GRAPHICAL EXCELLENCE IN ENVIRONMENTAL IMPACT STATEMENTS

applying data visualisation principles to environmental impact assessments

A DISSERTATION

by Daniel Garvey

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Project Supervisor: Eamonn Grennan

ABSTRACT

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Planning and development involves balancing potentially conflicting goals. Development control systems attempt to optimise the trade-offs between ecology, economy and society. Environmental impact assessment (EIA) is one of the tools used to improve the way in which decisions to develop are made. EIA is now well established in national and international legislation and declarations, and in policy and practice. As implemented in Ireland, EIA is carried out by statutory planning and licensing authorities, with the assessment based on the information provided in Environmental Impact Statements (EIS). There is scope for improvement in the effectiveness of communication of graphic, text and tabular information, which would benefit the assessment and decision-making process. Data visualisation theory is considered in the context of the prediction of environmental impacts, and the following suggestions are made for best-practice in graphical presentation in EISs:

Use horizontally-oriented histograms to illustrate impact significance.
Compile the predicted impacts in 'small multiples' of histograms.
Use sequential colour schemes.
Avoid tones that cannot be differentiated by colour blind viewers.
Use double-ended colour schemes to encode the adverse-to-beneficial data range.
Use techniques such as 'TableLens' to aggregate and summarise the data.
Illustrate additional characteristics, such as uncertainty, using bullet graphs.

KEY WORDS

Ireland, Environmental Impact Assessment, Graphics, Environmental Impact Statement, Data Visualisation

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSSARY

CEAA

Canadian Environmental Assessment Agency

CEQ

Council for Environmental Quality (USA)

Chartjunk

This term was coined by Edward Tufte. It describes poorly-designed visualisations with unintentional optical-art effects - such as moiré vibration, dominant grid lines or redundant decorative elements.

Competent Authority

[under the EIA Directive] the body or bodies designated by the Member State to perform the duties arising from the EIA Directive

Data Visualisation

These are the techniques used to turn a set of abstract data into visual understanding. Data visualisation also refers to the graphics which result from implementing these techniques.

Effect

[in the context of EIA] any change to the environment that arises as a result of the construction or operation of a proposed development

EIA

Environmental Impact Assessment

EIA Directive

Directive 85/337/EEC as amended by 97/11/EC and 2003/35/EC on the assessment of the environmental effects of those public and private projects which are likely to have significant effects on the environment

EIS

Environmental Impact Statement

EIT

Environmental Impact Tables – a tabular presentation of data summarising the main likely direct and indirect effects of a proposed development, taking into account any agreed mitigation

EPA

Environmental Protection Agency (Ireland)

ES

Environmental Statement – the UK equivalent to the Irish EIS

GIS

Geographical Information System

Glyph

a graphical symbol with an appearance that conveys information

IEEM

Institute of Ecology and Environmental Management

IEMA

Institute of Environmental Management & Assessment

Impact

[in the context of EIA] the consequences for the environment that arise as a result of the construction or operation of a proposed development

Information Visualisation

the use of visual representations of abstract data to amplify cognition and communicate

IPPC

Integrated Pollution Prevention and Control

LI

Landscape Institute

Material Considerations

[in the context of the planning process] the full range of information which may affect a competent authority's decision in relation to a planning application

Multidimensional

having many independent variables clearly identified, and one or more dependent variables associated to them – usually associated with continuous data models

Multivariate

having many dependent variables that may be correlated to each other to varying degrees – usually associated with discrete data models

NRA

National Roads Authority (Ireland)

Scientific Visualisation

a visualisation that typically involves scientific data with a spatial component

Steven's Law

describes the relationship between the actual physical magnitude x and its perceived magnitude p(x)

$P(x) = cx^{\beta}$ β is empirically determined for particular physical quantities.

USEPA

United States Environmental Protection Agency

Visualisation Pipeline

the process of converting information into a visual form that users can assimilate

Visual Language

'The tight integration of words and visual elements' which has characteristics that distinguish it from natural languages as a separate communication tool as well as a distinctive subject of research (Horn 2001 p1)

PREFACE

THE SPELLING OF WORDS

Most of the literature on the subject of data visualisation that has been referred to in this research is written using US English spellings. In a dissertation on this topic there are words that occur frequently, such as 'visualization' and 'color'. In direct quotations and references to the titles of books, papers and reports, these are recorded and quoted as originally written.

THE TITLE OF THIS DISSERTATION

The original title proposed for this dissertation was 'communicating impacts in Environmental Impact Statements'. This title was abandoned because it did not seem possible to eliminate the potential misinterpretations of meaning arising from those words. The essence of that title, however, remains the central theme of the research. Environmental Impact Statements document predicted impacts – and this dissertation examines the scope for optimising the communication of those impacts.

1. INTRODUCTION AND METHODOLOGY

In this chapter, the themes and objective of the study are described. The limitations to the dissertation are outlined, and the research methodology is explained.

1.1 PREAMBLE

The effectiveness of Environmental Impact Assessment (EIA) in protecting the environment depends on the quality of information provided to the decision-making authority. In the Irish planning and development control regime, planning authorities carry out EIA based on Environmental Impact Statements (EIS) and other information prepared for proposed developments. Improvements to the quality of presentation and communication in EISs will enhance the EIA, leading to better-informed decision making and a more robust protection of the environment.

1.2 RESEARCH OBJECTIVE

The objective is to contribute to an improvement in the quality of presentation in Environmental Impact Statements, and in particular the communication of the most significant predicted impacts, so that competent authorities can make properly-informed assessments of proposed developments.

For each of the environmental topics scheduled in the EIA Directive (Directive 85/337/EEC as amended by 97/11/EC and 2003/35/EC), there will be a most suitable way to communicate the findings of an impact study on that topic.

The research concludes with suggestions for best practice in presenting and communicating the findings of environmental impact studies in EISs. The intention is that EIA practitioners will act on these suggestions, and competent authorities will be facilitated in carrying out a robust EIA of proposed developments or activities.

1.3 THE PROCESS OF ENVIRONMENTAL IMPACT ASSESSMENT

Environmental Impact Assessment (EIA) is a process in which the environmental consequences of development actions are examined in advance. The primary emphasis in EIA is prevention.

Article 2 of the EIA Directive states that:
'Member States shall adopt all measures necessary to ensure that, before consent is given, projects likely to have significant effects on the environment by virtue, inter alia, of their nature, size or location are made subject to a requirement for development consent and an assessment with regard to their effects.' (European Economic Community 1985)

The EIA Directive has been implemented in the Irish planning system through the Planning and Development Acts 2000 to 2006, along with other Acts, such as the Roads Act 1993, the Gas Act 1976, as amended, the Waste Management Acts 1996 to 2001, the Protection of the Environment Act 2003, etc., and Regulations deriving from these Acts.

1.4 ENVIRONMENTAL IMPACT STATEMENTS

Environmental Impact Statements arise from a study by a developer of the likely impacts of a proposed development on the environment. The findings of the study are compiled in a document called an Environmental Impact Statement (EIS). The EIS (along with other application documentation, objections, observations, appeals and material considerations) is considered by the competent authority, who decides to permit or refuse the development or activity on the basis of the information available.

Development proposals to which the EIA Directive applies have the potential to significantly affect the environment. To implement the Directive effectively, the decision to permit a development or activity must be made with due regard to the likely significant impacts. This research will provide a theoretical support for informing competent authorities in their decisions. No such support is currently available.

Although improving communication with competent authorities is the central objective for carrying out this research, the applications of best practice in data visualisation will also benefit public participation in EIA, by allowing interested parties to assimilate the important issues quickly.

The recommendations that will arise from this study will be relevant to all parties involved in EIA. These include:

environmental and planning consultants who compile EISs
environmental, social science and engineering specialists who carry out specialist impact assessments
competent authorities, including planning authorities, the EPA, An Bord Pleanála, and government departments
developers and clients who commission the preparation of EISs
members of the public with an interest in proposed developments or activities.

1.5 GRAPHICAL EXCELLENCE

Edward Tufte defines 'graphical excellence' in the following terms:
'Graphical excellence is the well-designed presentation of interesting data – a matter of substance, of statistics, and of design. Graphical excellence consists of complex ideas communicated with clarity, precision and efficiency. Graphical excellence is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space. Graphical excellence is nearly always multivariate. And graphical excellence requires telling the truth about the data.' (Tufte 1983 p52)

Applying these principles to the contents of Environmental Impact Statements in a structured way will improve the quality of decision making in the planning process, and ultimately serve to protect the environment.

There is a wide range of presentation methods employed to communicate the findings of impact studies. The methods include text descriptions, tables of data, matrices of data, and different types of maps, graphs and charts. In his *Semiology of Graphics* (1967) Jacques Bertin puts data visualisation in the context of decision-making: *'A graphic is not "drawn" once and for all; it is "constructed" and reconstructed until it reveals all the relationships constituted by the interplay of the data.... A graphic is never an end in itself; it is a moment in the process of decision-making.'* (Bertin 1967 p16)

A review of current legislation and guidance on preparing EISs shows that there is no comprehensive analysis of what are the most appropriate and effective means of communicating the various dimensions of predicted environmental impacts.

1.6 THE STRUCTURE OF THIS DISSERTATION

Chapter 1 introduces the study, states the research objectives, and describes the methodology that has been used.

Chapter 2 is a review of EIA in the context of European and National legislation, and in the context of the published guidance available for preparing Environmental Impact Statements.

Chapter 3 describes the contents of an EIS in detail.

In Chapter 4, the principles of data visualisation are outlined, and

Chapter 5 summarises some relevant data visualisation techniques.

Best practice in data visualisation or 'graphical excellence' is described in Chapter 6, and this is followed in

Chapter 7 with the findings of the questionnaire and EIS review research. The dissertation concludes with

Chapter 8, which discusses the research findings in the context of the literature reviewed.

1.7 THE LIMITATIONS OF THIS STUDY

A questionnaire survey was carried out, but it was limited to senior planning officials. There are also others who use EISs, such as inspectors in An Bord Pleanála, the EPA, the HSA, the general public, and governmental licensing authorities, who may also have useful opinions on EISs.

The list of impacts is limited to project types that have been proposed in Ireland (refer to **Appendix 1**). For example 'drilling for the purpose of storage of nuclear waste material' is scheduled in the Regulations, but no records of planning applications for this project type were encountered.

The questionnaire respondents raised a range of issues, some of which are outside the scope of this research, and there is an opportunity here for further work on the impact prediction activity itself.

The use of visualisation techniques in landscape and visual assessment is much more developed than in relation to other aspects of the environment, and significant research has already been done in the area (for example, see Prendergast and Rybaczuk 2005). This study's focus is on the nature of predicted environmental impacts across all aspects, and does not pursue the specialist areas of photomontage preparation and 3D modelling further.

Geographical and spatial attributes of environmental impact have been examined in detail in the geographical information systems (GIS) and cartography literature, so the research already carried out by *inter alia* MacEachren et al (1998, 1999), Slocum (1998), and Kraak (1998) has not been duplicated in this research.

1.8 METHODOLOGY

The literature and theories of information communication were reviewed, a questionnaire survey was administered and analysed, and a sample of current practice in Environmental Impact Statements was examined. Presentation options for impacts associated with environmental topics were considered, and in the light of those options, the scope for developing a consistent presentation methodology for environmental impacts was evaluated.

The characteristics of predicted impacts associated with each of the aspects scheduled in the Environmental Impact Assessment Directive (85/337/EEC, as amended by 97/11/EC and 2003/35/EC) were considered. The principles of graphical excellence were applied in communicating the assessment findings, with particular reference to visual explanation. The literature reviewed was selected with this particular aim in mind.

As defined in the Planning and Development Acts 2000 to 2006, the competent authority for Environmental Impact Assessment is the Planning Authority. The planners within these authorities recommend permission or refusal on the basis of the planning documentation and drawings, submissions from the public, and other relevant information. The time available to planning officials to consider the information is limited, so any improvement that can be made in communicating the most important issues within that time will benefit the decision-making process. Often, the predicted environmental impacts arising from a development will be of primary interest, and proposals for best practice in the graphical presentation of these have been suggested.

1.9 QUESTIONNAIRES

Survey Field

In most cases planning authorities are the city or county council for a given administrative area. They are structured in such a way that the planning department assesses development proposals and recommends planning permission, refusal, permission with conditions, or requests further information. This assessment is based on the planning documentation submitted, observations or objections by members of the public, and other material considerations. The planning department's recommendation is provided to the local authority manager, and a decision is made on the planning application.

A list of city and county councils was complied, with the names, addresses, email addresses and telephone numbers of senior planning officers in each case. The planning authorities surveyed are listed in **Table 1.1**.

Drafting and Administering the Questionnaire

The key information that was elicited is what the competent authority considers to be good practice in presentation and graphics, and what causes them most difficulty. The 16 questions were a combination of open and closed, with an opportunity at the end to add further comments or

Table 1.1 Planning Authorities Surveyed

Carlow
Cavan
Clare
Cork City
Cork County
Donegal
Dublin City
Dun Laoghaire – Rathdown
Fingal
Galway County
Galway City
Kerry
Kildare
Kilkenny
Laois
Leitrim
Limerick County
Limerick City
Longford
Louth
Mayo
Meath
Monaghan
North Tipperary
Offaly
Roscommon
Sligo
South Dublin
South Tipperary
Waterford City
Waterford County
Westmeath
Wexford
Wicklow

volunteer for further discussion.

A pilot survey was carried out first. Draft questionnaires were sent to a volunteer pool of ten recipients on Friday 8 February 2008. On the basis of responses received minor revisions were made to the wording, presentation and order of questions in the draft questionnaire.

Copies of the questionnaires were posted to individual planning officers in each authority on Tuesday 26 February 2008. This was followed two days later with an email, attaching electronic copies of the same questionnaire. In addition to these, questionnaires were sent to five practitioners known personally to the author, each of whom is experienced in preparing and reviewing EISs.

In total, 20 completed questionnaires were returned. The replies are summarised and analysed in Chapter 7, Current Environmental Impact Statement Practice.

The format and questions included in the questionnaire are indicated in **Table 1.2** overleaf. The electronic copies that were attached to the emails were provided in both Adobe Acrobat 'pdf' format, and in Microsoft Word 'doc' format.

Table 1.2 Questionnaire – **graphical excellence in environmental impact statements**

Please highlight or tick the response that most closely reflects your opinion or experience.

1	On average, how **frequently** do you encounter Environmental Impact Statements (EISs) in planning applications?	rarely or never			
		more than once per year, but less than once per month			
		more than once per month, but less than once per week			
		more than once per week			
2	On average, how much **time** do you spend reading or analysing an EIS?	less than an hour			
		between one and two hours			
		between two and four hours			
		between four and eight hours			
		more than eight hours			
3	On average, please state how much of that time you spend on **each part** of an EIS, as a percentage.	non-technical summary	main text, including summary of impacts	technical appendices	
4	Do you find it easy to **locate** the information you require within EISs?	yes	usually	not usually	no
5	Which EIS **structure** do you find is clearest and easiest to use?	direct format (separate descriptions of proposed development, existing environment, impacts and mitigation measures)	grouped format (each environmental topic, such as flora and fauna, is considered in a separate section)		
6	Please describe here any **improvements** that could be made to the **structure** of EISs, to make them clearer and more user-friendly.				
7	In your experience, what **topics** generally receive inadequate attention in EISs?				
8	Please describe here the best example of **graphic presentation** you have encountered in an EIS.				
9	Please give an example of an EIS (if any) that has impressed you with its **clarity and user-friendliness**.				
10	Please describe the **characteristics** you would expect a **clear and user-friendly** EIS to have?				
11	Do you prefer the **non-technical summary** to be a **separate** volume?	yes	usually	not usually	no
12	Which **format** do you prefer for EISs?	paper	electronic		
13	Are predicted significant impacts **clearly presented** in EISs?	yes	usually	not usually	no
14	Please describe what you consider to be the **qualities** of a good **summary of predicted impacts**?				
15	Please give an example of something that has **annoyed or frustrated** you in the **presentation or structure** of an EIS.				
16	Are you happy with the **EPA-recommended descriptions** for impacts (5 levels, from imperceptible to profound)?	yes	no (if 'no', please suggest an improved format)		

Thank you for your time. Please email the completed questionnaire to Dan Garvey comhshaol@gmail.com In the light of the responses received to this questionnaire, I may carry out follow-up survey and discussions, if time and resources permit. If you would be willing to participate, or would like to elaborate on any of your responses in this questionnaire, please let me know.

1.10 REVIEW OF DATA VISUALISATION LITERATURE

A significant component of the research for this study was the review of data visualisation literature relevant to environmental impact assessment. Other applicable literature included existing guidance and advice notes for EIA and EISs as published by the Environmental Protection Agency, the Institute of Environmental Impact Assessment, the Landscape Institute, the National Roads Authority and others.

1.11 REVIEW OF CURRENT EIS PRACTICE

A survey of the Irish Environmental Protection Agency (EPA) website in January 2008 revealed that the full contents of more than 50 EISs are available online. These EISs are associated with Integrated Pollution Prevention and Control Licence and Waste Licence applications. These were chosen as the primary survey field – reflecting as they do current practice in the presentation of environmental impacts. Because they are associated with licence applications, they could reasonably be considered to represent larger, more complex, and potentially significant projects.

The EPA website was used as the source of EISs from 28 different consultancy firms. Sampling a range of practitioners was considered most appropriate because it was assumed that the approach and presentation techniques will vary more widely across the different consultants than across EISs for different projects prepared by the same consultant. This assumption was found to be reasonable, as a number of samples of different EISs prepared by the bigger consultancies were viewed during the data-gathering phase of the study.

The environmental topics in **Table 1.3** (as scheduled in the Planning and Development Acts 2001 to 2006) were considered in relation to how predicted impacts are described in the sample EISs.

Table 1.3 Environmental Topics as Scheduled in the Planning and Development Acts 2001 to 2006

human beings
flora and fauna
soil
water
air
climatic factors
the landscape
material assets including the architectural and archaeological heritage, and the cultural heritage
the inter-relationship between the above factors.

The research focused specifically on that part of EISs where the nature of predicted impacts is described. Methodologies for impact assessment were excluded. If the 'grouped' format has been used in the EIS – where each environmental topic is covered in turn – then the predicted impacts are typically presented towards the end of the particular chapter, sometimes repeated in a 'summary of impacts' chapter, and further summarised in a non-technical summary. The sample covered a range of project types (as defined in Schedule 6 of the Regulations (SI 600 of 2001)), and reflects the graphical approaches of the various authors.

Only the sections relating to the presentation of predicted impacts were reviewed in detail in the published guidance on EIA.

Research into decision and data visualisation science was sufficiently comprehensive to provide a theoretical justification for the selection of appropriate communication methods.

1.12 CONCLUSION

Based on this review, suggestions were made for improvements to the communication of environmental impacts in EISs.

2. LEGISLATION AND GUIDANCE ON EIA

In this chapter the legislative context and published guidance for environmental impact assessment is reviewed. Literature of particular relevance to the objectives of this study is highlighted where appropriate.

2.1 EUROPEAN AND NATIONAL LEGISLATION

The EIA Directive (85/337/EEC as amended by 97/11/EC and 2003/35/EC on the assessment of the effects of certain public and private projects on the environment) is fundamental to current practice in the preparation of Environmental Impact Statements. The EIA Directive is implemented in Ireland through the Planning and Development Acts 2000 to 2006, and the implementing regulations, in particular the Planning and Development Regulations 2001 (SI 600 of 2001).

2.2 GENERAL AND SECTORAL GUIDANCE

An early technical guide for EIA was *Environmental Impact Assessment a Technical Approach* (Bradley K, Skehan C and Walsh G eds. 1991). More recent technical guidance is provided in Morris P and Therivel R (eds.) *Methods of Environmental Impact Assessment: Second Edition* (Morris P and Therivel R (eds.) 2004). This is a companion volume to *Introduction to Environmental Impact Assessment: Second Edition* (Glasson J, Therivel R and Chadwick A 2005).

The (UK) Department of the Environment, Transport and the Regions published a *Review of Technical Guidance on Environmental Appraisal* (DETR 1998). This presents EIA in the wider context of other environmental appraisal techniques, such as life cycle analysis, strategic environmental assessment, comparative risk assessment, risk benefit analysis, health-health analysis, risk-risk analysis, multi-criteria analysis, cost effectiveness analysis and cost benefit analysis.

John Fry of University College Dublin published a *Cumulative Review of Environmental Impact Assessment in Ireland* (Fry 2000) which is a useful summary of the state of EIA in Ireland at the turn of the millennium. The Environmental Protection Agency in Ireland has published *Advice Notes on Current Practice (in the preparation of Environmental Impact Statements)*

(CAAS 2003), and *Guidelines on the Information to Be Contained in Environmental Impact Statements* (CAAS 2002). The *Guidelines* were previously published as *Draft Guidelines* in 1995, and the *Advice Notes* were revised from *Draft Advice Notes* in 1994. These EPA publications are fundamentally important as they derive from Section 72 of the Environmental Protection Agency Act 1992, which provide for the preparation by the EPA of guidelines on the information to be contained in an EIS, and therefore have a quasi-statutory basis. The Advice Notes provide a 'glossary of impacts' (CAAS 2003 p139), which are widely referred-to in EISs. Quality, significance, duration and types of impact are considered. The EPA Act 1992 also states that those preparing and evaluating EISs shall have regard to such guidelines.

The Irish National Roads Authority (NRA) has also developed a suite of guidance documents for environmental assessment. This includes the following publications, which are available on the NRA website (NRA 2008).

Environmental Impact Assessment of National Road Schemes – A Practical Guide
A Guide to Landscape Treatments for National Road Schemes in Ireland
Guidelines for the Assessment of Archaeological Heritage Impacts of National Road Schemes
Guidelines for the Assessment of Architectural Heritage Impacts of National Road Schemes
Guidelines for the Assessment of Ecological Impact of National Road Schemes
Best Practice Guidelines for the Conservation of Bats in the Planning of National Road Schemes
Guidelines for the Treatment of Air Quality during the Planning and Construction of National Road Schemes
Guidelines for the Treatment of Noise and Vibration in National Road Schemes

The quality of EISs has improved over time. The Impact Assessment Unit (IAU) in the School of Planning, Oxford Brookes University (IAU 1996) found that although quality is improving, between one third and one half of 50 sample environmental statements were still unsatisfactory and, in several cases, poor. One particularly relevant finding of the IAU study was '*... many ESs were poor in terms of effective communication and accessibility to relevant audiences*' (IAU 1996 p52).

The *Design Manual for Roads and Bridges Guidance for Environmental Assessment* (The Highways Agency et al. 2007) describes the concept of 'environmental impact tables' (EIT). These are a tabular presentation of data summarising the main likely direct and indirect effects of a proposed development, taking account any agreed mitigation.

