modelling Process. Proceedings of the Sixth Annual Pittsburgh Conference Modelling and Simulation: Volume 6 part 2. 1975. pp747-752.

(GALI69) R. Galimberti and U. Montanari, An Algorithm for Hidden Line Elimination. Communications of the ACM. Vol.12 No.4 1969. p206-211.

(GARD80a) W. Gardner, S. Fitzau, C. Purdie, Norit Clydesdale Factory: Visual Impact Study. ABACUS Paper R47 Department of Architecture, Strathclyde University. 1980.

(GARD80b) W. Gardner and C. Purdie, Visualisation of Alternative Pylon lines for the South of Scotland Electricity Board at Torness in East Lothian. (Part1). ABACUS Report: R46. 1980. Department of Architecture, Strathclyde University.

(GARN79) Prof. J. Garner , EIS-in US and UK. Journal of Planning and Environmental Law. March 1979. p142.

(GERO82) J.S. Gero, A.D. Radford and N.S. Murthy, Exploring the Consequences of Design and Performance Decisions in Computer Aided Design. CAD82. Conference Proceedings, (edited by A. Pipes) Butterworths, Guildford, England. 1982. p633-646.

(GHOS71) S.K. Ghosh, Analytical Photogrammetry. International Textbook Co. Scranton, Penn., USA. 1971.

(GIBS50) J.J. Gibson, The Perception of the Visual World. Houghton Mifflin Co. Boston. 1950.

(GIBS51) J.J. Gibson, What is a Form? Psychological Review. Volume 58 No6. 1951 p403.

(GIBS68) J.J. Gibson, The Senses considered as Perceptual Systems. G. Allen and Unwin Ltd. London. 1968.

(GIOR82) A. Giorgini, Computational Prospective Rendering of Coloured Objects Illuminated by Multiple Colour Sources at Finite Distances. Harvard Computer Graphics Week. Harvard University Graduate School of Design, USA. 1982.

(GLAS82) Glasgow Herald, Luchers Gully Inquiry. 17th December 1982. p9.

(GLOA78) A. Gloag and M. Gold, Colour Co-ordination Handbook BRE Report HMSO publications. 1978.

(GOET65) J. Goetz, Quantitative Methods. McGraw-Hill. New York. 1965.

(GONI76) M. Gonin and T Moffett. ARTES - An Interactive Highway Design Program. Computer Graphics Vol. 10 No 2. 1976. p268. (From Proceedings of SIGGRAPH '76).

(GRAH65) C.H. Graham, Vision and Visual Perception. Wiley and Sons Ltd., New York. 1965. p516.

(GRAH77) G. Graham and Partners, Visual Impact Analysis. Practice Advice Note. G Graham and Partners, Lockington Hall, Lockington, Derby, DE7 2RH. 1977.

(GRAH79) G Graham, Engineering Architecture. Architects' Journal 28th November 1979. p1129.

(GRAS69) A Grasselli (ed), Automatic Interpretation and Classification of Images. A NATO Advanced Study Institute. Academic Press, New York. 1969.

(GUZM69) A Guzman, Decomposition of a Visual Scene into 3d Bodies. in (GRAS69) p250.

(HABE68) R.N. Haber, Contemporary Theory and Research in Visual Perception. Holt Rinehart Winston Inc., New York. 1968

(HABE80) R.N. Haber and M. Hershenson, The Psychology of Visual Perception. (Second edition). Holt Rinehart and Winston. New York. 1980.

(HAGG69) Haggett and Chorley, Network Analysis in Geography. Edward Arnold Publishers, London. 1969.

(HAKE66) H. Hake, Form Discrimination and the Invariance of Form. in (UHR 66). p142-173.

(HALL76) R. Hall, Master Environmental Impact Report - A Method for Evaluating the Environmental Impacts of General Plans. Design Methods and Theories Journal Vol. 10 No.1. 1976.

(HALL82) Peter Hall, Urban and Regional Planning. Penguin Books, Harmondsworth, Middlesex. 1982.

(HARD79) A.Hard and L. Sivik, Outlines of a Theory of Colours in Combination. Man-Environment Systems. Vol.9 Nos.4 and 5 p217.

(HARL75) J.B. Harley, Ordnance Survey Maps - a descriptive manual. Oxford University Press, England. 1975.