The Scottish Executive *Planning Advice Note 58 Environmental Impact Assessment* (1999) includes the following 'checklist of quality indicators':

Does the statement report on a systematic approach to the gathering and analysis of information?
Does it contain the information specified in Schedule 4 of the Regulations?
Is the information presented in a clear, comprehensive and objective manner?
Is there a relatively concise main report which draws on the technical studies and summarises them as necessary?
Is there sufficient cross-referencing for the reader to make the links between the NTS, the main report, appendices, and any separate studies?
Is the space devoted to environmental issues commensurate with their potential impacts, and are those issues with insignificant impacts identified?
Are mitigation measures presented as a hierarchy?
Are mitigation (and restoration) measures described in sufficient detail and timetabled?
Does it state the means by which monitoring will be carried out?
Are the methods by which the analysis was carried out and the ES prepared explained, and are the credentials of the experts involved stated?
Is the development plan context for the project set out?
Are detailed technical studies contained in appendices?
Are links to other consent regimes clearly indicated?
Is the Non-technical Summary a summary in every-day language?

[source: Scottish Executive 1999 p26]

Scottish Natural Heritage provides specific guidance on presentation in environmental statements, in *A Handbook on Environmental Impact Statements* (Scottish Natural Heritage 2005 p90), as follows:

Environmental Statements should be:

adequate for the purpose but succinct and not over-detailed;

clear and understandable;

consistent in content and presentation across issues;

well, but not lavishly, presented with the effective use of maps, diagrams, charts, drawings, illustrations, photographs, sketches, photo montages, tables and matrices to reduce text and explain complex issues and with summaries and key conclusions highlighted;

scientifically sound, but with the minimum use of scientific and technical language, with glossaries and the use of common names for species and an annexe for scientific nomenclature wherever possible;

inclusive of source data to allow readers to interpret this for themselves but with detailed information in appendices or separate volumes to avoid cluttering the main text of the assessment;

logical in its structure, presenting a clear description of the project, baseline information, prediction of effects and their significance, before mitigation measures, and then describing the mitigation measures and the residual effects of the project (including their significance) taking mitigation into account;

free standing and not reliant on key information in another document especially if that document is not publicly available;

based wherever possible on standard methods or standard forms of presentation that will be familiar at least to other specialists or professionals advising the Competent Authority.

[source: Scottish Natural Heritage 2005 p90]

The Scottish Executive has published an EIA template (2007), which includes summary tables. These consider the nature of each predicted impact – as frequency, reversibility, probability, duration, direct, indirect, secondary/ induced, short medium or long-term, permanent or temporary, positive or negative and cumulative. Under each of these characteristics of the impact, a discussion and quantification is required (where possible). Following this discussion, a score of high, medium or low is applied to the magnitude of impact. This approach usefully summarises the process of arriving at the severity of predicted impacts, but differs from the EPA guidance in only considering three levels of magnitude.

The UK Department of the Environment *Good Practice Guide to Preparing Environmental Statements* (UK DOE 1996) includes the following example summary table for a selection of key issues (**Table 2.1**). In this case, only two levels of significance are indicated, either 'major' or 'minor'.

Table 2.1 UK Department of the Environment Summary Table

Topic Area	Description of Impact	Geographical Level of Issue Importance					Impact	Nature	Significance	Mitigation Measure
		I	N	R	D	L				
Human Beings	Disturbance to Existing Properties from Traffic and Noise				*		Adverse	St, R	Major	Provision of double glazing for affected properties
	Coalescence of Existing Settlements			*			Adverse	Lt, IR	Major	Additional Screen Planting
Flora and Fauna	Loss of grassland of local nature conservation value					*	Adverse	Lt, IR	Minor	Creation of New Habitats
	Creation of new habitats					*	Beneficial	Lt, R	Minor	[none]
	Increased recreation pressure on SSSI		*				Adverse	Lt, IR	Minor	Provision of Ranger Service for SSSI
Soils and Geology	Loss of 100ha agriculture soils			*			Adverse	Lt, IR	Minor	None Proposed

Table 2.1 UK Department of the Environment Summary Table

Topic Area	Description of Impact	Geographical Level of Issue Importance					Impact	Nature	Significance	Mitigation Measure
		I	N	R	D	L				
Water	Increased rates of surface water run-off				*		Adverse	Lt, IR	Minor	Use porous material for parking areas
	Reduction in groundwater discharge			*			Adverse	Lt, R	Minor	[none]
Key:		I=International N=National R=Regional D=District L=Local					St=Short term Lt=Long term R=Reversible IR=Irreversible			

The US EPA (US EPA 2002) provides guidelines for developing and using data visualisation tools. The key recommendations in this document are:

Use data visualisation as much as possible, and minimise the use of lengthy text.
When using text, use language that is appropriate for your audience.
Use universal colours or images whenever possible.

The Department of Environment Affairs and Tourism in South Africa has a concise guide to the presentation of Environmental Impact Reports, which are their equivalent to the EIS (DEAT 2004). Of particular interest to this study is the following excerpt:

EIRs should ideally contain minimal written text and liberal use of visual display material. The use of this material is valuable where words won't suffice, where the information would be faster and easier understood in graphic or picture form, and/or where it can serve to highlight or emphasise important points. Charts, graphs, drawings, photographs or tables can be used; photographs can supply more realism than drawings or diagrams. All visual display material should be clearly and simply labelled, numbered sequentially within each chapter of the EIR, and footnotes used for extensive explanations of data or headings.

(DEAT 2004 p13)

2.3 OTHER PUBLISHED GUIDANCE

Other published guidance which was reviewed, but which did not contribute any further insight or guidance in relation to presentation of data in EISs included *Flood and Coastal Defence Project Appraisal Guidance – Environmental Appraisal* (Ministry of Agriculture, Fisheries and Food 2000), *Environmental Assessment: Good Practice* (Petts J ed. 1996), *International Study of the Effectiveness of Environmental Assessment* (Sadler B 1996), *Environmental Impact Assessment:: Planning Practice Standard* (RTPI 2001), *Evaluation of the Performance of the EIA Process* (Wood C et al. 1996), *Sustainable Measures – Evaluation and Reporting of Environmental and Social Performance* (Bennett M and James P eds. 1999), *Guidelines for Ecological Impact Assessment in the United Kingdom* (IEEM 2006), *Environmental Assessment Outlook, Capacity Building and Benchmarking Good Practice* (IEMA 2003), *Guidelines for Landscape and Visual Impact Assessment* (LI with IEMA 2002), *Guidelines for Environmental Impact Assessment* (IEMA 2004), *Environmental Assessment – Special Publication 96* (CIRIA 1994); four publications by the UK Department for Communities and Local Government: *Environmental Impact Assessment Guidance – Circular 2-99* (1999), *EIA A Guide to Procedures* (2000), *Amended Circular on EIA* (2006), and *Circular on EIA Good Practice Guide* (2006). There is also a series of EU guidance documents, covering scoping, screening, EIA review and cumulative and indirect impacts (ERM 2001a, 2001b, 2001c; EC 1999).

3. ENVIRONMENTAL IMPACT STATEMENTS IN THE EIA PROCESS

This chapter presents the context in which Environmental Impact Statements are prepared. The role of the competent authority in carrying out EIA is explained, and the legal requirements for the contents of an EIS are referred to.

3.1 INTRODUCTION

Environmental Impact Assessment (EIA) is the systematic examination of the likely impacts of development proposals on the environment. The term derives from section 102 (2) of the National Environmental Policy Act (NEPA) of 1969 in the United States of America. Further regulations were published in the US by the Council for Environmental Quality (CEQ) in 1973, 1978 and 1986. The primary emphasis in EIA is prevention.

3.2 EIA PRINCIPLES

In principle, EIA should apply to all actions likely to have a significant environmental effect. The potential scope of a comprehensive EIA system is considerable and may include the appraisal of policies, plans, programmes and specific projects.

The Environmental Impact Statement (EIS) looks at all the potential significant positive and negative effects of a particular project on the environment. This report is just one component of the information required to aid decision makers in making their ultimate choices about a project.

EIA can be considered as a mechanism which maximises the efficient use of natural and human resources. It can also reduce costs and time taken to reach a decision by ensuring that subjectivity and duplication of effort are minimised, as well as identifying and attempting to evaluate the primary and secondary consequences which might require the introduction of expensive pollution control equipment or compensation and other costs at a later date.

3.3 THE EIA PROCESS

The process involves discrete steps, as indicated in **Figure 3.1** (adapted from Ewing 2003). There may be cyclical feedback and interaction between the steps. Not all steps may be required, and the order of the steps may vary. Starting from a project concept, the following steps are usually taken.

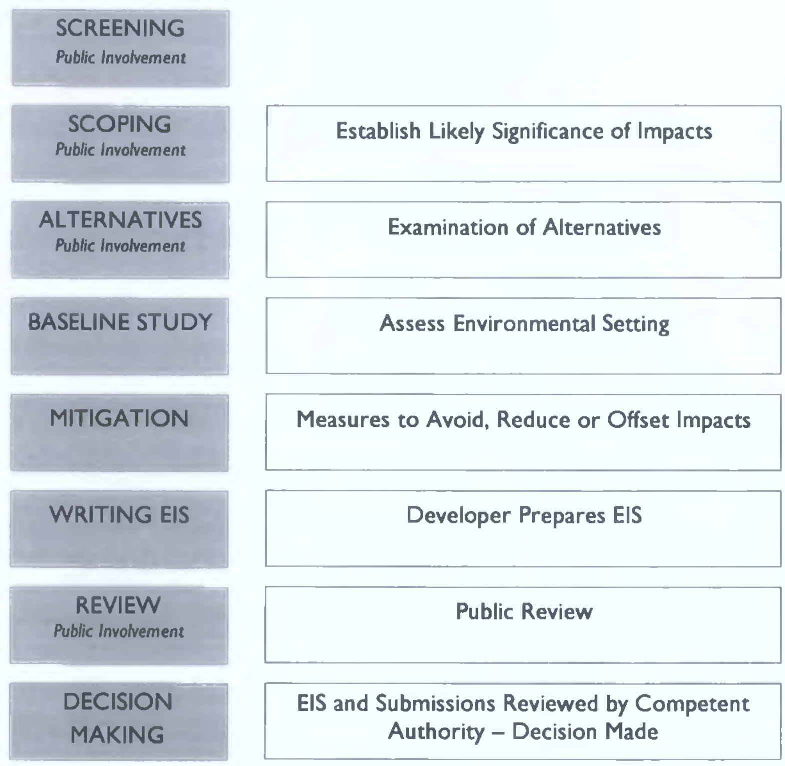

Figure 3.1 Typical Steps in the EIA Process

Project Screening

The objective of screening is to limit the application of EIA to developments or activities that may have significant environmental impacts.

Scoping

This involves identifying the most significant issues, of all the possible impacts, and of all the alternatives addressed. The Planning and Development Regulations 2001 (SI 600 of 2001) outline a formal mechanism for planning authorities or An Bord Pleanála to provide a written opinion on the information to be contained in an EIS.

Alternatives Considered

Feasible alternative locations, scales, processes, layouts, operating conditions, and a no-development option are outlined. The 2001 Regulations imply that only the alternatives that were considered by the developer should be described.

Scheme Description

The purpose and rationale of the proposed development is explained here. The physical attributes and the qualities of the scheme that have the potential to give rise to environmental impacts are described in sufficient detail.

Description of Environmental Baseline

This includes both the present and future state of the environment, in the absence of the project, considering changes that will occur as a result of natural processes and non-project human activities.

Identification and Prediction of Main Impacts

Drawing from the previous steps, all potentially significant impacts are identified. The magnitude and other dimensions of changes to the environment arising from the proposed development or activity are systematically identified.

Evaluation and Assessment of Significance

The relative significance of predicted impacts is assessed to allow a focus on the main adverse impacts. Beneficial impacts are also assessed, to facilitate a balanced consideration of all the main predicted impacts.

Mitigation

Measures are described to avoid, reduce, remedy or compensate for adverse impacts.

Public Consultation and Participation

The input of the public is necessary at appropriate stages in EIA, to ensure that their views are adequately taken into consideration in the decision-making process.

Decision-making

The competent authority considers the EIS, consultation responses and other material considerations, in deciding whether or not to permit the proposed development.

Post-decision Monitoring and Auditing

If post-decision monitoring is carried out, the outcomes associated with development impacts are recorded. An audit may be carried out to compare actual outcomes with predicted outcomes. This is used to assess the quality of predictions and the effectiveness of mitigation, and may guide future decision-making and recommended mitigation measures.

3.4 EIA IN IRELAND

The competent authority decides whether or not to permit or consent to the proposed development or activity. As defined in the EIA Directive, it is the competent authority (typically a planning authority, An Bord Pleanála, a Government Department, or the Environmental Protection Agency) that also actually carries out the Environmental Impact Assessment. Arising from this assessment, there is a risk of decision-makers not understanding or interpreting an EIS correctly, and consequently not making a properly informed assessment. The potentially weak link in the process which this dissertation addresses is the quality of communication of impacts in EISs.

Ireland has had a form of EIA since 1963 but more specifically since the 1976 Local Government (Planning and Development) Act. The 1976 Act specified that environmental studies should be carried out where a project was polluting, or likely to cause pollution, and where the project cost was in excess of 5 million pounds.

However, the studies were not mandatory, nor were they required at all for public developments. In addition there was an absence of a clear definition of the environment. The threshold criteria were also subject to criticism on the basis that the development had to satisfy both simultaneously. In other words a project costing less than 5 million pounds would not be required to have such a study carried out even if it was polluting.

EC Directive 85/337/EEC came into force in Ireland on 3 July 1988. The European Communities (Environmental Impact Assessment) (Motorways) Regulations, 1988 gave effect to the Directive for motorway projects. The European Communities (Environmental Impact Assessment) Regulations, 1989 provided for the incorporation of the Directive into Irish law. The EIA requirements associated with planning applications were subsequently consolidated in the Planning and Development Acts 2000 to 2006. The 2000 Act was implemented in the Planning and Development Regulations 2001 (SI 600 of 2001). These Regulations (and subsequent amendments) describe the scope and procedure for the preparation of EISs in the Irish planning and development control system. Other development consent systems, covering, for example, roads/motorway construction, foreshore development, light rail systems and the laying of gas pipelines have analogous requirements for EIA.

3.5 INFORMATION TO BE CONTAINED IN AN EIS

The Planning and Development Regulations 2001 (SI 600) substantially implemented the Planning and Development Act 2000. These Regulations are the current Irish legislative requirements for the information to be contained in an EIS. Schedule 6 under Article 94 of the Regulations summarises this information, as indicated in **Table 3.1**.

Table 3.1 Schedule 6 to SI 600 of 2001

1. (a) A description of the proposed development comprising information on the site, design and size of the proposed development.

(b) A description of the measures envisaged in order to avoid, reduce and, if possible, remedy significant adverse effects.

(c) The data required to identify and assess the main effects which the proposed development is likely to have on the environment.

(d) An outline of the main alternatives studied by the developer and an indication of the main reasons for his or her choice, taking into account the effects on the environment.

2. Further information, by way of explanation or amplification of the information referred to in paragraph 1, on the following matters:-

(a) (i) a description of the physical characteristics of the whole proposed development and the land-use requirements during the construction and operational phases;

(ii) a description of the main characteristics of the production processes, for instance, nature and quantity of the materials used;

(iii) an estimate, by type and quantity, of expected residues and emissions (including water, air and soil pollution, noise, vibration, light, heat and radiation) resulting from the operation of the proposed development;

(b) a description of the aspects of the environment likely to be significantly affected by the proposed development, including in particular:

- human beings, fauna and flora,
- soil, water, air, climatic factors and the landscape,

Table 3.1 Schedule 6 to SI 600 of 2001

- material assets, including the architectural and archaeological heritage, and the cultural heritage,
- the inter-relationship between the above factors;

(c) a description of the likely significant effects (including direct, indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative) of the proposed development on the environment resulting from:

- the existence of the proposed development,
- the use of natural resources,
- the emission of pollutants, the creation of nuisances and the elimination of waste,

and a description of the forecasting methods used to assess the effects on the environment;

(d) an indication of any difficulties (technical deficiencies or lack of know-how) encountered by the developer in compiling the required information.

In addition, a non-technical summary must be included.

3.6 LIST OF ENVIRONMENTAL IMPACTS

The EIA Directive lists the aspects of the environment that must be considered in the EIA process. These are repeated in slightly different forms in the legislation, policy documents and guidance deriving from the Directive. The most relevant list for this study is the schedules included in the EIA Act and Regulations, and the Planning and Development Acts 2000 to 2006 and Regulations – particularly SI 600 of 2001; refer to **Table 3.1**.

3.7 IMPACT TYPES

The EPA *Advice Notes* (CAAS 2003) provide a list of impact types under headings for each of the environmental topics listed in the 2001 Regulations. An example of this is provided in **Table 3.2** overleaf, in relation to human beings, and the full list is provided in **Appendix 1**. Boxed text is directly quoted from the Advice Notes. The detailed guidance provided on the specific project types as described in the Notes is then summarised, and impact types encountered in the review of sample EISs are included, where these are not covered in the Advice Notes.

Table 3.2 EPA Impact Types - Human Beings

number, population, type and location of persons or communities affected
changes in overall population and their activities
changes in patterns of employment, land use and economic activity
consequences of change, referring to indirect, secondary and cumulative impacts
potential for interaction with other impacts
worst case for human beings if all mitigation measures fail
Typical significant impacts listed in the Advice Notes relate to:
Employment
Accommodation
Power generation
Pollution impacts (noise, dust or other emissions)
Leakage hazard through accident or external event (eg earthquake)
Cross-site transfers of radioactive waste
Fire hazard or explosion hazard
Dust and air emission effects on health
Health impacts to workers and the general population
Light nuisance.

(CAAS 2003)

3.8 ANALYSIS OF IMPACT TYPES

Predicted impacts should be assessed under three headings:
direct/ primary impacts – as a direct result of a development
indirect / secondary impacts – 'knock-on' effects of direct impacts – often produced in other locations or as a result of a complex pathway
cumulative impacts – accruing over time and space from a number of developments or activities, and to which a new development may contribute.

An additional possibility is impact interactions, either between different impacts of a project - or between these and impacts of other projects - that result in one or more additional impacts. All impacts may be beneficial or adverse, short, medium or long term, reversible or irreversible, and permanent or temporary. The assessment of the magnitude of an impact may be qualitative or quantitative, and will be categorised as negligible, slight, moderate, significant or profound.

Rossouw (2003) provides examples of definitions or interpretations of the concept of 'significance', as outlined in **Table 3.3**. The details of interpretation are not particularly relevant to this dissertation, but it is of interest that it is a contested and anthropocentric concept. Different stakeholders have substantially different views on what comprises a significant impact. The comment received in one of the completed questionnaires (see **Section 7.3**) [EPA recommended descriptions for impacts] *'mean nothing to the public and [are] very subjective. Each situation has to have some localised relativity placed on it, ie % traffic increase, visual models, etc'*, supports this view.

Table 3.3 Sample Interpretations of 'Significance' in EIA

Source	Definition or Interpretation
Haug et al. (1984)	Determining significance is ultimately a judgement call. The significance of a particular issue is determined by a threshold of concern, a priority of that concern, and a probability that a potential environmental impact may cross the threshold of concern.
Duinker and Beanlands (1986)	Significance of environmental impacts is centred on the effects of human activities and involves a value judgement by society of the significance or importance of these effects. Such judgements, often based on social and economic criteria, reflect the political reality of impact assessment in which significance is translated into public acceptability and desirability.
Council on Environmental Quality (1987)	The United States' National Environmental Policy Act requires significance to be determined within the framework of context and intensity. *Context:* The significance of an action must be analysed in several contexts such as society as a whole, the affected region, the affected interests, and the locality. *Intensity:* This refers to the severity of impact.
Thompson (1988, 1990)	The significance of an impact is an expression of the cost or value of an impact to society. The focus of EIA must be a judgement as to whether or not impacts are significant, based upon the value-judgements of society, or groups of people chosen to represent the wishes of society.

Table 3.3 Sample Interpretations of 'Significance' in EIA

Source	Definition or Interpretation
Canter and Canty (1993)	Significance can be considered on three levels: (1) significant and not mitigatible, (2) significant but mitigatible, and (3) insignificant. Significance is sometimes based on professional judgement, executive authority, the importance of the project/issue, sensitivity of the project/issue, and context, or by the controversy raised.
US Environmental Protection Agency (1993)	Determination of significance requires predicting change. These impact predictions are along with societal values, the major input to significance determination. Ideally, change should be compared against thresholds of concern, some of which may be legally mandated and others, which may be levels or states of valued components determined by the public, authorities or the EIA team.
Sadler (1996)	The evaluation of significance is subjective, contingent upon values, and dependent upon the environmental and community context. Scientific disciplinary and professional perspectives frame evaluations of significance. Scientists therefore evaluate significance differently from one another and from local communities.
Sippe (1999)	Environmental significance is an anthropocentric concept, which uses judgement and values to the same or greater extent than science-based criteria and standards. The degree of significance depends upon the nature (i.e. type, magnitude, intensity, etc.) of impacts and the importance communities place on them.

[Source: Rossouw 2003]

The EPA's definition of a significant impact is 'an impact which, by its character, magnitude, duration or intensity alters a sensitive aspect of the environment' (CAAS 2003).

The Canadian Environmental Assessment Agency (1992) has published a methodology for determining whether impacts are adverse, significant and likely. The determination is carried out in three steps, as set out in **Table 3.4**.

Table 3.4 CEAA Methodology for Determining Characteristics of Impacts

Step	Criteria
1 Deciding whether the environmental effects are adverse	The quality of the existing environment is compared with the predicted quality of the environment once the project is in place. For example, negative effects on human health, well-being or quality of life.
2 Deciding whether the adverse environmental effects are significant	Criteria used are: magnitude, geographic extent, duration and frequency, degree to which the adverse environmental effects are reversible or irreversible, ecological context.
3 Deciding whether the significant adverse environmental effects are likely	Criteria used are: probability of occurrence, scientific uncertainty.

[Source: Canadian Environmental Assessment Agency 1992]

3.9 DIMENSIONS OF ENVIRONMENTAL IMPACTS

Predicted impacts are generally described in words, describing the environmental aspect or topic, whether predicted, worst-case or residual, with their spatial or geographical extent defined. Following that, impacts can have a severity (or intensity) on a scale from imperceptible, through slight to moderate, significant and profound (CAAS 2003). The acceptability or legal status can be used to inform this decision. The quality or status of the impact is described as adverse, neutral or beneficial. The reversibility of the impact is stated. The mitigatory potential for the impact is outlined. The duration of the impact can be described as short-term, medium-term or permanent. Its likelihood can range from extremely unlikely to certain. Interactions, synergies and cumulative effects may occur in each case. The level of certainty of the prediction methods is expressed, and whether the impact is direct or indirect is stated. The frequency of the impact is provided, where relevant.