(HEAP82) Sir D. Heap, Planning Law. in AJ legal Handbook (third Edition) editors: Speaight and Stone, Architectural Press, London. 1982.

(HEBB49) D.O. Hebb, Organisation of Behaviour. Wiley and Co. New York. 1949.

(HEBB75) R. Hebblethwaite, The Determination of Zones of Visual Influence by Computer and Photogrammetry. Technical Disclosure Bulletine No.255 Central Electricity Generating Board. December 1975.

(HESS71) S. Hesselgren, Experimental Studies on Architectural Perception. National Swedish Building Research. Document D2: 1971. Pettersons. Stockholm.

(HESS75) S. Hesselgren, Man's Perception of Man-Made Environment. Dowden, Hutchinson and Ross Inc. Pennsylvania, USA. 1975.

(HESS72) S. Hesselgren, The Language of Architecture Vol. 1. Applied Science Publishers Ltd. Barking, Essex. 1972.

*
(HOCH48) J.E. Hochberg, L. Gleitman and H. Macbride, Abstract from a paper presented at the Western Psychological Association Conference. American Psychologist. Vol.3. 1948. p341/342.

(HOCH64) J.E. Hochberg, Perception. Prentice-Hall Inc. New Jersey, USA. 1964.

(HOHA70) S. Hohauser, Architectural and Interior Models. Van Nostrand Reinhold Co., New York. 1970.

(HOLM74) J. Holmes Planning Group, An Examination of Sites for Gravity Platform Construction on the Clyde Estuary. Glasgow. 1974.

(HOLW41) A. Holway and E. Boring, Determinants of Apparent Visual Size with Distance Variant. American Journal of Psychology. Vol. 54. p21-37. 1941.

(HOPK71) R.G. Hopkinson, The Quantitative Assessment of Visual Intrusion. Journal of the Town Planning Institute. Vol.57. No.10. December 1971.

(HOUG38) H.G. Houghton and W.H. Radford, On the measurement of drop size and liquid water content in fogs and clouds. Papers in Physics, Oceanography and Meteorology. Volume 6 No.4. Cambridge, Massachusetts, USA. 1938.

* See addendum to bibliography

(HOUS81) House of Lords Select Committee of the European Communities, Eleventh Report, 1980-81. Environmental Assessment of Projects. House of Lords Paper 69. HMSO, London. 1981.

(HOWM82) C. Howman and P. Woodsford, The Laser-Scan FASTRAK Automatic Digitising System. Technical Note from Laser-Scan Laboratories Ltd. Cambridge, England. 1982.

(HULL43) C.L. Hull, Principles of Behaviour. Appleton-Century-Crofts. New York. 1943.

(IMHO65) E. Imhof, Kartographische Gelandedarstellung. W. De Gruyter and Co. Berlin. 1965. p.34-42.

(ITTE51) W.H. Ittelson, Size As A Cue To Distance. American Journal of Psychology. Vol.64. p54-67. 1951.

(ITTE60) W.H. Ittelson, Visual Space Perception. Springer Publishing Company, Inc. New York. 1960.

(ITTE74) W.H. Ittelson, L. Proshansky, K. Rivlin, H. Winkel, An Introduction to Environmental Psychology. Holt Rinehart and Winston Inc., New York. 1974.

(JANS79) J. Janssens, Building Exteriors as Informative Components in the Environment. Man-Environment Systems Vol.9 Nos.4 and 5, p252.

(JACO70) P. Jacobs and D. Way, Visual Analysis of Landscape Development Department of Landscape Architecture. Harvard University Graduate School of Design, USA. 1970.

(JACO78) W. Jacobsen, P. Ray, H. Altridge, J. Axford, Manual of Photography. Focal Press, London. 1978.

(JANK68) R. Janke, Architectural Models. Thames and Hudson, London. 1968.

(JEFF80) Personal communications with Mr R.L. Jeffrey of L.G. Angus (Model Makers), Glasgow. June 1980.

(JOHN83) K. Johnson, Research into an objective method of Assessing Visual Impact in the Landscape. Perception Essay in B.A. (Landscape Architecture) course. Dept. of Architecture, Heriot Watt University. 1983.

(JONE80) C. Jones, Design Methods. John Wiley and Sons. Chichester, UK. 1981.

(JOUR79) Vale of Belvoir-coal mining application. Journal of Planning and Environmental Law. March 1979. p139.