Impact magnitude is based on numerical methods; impact significance is an expression of the cost of a predicted impact on society (Thompson 1990). Methods that may be used to characterise impact significance are outlined in **Table 3.5**.

Table 3.5 List of Formal Methods of Characterising Predicted Impacts

Formal methods of identifying, quantify and evaluate impact significance	Comment
The Battelle Method (Dee et al. 1973), the Water Resources Assessment Method (Solomon et al. 1977), the Optimum Pathway Matrix Approach (Odum 1971), the Tulsa Method (US Army Corps of Engineers 1972), the Component Interaction Matrix (Ross 1976), the Krauskopf and Bunde Method (Krauskopf and Bunde 1972)	Methods where aggregation is used to facilitate comparison of project alternatives. These methods handle impact significance distinct from impact magnitude. The methods utilise aggregation to facilitate comparison of project alternatives. None of the methods has specific provision for inclusion of public opinion.
The Hill Goals Achievement Matrix (Hill 1966), the Sondheim Method (Sondheim 1978), the Crawford Method (Crawford 1973) the Stover Method (Stover 1972)	Methods where there is limited consideration of impact significance. Public input forms part of the process in three of the four methods.
The Project Appraisal for Development Control Method (Clarke et al. 1983)	Method adapted to planning.
The Leopold Matrix (Leopold et al. 1971)	Method with no guide on significance determination.
The Soil Conservation Service Guidelines (US Soil Conservation Service 1977), the Fischer and Davis Method (Fischer and Davis 1973), the Multi-Agency Task Force Method (US Bureau of Reclamation 1972), Environmental Impact Centre Method (US Department of the Interior 1973), the Walton and Lewis Method (Walton and Lewis 1971)	Methods where significance is determined by the collective professional judgement of an interdisciplinary team.

Table 3.5 List of Formal Methods of Characterising Predicted Impacts

Formal methods of identifying, quantify and evaluate impact significance	Comment
The McHarg Technique (McHarg 1971), the Loran Method (Loran 1975), the Adkins and Burke Method (Adkins and Burke 1974), the Environment Canada Method (Environment Canada 1974), the KSIM Technique (Kane et al. 1973), the Sorensen Method (Sorensen 1971), the Keeney and Robilliard Method (Keeney and Robilliard 1977)	Methods that involve no consideration of impact significance. These methods are characterised by a lack of consideration of impact significance, either intentionally or as a result of using procedures that mask the issue of significance.

[Sources: Munn (1979), Shopley and Fuggle (1984), Thompson (1988, 1990), Rossouw (2003)]

Rossouw (2003) cautions that the process of determining impact magnitude and significance should never become mechanistic. The impact magnitude is determined empirically, but impact significance will always involve a process of determining the acceptability of the impact on society. In summary, the magnitude and significance of impacts can be described in accordance with the following criteria.

extent or spatial scale of the impact
intensity or severity of the impact
duration of the impact
mitigatory potential
acceptability
degree of certainty
status of the impact
legal requirements.

(adapted from Rossouw 2003 p53)

4. DATA VISUALISATION THEORY AND PRINCIPLES

In this chapter, the literature relating to data visualisation is reviewed with particular reference to the requirements of the EIA process. The taxonomy of environmental impacts provided in **Appendix 1** has informed the selection of the literature considered here.

4.1 INTRODUCTION

Of the total sense receptors in the human body, 70% are in our eyes (Ackerman 1991). The eyes, therefore, have enormous potential to convey external information to the brain. Visualisation research has shown that information transfer can be enhanced by combining text with graphics, or (where appropriate) replacing the text with a data visualisation.

'Why should we be interested in visualization? Because the human visual system is a pattern seeker of enormous power and subtlety. The eye and the visual cortex of the brain form a massively parallel processor that provides the highest-bandwidth channel into human cognitive centres. At higher levels of processing, perception and cognition are closely interrelated, which is the reason why the words 'understanding' and 'seeing' are synonymous. However, the visual system has its own rules. We can easily see patterns presented in certain ways, but if they are presented in other ways, they become invisible…The more general point is that when data is presented in certain ways, the patterns can be readily perceived. If we can understand how perception works, our knowledge can be translated into rules for displaying information. Following perception based rules, we can present our data in such a way that the important and informative patterns stand out. If we disobey the rules, our data will be incomprehensible or misleading' (Ware 2004).

Visual elements and their interrelations in a data visualisation denote data elements and how they are related. The relationship between data and their visualisation is therefore essentially a denotation relation (Dastani 2002). The visualisation then helps the viewer to understand the data, and provides a means by which information can be communicated to other people. It provides 'cognitive support' in the information transfer (Tory and Möller 2004).

The wide bandwidth of vision therefore has the potential to lead to the efficient transfer of data from the information source to the human mind. There are also opportunities in the human ability to visually reason about data, and extract higher level knowledge, or insight, beyond simple data transfer (Card et al. 1999). The reader can develop mental models of the real phenomena, as represented in the data visualisation (North 2005). Improvements on human performance from 23% to 89% have been recorded by using integrated visual-verbal 'stand-alone' diagrams. Such diagrams have all the verbal elements necessary for complete understanding without reading text elsewhere in a document (Horn 2001).

4.2 PERCEPTION

Data visualisation provides 'cognitive support' in assisting humans in analysing data or concepts graphically (Tory and Möller 2004). This support can be provided in various ways. These are summarised in **Table 4.1**.

Table 4.1 Cognitive Support Provided by Data Visualisation

Method	Description
Increased Resources	
Parallel processing	Parallel processing by the visual system can increase the bandwidth of information extraction from the data.
Offload work to the perceptual system	With an appropriate visualisation, some tasks can be done using simple perceptual operations.
External memory	Visualisations are external data representations that can reduce demands on human memory.
Increased storage and accessibility	Visualisations can store large amounts of information in an easily accessible form.
Reduced Search	
Grouping	Visualisations can group related information for easy search and access.
High data density	Visualisations can represent a large quantity of data in a small space.
Structure	Imposing structure on data and tasks can reduce data complexity.
Enhanced Recognition	
Recognition instead of recall	Recognising information presented visually can be easier than recalling information.
Abstraction and aggregation	Selective omission and aggregation of data can allow higher level patterns to be recognised.
Perceptual Monitoring	Using pre-attentive visual characteristics allows monitoring of a large number of potential events

[Summarised from Card et al. 1999]

4.3 THE DATA VISUALISATION PROCESS

Data visualisation can be considered as the reverse of the interpretation process. A visualisation is most effective when the intended interpretation is easily and directly acquired by the viewer. This interpretation depends on visual perception, so therefore an effective visualisation must take advantage of the capabilities of the human visual system (Dastani 2002).

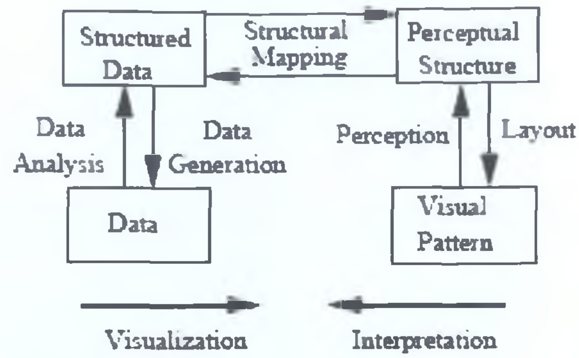

Figure 4.1 The Visualisation Process

On the basis of these principles, Dastani proposes this process model for effective data visualisation. The first step determines the structure of the data, and the relationship between the data elements. Such relationships may be nominal, ordinal or quantitative. Visual elements are then determined which represent the structured data elements; and finally, the visual elements are laid out in a data visualisation graphic.

Different visual attributes are not equally well suited to the display of quantitative information (Wünsche 2004). In the case of some attributes, the perceived scale is a power of the actual scale (Steven's law) (Cleveland 1985). The power is close to one for the perception of length. This means that length variations can be estimated quite accurately. For area and volume changes the power varies more widely from one - small areas tend to be perceived as larger than they actually are, and larger areas smaller. In addition perception of visual attributes can be influenced by orientation, e.g., angles with a horizontal bisector are seen larger than angles with a vertical one (Cleveland 1985). Also it has been shown that slope changes influence the perception of vertical distances.

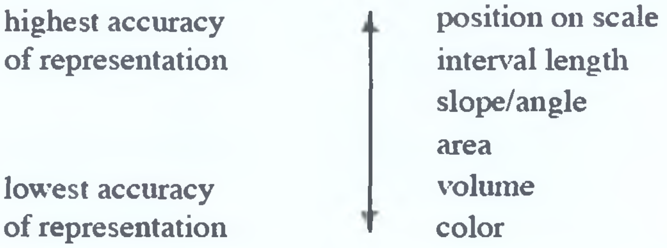

Figure 4.2 Cleveland's Hierarchy of Data Display

Cleveland (1993) developed a widely-referenced hierarchy of data display methods, ordered by their accuracy of representation (**Figure 4.2**). He concluded that position on a scale is the most accurate method of conveying numerical data in graphs.

Elementary perceptual tasks can be ranked, as indicated in **Table 4.2**.

Table 4.2 Ranking of Elementary Perceptual Tasks

quantitative	ordinal	nominal
position	position	position
length	grey saturation	colour hue
angle	colour saturation	texture
slope	colour hue	connection
area	texture	containment
volume	connection	grey saturation
grey saturation	containment	colour saturation
colour saturation	length	shape
colour hue	angle	length
(texture)	slope	angle
(connection)	area	slope
(containment)	volume	area
(shape)	(shape)	volume

[source: Csinger 1992]

Wünsche (2004) expanded on Cleveland's hierarchy, by considering the information dimensions, spatial requirement, information content, and information density, as indicated in **Table 4.3**.

Table 4.3 Characteristics of Visualisations of Cleveland's Hierarchy

	information dimension	information accuracy	spatial requirement (dimension)	information content	information density
position on scale	1-3	high	low (0)	high	high
length	1	high	medium (1)	medium	low
3D direction	2	medium	medium (1)	medium	medium
area	1	medium	medium (2)	low-medium	low
volume	1	medium	high (3)	low-medium	very low
shape	≥3	low-medium	high (3)	medium-high	medium-high
texture	≥3	low-medium	medium (1-3)	medium-high	medium-high
colour	2	low	low (≥0)	medium	high

[source Wünsche 2004]

4.4 VISUALISATION DESIGN

The purpose of data visualisation is to make abstract information easier to assimilate. Two of the key characteristics of information that make designing effective data visualisations difficult are complexity and scalability (North 2005). Both of these are directly relevant to the preparation of EISs, where the assessment findings may be complex, and there is a requirement to summarise the predicted impacts in both technical and non-technical formats.

The visualisation design process involves a series of iterations of analysis, design, and evaluation. In analysis, two primary inputs to the design are identified: the information characteristics to be visualised, and the intended insights which will arise from viewing the visualisation.

In designing data visualisations, the key design decisions are the visual mapping of the information, the representation of the structure of the information, strategy for aggregating and overview, and the methods of navigation and interaction (North 2005). The evaluation phase needs to be considered throughout the design of a data visualisation (Plaisant 2004). The objectives of the visualisation will be certain insights for the viewer, and these should be identified.

4.5 PREATTENTIVE PROCESSING

Some visual properties are 'preattentively' processed (Healey et al. 1993). These properties are detected immediately, in a way that the viewer does not have to focus their attention on the visualisation. Typically, tasks which can be performed on large multi-element images in a time of less than 250 milliseconds are considered to be preattentive (Healey et al. 1994).

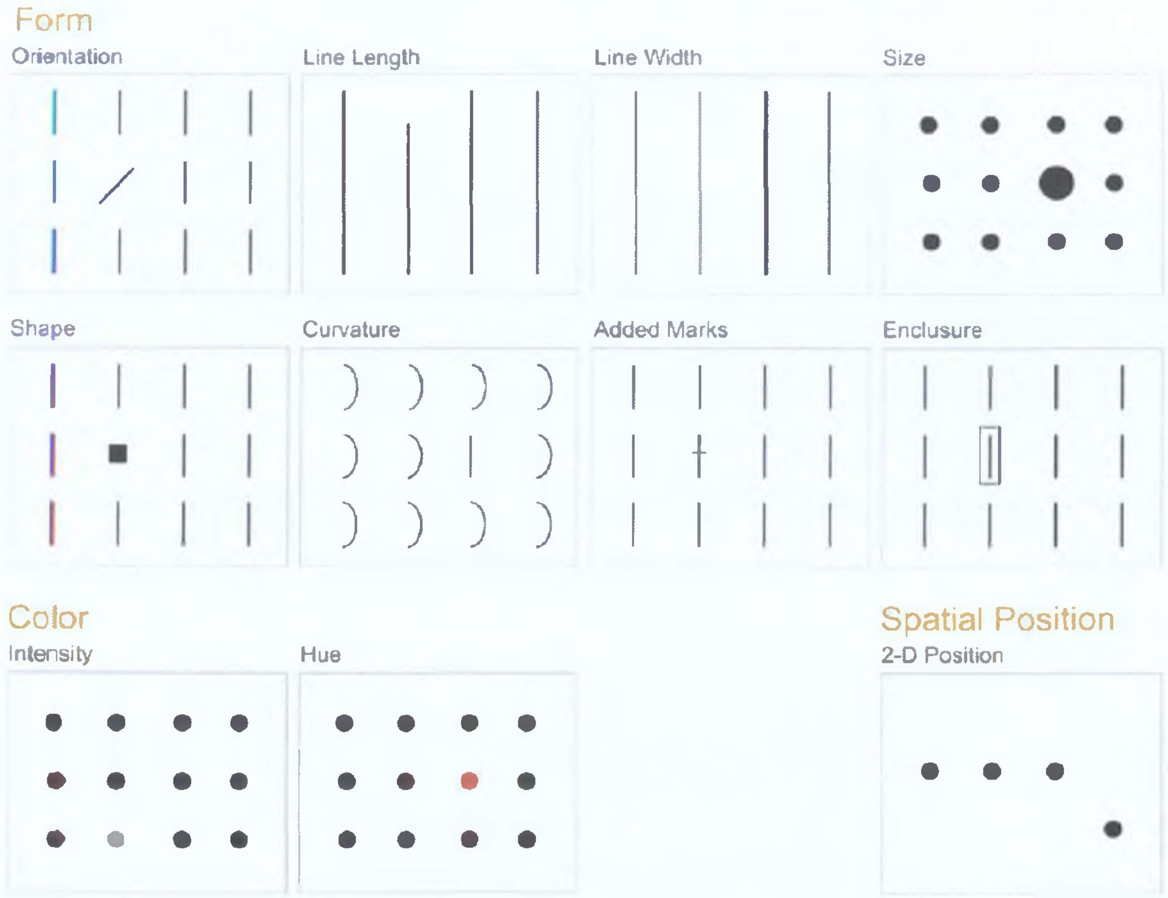

Figure 4.3 Preattentive Attributes of Visual Perception (Few 2004a)

4.6 THE VISUALISATION PIPELINE

The 'visualisation pipeline' is the process of converting information into a visual form that users can assimilate (Card et al. 1999). The first step is to transform raw information into a well-organized data format. The resulting format typically consists of a dataset containing a set of data entities each of which has associated data attribute values.

Data processing steps can be used in various ways to manipulate the data. Derived data, such as data mining or clustering results, can be very useful in helping to generate insight (Fayyad et al. 2001). The second step is to map the dataset into visual form. The visual form contains visual glyphs that correspond to the dataset entities. The third step embeds this visual form into a graphic, which displays the visual form on the page. The view is then presented to the user through the human visual system. Users interpret the view to (partially) reconstruct the underlying information. Users can interact with any of the steps in the pipeline to alter the resulting visualisation, and make further interpretations. This entire pipeline comprises an information visualisation.

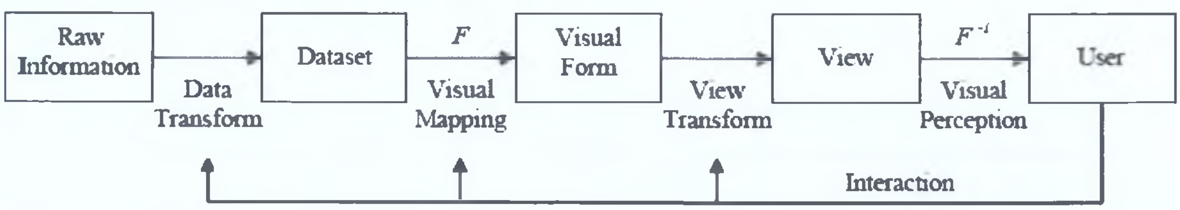

Figure 4.4 The Visualisation Pipeline (adapted from Card et al. 1999)

Visual Mapping

The visual mapping at the second step is one of the most important stages in visualisation, and requires careful design. The goal is to communicate information through the medium of visual representation. The dataset is mapped into visual form by some function *F* (Refer to **Figure 4.4**), which takes the dataset as input and generates the visual representation as output. Then, when the graphic is communicated to the users, they must cognitively reverse the visual mapping by inverting the function *F* to decode the information from the visualisation. This visual communication process implies four important characteristics of the visual mapping function *F*, as summarised in **Table 4.4**.

Table 4.4 Characteristics of the Visual Mapping Function *F*

Computable	*F* is a mathematical function, computable by using some algorithm. Although there is scope for creativity in the design of the function, the execution of the function must be algorithmic.
Invertible	It should be possible to use F_{-1}, the inverse of mapping function *F*, to reconstruct the data from the visual representation to a desired degree of accuracy. If this is not possible, the visualisation will be ambiguous, misleading, or not fully interpretable.
Communicable	*F* (or preferably F_{-1}) must be known by the user to decode the visual representation. It must be communicated with the visualisation, or already known by the user through prior experience.
Cognisable	F_{-1} should minimise the cognitive load associated with decoding the visualisation - this is dependent on the human perception and performance.

(adapted from Card et al. 1999)

The visual mapping step is accomplished by two sub-steps. First, each data entity is mapped into a visual *glyph*. The vocabulary of possible glyphs consists primarily of points (dots, simple shapes), lines (segments, curves, paths), regions (polygons, areas, volumes), and icons (symbols, pictures). Second, attribute values of each data entity are mapped onto *visual properties* of the entity's glyph. Common visual properties of glyphs include spatial position, size (length, area, volume), colour (greyscale, hue, intensity), orientation (angle, slope, unit vector), and shape. Other visual properties include texture, motion, blink, density, and transparency.

Visual Properties

In general, data attributes should be prioritised according to the analytical requirements and desired insights. This is then applied to map the higher priority data attributes to the most effective visual properties. As Cleveland (1993) notes, spatial position properties are the most effective, and these should be applied to lay out the visualisation according to the most important data attributes.

The remaining visual properties, called *retinal properties* (Bertin 1967), can be used next. Predicting the effectiveness of these properties can be challenging, as it is determined by a number of interdependent factors, as outlined in **Table 4.5**.

Table 4.5 Factors Determining the Effectiveness of Retinal Properties

Factor	Reference
preattentive processing	Healey et al. 1993
perceptual independence (separability)	Ware 2004
data type (quantitative, ordinal, categorical)	Card et al. 1999
polarity (greater than, less than)	Ware 2004
task	(Carswell 1992, Wickens and Hollands 2000) in North 2005
attention	(Chewar et al 2002) in North 2005

[adapted from North 2005]

Hierarchies of the effectiveness of these factors are based both on empirical evidence as well as experience (North 2005). For any remaining attributes, interaction techniques can be applied. In general, direct visual mapping of information is the most effective for quick insights, while interaction techniques require physical actions by the user to gain insights. By viewing the resulting changes in the visual representation, users can infer additional information about those attributes.

4.7 INFORMATION STRUCTURE

The visual mapping process is the starting point for visualisation design, but other methods are required as data complexity increases. Identifying the underlying structures within the data can help to guide the design process at this stage. These structures provide the high-level organisation to a dataset, and can provide direction for the design of appropriate visualisations. Such structures are likely to be very important to users' mental models of the information, and they are typically mapped to the spatial position attributes and form the primary layout of the visualisation. North (2005) outlines four common types of information structures (adapted from Shneiderman 1996, Card et al. 1999 and Spence 2001): Tabular, Spatial and Temporal, Tree and Network, and Text and Document Collection. North notes that these are not strict or mutually exclusive classifications. The most relevant structures to the presentation of predicted impacts in EISs are the tabular and text and document collection structures, and these are described below.

Tabular Structure

Tables consist of rows (entities) and columns (attributes). This is often referred to as multidimensional or multivariate data - each attribute defines a dimension of the data space, and within this dimension, each entity identifies a single point. The most common examples are databases and spreadsheet tables. Visualisations of tables that contain a small number of attributes can be designed relatively easily using the visual mapping process. This is a potential solution to the challenge of visualising predicted impacts. There are limitations, however. The visualisations have limited scalability to many attributes, because of the limited number of non-conflicting visual properties to choose from. A variety of creative methods have been developed for tables of many attributes, and these are described further in Chapter 5. In general, they involve the use of more complex glyphs and spatial layouts.

TableLens (Rao and Card 1994) preserves the tabular spreadsheet visual representation, but converts cells to horizontal bar glyphs with cell values mapped to bar length. This exploits the length property, which, as Cleveland (1993) notes, is excellent for encoding quantitative data. Also, since the bars are very thin, many values can be packed onto the screen, providing a powerful overview of a large dataset. Each data entity (row) is encoded with multiple glyphs (bars), one glyph for each of the entity's attribute values (columns). Users can vertically sort the table by any attribute. In presenting the characteristics of predicted environmental impacts, this sorting of the horizontal bar glyphs could potentially produce a summary of predicted impacts, ordered by dimensions such as significance, geographic area, duration, reversibility, or any other characteristic. Much larger datasets can be explored electronically in TableLens by using its aggregation and interactive navigation (scrolling) strategies. For datasets larger than a screen size, TableLens aggregates adjacent rows by showing averages or minimum and maximum values.

Orthogonal axes are used in the Cartesian coordinate system to visually map two or three attributes of a tabular dataset. However, orthogonal axes limit the scalability of attributes. As an alternative, parallel coordinate systems can be used, with attribute axes as parallel vertical lines. Each data entity is mapped to a line that connects the entity's attribute values on each attribute axis. Attributes are mapped to the vertical position of the respective vertices of the line. Users can recognise clusters of similar entities and relationships between adjacent attributes. Patterns of crossing lines between adjacent axes indicate an inverse relationship between those two attributes, while non-crossing lines indicate a proportional relationship.

More complicated iconic glyphs are used in Chernoff faces (Chernoff 1973), which are designed to take advantage of the human ability to rapidly recognise facial features and expressions.

Text and Document Collection Structure

This structure consists of arbitrary collections of documents, often in the form of text. Examples include digital libraries, news archives, digital image repositories, and software code. Of the four types of information structure described here, this type is the least structured and can be the most challenging to design visualisations for. Mapping functions take advantage of the characteristics of text to generate useful data for generating visual representations. Solutions range from the macro scale (overview of large collections) to the micro scale (a single document fragment).

4.8 OVERVIEW STRATEGIES

Designing methods for the visual representation of very large quantities of information is one of the fundamental challenges in visualisation. As information quantity increases, it becomes more difficult to select the most relevant information on the page. The risk in this selection process is that full detail is provided for a limited portion of the data, with significant information concealed. This has been compared to looking into a large room through a keyhole, and is referred-to as the 'keyhole problem' (North 2005).

A solution to the keyhole problem is to start with an overview of the full information, and hiding details. Then, provide a path to desired detailed information, filtering out irrelevant data.

The advantages to providing an initial overview are as follows:

supports formation of mental models of the information space
reveals what information is present or not present
reveals relationships between the parts of the information, providing broader insights
facilitates direct access and navigation to parts of the information, by selecting it from the overview
encourages exploration.

(North 2005)

The use of visual overviews improves performance in various information seeking tasks (some examples of studies are listed in North 2001). In general, the visualisation designer should compile as much information into the overview as clearly possible. A major design decision is choosing which information to bring into the overview and which information to leave in the lower levels of detail. There are two fundamental approaches in visual mapping to pack a large dataset onto a page:

reducing the quantity of data in the dataset before the mapping is applied
reducing the physical size of the visual glyphs created in the mapping.

Reducing Data Quantity

One method for reducing the data quantity, while maintaining reasonable representation of the original data, is aggregation. This is particularly relevant to EISs, where predicted impacts are often described at three, or even four levels of detail:

detailed assessment of an environmental topic – often presented as an appendix to the EIS
EIS chapter describing a particular environmental topic – sometimes summarising a more detailed assessment
summary of predicted impacts, mitigation measures and residual impacts
non-technical summary of EIS

Aggregation groups entities within the data set, creating a new dataset with fewer total entities. Each aggregate becomes an entity itself, temporarily replacing the need for all entities within the aggregate. For example, a histogram applies aggregation to represent data distribution on one attribute (Spence 2001).

In aggregating data, the primary decision is choosing what should be grouped together, and for what reason. At a basic level, data entities can be grouped by common attribute values (Stolte et al. 2002), or by using clustering algorithms (Yang et al. 2003). Attribute values are then assigned to the aggregated data. The aggregates' values should be representative of the contained member entities. Often statistical methods, such as mean, minimum, maximum and count, are used to summarise the data. Aggregation can be iteratively applied, but ideally the visual representation of aggregates should reveal some hint of their contents.

Aggregation can also be applied to data attributes. Methods for reducing the dimensionality reduce the number of data attributes, so that they can be more easily visualised. The reduced set of attributes should approximately capture the main trends found in the full set of attributes.

There are a number of techniques used to reduce data quantity, based on filtering (Woodruff et al. 1998, Ahlberg and Wistrand 1995). In this process, less-relevant data can be accessed through interactive methods, where they are eliminated from the visual-mapping function. Tree structured information can then be reduced by filtering deeper levels of the tree to visualise the upper levels as an overview.

Miniaturising Visual Glyphs

Alternatively, emphasis can be placed on miniaturisation of the visual glyphs generated by the visual mapping process. Tufte (2001) argues for increased data density in visual displays, by maximizing the data per unit area of screen space, and maximizing the data-ink ratio. Higher data-ink ratio is accomplished by minimising the quantity of 'ink' required for each visual glyph, and eliminating chart junk that wastes ink on unimportant non-data elements.

The building blocks of all graphics can be considered in three categories, the graphic objects, or glyphs, the meaningful graphic spaces (for example geographic coordinate system), and the graphic properties, such as colour and size (Engelhardt 2007). **Table 4.6** outlines a typology of graphic space, under four headings: metric, topological, grouping and composite. The predicted impacts in the EIA process can be considered in both metric and topological space, and therefore may be most appropriately considered in composite space.

Table 4.6 Engelhardt's Typology of Graphic Space

<table>
<tr><td colspan="2">A Typology of Meaningful Graphic Space
alternative terminology and explanations</td><td>representation of
physical space</td><td>representation of
conceptual space</td></tr>
<tr><td>'proportion'</td><td rowspan="5">metric space (show proportions)</td><td rowspan="5">e.g. a topographic map, most pictures</td><td rowspan="5">e.g. a time axis, any other quantitative axis</td></tr>
<tr><td>'interval'</td></tr>
<tr><td>'quantitative'</td></tr>
<tr><td>'ratios of spatial distances'</td></tr>
<tr><td>'quantitative grid'</td></tr>
<tr><td>'ordre' (Bertin 1967)</td><td rowspan="4">topological space (shows order)</td><td rowspan="4">e.g. the London Underground map, an 'exploded view' of a machine</td><td rowspan="4">e.g. chronological ordering of panels in a comic, any other meaningful spatial ordering</td></tr>
<tr><td>'ordinal'</td></tr>
<tr><td>'a metric space . . .stretched non-homogenously'</td></tr>
<tr><td>'ordinal grid'</td></tr>
<tr><td>'association'</td><td rowspan="5">grouping space (shows association)</td><td rowspan="5" colspan="2">e.g. columns and rows in a table, any other meaningful spatial grouping</td></tr>
<tr><td>'categorical'</td></tr>
<tr><td>'segmentation'</td></tr>
<tr><td>'spatial clustering'</td></tr>
<tr><td>'nominal grid'</td></tr>
<tr><td>'recursion in the repeated subdivision of space'</td><td rowspan="4">composite space (constructed from combinations of the spaces above)</td><td rowspan="4" colspan="2">e.g. the (metric, physical) space of a picture within the (topological, conceptual) space of a chronological sequence, or
a chart that combines a (metric, conceptual) horizontal time axis with a (metric, conceptual) vertical quantitative axis</td></tr>
<tr><td>'nesting', 'embedding'</td></tr>
<tr><td>'orthogonal placement of axes'</td></tr>
<tr><td>'simultaneous combination'</td></tr>
</table>

[adapted from Engelhardt 2007]

4.9 VISUAL LANGUAGE

Horn (2001) argues that when words and visual elements are closely intertwined, we create something new, which he defines as 'visual language', or 'visual-verbal language'. Visual-verbal language enables efficiencies of communication, in the form of 'stand-alone' diagrams which contain all the verbal elements necessary for complete understanding. **Figure 4.5** is typical of Horn's approach, which combines diagrams, clip-art and focussed text.

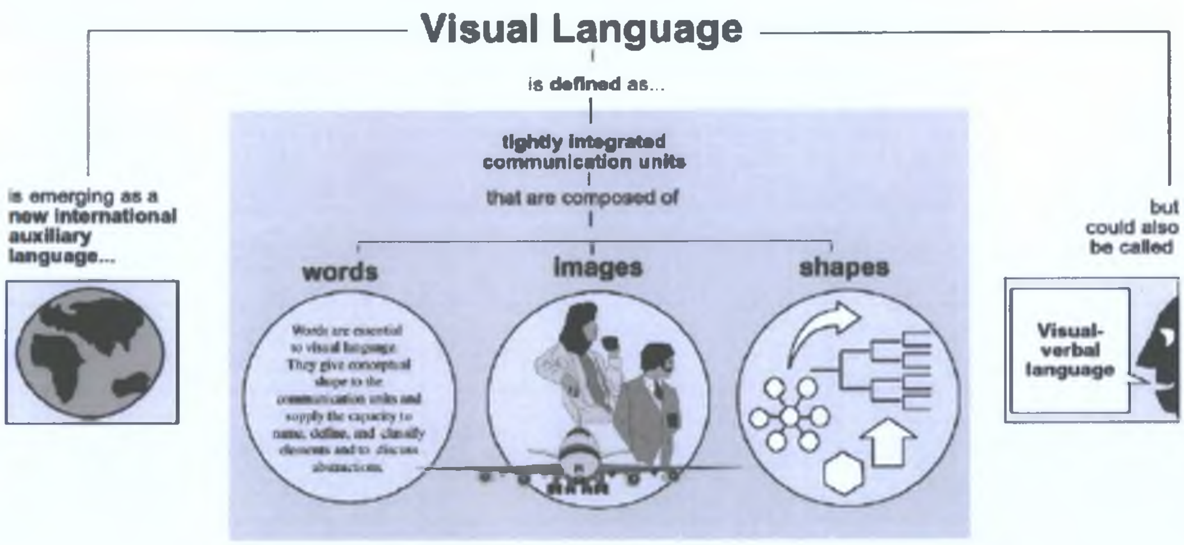

Figure 4.5 A Definition for Visual Language (from Horn 2001 p2)

4.10 COLOUR

There are some widely-understood meanings associated with colours. These are not universal, and may have contradictory meanings in some cultures, but the summary in **Table 4.7** below includes some of the more commonly known colour meanings.

Table 4.7 Some Meanings Associated with Colours

Colour	Meaning
Red	danger, urgency, passion, heat, love, blood
Orange	warning, energy, warmth, enthusiasm, the sun, change
Yellow	caution, warmth, sunshine, cowardice
Purple	wealth, royalty, sophistication, intelligence
Black	death, rebellion, strength, evil

Table 4.7 Some Meanings Associated with Colours

Colour	Meaning
Blue	taking notice, truth, dignity, power, coolness, melancholy
Green	safety, nature, health, good cheer, the environment, money, vegetation
In addition to these meanings, colours convey emotion too - from cool detached tones to warm, engaged ones.	

[source: Hewlett Packard website www.hp.com, accessed 23 April 2008]

Rheingans (1999) discusses the principles and issues that drive the selection of an appropriate colour scale in data visualisation. Although she concludes with the question 'the true test of the value of a colour scale is "does it work?"' (Rheingans 1999 p6) - which is a fundamental criterion for any visualisation - she also includes useful samples of nine different colour scales. These are illustrated in **Figures 4.6** to **4.14**. In her discussion of the advantages and disadvantages of each colour scale, it becomes evident that there the redundant hue lightness scale (**Figure 4.10**) is particularly effective for illustrating difference across an incremental range. The darkness varies linearly as for the grey scale (Figure 4.6), but this is reinforced by the use of the hue range. This redundancy is likely to enhance the effectiveness of the visualisation.

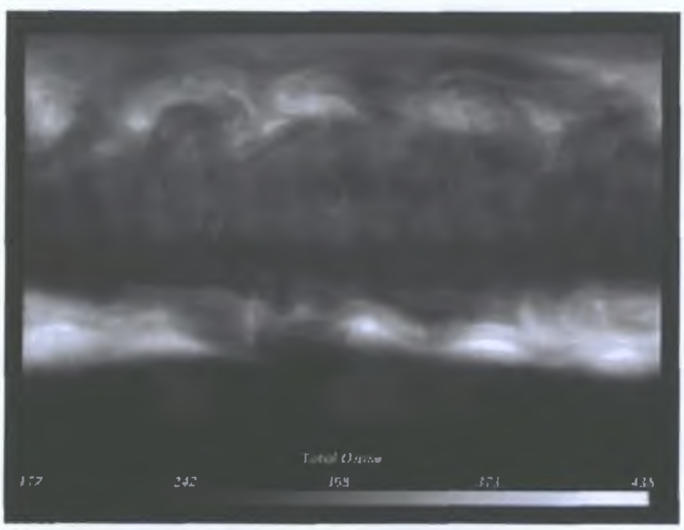

Figure 4.6 Grey Scale

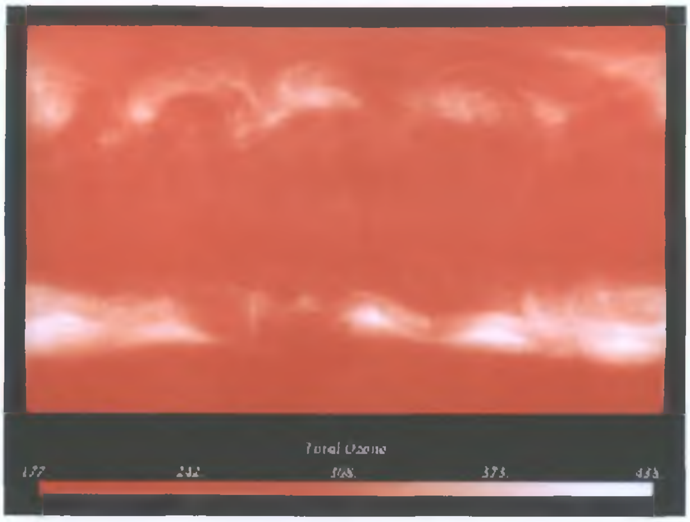

Figure 4.7 Saturation Scale

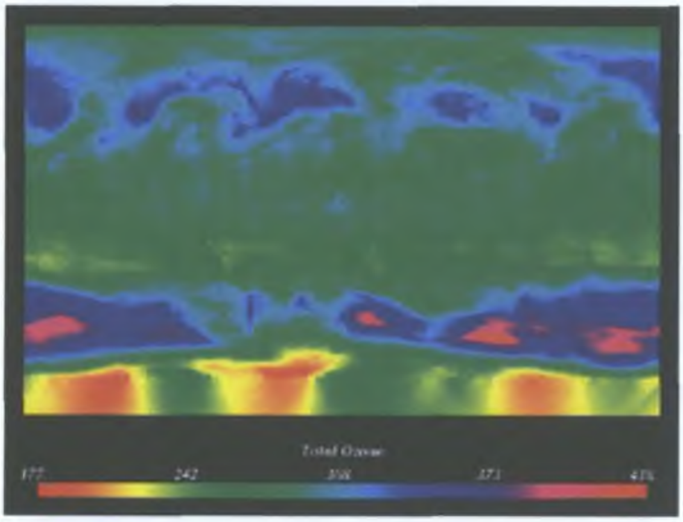

Figure 4.8 Spectrum Scale

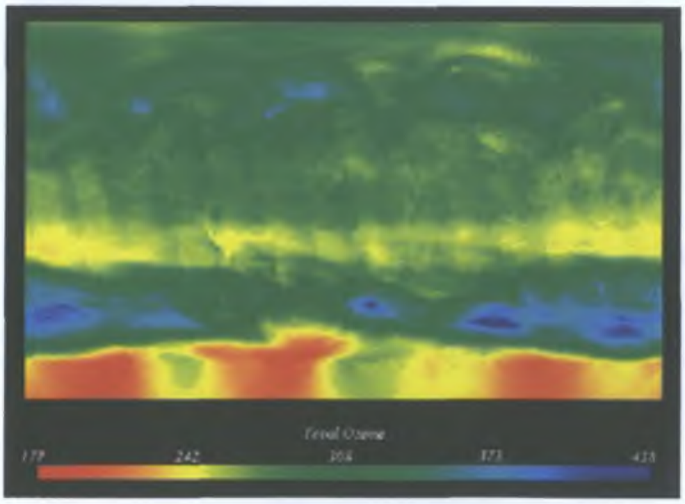

Figure 4.9 Limited Spectrum Scale

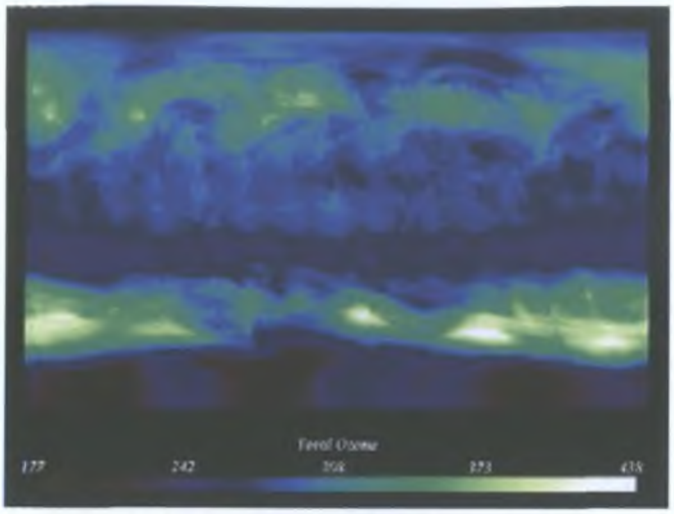

Figure 4.10 Redundant Hue Lightness Scale

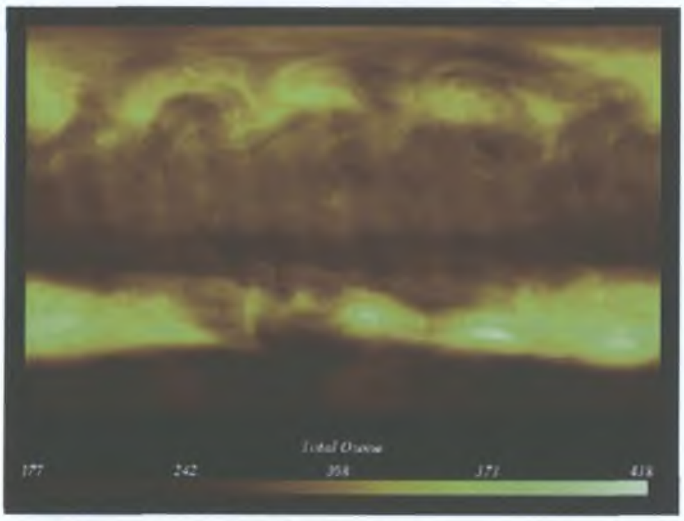

Figure 4.11 Heated Object Scale

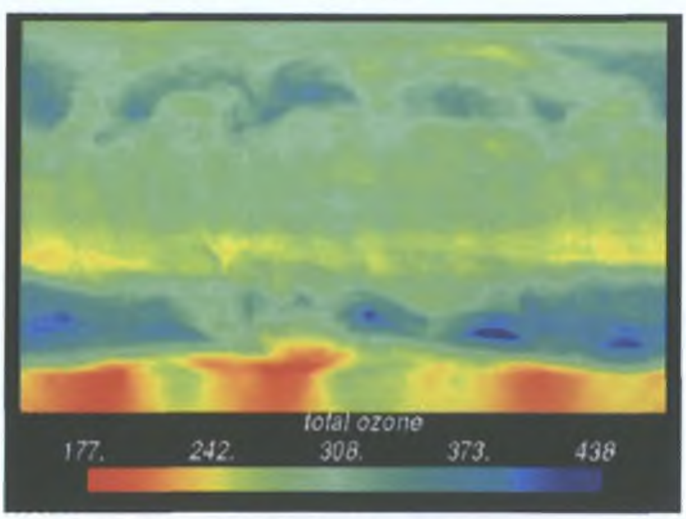

Figure 4.12 Double-Ended Scale

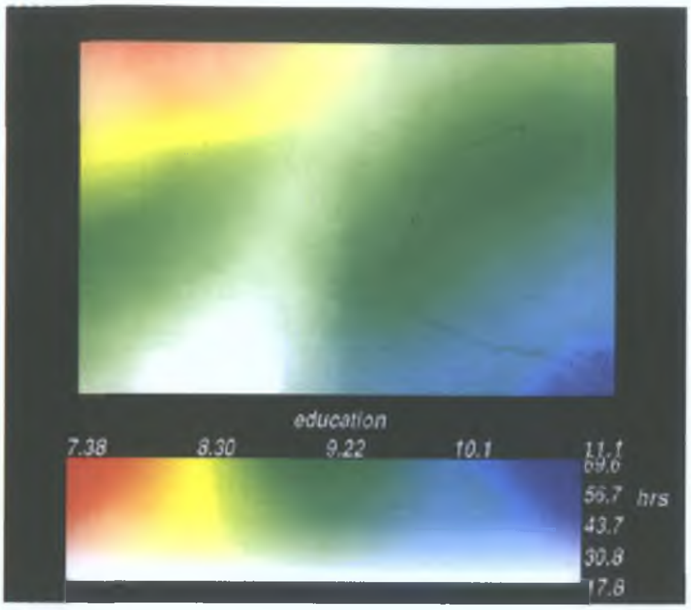

Figure 4.13 Hue-Saturation Scale

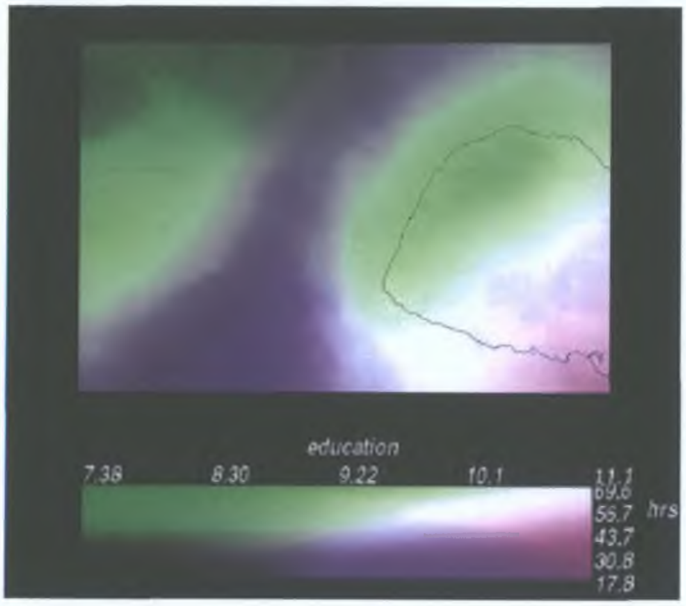

Figure 4.14 Bivariate Complementary Colour Scale

Cynthia Brewer (1994) presents guidelines for choosing colour schemes in mapping and data visualisation. Under four key headings, she outlines the particular strengths and limitations of binary, qualitative, sequential and diverging schemes. These are illustrated in **Figure 4.15**. In the comparison of predicted environmental impacts, correlating the impact significance with a sequential (rather than continuous) colour scheme is likely to be most effective. Examples of single-ended and double-ended sequential scales are shown in **Figure 4.16**.

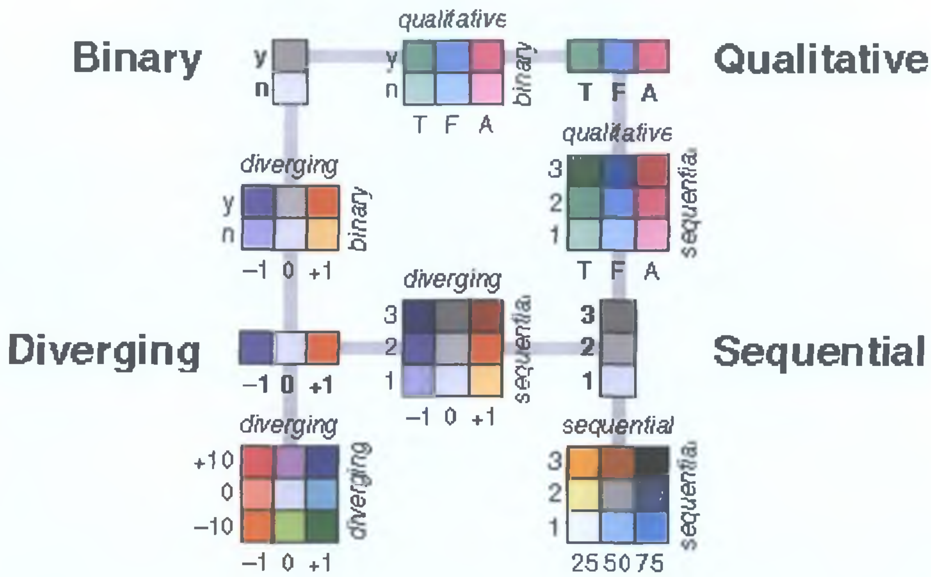

Figure 4.15 Four Key Colour Scheme Types (Brewer 1994)

Figure 4.16 Single-Ended and Double-Ended Sequential Colour Schemes

Rigden (1999) describes a technique for simulating the effects of colour-blindness, and proposes specific colour palettes which are effective for viewers with the most common red and green vision deficiencies. **Figure 4.17** illustrates a standard colour palette (the so-called web-safe palette), and two alternative palettes which are equivalent to how viewers with red (protan) and green (deutan) deficiencies will perceive these colours.