(KELL77) D.R. Kelley (Editor), The Energy Crisis and the Environment. Praeger Publishers, New York. Chapter 6. p103. 1977.

(KOHL47) W. Kohler, Gestalt Psychology (revised Edition). Liveright: New York. 1947.

(KRAM79) M. Krampen, Meaning in the Urban Environment. Pion Ltd., London. 1979.

(LANG74) M. Langford, Advanced Photography: Focal Press; London, 1974.

(LANG78) J. Lange, Scale Model Building as a Method of Learning Architectural Design. Design Methods and Theories Vol.12. No.1. p11. 1978.

(LaME43) V.K. LaMer and D.Sinclair, Verification of the Mie theory. Optical Science Research and Development Report No.1857. Department of Commerce, Office of Publication Board, Washington, USA. 1943.

(LASS76) A. Lassière, The Environmental Evaluation of Transport Plans. Dept. of Environment Research Report No.8. HMSO. 1976. pp70-109. chapter 5 "Visual Effects".

(LAWS80) B. Lawson, How Designers Think. Architectural Press Ltd. London. 1980.

(LEE 78a) N. Lee and C. Wood, The Assessment of Environmental Impacts in Project Appraisal in the European Communities. Journal of Common Market Studies. Vol.16. p189-210.

(LEE 78b) N. Lee and C. Wood, Environmental Impact Assessment of Projects in EEC Countries. Journal of Environmental Management. Vol. 6 pp57-71.

(LEE 78c) N. Lee and C. Wood, Environmental Impact Analysis.- A European Perspective. Built Environmental Journal. Vol.4,No.2. June 1978. p101-110.

(LEEU78) E.L.J. Leeuwenberg and H.F.J.M. Buffart. (eds.) Formal Theories of Visual Perception. John Wiley and Sons, New York. 1978.

(LEHM77) R. Lehman, Computer Simulation and Modelling. John Wiley and Sons Ltd., New York. 1977. pp15, 224-226.

(LIPK70) C. Lipkin and A. Rosenfeld. (ed), Picture Processing and Psychopictorics. Academic Press. New York. 1970.

(LOVE73) D Lovejoy (ed), Land Use and Landscape Planning. Leonard Hills Books. Aylesbury. 1973. first edition.

(LOVE79) D. Lovejoy (ed), Land Use and Landscape Planning. Leonard Hill (a member of the Blackie Publishing Group). Glasgow. 1979. Second Edition.

(LOVE82) Personal communications with Derek Lovejoy and Partners, Manchester. : notes on Visual Intrusion Calculations based on guidelines in the Jefferson Report by Ministry of Transport.

(LUCK69) J. Luckman, An Approach to the Management of Design. in (BROA69).

(LYNC64) K. Lynch, The Image of the City. MIT Press, Massachusetts, USA. 1964.

(LYNC71) K. Lynch, Site Planning. MIT Press, Massachusetts, USA. 1971.

(LYNC76) K. Lynch, Managing the Sense of a Region. MIT Press, Massachusetts, USA. 1976.

(MacD82) E.B. MacDougall, Sun and Shadow Plotting with a Microcomputer. Paper presented at the Harvard Computer Graphics Week, Harvard University, Graduate School of Design. July 1982.

(Mack82) M. Mackinder and H.Marvin, Design Decision-Making in Architectural Practice. Building Research Establishment Information Paper (IP 11/82). Watford. July 1982.

(MacL79) A. MacLeary, Energy Development and Land in the United Kingdom. The Planner. March 1979. p38-40.

(McLO69) B. McLoughlin, Urban and Regional Planning - A systems approach. Faber and Faber. London. 1969.

(MAKA73) B. Makarovic, Progressive Sampling for Digital Terrain Models. Journal of the International Institute for Aerial Survey and Earth Sciences.(ITC). No.3 p397. 1973.

(MAKA76) B. Makarovic, A Digital Terrain Model System. Journal of the Institute for Aerial Survey and Earth Sciences (ITC). No.6 1976. p57. 1976.

(MALL77) R. Mallary and M. Ferraro, ECOSITE An Application of Computer-Aided Design to the Composition of Landforms for Reclamation. Computer Graphics. Vol.11. No.2 1977. p1-7.

(MANC76) Manchester University (Laurie, Robinson, Traill, Wager) Landscape Evaluation. Research Project 1970-75. Revell and George, Manchester. 1976.