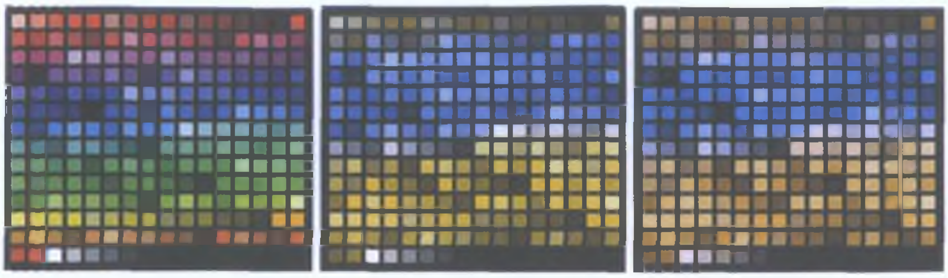

Figure 4.17 Standard, Protan and Deutan Palettes (Rigden 1999 p4)

4.11 GESTALT THEORY

Gestalt theory is a family of psychological theories that have influenced visual design since 1924 (Chang, Dooley and Tuovinen 2002). The theories are usually expressed as laws. The Gestalt laws explain how individual environmental elements can be organised into fields and structures. Patterns take precedence over elements, and have properties that are not inherent to the individual elements.

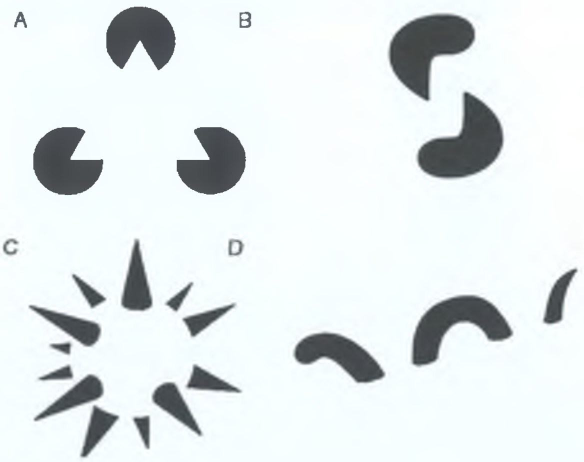

Figure 4.18 Sample Gestalt Images

In the image opposite, shapes are perceived and visually-linked by the viewer, beyond that which is actually illustrated (Image from Lehar 2003 p52).

Some of the laws most relevant to graphical presentation in EISs are as outlined in **Table 4.8** below.

Table 4.8 A Selection of Key Gestalt Laws

Gestalt Law	Summary Description
Law of Balance/ Symmetry	A visual object will appear as incomplete if it is not balanced or symmetrical (Fisher and Smith-Gratto 1998-1999).
Law of Continuation	Continuation can be defined as the eye's instinctive action to follow a direction derived from the visual field (Fultz 1999).

Table 4.8 A Selection of Key Gestalt Laws

Gestalt Law	Summary Description
Law of Closure	'Open shapes make the individual perceive that the visual pattern is incomplete' (Fisher and Smith-Gratto 1998-1999). We tend to close gaps and complete unfinished forms.
Law of Figure-Ground	Two different foreground colours can cause confusion by letting a viewer perceive different things in the same graphical image.
Law of Focal Point	The focal point catches the viewer's attention, and should encourage following the visual message further (Lauer 1979).
Law of Isomorphic Correspondence	We associate meanings with images based on our experiences, and prior exposure to similar images or glyphs.
Law of Prägnanz (Good Form)	This is simply as good a figure as possible, with a simple, symmetrical layout.
Law of Proximity	Items placed near each other appear to form a group. Viewers will mentally organise closer elements into coherent objects
Law of Similarity	Similar objects will be counted as the same group, and will be perceived as separate from dissimilar objects.
Law of Simplicity	'There is an unconscious effort to simplify what is perceived into what the viewer can understand' (Fisher and Smith-Gratto 1998-1999). If graphics are complex and ambiguous, there is a risk that simplification may lead to misinterpretation.
Law of Unity/ Harmony	'Unity implies that a congruity or arrangement exists among the elements in a design; they look as if they belong together, as though there is some visual connection beyond mere chance that has caused them to come together' (Lauer 1979).

4.12 OVERVIEW OF OTHER DATA VISUALISATION LITERATURE

Larson and Edsall (2007) found that incorporating visual information technology into environmental decision making is most effective for sharing understanding of problems and focussing viewers on particular issues.

In the *Semiology of Graphics* (Bertin 1967) the illustrations are small, with minimal descriptions, but the text covers in 432 pages most possible means for showing information. Bertin's arrangement of 'graphic variables': position, form, size, contrast, 'grain' colour and direction are illustrated in **Figure 4.19** (as presented in Zhang 2007). A similar compendium is *Information Graphics* (Harris 1996) which comprises numerous small illustrations and detailed, but very brief descriptions and explanations of most chart and diagram types.

Few's (2004) *Show Me the Numbers: Designing Tables and Graphs to Enlighten* is a detailed introductory text in graphical communication. His focus is on business, as opposed to scientific/ technical, academic, consumer, design, and other specialized realms, but the principles cover all the essentials of communication through tables and charts. He seeks to convey quantitative data and their relationships, especially those that summarize. All of the fundamentals are stated succinctly, such as when to use tables and when to use charts, definitions of charting types, and even a brief history of chart-making. Deviation charts, correlation charts, scatter plots, line charts, bar charts, and others are described in detailed. They are defined and demonstrated, and advice is given for their best presentation attributes. The chapters focus on details of arrangement, labels, colour and highlighting. Few has also written dozens of short papers

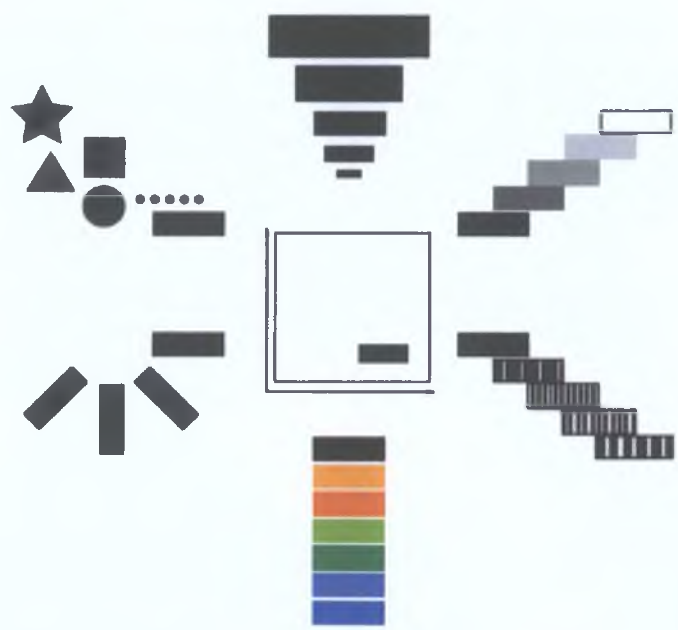

Figure 4.19 Bertin's Graphic Variables

on particular aspects of the graphic presentation of numerical data (Few 2004-2008) which are published on the website www.perceptualedge.com.

5. DATA VISUALISATION TECHINQUES

5.1 INTRODUCTION

This chapter summarises some of the most widely used visualisation techniques, which are the field from which recommended methods will be selected for use in Environmental Impact Statements.

5.2 LIST OF VISUALISATION TECHNIQUES

Grinstein et al. (2002) in their review of the literature on the main streams of high-dimensional visualisation generated a list of such techniques, as follows:

2D and 3D scatterplots
matrix of scatterplots
heat maps
height maps
table lens
survey plots
iconographic displays
dimensional stacking (general logic diagrams)
parallel coordinates
line graphs, multiple line graphs
pixel techniques, circle segments
multi-dimensional scaling and sammon plots
polar charts
rad viz
poly viz
principal component and principal curve analysis
grand tours
projection pursuit
kohonen self-organising maps

Drawing from Shneiderman (1996), and his own previous work, Chi (2000) developed a substantial taxonomy of visualisation techniques, which is summarised below in **Table 5.1**.

Table 5.1 A Taxonomy of Visualisation Techniques

visualisation technique	within value	data transformation	within analytical abstraction	visualisation transformation	within visualisation abstraction	visual mapping transformation	within view
some example scientific visualisations							
visible human project	data: image scans of slices of human	matching cubes: creating voxels	abstraction: voxels	→	→	create slices of volumes	specifying slices using sliders
MapQuest	data: geographical road maps	parse information into records	abstraction: parsed record set – dynamic value-filtering of records	create linear list of records	visualisation abstraction: linear list with features	icons depicting different locations and their types: restaurants, etc	scroll, zoom, view-filtering of interested locations
ozone layer visualisation	data: ozone layer geographical samples into quantitative variables	extract geographical samples into quantitative values	normalise samples and quantitative values	direct spatial mapping of quantitative values to longitude, latitude, height	abstraction: earth with overlaid information	map quantitative variables to longitude, latitude, and height; map ozone level to colour	rotate, scale, animate, change colourmap
geographical-based information visualisation							
profit landscape	data: profit statistics linked to geographical regions	extract into quantitive variables	normalise sample	direct spatial mapping of geo-coordinate variables	→	map geo-coordinate variables onto a geographical map; map profit variable to glyph (size of lines)	rotate, scale, animate, change colourmap
2D							
TileBars	example data: text documents	parse into feature vectors	search through vector; compute intersection of vectors	each rectangle corresponds to a document	→	squares represent text segments; darkness indicates frequency of terms	browse
ValueBars	example data: text documents, file system records	parse into feature vectors, then choose one attribute	allow multiple attributes to be chosen for several ValueBars	→	→	lines represent the value of the attribute of an item in the text document	scroll

Table 5.1 A Taxonomy of Visualisation Techniques

visualisation technique	within value	data transformation	within analytical abstraction	visualisation transformation	within visualisation abstraction	visual mapping transformation	within view
Information Mural	example data: software code, documents, stock prices, sun spot data	parse into feature vectors	dynamic value-filtering	→	→	lines represent the value of the attribute of an item in the document; colour maps another value or type	scroll; zoom
LifeLines	example data: medical and court records	parse into feature records	dynamic value filtering	create lines on 2D plot	dynamic value filtering; apply unmapped variable filtering	icons indicate discrete events; line colours and thickness indicate relation or significance	dynamic view-filtering
multi-dimensional plots							
Dynamic Querying	example data: home, movies sales data	parse into feature records	→	create multi-dimensional point sets	dynamic value-filtering; apply unmapped variable filtering	map into scatter plot; choosing variables-to-axes mappings	dynamic view-filtering
Parallel Coordinates	example data sets: production run of VLSI chip yield and its defect parameters	extract corresponding yield and parameter feature set	choosing a subset of records using dynamic value-filtering	create point set from records	visualisation abstraction: point set	plot point set using parallel coordinates	dynamic view-filtering; sorting of axis; interactive permutation of axis
World-Within-World	data: high dimensional point set or surfaces – dynamic value-filtering	→	abstraction: point set or surfaces – normalise samples	→	→	map high dimensional surface to local area	dynamic view-filtering; rotate, scale, focus
Information Landscapes and Spaces							

Table 5.1 A Taxonomy of Visualisation Techniques

visualisation technique	within value	data transformation	within analytical abstraction	visualisation transformation	within visualisation abstraction	visual mapping transformation	within view
Perspective Wall	example data: schedule, file system	parse information into records	abstraction: parsed record set – dynamic value-filtering of records	create linear list of records	visualisation abstraction: linear list with item features	create wall panels in 3D with glyphs, with focus and content distortion-based display	focus on a particular wall; focus an item; dynamic view-filter; choose different levels of detail
Pad++	example data: many types including text documents, file system, drawings	→	abstraction: windows, lines, icons, points, polygons	→	many abstractions are compatible	many representations	zoom: some objects will fade in, some will fade out; scroll
Elastic Windows	example data: mail reader, web browser, window based interfaces	→	abstraction: windows	→	many kinds of windows are compatible	create Elastic Window mapping to screen (space-tiling)	change focus, enlarge, zoom-out
WebBook and WebForager	data: URLs for web pages	retrieve web pages; generate images of each web page	abstraction: images of HTML pages generated by getting the web pages	create linear list of pages; aggregate into a book or a pile, place piel on book shelf (creating list of lists); crawl from a URL and create a book from the collection	abstraction: linear page lists, collection of page lists – merge page lists; merge sets of page lists	create books with multiple pages; view using Document Lens; create bookshelf, table, piles	focus on a book; focus on a page; flip through pages in a book; view book using Document Lens; ptu onto history pile
Trees							

Table 5.1 A Taxonomy of Visualisation Techniques

visualisation technique	within value	data transformation	within analytical abstraction	visualisation transformation	within visualisation abstraction	visual mapping transformation	within view
Cone tree, Hyperbolic browser, TreeMap, DiskTree, Cheops, WebTOC, Information Cube	data: file system, organisation charts, hypertext or web linkage structure	extract into graph	abstraction: graph – apply dynamic value-filtering or nodes or edges	do breath first traversal	visualisation abstraction: tree-hierarchy	layout using 3D cones, hyperbolic tree, disk tree, space filling treemap, cheops approach, expanding trees, using Information Cube technique with semi-transparent cubes	focus node, hide subtree, change orientation and position of tree, apply dynamic level-filtering
Network							
GraphViz	example data: software code modules, file system, all kinds of graphs	extract edges and nodes into a graph	abstraction: graph	→	→	sophisticated graph layout algorithm that places nodes on 2D plane intelligently	view: graph with minimised edge crossings
GV3D or lpNV3D	example data: software code modules	extract connections between code	filter nodes	form nested graphs from earlier extracted graphs	dynamic value filtering; apply unmapped variable filtering	map code modules into cubes in 3D, with linkages between cubes specifying relationships	dynamic view-filtering

Table 5.1 A Taxonomy of Visualisation Techniques

visualisation technique	within value	data transformation	within analytical abstraction	visualisation transformation	within visualisation abstraction	visual mapping transformation	within view
SeeNet	example data sets: phone calls made, internet packet flows, email communication patterns	parse into source and destination links	analytical abstraction: parsed records of source and destination and associated feature sets – unmapped variable value-filtering; choose variables of displayed statistics; aggregate records	transform into graphs and networks	visualisation abstraction: graphs, and networks	display graph as matrix, geographical linkmaps, or nodemaps	for all three views: sound feedback; unmapped variable view-filtering. for matrix display: threshold time view-slider; permute rows and columns. for nodemaps and linkmaps, etc.
Text							
Alignment Viewer	data: similarity reports from comparing a single sequence against a database of many other sequences	parsing textual reports; addition, subtraction between reports, unmapped variable value-filtering	abstraction: alignment records (data structure representing parsed information)	extracting information from records	visualisation abstraction: feature point set with vector	map into comb-glyphs	rotation, translate zoom, focus on a single alignment, detail-on-demand, animation (by using an iterator over the view-filtering
ThemeScape and Galaxies	data: CNN news stories	create textual word frequency vector; choose an item and then perform weighted query	analytical abstraction: text vectors	multi-dimensional scaling (MDS), principal component analysis	visualisation abstraction: 2D positions from MDS	map into surfaces of hills and valleys	zoom, rotate, focus on detail spot for ThemeScape, create slices for Galaxies, animate scatter plot
Web Visualisation							
WebSpace	data: web site	walk web site and create web linkage graph	value-filtering	create breadth first traversal tree	visualisation abstraction: tree	layout using cone tree	dynamic view-filtering

Table 5.1 A Taxonomy of Visualisation Techniques

visualisation technique	within value	data transformation	within analytical abstraction	visualisation transformation	within visualisation abstraction	visual mapping transformation	within view
3D Hyperbolic	data: web site	walk web site and create web linkage graph	value-filtering	create breadth first traversal tree	visualisation abstraction: tree	layout using 3D hyperbolic tree	dynamic view-filtering
WebMap	data: web site traversal history	extract user path from traversal history graph	abstraction: traversal history graph	form navigation spanning trees	visualisation abstraction: tree	map to tree layout, circle layout, rectangle layout, horizon tree layout	dynamic view-filtering
Time Tube	data: web structure evolving over time and its associated usage statistics	create graph from web structure by crawling the web site	analytical abstraction: evolving graph represented as ordered collection of graph	do breadth first traversal with global node position over time	visualisation abstraction: evolving tree as ordered list of trees	create Time Tube, which is represented as aggregation of Disk Trees	recognise gestures for: focus on a slice, bring slices back into the Time Tube, zooming focus on the connectivity of a note, rotate slices, brushing on pages, animate through the slices
Visualisation Spreadsheets							
Table Lens	data: baseball player statistics	parse statistics into numeric records	analytical abstraction: numeric records – sort records	construct numeric table from records	visualisation abstraction: constructed numeric table	represent number using bars, with focus+context distortion-based table	change distortion focus
spreadsheet for images (direct mapping from data to view)	data, analytical and visualisation abstraction: pixels, voxels, rotate image, filter, change colour scale, other image processing mechanisms	→	→	→	→	→	view: images from pixels, volumes from voxels – rotate image, filter, change colour scale, other image processing operations, rocking the volume visualisation

Table 5.1 A Taxonomy of Visualisation Techniques

visualisation technique	within value	data transformation	within analytical abstraction	visualisation transformation	within visualisation abstraction	visual mapping transformation	within view
FINESSE	data: financial data	compute call and put option prices	abstraction: matrix records, mathematical functions – change parameter of functions, change arithmetic relationships	compute curves from math function models	visualisation abstraction: matrix, computed curves	create heat map, create surfaces in 3D, plot using 3D bar charts, 2D line plots, create text for filenames, represent variables using value sliders	change orientation of geometric objects, change to common colourmap or font, view using same geometric orientation, show cell dependency relationships, picking a data item, input math function
Spreadsheet for Information Visualisation (allows value and view dependencies between cells)	example data sets, point sets, matrix, sequence similarity reports, web structure, web usage pattern, etc	normalise matrices, parse textual reports, create random point sets, create graph from web structure by crawling the web site	abstraction: normalised matrix and point sets, value tuples, evolving graph represented as ordered collection of graph – dynamic value-filter, algebraic data set operators	perform Delaunay Triangulation, extract data features from records, do breadth first traversal with global node position over time	visualisation abstraction: point set, matrix, triangulated surface, point set with feature vector, hierarchy, list of trees, etc	create heat map, matrix cube visualisation, matrix bar visualisation, Cone Tree, Disk Tree, glyphs, scatter plot, choosing variable-to-axes mapping, change cells to share same visual mapping transformation	dynamic view-filter, change object position and orientation, pixel image addition between cells, object addition between cells, animation, coordinated direct manipulation
Web Analysis Visualisation Spreadsheet	data: web site usage analysis – filter-value	extract linkage information, extract usage information	cluster nodes	breadth first traversal	perform usage frequency pattern algebra, apply spreading activation pattern algebra	display Disk Tree, display Cone Tree, apply Colouring Pattern, display Pattern Glyph	apply geometric operators, detail-on-demand zoom, animation

[adapted from Chi 2000]

6. GRAPHICAL EXCELLENCE

This chapter provides an overview of design principles for data visualisation, with particular emphasis on Tufte's (1983) principles of graphical excellence.

6.1 DESIGN PRINCIPLES FOR DISPLAYING QUANTITATIVE INFORMATION

Few (2006) summarises seven core design principles for displaying quantitative information as summarised below.

6.1.1 Display neither more nor less than what is relevant to your message.

In getting a message across, irrelevant content is distracting. It has become common practice in visualisations to include background images, unnecessary 3-D effects, and other 'chartjunk' (Tufte 1983). Visual content of this sort is something that people's eyes must scan and brains must process, without getting any value, because it is meaningless. This wastes the viewer's time and makes it harder for them to get at the message.

The reverse is true as well. A visualisation must include everything that people need to make sense of it. Include every piece of information that is part of the message—even notes to explain what might not be clear.

6.1.2 Do not include visual differences in a graph that do not correspond to actual differences in the data.

Graphs encode quantitative data in the form of objects, such as bars, lines, and data points, and visual properties of those objects, such as colour to group objects. Because differences in visual properties, such as colour, are used to communicate actual differences in the information itself, visual differences should never be arbitrary. When people notice visual differences, they try to discern the meaning of those differences.

6.1.3 Use the lengths or 2-D locations of objects to encode quantitative values in graphs unless they have already been used for other variables.

Preattentive attributes (Healey 1993) are important in visual perception. The process of perceiving them does not involve conscious thought; it is automatic and immediate. Examples include such properties as an object's length (for example, the length of bar in a bar graph), its 2-D location (for example, the position of a data point in a scatterplot), its size, its shape, its orientation, its hue, and so on. If objects in a graph vary from one another along one of these properties to a great enough degree to appear different, those differences are seen immediately.

Of the full set of preattentive attributes, a few are perceived quantitatively. We perceive differences between varying expressions of a visual property (for example, length, exhibited as long bars, short bars, medium-length bars, etc.) as greater than or less than one another. Apart from these pre-attentive attributes, those that are not perceived quantitatively are simply seen as different, such as the different hues of black, green, blue, orange, purple, and so on. Two of the pre-attentive attributes that are perceived quantitatively are also perceived with a fair amount of quantitative precision: length and 2-D position. It is not accidental that the primary means of encoding quantitative values in graphs involves the use of length, as in the length of bars, and 2-D location, as in the position of data points. When lines are used to encode values in graphs in the form of a line graph, the 2-D locations where the data points are positioned along the line are what encode their values.

6.1.4 Differences in the visual properties that represent values (that is, differences in their lengths or 2-D locations) should accurately correspond to the actual differences in the values they represent.

Graphs are sometimes intentionally designed to misrepresent the truth by visually encoding values in a way that does not correspond to the actual values themselves and the differences between them. The most common way that this occurs involves bar graphs with quantitative scales that do not begin at zero. Because the lengths of bars encode the values they represent, the full length of the bar must be displayed, beginning from zero, for the values to be encoded properly.

6.1.5 Do not visually connect values that are discrete, thereby suggesting a relationship that does not exist in the data.

Values that are displayed in graphs are sometimes intimately related to one another and sometimes they are discrete. The way in which values are visually displayed should make it easy to see this distinction.

6.1.6 Make the information that is most important to your message more visually salient in a graph than information that is less important.

Not all information is of equal importance. It is often the case that some information is more important to your message than other information. This can be communicated in a graph by making those items that are most important more visually dominant. In effective communication, people's eyes are directed to the most important parts of the display.

Many visual properties can be used to make something stand out as important, including a brighter or darker colour, or even a colour that is simply different from the norm.

6.1.7 Augment people's short-term memory by combining multiple facts into a single visual pattern that can be stored as a chunk of memory, and by presenting all the information they need to compare within eye span.

Short-term memory is where information is stored while it is being processed. However, short-term memory has an extremely limited capacity. Information that is stored temporarily in short-term memory comes either from the outside world through our five senses or from long-term memory, where it is stored until it is needed. Human brains have the ability to combine multiple pieces of information into a single chunk of memory. By presenting quantitative information visually as patterns, more information can be simultaneously stored in short-term memory, thereby augmenting it in a way that extends people's ability to think about it. When a person examines information on a computer screen or the page of a printed report, a limited amount of the information can be held in short-term memory if comparisons must be made to information on another computer screen or page. Information that is never attended to does not get stored in short-term memory, and even if several chunks of information are attended to, only around four will be remembered when the person moves from one display to the next.

This makes comparisons difficult. Short-term memory can be augmented, however, by placing everything that needs to be compared within eye span, so it is readily available for rapid swapping in and out of short-term memory as it is being processed.

Leyland Wilkinson (2001) presents a complementary set of guidelines for effective graphical communication, as outlined below.

avoid clutter – especially do not clutter the data region inside the plotting frame demarcated by axes
maximise the data/ ink ratio, but do not remove redundant features that can reinforce an accurate perception
avoid unnecessary embellishment
avoid visual illusions, pseudo-3D, and gratuitous use of colour, angles, area or volume
seek simple geometric forms – straight lines, circles, triangles, squares
when it helps to simplify a relationship, use logs or square roots – to convert curves to straight lines, for example
use polar coordinates when variables are cyclical (astronomical, perceptual, directional)
sort and organise –this is especially important for complex graphics
annotate extensively – make legends comprehensive and informative
figure captions should describe the source of the data, and explain the relation of the data to the graphic

[adapted from Wilkinson 2001]

6.2 EDWARD TUFTE'S PRINCIPLES OF DATA VISUALISATION

Edward R Tufte four books on data visualisation design are central to this study. From 1983's *The Visual Display of Quantitative Information* through *Envisioning Information* (1990) and *Visual Explanations, Images and Quantities* (1997) to *Beautiful Evidence* (Tufte 2006), Tufte has offered a comprehensive critique of the way information is depicted in graphs, tables, illustrations and PowerPoint® slides. In Tufte's thesis, graphics are not simply sideshows to spruce up text or entertain readers. Graphics shape, or even distort, our understanding of key information.

In *The Visual Display of Quantitative Information*, Tufte outlines some key themes, and presents examples of best and worst practice. He then presents six principles of graphical integrity:

'The representation of numbers, as physically measured on the surface of the graphic itself, should be directly proportional to the numerical quantities represented. Clear, detailed, and thorough labelling should be used to defeat graphical distortion and ambiguity. Write out explanations of the data on the graphic itself. Label important events in the data. Show data variation, not design variation. In time-series displays of money, deflated or standardized units of monetary measurement are nearly always better than nominal units. The number of information-carrying (variable) dimensions depicted should not exceed the number of dimensions in the data. Graphics must not quote data out of context.' (ibid p77)

He then moves to provide five principles in the theory of data graphics: *'Above all else show the data. Maximise the data-ink ratio. Erase non-data-ink. Erase redundant data-ink. Revise and edit'* (ibid p105).

Data-ink Ratio

Data-ink is the non-erasable core of a graphic - the ink varies as the data changes. Tufte coined the term 'data-ink ratio', which he defined as 'the proportion of a graphic's ink devoted to the non-redundant display of data information' (Tufte 1983 p93). The most efficient graphics have the lowest data-ink ratio.

Chartjunk

Another term that Tufte has popularised is 'chartjunk', which describes unintentional optical-art effects - such as moiré vibration, dominant grid lines, and redundant decorative elements - 'the duck' (Tufte 1983 p117). Chartjunk patronises the audience:

'consumers of graphics are often more intelligent about the information at hand than those who fabricate the data decoration. And no matter what, the operating moral premise of information design should be that our readers are alert and caring; they may be busy, eager to get on with it, but they are not stupid. Clarity and simplicity are completely opposite simple-mindedness. Disrespect for the audience will seep through, damaging communication' (Tufte 1990 p34). This can have catastrophic consequences. Tufte asserts, for example, that poorly designed charts played a decisive role in both space shuttle disasters.

Tufte tackles a fundamental problem: how to accurately render complex, interrelated information on a two-dimensional paper surface or computer screen—how to, as he puts it, 'escape flatland." Tufte explains how to do it well and demonstrates the many ways that it has been done badly.

In *Envisioning Information* (1990) Tufte outlines design strategies for enhancing the dimensionality and density of portrayals of information. He attempts to reveal general principles that have specific visual consequences, governing the design, editing, analysis and critique of data representations.

Like the earlier books, *Beautiful Evidence* (2006) includes a statement of Tufte's design principles:

show comparisons
show causality
show data in their full complexity
document and display your sources
above all, respect the intelligence of the audience and tell the truth.

[summarised from Tufte 2006]

6.3 PRINCIPLES OF GRAPHICAL EXCELLENCE

Measured data can be presented in the form of any combination of points, lines, a coordinate system, numbers, symbols, words, shading or colour. The attributes of clear, precise and efficient graphics are such that graphical displays should:

show the data
induce the viewer to think about the substance, rather than about methodology, graphic design, the technology of graphic production, or something else
avoid distorting what the data have to say
present many numbers in a small space
make large data sets coherent
encourage the eye to compare different pieces of data
reveal the data at several levels of detail, from a broad overview to the fine structure
serve a reasonably clear purpose: description, exploration, tabulation or decoration
be closely integrated with the statistical and verbal descriptions of a data set

(Tufte 1983 p13)

Small Multiples

Principles for improving the density of data in graphics are outlined as follows:

[Well-designed small multiples are]

'inevitably comparative, deftly multivariate, shrunken high-density graphics, usually based on a large data matrix, drawn almost entirely with data-ink, efficient in interpretation, often narrative in context, showing shifts in the relationships between variables as the index variable changes (thereby revealing interaction or multiplicative effects)' (Tufte 1983 p175).

6.4 AESTHETIC QUALITIES OF DATA GRAPHICS

If a data visualisation is aesthetically attractive, it will engage the viewer, and may extend the time the viewer will spend absorbing the data. There will be a consequent improvement in the communication of information. Tufte (1983) presents some guidelines for aesthetics: *'have a properly chosen format and design; use words, numbers and drawing together; reflect a balance, a proportion, a sense of relevant scale; display an accessible complexity of detail; are drawn in a professional manner, with the technical details of production done with care; avoid content-free decoration, including chartjunk'* (p177).

6.5 INTEGRATING GRAPHICS WITH TEXT

Of particular interest is the use of graphics in EISs is the integration of words, numbers and pictures. The flow of information should not be broken up by technical conventions and production requirements.

'Imagine if graphics were replaced by paragraphs of words, and those paragraphs scattered over the pages out of sequence with the rest of the text - that is how graphical and tabular information is now treated in the layout of many published pages, particularly in scientific journals and professional books' (ibid p181, see also Mayer 2001 and DEAT 2004).

Tufte outlines the qualities of a friendly data graphic:

words are spelled out, mysterious and elaborate encoding avoided

words run from left to right, the usual direction for reading occidental language

little messages help explain data

elaborately encoded shadings, cross-hatching and colors are avoided; instead labels are placed on the graphic itself; no legend is required

graphic attracts viewer, provokes curiosity
colors, if used, are chosen so that the color-deficient or color-blind (5 to 10 percent of viewers) can make sense of the graphic (blue can be distinguished from other colors by most color-deficient people)
type is clear, precise, modest; lettering may be done by hand
type is upper-and-lower case, with serifs.

(Tufte 1983 p183)

6.6 VISUAL PERCEPTION AND COGNITION

The integration of text and visual elements in a document has been found to improve communication by large and measurable amounts (Mayer 2001). Richard E Mayer found that adding visuals to words improved learning by between 23% and 89%, when compared with text separated from visual elements (Mayer, in Horn 2001).

6.7 THINKING AND DESIGN

Tufte draws a correlation between statistical thinking and display design, which share the following principles:

documenting the sources and characteristics of the data
insistently enforcing appropriate comparisons
demonstrating mechanisms of cause and effect
expressing these mechanisms quantitatively
recognising the inherently multivariate nature of analytic problems
inspecting and evaluating alternative explanations.
When consistent with the substance and in harmony with the content, information displays should be documentary, comparative, causal and explanatory, quantified, multivariate, exploratory.

(Tufte 1997 p53)

6.8 VISUALISING UNCERTAIN INFORMATION

If predicted environmental impacts are uncertain, then the extent of the uncertainty should be conveyed in any associated data visualisation. Thomson et al. (2005) summarise the main causes of imperfect knowledge as indicated in **Figure 6.1**.

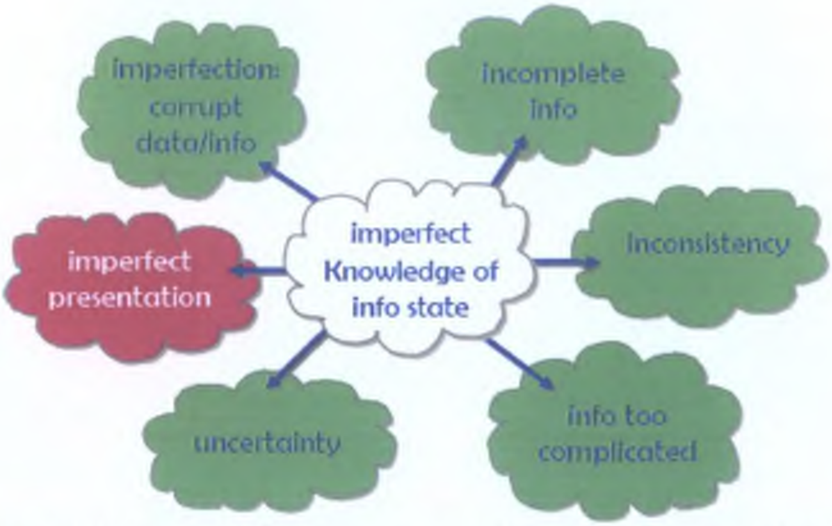

Figure 6.1 Causes of Imperfect Knowledge (Thomson et al. 2005)

There are two basic methods for representing this uncertainty in a graphic – sharp error bounds, or blurred estimates (Wilkinson 2001). Sharp error bars can typically be used to represent 95 per cent confidence intervals, one standard deviation or one standard error. Sharp error bars can be incorporated in bullet graphs, for example (Few 2008). An example of the use of fuzziness to represent uncertainty is shown in **Figure 6.2** (source: Matt Ward, Worcester Polytechnic Institute).

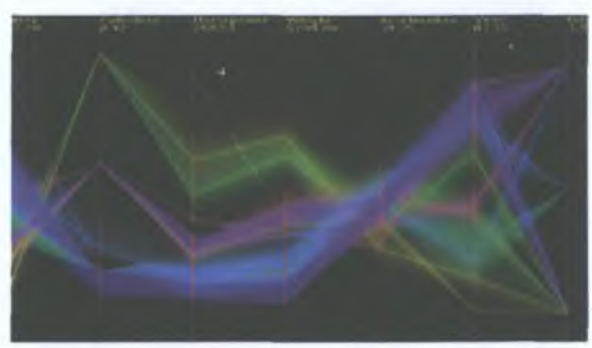

Figure 6.2 Uncertainty Represented by Fuzziness

6.9 PRINCIPLES OF ENVIRONMENTAL COMMUNICATION

The International Organization for Standardization (ISO) provides guidance on environmental communication (BS ISO 14063:2006). The principles, which can be directly applied to environmental communication in the EIA process, are as follows:

Table 6.1 ISO Guidance for Environmental Communication

Transparency	Make the processes, procedures, methods, data sources and assumptions used in environmental communication available to all interested parties, taking account of the confidentiality of information as required. Inform interested parties of their role in environmental communication.
Appropriateness	Make information provided in environmental communication relevant to interested parties, using formats, language and media that meet their interests and needs, enabling them to participate fully.
Credibility	Conduct environmental communication in an honest and fair manner, and provide information that is truthful, accurate, substantive and not misleading to interested parties. Develop information and data using recognized and reproducible methods and indicators.
Responsiveness	Ensure that environmental communication is open to the needs of interested parties. Respond to queries and concerns of interested parties in a full and timely manner. Make interested parties aware of how their queries and concerns have been addressed.
Clarity	Ensure that the environmental communication approaches and language are understandable to interested parties to minimize ambiguity.

[Source: British Standard 2006 pp2-3]

7. CURRENT ENVIRONMENTAL IMPACT STATEMENT PRACTICE

In this chapter the main issues raised in the responses to the questionnaires, and the main findings of the EIS review are reported. Relevant aspects are highlighted for consideration in Chapter 8, Discussion and Conclusions.

7.1 INTRODUCTION

Prendergast and Rybaczuk (2005), in their survey of visualisation techniques in EISs, conclude that there is a need to examine the way such information is currently presented in EISs, to maximise communication, understanding and participation for all stakeholders in an application for planning permission. They note that there are particular difficulties with communicating technical and scientific information in text and tabular form, and suggest that concepts can be grasped much more quickly if presented graphically.

However, Prendergast and Rybaczuk's particular focus is on landscape and visual impact assessment, and there is an evident opportunity to apply such principles across the full scope of an environmental impact assessment. The methodology outlined in Chapter 1 has been implemented to ascertain both what the representatives of the competent authorities (the planners sampled) think about current practice in EIS presentation, and also to evaluate what techniques are currently being used in summarising and communicating predicted impacts.

Wood et al. (1996) in their evaluation of the EIA process found that the key features determining the quality of EIA reports were as follows:

Nature of consultancies
Experience of participants
Scoping
Length of EIA reports
Nature of projects.

7.2 ANALYSIS OF RESPONSES TO OPEN QUESTIONS IN QUESTIONNAIRES

A wide range of issues have been raised in the responses to the questionnaires. Of relevance to this study are the comments tabulated below. References to particular locations, or other comments made which might identify the person who completed the questionnaire, have not been included here to provide anonymity.

The comments are tabulated below under two headings – problems identified with current practice, and suggestions for improvement, or for best practice. Each response is considered in the context of the objectives of this dissertation, and assigned a rating of low, medium or high, based on its relevance to the study. They are listed in **Tables 7.1** and **7.2**, and assigned reference numbers. These are then discussed in **Chapter 8**.

Table 7.1 Problems Identified with Current Practice – as Recorded in Completed Questionnaires

Problem	Relevance to this Dissertation	Reference
'Often information is repeated.'	Low	1
'Lack of photographic surveys'	Low	2
'unedited, badly presented work'	Medium	3
'too much repetition'	Medium	4
'use of out of date information and inconsistencies across sections of the EIS'	Low	5
'vague use of terminology "impact could be mitigated" not we will mitigate by. . . requires planning authority to condition all mitigation'	Low	6
'on graphics the lazy failure to use the proper version of drawings, maps or models or inconsistencies in the text from bad "cut and pastes" ie bad quality control'	Medium	7
[EPA recommended descriptions for impacts] 'mean nothing to the public and [are] very subjective. Each situation has to have some localised relativity placed on it, ie % traffic increase, visual models, etc'	Medium	8
'no clear commitment to implementing mitigation measures, MAY instead of SHALL'	Low	9
'Climate, cumulative impacts' [receive inadequate attention]	Medium	10
'Inadequate graphics. Inadequate description of the project.'	High	11

Table 7.1 Problems Identified with Current Practice – as Recorded in Completed Questionnaires

Problem	Relevance to this Dissertation	Reference
'visual impact assessment, groundwater/ dewatering, alternative layouts considered, sub-threshold EIS' [receive inadequate attention in EISs]. 'The visual impact assessment is occasionally flawed because the viewpoints are selective, the methodology is selective, the description in the text of the impact is often flawed, ie if there is going to be a significant adverse impact, say so, rather than "mislead."'	Medium	12
'Roads issues, traffic implications' [receive inadequate attention in EISs]	Medium	13
'cumulative effects/ interaction' [receive inadequate attention]	Medium	14
'poor/ bad quality mapping/ plans'	High	15
'the reasons for not selecting alternative sites/ locations is usually poor and/ or inaccurate'	Low	16
'laborious text – excessive cutting and pasting'	Medium	17
'overlapping information in sections'	Low	18
'referenced drawings difficult to locate'	Medium	19
'excessively large volumes – rather than separate sections'	Low	20
'mitigating measures, impacts on flora and fauna' [receive inadequate attention]	Low	21
'lack of clarity in language'	High	22
'evasion in mitigating measures'	Medium	23
'inconsistency in statements'	Medium	24
'alternative locations' [receive inadequate attention]	Low	25
'non-technical summary sometimes appears to be simply lifting text from the main body of the EIS'	Medium	26
'EIS side steps critical issues'	Low	27
'some combined volumes too large'	Medium	28

Table 7.1 Problems Identified with Current Practice – as Recorded in Completed Questionnaires

Problem	Relevance to this Dissertation	Reference
'poor quality of photocopied text'	Low	29

Table 7.2 Suggestions for Improvement, or for Best Practice – as Recorded in Completed Questionnaires

Suggested Improvement	Significance to this Dissertation	Reference
[improvements could be made to] 'simplicity and clarity in presentation'	High	30
[a good summary of predicted impacts] 'needs to have context. . . or mitigated versus non mitigated to see the relative effect of measures taken'	High	31
[a good summary of predicted impacts should] 'clearly identify effects - individual and cumulative - short and long-term impacts'	High	32
[improvements could be made by] 'grouping all mitigation commitments'	High	33
[a clear and user-friendly EIS will] 'adhere to issues requiring to be addressed'	High	34
[a clear and user-friendly EIS is] 'concise, [with] non-technical explanations where possible'	High	35
[a good summary of predicted impacts should be] 'clear + user friendly - unambiguous - [with] non-technical explanations'	High	36
[improvements could be made to] 'use of . . . visualisation techniques'	High	37
[a good summary of predicted impacts should have] 'clear and adequate description in text and where appropriate graphical form, easy to read and readily understood'	High	38
[improvements could be made to] 'better use of graphics'	High	39
[a clear and user-friendly EIS has] 'short text'	High	40
[a good summary of predicted impacts should have] 'easy to read matrix'	High	41
[a clear and user-friendly EIS has] 'pictures in colour'	High	42

Table 7.2 Suggestions for Improvement, or for Best Practice – as Recorded in Completed Questionnaires

Suggested Improvement	Significance to this Dissertation	Reference
[a good summary of predicted impacts will] 'include quantitative and qualitative impacts'	High	43
[a good summary of predicted impacts will reflect] 'brevity and accurate description of adverse as well as benign impacts of development'	High	44
[a good summary of predicted impacts will be] 'clear and concise'	High	45
[improvements could be made to] 'clear distinction of likely impacts and their severity'	High	46
[a good summary of predicted impacts will be in] 'tabular format'	High	47
[descriptions of impacts should be in the form of a] 'matrix with various headings, such as in SEA'	High	48
[improvements could be made by including a] 'matrix of impact significance'	Medium	49
[a clear and user-friendly EIS will have] 'good NTS, good indexing'	High	50
'very technical sections such as noise or traffic do need a clear explanation up front of the monitoring and assessment process and any assumptions made'	Low	51
[a clear and user-friendly EIS] 'identifies and narrows down to main issues quickly and clearly sets out the assessment criteria and methods used'	Medium	52
'Well defined table of contents including list of figures, tables and appendices. Should use same headings for each environmental topic e.g. intro/ methodology/ receiving environment/ impacts/ mitigation measures/ residual impacts/ references etc. Separate volume for graphics.'	Medium	53

Table 7.2 Suggestions for Improvement, or for Best Practice – as Recorded in Completed Questionnaires

Suggested Improvement	Significance to this Dissertation	Reference
'Not too wordy and less waffle, e.g. describes the impacts precisely. Not too repetitive. Should have enough graphics to assist the reader. Main volume should have the key information to describe the various impacts etc. Appendices should assist as technical back-up, i.e. the reader should not have to read every appendix to get a good idea of the scheme. NTS should be exactly that – non-technical.'	High	54
[a good summary of predicted impacts is] 'concise yet descriptive'	High	55
'Succinct, easy to reference or cross-reference, how does it fit in with key policy issues/ objective in City/ County/ Regional plan'	High	56
[a good summary of predicted impacts is] 'Succinct, honest, verifiable, relates to the "bigger picture" ie City Plan/ National Policy'	High	57
'Simple language, graphs, colour, examples used'	High	58
[a good summary of predicted impacts will have] 'precise details, bullet points, should be numbered by importance'	High	59
'glossary of items at end'	Low	60
'use of colour and variety in presentation'	High	61
[a good summary of predicted impacts will have] 'small number of important effects'	High	62
'a specific list of instances where the proposed development impacts shall extend beyond accepted parameters'	Medium	63
'a specific list of all mitigated [sic] measures proposed'	Medium	64

Table 7.2 Suggestions for Improvement, or for Best Practice – as Recorded in Completed Questionnaires

Suggested Improvement	Significance to this Dissertation	Reference
'graphics are proposal dependent, however, the critical aspect is that they are clear and the relevant information easily extracted'	High	65
'it was a wind farm application that was hard bound, the sections colour coded and blank spaces within sections to allow for noted [sic] by the reader'	High	66
'easily navigated, colour coded, separate book of appendices (from main text)'	High	67
[a good summary of predicted impacts will be] 'clear, bullet point format, suggesting means of controlling/ monitoring (planning conditions, etc)'	High	68
[a best example of graphic presentation is] 'an electronic EIS with 3D presentation (relating to a housing development)'	Medium	69
'Electronic EIS that allowed for easy movement between sections'	Medium	70
[a good summary of predicted impacts will be] 'clear, well-defined within statutory criteria, cumulative impacts separated from individual impacts'	High	71
'critical element of graphics is that they adequately and clearly describe the proposal – electronic form is often useful'	Medium	72
[an EIS that impressed with its clarity and user-friendliness was] 'a large windfarm application that included high quality information relating to visual impacts. Did not attempt to 'sugar coat' presentation, but justified impacts within a wider policy context'	Medium	73
'efficient use of text – not repetitive, no ambiguity, no contradictions, concise and accessible summary'	High	74

Table 7.2 Suggestions for Improvement, or for Best Practice – as Recorded in Completed Questionnaires

Suggested Improvement	Significance to this Dissertation	Reference
[a good summary of predicted impacts will be] 'accurate, and relate to discussion within EIS'	Medium	75

In addition to these, examples of good practice in EIS graphics and presentation were requested in the questionnaires. The suggestions returned were considered in the context of the methodological objective of reviewing the work of as wide a range of practitioners as possible. The following suggestions were therefore included in the EIS review.