(MARC74) L. March and P. Steadman, The Geometry of Environment. Methuen and Co. Ltd., London. 1974.

(MARC76) L. March (ed), The Architecture of Form. Cambridge University Press, Cambridge. 1976. Page 1-40. The Logic of Design and the Question of Value.

(MARK67) T. Markus, The Role of Building Performance Measurement and Appraisal in Design Method. Architect s' Journal, 20th December 1970. pp1567-73.

(MARK72) T. Markus, T. Maver, D.Canter, P. Whyman, J. Fleming, Building Performance. Applied Science Publishers Ltd. London. 1972.

(MASS71) D.B. Massey, M. Cordey-Hayes, The Use of Models in Structure Planning. Town Planning Review. Vol.42 No.2 1971. pp28-44.

(MAVE70) T.W. Maver, A Theory of Architectural Design in which the Role of the Computer is Identified. Building Science. Vol. 4. 1970 pp199-207.

(MAVE75) T. Maver, Three Design Paradigms: A Tentative Philosophy. Design Methods Group and Design Research Society Journal. Vol.9. No.2. pp130-137.. 1975.

(MAVE82) T.W. Maver et al, Integrated System for Computer Aided Visual Impact Analysis. - Grant proposal. ABACUS, Dept. of Architecture, Strathclyde University. December 1982.

(MAYC83) G. Maycock, Torness Transmission Lines: Report on Public Local Inquiry. Published by the Scottish Economic Planning Department, New St. Andrew's House, Edinburgh. 1983.

(MEAR69) Sir F. Mears and Partners, B.S.C. Report on landscape treatment of proposed ore terminal and settlement at Hunterston. Sir F. Mears and Partners, Edinburgh. 1969.

(METR69) Metra Consulting Group Ltd. and A.E. Weddle, Metra-Weddle Report; on Possible Industrial Developments in the Clyde Estuary. Jamuary 1969.

(MICH65) K. Michels and L Zusne, Metrics of Visual Form. Psychological Bulletin. Vol.63 No.2. 1965. p74-86.

(MIDD68) W.E.K. Middleton, Vision through the Atmosphere. University of Toronto Press, Canada. 1968.

(MILL49) G.A. Miller and F.C. Frick, Statistical Behaviouristics and Sequences of Responses. Psychological Review. Vol.56. p311-324. 1949.

(MINN59) M. Minnaert, Light and Colour in the Open Air. G Bell and Sons Ltd. London. 1959.

(MITC77) W.J. Mitchell, Computer Aided Architectural Design. Petrocelli/Charter. New York. 1977.

(MONT79) F.S. Montalvo, Human Vision and Computer Graphics. Association of Computing Machinery. Vol.4. 1979 p121-125.

(MURR67) A.C. Murray (editor), Methods of Landscape Analysis. Symposium, London. May 1967. Published by Landscape Research Group.

(NATI69) National Environmental Policy Act 1969. p355 in (CHER77).

(NEWM82) W. Newman and R. Sproull, Principles of Interactive Computer Graphics. Second Edition. McGraw-Hill International Book Company. New York, US, 1982.

(OGLE64) K.N. Ogle, Binocular Vision. Hofner, New York. 1964.

(ORIO76) T. O'Riordan and R Hey (Editors), Environmental Impact Assessment. Saxon House Publishers, Farnborough, Hants, England. 1976. pp40-41.

(OTTO78) L. Ottoson, Establishment of a High Density Terrain Elevation Data Base in Sweden. Proceedings of International Conference on Cartography, Maryland, USA. July/August 1978.

(PARK79) R. Parkins, BIBLE: A Computer Program for Generating Perspective Views of Buildings. ABACUS. Occasional Paper No.75. Dept. of Architecture, Strathclyde University. 1979.

(PAST71) N. Pastore, Selective History of Theories of Visual Perception 1690-1950. Oxford Univeristy Press, England. 1971.

(PERR74) Edited by J Perraton and R Baxter, Models, Evaluations and Information Systems for Planners. Medical and Technical Publishing Company Limited. Lancaster, England. 1974.

(PERR81) D.F. Perry, J.K. Nickerson, E.S. Zobel, An Approach to Assessing Visual Compatibility of Transmission Lines and the Landscape. Paper210-06. In the proceedings of a symposium held in Stockholm 1981. International Conference on Large High Voltage Electric Systems. Published: 112, boulevard Haussmann, 75008 Paris. 1981.

(PETR80) G. Petrie and M. Adam, The Design and Development of a Software-Based Photogrammetric Digitising System. Photogrammetric Record Vol.9. No.56. April 1980.

(PICK72) R.W. Pickford, Psychology and Visual Aesthetics. Hutchinson Educational Ltd. London. 1972.

(PICK81) M.E. Pickering, EIA - who is competent to judge? Consulting Engineer Vol.45. No.2. February 1981. p25-27.

(PIGG79) M. Piggot, A Critical Appraisal of Visual Impact Assessment Techniques in Use in Current Environmental Impact Analysis Practice. MSc. Diploma Dissertation - Heriot Watt University, Edinburgh. September 1979.

(PIRE67) M.H. Pirenne, Vision and the Eye Chapman and Hall Ltd. London. 1967.

(PHIL83) Philips Electronics, Professional Laser Vision. Published by Philips Electronics, Croydon, London. 1983.

(PLAN71) J.A. Plant, The Climate of the Ayr/Kilmarnock/Irvine Region of Ayrshire. Climatological Memorandum 67. Meteorological Office, Edinburgh. 1971.

(PLAN79) Energy and the Built Environment. The Planner. December 1979. p176-177. (Energy and land use in the UK. A. MacLeary) - a review.

(PLAN81a) EIA Directive too Inflexible. Planner News. January 1981. p12.

(PLAN81b) RTPI Urges Adoption of Environmental Assessment. Planner News. June 1981. p1.

(POGA76) A. Pogacnik, Visual-aesthetic Components in the Cybernetics of Urban Planning. Computer Aided Design. Vol.8 No.1. Jan. 1976. p41.

(PORT76) T.Porter and B. Mikellides, Colour for Architecture. Studio Vista, London. 1976.

(PORT79) T. Porter, How Architects Visualize. Studio Vista, London. 1979.

(PRAK77) N. Prak, The Visual Perception of the Built Environment. Delft University Press, Holland. 1977.

(PROS83) Building Not So Fine an Art. (comments on the Ninth Report of the Royal Fine Art Commission for Scotland). Prospect. No.17. Spring 1983. p4.

(PURD80a) C.Purdie, Notes on the Relationship between Grid Size and Elevational Error for Digital Terrain Models in the Computer Program VIEW. Dept. of Architecture, Strathclyde University. 1980.

(PURD80b) C. Purdie, Visualisation of Alternative Pylon lines for the South of Scotland Electricity Board at Torness in East Lothian (Part 2) ABACUS Report: R48. 1980. Department of Architecture, Strathclyde University.

(PURD80c) C. Purdie, Discrepancies between the programs VIEW and BIBLE Dept. of Architecture, Strathclyde University. 1980.

(PURD81) C. Purdie, Visual Impact Studies using BIBLE. ABACUS Occasional Paper no.85. Dept. of Architecture, Strathclyde University. 1981.

(PURD82a) C. Purdie, VIEW and BIBLE, an accuracy study for the South of Scotland Electricity Board. Occasional Paper No. 87. ABACUS Department of Architecture, Strathclyde University. January 1982.

(PURD82b) C. Purdie, Comparison of programs VIEW2 and VIEW2I. Dept. of Architecture, Strathclyde University. 1982.

(PURD82c) C. Purdie, Analysis of Alternative Pylon Lines on the Torness/Dalkeith route by Nunraw Abbey - A Supplementary Report for the South of Scotland Electricity Board. ABACUS Occasional Paper: 088. Dept. of Architecture, Strathclyde University. 1982.

(PURD82d) C. Purdie, Notes on the algorithm used in BIBLE to calculate corrections for Earth's Curvature and Light Refraction. Dept. of Architecture, Strathclyde University. 1982.

(PURD83a) C. Purdie, Accuracy in Computer Aided Visual Impact Analysis. Paper presented at the Greenchips Symposium held by the Institute of Landscape Architecture (Scottish Chapter) at Strathclyde University. 1983.

(PURD83b) C. Purdie, Computer Aided Visual Impact Analysis. Proceedings of International CAD Congress "Datenverarbeitung in der Konstruktion '83".Association of German Engineers. Munich 1983.

(RAMS80) A. Ramsay and E. Young (eds.), Enforcement of Planning Control: Law and Practice. Dept. of Urban and Regional Planning, Strathclyde University. 1980.