Lansdowne Road Redevelopment
Wyeth
Shannon LNG Terminal, County Kerry
Corrib Terminal, Bellanaboy, County Mayo

7.3 NUMERICAL ANALYSIS OF QUESTIONNAIRE RESPONSES

A total of twenty responses to the questionnaires were received. Nine of the questions were closed questions, where the respondent was requested to tick a box. The responses to the closed questions are analysed below, on a question-by-question basis.

Question 1

All respondents encounter EISs more than once a year, with 75% less than once per month, and 25% more than once per month, but less than once per week. It can be assumed, therefore, that the responses represent the opinions of individuals who have substantial experience of reading and analysing EISs.

Question 2

All respondents spend more than an hour reading or analysing EISs, with 15% spending less than two hours. 35% spend between two and four hours, and 30% spend between four and eight hours. 20% of the respondents report that they spend more than eight hours considering each EIS.

Question 3

Most of the respondents' time is spent considering the main text of the EIS (68%). An average of 17.5% of the total time is spent reading the non-technical summary, and 14.5% of the time is dedicated to considering the technical appendices.

Question 4

All respondents report that they can usually locate the information they require in EISs, with 25% recording a firm 'yes', and the remainder recording 'usually'.

Question 5

Most respondents (70%) prefer the grouped format, where each environmental topic is considered in a separate section. 30% prefer the direct format, with one respondent clarifying that they preferred the direct format for smaller projects, and the grouped format for large and complex developments.

Questions 6 to 10

Refer to **Tables 7.1** and **7.2**, which summarise the responses to the open questions.

Question 11

Half of the respondents prefer the non-technical summary (NTS) to be a separate volume, 5% usually prefer a separate NTS. 20% usually do not, and 25% stated 'no'.

Question 12

Paper versions of EISs are favoured by 90% of the respondents, with only 10% expressing a preference for electronic formats.

Question 13

No definite 'yes' or 'no' was recorded in relation to whether predicted significant impacts are clearly presented. 60% of respondents consider that they are usually clearly presented, with 40% stating that they are not usually clearly presented.

Questions 14 and 15

Refer to **Tables 7.1** and 7.2, which summarise the responses to the open questions.

Question 16

80% of the respondents are happy with the EPA-recommended descriptions for impacts, 5% did not complete this section, and the three comments provided are as follows:

'a matrix with various headings, such as in SEA'

[EPA descriptions are inadequate because] 'use varies between practitioners'

'means very little to the public and is very subjective – each situation has to have some localised relativity placed on it, i.e. % traffic increase, visual models, etc'.

7.4 REVIEW OF ENVIRONMENTAL IMPACT STATEMENTS

Twenty eight EISs were reviewed. A wide range of different consultants' work was covered, to gather as wide a range of approaches to the presentation of impacts as possible. These are listed in **Table 7.3** below.

Table 7.3 List of EISs Reviewed

Consultant	Date	Project Description
Arup Consulting Engineers	2007	Shannon LNG Terminal at Ralappane, County Kerry
AWN Consulting	2007	Pfizer MAbs SSF, Ringaskiddy
Bord Na Mona Environmental Ltd	2005	Waste Transfer Station at Proudstown, Navan
Brady Shipman Martin	2003	Carrigaline Housing Development
Cunnane Stratton Reynolds	2008	Atlantic Quarter, Cork City Docklands
Environment and Resource Management Ltd	2004	Lansdowne Road Stadium Redevelopment, Dublin
EIS Ltd	2001	Abbott Ireland Pharmaceutical, Sligo
Farningham McCreadie Partnership Limited	2003	Proposed High-technology Business Park on Land at Ardmore, Mullingar
Fehily Timoney & Company	2007	Inert Landfill at Beaumont Quarry
Fluor Ireland Ltd	2004	Wyeth Medica Newbridge
Golder Associates/ RPS	2005	Expansion of BRDA at Aughinish Alumina
John Barnett and Associates	2004	Remediation of Unauthorised Landfill at Blessington, County Wicklow
Kirk McClure Morton	2004	Landfill Facility at Meenaboll, Donegal

Table 7.3 List of EISs Reviewed

Consultant	Date	Project Description
Manahan Planners	2007	Restoration of Quarry at Hollywood Great, Naul
Nigel Barnes & Associates	1999	Windfarm at Letteragh, County Clare
O'Callaghan Moran and Associates	2004	Materials Recovery Facility at Fassaroe, Bray
Onyx Ireland Ltd	2006	Waste Transfer Facility at Carrignard, Kilbarry
Patel Tonra Ltd Environmental Solutions	2005	Civic Amenity Facility at Labre Park, Ballyfermot
Project Management Ltd	2006	Amgen Proposed Biotechnology Facility at Ballyadam
RPS Kirk McClure Morton	2005	Dunmore East Fishery Harbour Development
RPS-MCOS	2006	Sustainable Resource Recovery Centre, Clondalkin
RSK-ENSR Environment Ltd	2006	Bellanaboy Gas Terminal, Bellagelly South
SWS Environmental Services	2004	Waste Recovery/ Transfer Facility at Foxhole, Youghal
TES Consulting Engineers	2005	Kilshane Cross Recycling Park, Fingal
Tobin Consulting Engineers	2007	Derrinumera Sludge Hub Centre, Mayo
Tougher Environmental Ltd	2005	Schlotter Ireland Ltd Metal Finishing, Naas
White Young Green Environmental	2006	Carbury Composting Facility at Drummin, Carbury

[source: generally EPA 2008]

The *Shannon LNG Terminal EIS* (Arup 2007) uses a grouped format to describe predicted impacts in both the main EIS text, and the non-technical summary. These are complied in a separate chapter at the end of the main text, in the form of a summary table with the headings 'source/scale of effect', 'control and mitigation' and 'environmental consequence significance level'. This last column includes descriptions which follow the EPA guidance (CAAS 2002 p33).

The *Pfizer Monoclonal Antibodies Small Scale Facility* (MAbs SSF) EIS (AWN 2007) also uses a grouped format, with predicted impacts described in a similar way to Arup (2007). However, no summary of impacts is provided as part of the main text of the EIS. Predicted impacts are grouped in the non-technical summary, and impacts are described in accordance with CAAS (2002).

The *Waste Transfer Station at Proudstown, Navan EIS*, for Midland Waste Disposal Company Ltd (Bord na Mona Environmental Ltd 2005) is in the grouped format, with predicted impacts associated with each environmental topic described in text in the relevant chapters. The predicted significance of the impacts is generally not stated, and the EPA guidance on description of impacts has not been applied in most places.

Carrigaline Housing Development EIS (Brady Shipman Martin 2003) is in the grouped format, and makes reference to the EPA guidance on description of impacts. Predicted impacts are described in the text of the main chapters, and summarised in the non-technical summary. The final chapter in the main text is titled 'Conclusion', which summarises some of the predicted impacts in the context of the planning objectives for the site.

Atlantic Quarter EIS (Cunnane Stratton Reynolds 2008) is also in the grouped format, with predicted impacts described in text in the main topic chapters, and in a condensed form in the non-technical summary. Predicted impacts are generally described using the EPA guidance, but the application is inconsistent through the document. No summary of impacts is provided, apart from the non-technical summary.

Abbott Ireland Pharmaceutical Manufacturing Plant, Sligo EIS (EIS Ltd 2001) is in the grouped format. It quotes directly from the EPA guidance, in the form of a 'glossary of impacts'. Predicted impacts are described in the main text, and the non-technical summary in accordance with the EPA guidance.

Redevelopment of Lansdowne Road Stadium EIS (ERM 2006) is in the direct format, with a number of specific impact assessments provided as appendices to the main document. The EPA guidance is quoted, and is used consistently to describe predicted impacts. The predicted impacts are presented in bullet-point format, under the chapter headings 'demolition and construction impacts' and 'operational impacts'. The main text of the EIS concludes with a two-page chapter 'statement of assessment' which includes a tabular 'summary of residual impacts'; refer to **Figure 7.1**.

Project Activity	Flora & Fauna	Water resources & Flood Risk	Traffic & Transport	Geology	Noise	Air Quality	Landscape and Visual	Waste management	Heritage resources	Human beings – O'Connell Gardens & Havelock Square	Human beings - other
Demolition & Construction											
General demolition works											
General construction works											
Operation											
Presence of permanent structures											
Sporting & concert event-day activities											
Non event-day activities											
New spectator access/egress routes											
New railway underpass											
New Dodder Walk											
Sports & Architectural Lighting											

Key	
Profound negative	
Significant negative	
Moderate negative	
Slight negative	
Imperceptible	
Slight positive	
Moderate positive	
Significant positive	
Profound positive	
Not of direct relevance	

Figure 7.1 Summary of Residual Impacts (ERM 2006)

Proposed High-Technology Business Park on Land at Ardmore, Mullingar EIS (Farningham McCreadie Partnership 2003) is in the grouped format. In some cases, predicted impacts are either not clearly described in accordance with the EPA guidelines, or are difficult to locate in the document. This applies to the main text and the non-technical summary.

Inert Landfill at Beaumont Quarry, Cork EIS (Fehily Timoney & Co 2007) is in the grouped format, with impacts generally described in the text of the individual chapters. The predicted impacts are not consistently described, but some chapters, such as flora and fauna, provide comprehensive impact descriptions in accordance with the EPA guidance.

No summary of residual impacts is included, apart from the descriptive text in the non-technical summary.

Wyeth Medica Ireland Proposed Premarin New Facility Transfer (PNFX) Development (Fluor Ireland Ltd 2004) is in the grouped format, with predicted impacts described in the text of each chapter. The EPA guidance is used, in both the main text, and the non-technical summary. No other summary of predicted impacts is provided.

Expansion of Bauxite Residue Disposal Area (BRDA) and Increase in Alumina Production Capacity at Aughinish Alumina EIS (Golder Associates/ RPS 2005) is in the grouped format, and uses impact significance descriptions which are similar to the EPA recommendations in that it has five levels. The predicted impacts are described in the text of the main chapters. No summary of impacts is provided, apart from a comprehensive non-technical summary.

Remediation of Unauthorised Landfill Sites at Blessington, County Wicklow EIS (John Barnett and Associates 2004) is presented in the grouped format, and does not consistently use the EPA recommended descriptions for predicted environmental impacts. Impacts are described in the main text, and in the non-technical summary.

Landfill Facility at Meenaboll, Letterkenny EIS (Kirk McClure Morton 2004) is also in the grouped format. The terminology used to describe impacts is generally in accordance with the EPA guidelines, both in the main text of the EIS and the non-technical summary. The EPA guidelines are specifically referred-to, and scheduled, in Section 15 of the main text 'Landscape and Visual' (ibid p15-3). A summary chapter of predicted impacts and mitigation measures is provided, in addition to the non-technical summary.

Restoration and Filling of Quarry at Hollywood Great, Naul, County Dublin EIS (Manahan Planners 2007) is in a modified version of the grouped format, and impacts are described in the main text and non-technical summary in accordance with the EPA guidelines. A detailed summary table of predicted impacts, mitigation measures, and residual impacts is also provided, covering the aspects of the environment scheduled in SI 600 of 2001.

Proposed Windfarm at Letteragh and Boolynagleragh, Kilmaley, County Clare EIS (Nigel Barnes & Associates 2001) is in the grouped format. While reference is made to the EPA guidelines, predicted impacts are not consistently described in accordance with the guidelines. No summary of predicted impacts is provided, apart from the brief non-technical summary text.

Materials Recovery and Transfer Facility at Fassaroe, Bray, County Wicklow EIS (O'Callaghan Moran and Associates 2004) is in the grouped format. Predicted impacts are described in the main text and the non-technical summary in accordance with the EPA guidelines, and a summary table is also provided in the non-technical summary, under the headings: 'description, impact no., character, magnitude, duration, consequences, significance of impact, and certainty' (ibid 2004).

Waste Transfer and Recycling Facility at Carrignard, Kilbarry, Waterford EIS (Onyx Ireland Ltd 2006) is in the grouped format, and predicted impacts are described in the main text and the non-technical summary in general accordance with the EPA guidelines. A separate section in the non-technical summary focuses specifically on 'significant environmental effects and mitigation measures' (ibid p23), where the key predicted impacts are set out in bullet-point format. Residual impacts are not scheduled here.

Civic Amenity Facility at Labre Park, Ballyfermot, Dublin 10 EIS (Patel Tonra Ltd 2005) is in the grouped format, and predicted impacts are described in accordance with the EPA guidelines. In each of the chapters and in the non-technical summary, predicted impacts are outlined in text format.

Proposed Biotechnology Facility at Ballyadam, Carrigtohill, County Cork EIS (Project Management Ltd 2006) is in the grouped format, and includes a reproduction of the EPA guidance for the description of predicted impact (ibid page xv). Predicted impacts are described in the text of the chapters and in the non-technical summary, following the EPA guidance.

Dunmore East Fishery Harbour Development EIS (RPS Kirk McClure Morton 2005) is presented in a modified version of the grouped format. In addition to describing the predicted impacts in the main text (in accordance with the EPA guidance) the non-technical summary includes a table titled 'summary of impact and mitigation measures' which schedules impacts, comments and mitigation measures against environmental topics.

Sustainable Resource Recovery Centre at Crag Avenue, Clondalkin, County Dublin EIS (RPS MCOS 2006) is in the grouped format. The EIS makes reference to the EPA guidelines, but these are not applied consistently across the individual chapters and in the non-technical summary. However the predicted impacts are summarised in a table 'summary of potential environmental effects' which does follow the EPA recommendations.

Fingal Landfill Project EIS (RPS Planning Transport and Environment 2006) is in the grouped format, with predicted impacts described in the main text and the non-technical summary in accordance with the EPA guidelines. In many of the individual chapters predicted impacts are also tabulated in detail, using the EPA terminology.

Bellanaboy Bridge Gas Terminal and Associated Srahmore Peat Deposition Site EIS (RSK ENSR Environment Ltd 2006) is in the grouped format. Predicted impacts are described using terminology similar to the EPA guidelines, in the main text, and also in the non-technical summary. A summary of impacts and proposed mitigation measures is also provided in the form of a table. In addition, a table outlining an environmental risk assessment associated with key hazard scenarios is included.

Waste Recovery/ Transfer and Sludge Drying Facility at Foxhole, Youghal EIS (SWS Environmental Services 2004) is in the grouped format, with predicted impacts described in the main text and the non-technical summary in accordance with the EPA guidelines. No separate summary of impacts and mitigation measures is provided.

Kilshane Cross Recycling Park, Newtown, Dublin 15 EIS (TES Consulting Engineers 2005) is in the direct format. Impacts are described broadly in accordance with the EPA guidelines, in text in the main document and in the non-technical summary. No other summary chapter or table is included in the EIS.

Derrinumera Sludge Hub Centre and Leachate Treatment Facility, Mayo EIS (Tobin Consulting Engineers 2007) is in the grouped format. Predicted impacts are described in each of the chapters of the main EIS, and in the non-technical summary, in text. A chapter is included titled 'Interaction of Environmental Effects and Summary of Mitigation Measures', but this only summarises (in bullet point format) the mitigation measures associated with the predicted interactions, and does not appear to comprehensively summarise all predicted impacts.

Proposed Relocation of Schlotter Ireland to Tougher Business Park, Lewistown, Naas EIS (Tougher Environmental Ltd 2005) is in a modified version of the grouped format. The EPA guidelines are not followed in describing predicted impacts, and no evidence of a non-technical summary was noted in the EIS. Predicted environmental impacts are described in five sentences in a section titled ‘environmental effects’.

Carbury Composting Ltd Facility at Drummin, Carbury, County Kildare EIS (White Young Green Environmental (Ireland) 2006) is in the direct format. Predicted impacts are described in the text and the non-technical summary, using some of the terminology of the EPA guidelines, but not fully in accordance with them. No summary of predicted impacts is included, apart from the non-technical summary.

7.5 ANALYSIS OF SAMPLE ENVIRONMENTAL IMPACT STATEMENTS

Some conclusions can be drawn, both directly and indirectly from the sample EISs. Firstly, there was no evidence of the use of data visualisation techniques, beyond the tabular presentation of residual impacts in the Lansdowne Road Redevelopment EIS (ERM 2006). Secondly, the EPA guidelines have not been adopted fully by practitioners. Even in the EISs which make specific reference to them, predicted impacts are not described to a consistent level of detail across all chapters. There is a clear tendency towards structuring EISs in the grouped format, and there may be scope for reappraising which of the EPA formats can most effectively convey critical environmental information. Non-technical summaries are generally exclusively in text format, with no tabular or graphic representation of predicted impacts.

8. DISCUSSION AND CONCLUSIONS

This Chapter suggests some potential improvements to current presentation practice in EISs. Reference is made to the findings of the questionnaire research, the review of EISs, and some data visualisation literature. Opportunities for future research are also outlined.

8.1 TIME CONSTRAINTS FOR CONSIDERING ENVIRONMENTAL IMPACT STATEMENTS

It is evident from the responses to the questionnaires that planners have limited time to consider the environmental consequences of decisions relating to proposed developments. 80% of the respondents reported that they spend less than eight hours considering the EIS for a typical planning application. Considering the complexity of the information provided - with a range of predicted impacts for each of the environmental topics, and also the interactions, cumulative and synergistic effects, for both construction and operational phases - presentation and communication of information must be as clear as possible.

8.2 WEAKNESSES IN CURRENT ENVIRONMENTAL IMPACT STATEMENTS

There is also considerable frustration with the quality of the information, and its presentation, as currently being presented in EISs (Refer to **Table 7.1**). For example, responses such as 'inadequate graphics' (reference 10 in **Table 7.1**) 'lack of clarity in language' (reference 22) suggest that in these cases, the information that should be readily accessible in EISs is not. The negative consequences that can arise from this include delays to the development, as further information on the application is requested by the planning authority. More fundamentally, the quality of the EIA is also affected, as the competent authority does not have the level and quality of information required to properly assess the consequences of permitting the proposed development.

The suggested improvements recorded in **Table 7.2** support this. Examples such as 'simplicity and clarity in presentation' (reference 30 in **Table 7.2**), 'clearly identify effects' (reference 32), 'adhere to issues requiring to be addressed' (reference 34), 'concise, non-technical explanations where possible' (reference 35), 'use of visualisation techniques' (reference 37), 'clear and adequate description in text and where appropriate graphical form, easy to read and readily understood' (reference 38), 'better use of graphics' (reference 39) 'clear and concise' (reference 45) and finally 'simple language, graphs, colour, examples used' (reference 59) represent an unambiguous desire on the part of planners for improvement in the quality of data communication in EISs. In this context, the decision-making process may be improved by communicating the important predicted impacts in the EIS in the most effective way possible.

As discussed in Chapter 2, the Impact Assessment Unit of the School of Planning, Oxford Brookes University concluded that 'many ESs were poor in terms of effective communication and accessibility to relevant audiences' (IAU 1996 p52). The findings of this dissertation's research outlined in Chapter 7 demonstrate that there has not been a significant improvement in that position in the intervening twelve years.

8.3 OPPORTUNITIES FOR IMPROVEMENT

In Chapter 7, the various techniques used in sample EISs to present the predicted impacts that proposed developments will have on the environment are considered. It is evident that in most of the sample, text is used exclusively to describe the impacts. In the context of the text used, there is also widespread inconsistency in applying the EPA guidelines (CAAS 2002, 2003), or other equivalent guidance. The fundamental question that this dissertation attempts to answer is, how can this current practice be improved? – improve the quality of the information presentation, and the quality of the competent authority's decision making can improve accordingly. Ultimately, this will facilitate a move closer to the objectives of the EIA Directive.

The literature review indicated that an appropriate combination of text and data visualisation techniques will provide the best opportunity to meet this objective (see, for example, Mayer 2001, Horn 2001, US EPA 2002, DEAT 2004, Ware 2004 and Tory and Möller 2004, SNH 2005).

8.4 DEVELOPING A HIERARCHY OF PREDICTED IMPACTS

Although the factors that give rise to predicted impacts in an EIS are varied and multi-dimensional, it is clear that for each of the environmental topics, an appropriate study should conclude with a schedule of likely effects, which can be described as imperceptible, slight, moderate, significant or profound, and either adverse or beneficial.

This schedule should then communicate the most important issues, in the most efficient way. The means of communication must be suitable for use within the detailed study, in a summary of impacts, and in a non-technical summary.

The range of environmental aspects and types of impacts which must be covered may also inform the means of communication. Refer to **Appendix 1** for the EPA's detailed schedule of typical environmental impacts associated with each of the aspects as scheduled in the EIA Directive. Some predicted impacts can be directly mapped to a data visualisation technique. A good example of this would be the findings of an air dispersion model, where predicted ground level concentrations of pollutants can be compared with established air quality standards. In this case, it is straightforward to present the findings of the study in a clear and unambiguous way. However, it becomes more problematic to apply the same quantitative methods to some impacts on human beings, for example. These difficulties may also be compounded when considering cumulative and synergistic impacts, as the level of certainty reduces. For this reason, this study focuses strongly on the stage of assessment when all the contributing factors to a predicted impact have been considered, and the impact is then being described in accordance with the EPA guidance.

8.5 APPLICATION OF THE HIERARCHY

Before determining how to effectively present this information, it must be clear exactly what the most important messages are. It is evident from the questionnaire responses that planners need to understand what the most significant issues are relating to a proposed development. This suggests that some kind of hierarchy of predicted impacts would be beneficial, with the most significant being given the greatest prominence in the EIS, and all other information being assigned a secondary status. Such an approach could potentially lead to a radical re-ordering of the contents of an EIS.

Combining the Canadian Environmental Assessment Agency (1992) with Rossouw's (2003) analysis, the EPA guidance and glossary of impacts (CAAS 2002, 2003) and the Scottish Executive EIA template (2007) one can define the potential dimensions of predicted impacts, ordered in an implied hierarchy of importance as suggested in the literature. Note that the hierarchy is not clearly defined, and it may be appropriate to move the dimensions up or down the list in particular circumstances.

Magnitude (imperceptible-slight-moderate-significant-profound)
Likelihood (extremely unlikely-unlikely-likely-certain)
Quality (adverse-neutral-beneficial)
Spatial Extent
Duration (short term-medium term-permanent)
Mitigatory Potential
Reversibility
Certainty of Prediction
Frequency
Interactions-Synergies-Cumulative Effects

At this stage it is worth bearing in mind Rossouw's caution: that describing impacts should never become mechanistic (Rossouw 2003). Any improvements made to the quality of presentation and communication of the basic information will be useless if it is not based on good scientific methods.