(RATL65) F. Ratliff, Mach Bands: Quantitative Studies on Neural Network in the Retina. Holden Day Inc., New York. 1965.

(REDE68) L. Redei, Foundations of Euclidean and Non-Euclidean Geometries. Pergammon Press. Oxford. 1968.

(REED72) F. Reed and J. Drance, The Essentials of Perimetry Oxford University Press. London. 1972.

(RIBA83) ABACUS. RIBA Journal, April 1983, Vol. 90 No.4 p39.

(ROBE75) M. Roberts, Town Planning Techniques. Hutchinson and Co. Ltd. London. 1975.

(ROSE69) A Rosenfeld, Picture Processing by Computer. Academic Press, New York. pp4,5,79-103. 1969.

(ROYA76) Royal Town Planning Institute, Planning and the Future. published by RTPI: London. 1976.

(ROYA80) RIBA Handbook of Architectural Practice and Management. (4th Revised Edition). Royal Institute of British Architects. RIBA Publications Ltd. London. 1980.

(SAMI82) M.L.Samit, Colour Basics for Computer Graphics. Harvard Computer Graphics Week, Harvard University Graduate School of Design, USA. 1982.

(SCOT71) Scottish Development Department, Hunterston - a Preliminary Study. S.D.D., Edinburgh. 1971.

(SCOT74) Scottish Development Department, North Sea Oil and Gas: Coastal Planning Guidelines. Published by the Scottish Development Department, Edinburgh. 1974.

(SCOT76) Scottish Development Department, Environmental Impact Analysis - Scottish Experience 1973-75. published by SDD, Edinburgh. 1976.

(SCOT77) Scottish Development Department, National Planning Guidelines for large Industrial Sites and Rural Conservation. Published by the Scottish Development Department, Edinburgh. 1977.

(SEGA66) M.H. Segall, D.T. Campbell and M.J. Herskovits, The Influence of Culture on Visual Perception. Bobbs Merrill Co., Indianapolis, USA. 1966.

(SHAN48) C.E. Shannon, A Mathematical Theory of Communication. Bell System Technical Journal. Vol.27. p379-423 and 623-656. 1948.

(SHUL77) J. Shulmann, The Photography of Architecture and Design. Architectural Press, London. 1977.

*
(SIMO78) J.O.Simonds, Earthscape. McGraw-Hill Book Company, New York. 1978.

(SIVI79) L. Sivik and A Hard, Colour - Man - Environment. A Swedish Building Research Project. Man Environment Systems, Vol 9 No.4 and 5. p213.

(SMAL61) A. Small, Judged Similarity of Visual Forms as Functions of Selected Stimulus dimensions. Unpublished PhD thesis. Purdue University, USA. 1961.

(SMIT81) P. Smith, A Theory of Aesthetics. RIBA Journal. December 1981. p44.

(SPEI76) J.G. Speight, Description of Landform Patterns on Air Photos Journal of the International Institute for Aerial Survey and Earth Sciences (ITC). July 1976.

(STEA82) D.Stearn, VISTA Visual Impact Simulation Technical Aid. Proceedings of Eurographics '82. p333. North Holland Publishing Company, Amsterdam. 1982.

* See addendum to bibliography

(STEA83) D. Stearn and J. Roos, VISTA User Manual 31. ABACUS Dept. of Architecture, Strathclyde University, Glasgow. 1983.

(STEI74) A.W.Steiss, Models for the Analysis and Planning of Urban Systems. Lexington Books. London. 1974.

(STEN66) H.H.Stenson, The Physical Factor Structure of Random Forms and their Judged Complexity. Perception and Psychophysics. Vol.1. 1966. p303-310.

(STRA72) Strathclyde University, Dept. of Urban and Regional Planning, Hunterston - Le Havre Study. Strathclyde University. 1972.

(SURV81) EEC Draft Directive. Surveyor. Vol.156. No.4630. p16. 12 March 1981.

(SUSS81) H. Sussock, GOAL User Manual. ABACUS: user manual series M26. Dept. of Architecture, Strathclyde University, Glasgow. 1981.

(SUSS82) H. Sussock, J. Roos, BIBLE User Manual II: Version 3.4. ABACUS Dept. of Architecture, Strathclyde University, Glasgow. 1982.

(SUSS83) H. Sussock, Visual Impact Study: Calton Housing, Glasgow. unpublished ABACUS report. February 1983.

(TABO82) P Tabor, Fearful Symmetry. Architectural Review. Vol.171. No.1023. May 1982. p19.

(TAND75) C.R.V. Tandy, The Landscape of Industry. Leonard Hill Books, Aylesbury. 1975.

(TEIC83) E.Teicholz and B. Berry, Computer Graphics and Environmental Planning. Prentice-Hall Inc. Englewood Cliffs, New Jersey, USA. 1983.

(THEI70) P.Theil, Notes on the Description, Scaling, Notation and Scoring of some Perceptual and Cognitive Attributes of the Physical Environment. in "Environmental Psychology". edited by Proshansky et al. Holt/Reinhart Co. publishers. 1970. p593.

(THOM59) D'A.W. Thompson, On Growth and Form. Cambridge University Press, England. p16. 1959.

(THOR83) A. Thorburn, Towards a Better Planning System. Planner News. February 1983. pp4-7.

(TRAN76) Transport, Department of Route location with regard to Environmental Issues. The Jefferson Report. 1976. Discussion Paper 5: Visual Effects.

(TRIC70) R.A.R. Tricker, Introduction to Meteorological Optics. Mills and Boon Ltd., New York. 1970.

(TURN79) M. Turnbull, PERSPX: User Manual. Design Innovations Research, Edinburgh. 1979.

(TURN81a) M. Turnbull, SYMCON: User Manual. Design Innovations Research, Edinburgh. 1981.

(TURN81b) M. Turnbull, SECT: User Manual. Design Innovations Research, Edinburgh. 1981.

(TURN82a) M. Turnbull, VIEW1: User Manual. Design Innovations Research, Edinburgh. 1982.

(TURN82b) M. Turnbull, VIEW2: User Manual. Design Innovations Research, Edinburgh. 1982.

(TURN82c) M. Turnbull, Private communication on 'Dead Ground Analysis' October 1982.

(TURN83) Turnbull Jeffrey Partnership and ABACUS, Hitchin Priory Development: Visual Impact Assessment. Unpublished paper. 1983. Turnbull Jeffrey Partnership, 44 North Castle Street, Edinburgh.

(UHR 66) L. UHR (ed), Pattern Recognition: Theory, Experiment, Computer Simulations, and Dynamic Models of Form Perception and Discovery. John Wiley and Sons Inc., New York. 1966.

(WATH67) W. Wathen-Dunn (ed), Models for the Perception of Speech and Visual Form. Proceedings of a symposium on above. MIT press, Massachusetts, USA. 1967

(WATS78) A.S. Watson, A Riemann Geometric Explanation of the Visual Illusions and Figural After-effects. Part 1, chapter 7 in (LEEU78) page 139. 1978.

(WATT79) Watt Committee on Energy, Energy Development and Land in the United Kingdom. Report No.4. Published by The Watt Committee on Energy Ltd. March 1979.

(WEDD70) A.E. Weddle, Techniques of Landscape Architecture. Heinemann, London. 1970.

(WEIN48) N. Weiner, Cybernetics. Wiley and Co. New York. 1948.

(WEIN66) D.J. Weintraub and E.L. Walker, Perception. Brooks/Cole Publishing Company, Belmont, California. 1966.

(WHIT81) T. Whitelegg, J Gourlay, R. Beaumont, P. Taylor, G. Aylward, M Turnbull, Environmental Assessment Methodology and Computer Aided Design Techniques for the Visual Analysis of Transmission Line Routes. Paper210-11. Proceedings of a Symposium held in Stockholm 1981. International Conference on Large High Voltage Electric Systems. Published: 112 Boulevard Haussmann, 75008 Paris. 1981.

(WOLF74) P. Wolf, Elements of Photogrammetry. McGraw-Hill, New York. 1974.

(YOVI79) M. Yovits (Editor), Advances in Computers. Academic Press New York. Volume 18 p1-55. 1979.

(ZUSN62) L. Zusne and K.M. Michels, Geometricity of Visual Form. Perceptual and Motor Skills. Vol.14 p147-154. 1962.

(ZUSN70) L. Zusne, Visual Perception of Form. Academic Press, New York. 1970.

* (HICK80) M. Hickman. Found in (BARR80)p.76

(SIEG80) P Sieghart. The Big Public Enquiry. Outer Circle Policy Unit, London. 1980.