The ten dimensions listed above then have to be considered in the context of the most important information for the reader and viewer of the EIS. For each individual predicted impact associated with each aspect of the environment, the residual impact (predicted impact after effective mitigation, if necessary) will have data attributes that can be incorporated in a data visualisation.

None of the sample EISs used environmental impact tables (The Highways Agency et al. 2007). Although these have been developed in the specific context of the design of roads and bridges, they could be used to organise the data in any EIS prior to mapping predicted impacts to a visualisation.

8.6 DATA VISUALISATION OF PREDICTED ENVIRONMENTAL IMPACTS

The data visualisation must be as clear as possible. Tufte's (1983) advice is to avoid chartjunk, the irrelevant information that distracts the reader or viewer from thinking about the information. It is essential that critical information is given prominence and explained as clearly as possible, and chartjunk will get in the way.

One of the characteristics which a data visualisation of predicted impacts should have is that it facilitates summary. The information must be available at various levels of detail, while retaining truthfulness and legibility at each level (see for example Rao and Card 1994). It should harness preattentive processing where possible (Healey et al. 1994, Few 2004a) so that the eye is immediately drawn to the most important information.

Considering then Cleveland's (1985) hierarchy of data display (see **Figure 4.2**), it is appropriate to consider visualisations that take advantage of our perception of length, and in particular, position on a scale (Wünsche 2004, see also **Table 4.3**). If the data associated with the dimensions of predicted impact are encoded in this way, the information accuracy will be maximised.

So, for example, in the particular location in text of a chapter where a predicted impact is described, a glyph could be included alongside the text, giving an instant indication of the magnitude of the impact. See **Figure 8.1**, for an example which maximises the data-ink ratio (Tufte 1983). Having the glyph at the same location as the description would contribute to the legibility and effectiveness of the EIS (Tufte 1983, Mayer 2001 and DEAT 2004). In particular, Tufte's argument for the integration of graphics with text is relevant to the information in EISs; *'imagine if graphics were replaced by paragraphs of words, and those paragraphs scattered over the pages out of sequence with the rest of the text – that is how graphical and tabular information is now treated in the layout of many published pages'* (Tufte 1983 p181). The glyphs can then be combined in summary histograms.

Figure 8.1 Impact Glyph

However, it is not so simple. A simple histogram will encode a single dimension very effectively, but a more complicated solution will be required to get closer to the ten that are listed above. **Figure 8.2** illustrates how the magnitude of predicted impacts could be illustrated, with five specific items ordered by length.

Figure 8.2 Simple Histogram

A further dimension can be added by presenting a small multiple (Tufte 1983 p175) of such histograms. This will allow the viewer to benefit from the Gestalt Laws of Proximity and Similarity (see Chang Dooley and Tuovinen 2002, and **Table 4.8**). The impacts with the greatest magnitude will still be clearly evident, see **Figure 8.3** for example.

Figure 8.3 Small Multiple of Simple Histograms

The addition of colours (see for example Rheingans 1999, and **Figures 4.6** to **4.14**) can add at least another dimension. Brewer's key colour scheme types suggest that a sequential type scheme (see Brewer 1994, and **Figure 4.15** and **4.16**) may be appropriate. On considering the double-ended colour scheme in **Figure 4.16**, the opportunity presents itself to encode a further dimension, the quality (whether adverse, neutral or beneficial).

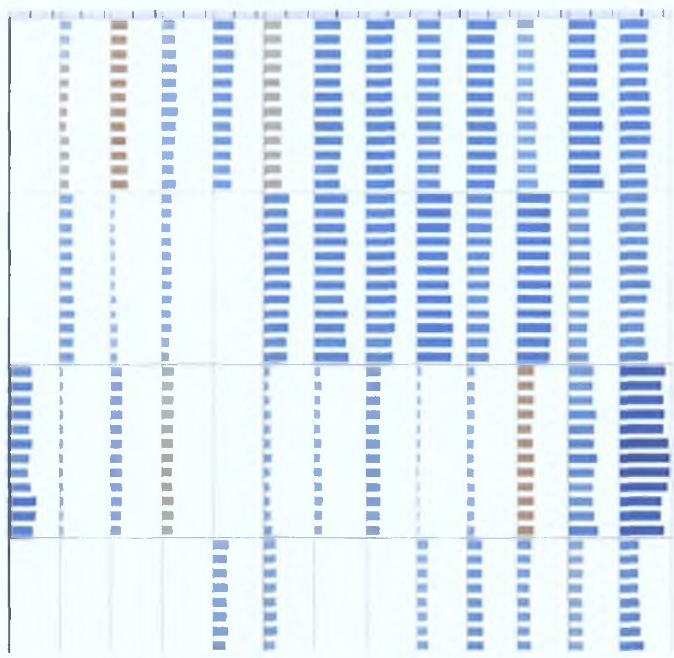

Figure 8.4 Small Multiple Histograms with Colour

A review of colours selected for a data visualisation should ensure that no key information is encoded only with colours that cannot be differentiated by red-green colour blind viewers (Rigden 1999). Use of colour scales such as the redundant hue lightness scale

(**Figure 4.10**), and palettes such as Rigden's Protan and Deutan palettes (**Figure 4.17**) should be considered. Refer to **Figure 8.4** for a sample small multiple of simple histograms, incorporating colour as a dimension.

Other Bertin (1967) dimensions can be encoded, with care, using form, size, contrast, grain (texture), and direction in the histograms, mindful that adding each dimension must improve the usefulness and legibility of the visualisation. The ERM summary of residual impacts (ERM 2006, **Figure 7.1**) is an example of mixed Bertin dimensions which are not completely coherent. For example, the grey scale used for adverse impacts is not sequential. Another example of colours being used as a data dimension is shown in **Figure 8.5** (from OldenKamp 2008).

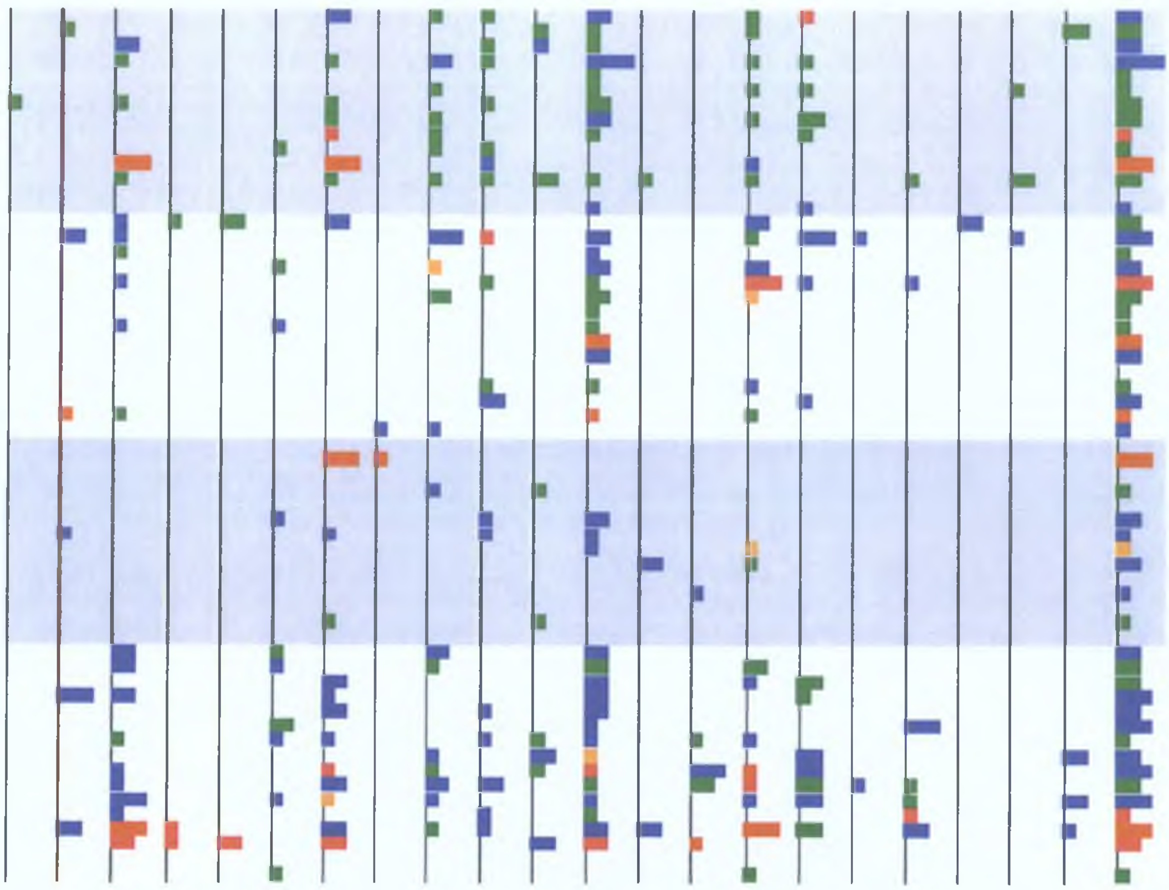

Figure 8.5 Colours Encoding Data in a Small Multiple Histogram

8.7 SCALABILITY AND MULTIDIMENSIONALITY

To achieve the goal of scalability and coherence (from specialist report, to EIS chapter, to summary, to non-technical summary), a method of aggregating the data will be required. Reference to Chi's (2000) taxonomy of visualisation techniques (**Table 5.1**), and to Rao and Card's (1994) TableLens software in particular suggests that the TableLens technique of aggregating adjacent rows in a large histogram by showing averages of maximum and minimum values may be applicable. In this context, the focus must be placed on the most significant issues - it is crucial to ensure that no significant data is lost in aggregation. If a planner is most interested in any incident of a predicted significant adverse impact, then that must be communicated at each level of summary and aggregation.

It would be possible to reach the desired level of multi-dimensionality in the data visualisation using the combination of techniques outlined above. However, the recent development of bullet graphs (Few 2008) suggests that additional dimensions and richness in data encoding could be achieved by combining the multiple histograms with the bullet graph format. The bullet graph also allows uncertainty to be displayed, using error bounds (Wilkinson 2001). Refer to **Figure 8.6** for a typical bullet graph, with its parts labelled.

The use of fuzziness to illustrate uncertainty, as indicated in **Figure 6.2**, is more appropriate to line-based graphics, so could be excluded from further consideration in the context of histogrammatical analysis.

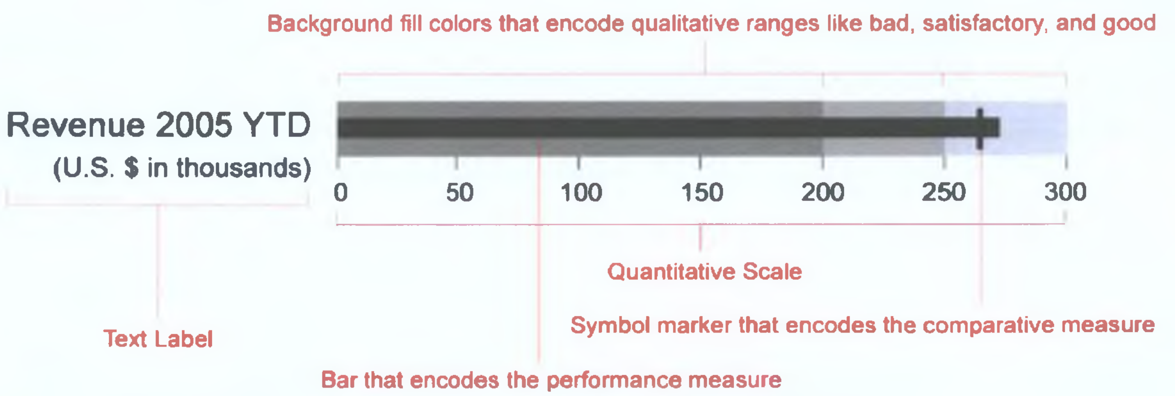

Figure 8.6 Typical Bullet Graph, with its Parts Labelled [source: Few 2008]

Figure 8.6 is monochrome, but colour can also still be used to encode additional dimensions, as in **Figure 8.7**.

Figure 8.7 Unlabelled Colour Bullet Graph [source: Few 2008]

An appropriately arranged histogram, incorporating bullet graphs, presented as a small multiple, and using data-aggregation principles similar to TableLens will meet the requirements of encoding predicted environmental impacts. If Tufte's principles of graphical excellence (Tufte 1983 p52) are incorporated at each stage in the development of a data visualisation developed in this way, then there is a real opportunity to improve how EISs convey the environmental information required for the EIA of a proposed development.

8.8 SAMPLE DATA VISUALISATION FORMATS

Recent developments in data visualisation for corporate dashboard design have the potential to provide templates and graphic structures suitable for use in EISs. Few (2006, for example) has focussed on this field in recent years, and has prepared sample dashboard graphics which incorporate many of the same attributes as an EIS data visualisation as described above. Other examples (xlcubed.com 2008) which represent current best practice in the condensed visualisation of quantitative data are reproduced in **Figures 8.8, 8.9** and **8.10**.

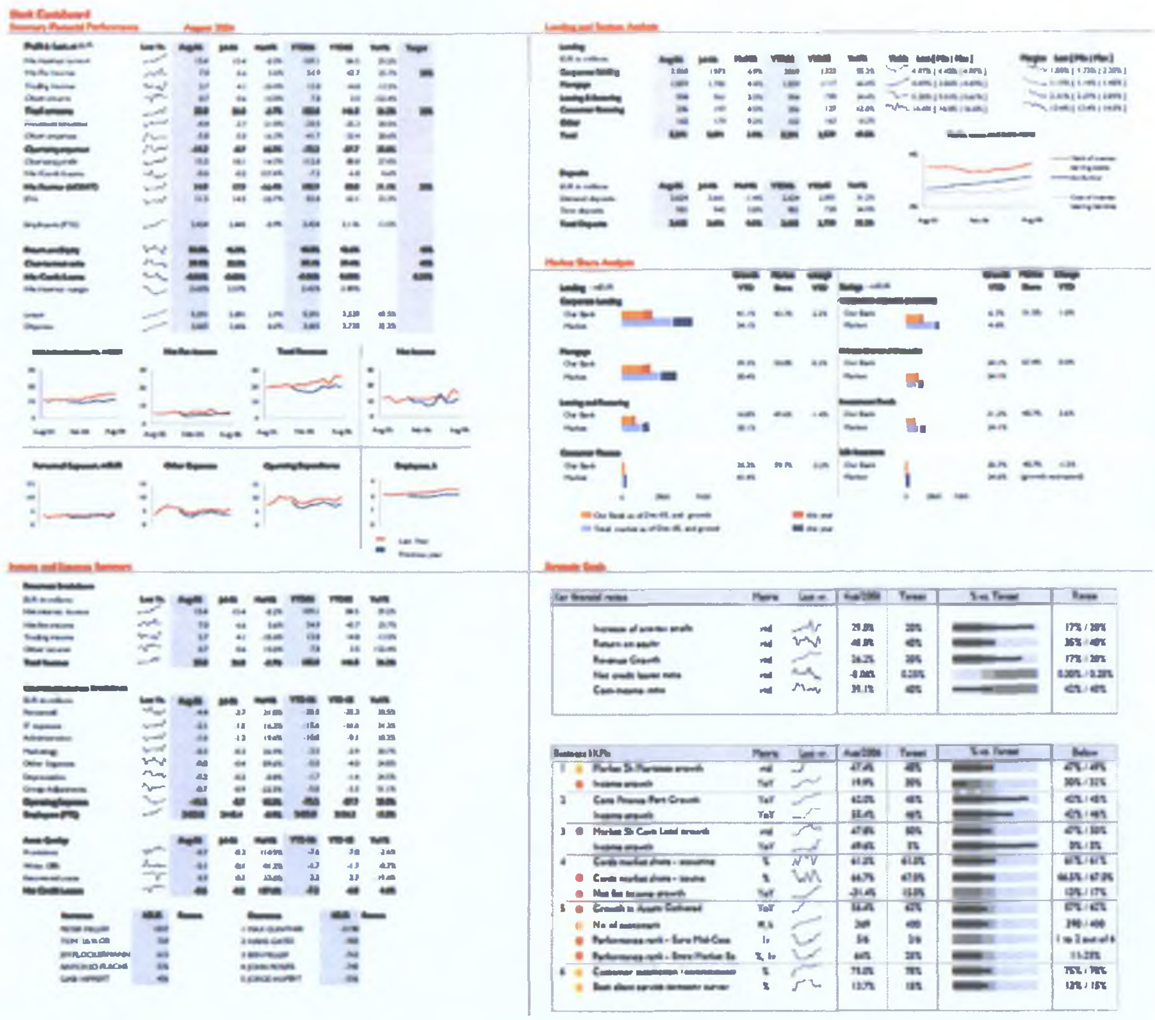

Figure 8.8 Wades Stokes Bank Dashboard – xlcubed dashboard competition winner 2008 [source xlcubed.com, accessed 13 August 2008]

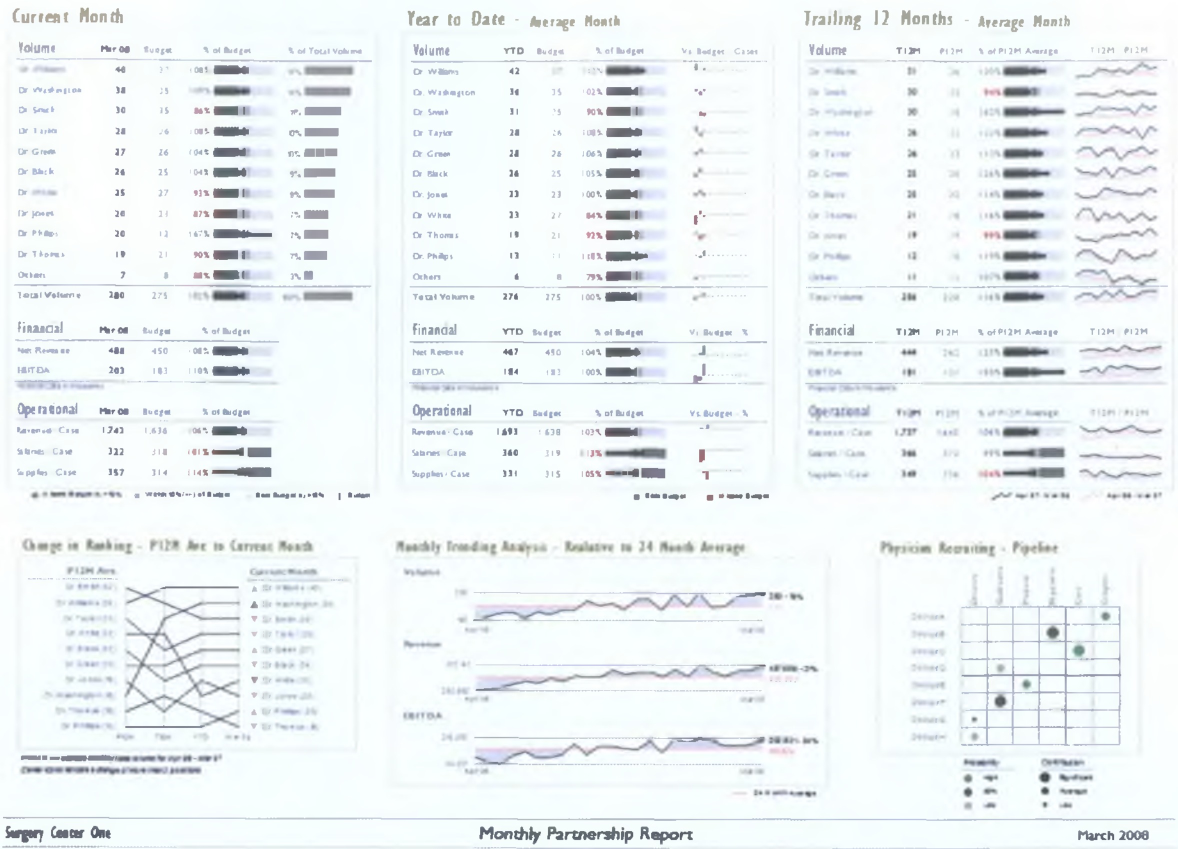

Figure 8.9 Meridian Surgery Partners Outpatient Dashboard – xlcubed dashboard competition runner-up 2008 [source xlcubed.com, accessed 13 August 2008]

	Sales May-08	Sales QTR 05/08	Sales MAT 05/08	Share May-08	Share QTR 05/08	Share MAT 05/08	Growth May-08	Growth QTR 05/08	Growth MAT 05/08
Amias	6,565,902	4,208,997	6,262,113	9.2%	41.2%	72.1%	9.1%	47.2%	24.3%
Aprovel	6,402,911	1,018,540	10,268,427	24.7%	87.3%	12.5%	6.3%	69.2%	14.5%
Cozaar	722,738	11,462,161	9,884,631	56.0%	11.1%	25.4%	2.9%	11.1%	30.0%
Diovan	3,502,532	10,450,955	7,240,452	59.4%	88.0%	81.9%	69.1%	88.0%	99.5%
Micardis	10,318,262	10,097,307	11,975,548	36.4%	38.0%	6.8%	99.2%	38.0%	75.7%
Olmetec	6,745,503	315,408	5,669,022	54.8%	50.4%	36.8%	38.1%	50.4%	50.5%
Teveten	11,799,322	3,946,906	2,940,952	87.2%	46.9%	90.7%	41.6%	46.9%	93.1%

Figure 8.10 Bristol Myers Squibb Pharmaceutical Sales Dashboard – xlcubed dashboard competition 2008 third placed entrant [source xlcubed.com, accessed 13 August 2008]

8.9 CONCLUSION, LIMITATIONS AND AREAS FOR FUTURE RESEARCH

The EIA Directive has had effect in Ireland since 1985. It is evident from the research in this dissertation that the individuals who have the most important responsibility in implementing the Directive are not satisfied with the quality of information they review in making their decisions to permit or refuse projects. That is to say, the planners, who have the responsibility of competent authorities in the meaning under the Directive, have reported difficulty in getting quickly to the unambiguous predicted impacts they need to see in EISs.

This dissertation has considered how incorporating the principles of graphical excellence in data visualisation could improve EISs, and therefore contribute to the environmental protection objectives of the Directive.

There are now opportunities to implement some of the suggested data visualisation techniques in EISs, and subsequently test whether they contribute to improvements in decision making and the implementation of the EIA Directive. The recommendations apply at the 'impact description' stage in the EIS. There is scope for exploring how these data visualisation techniques could be integrated into the earlier stages of considering likely impacts, and using the techniques to consider and balance possible impacts earlier in the design process.

As outlined in section 1.7 of Chapter 1, this study has not considered the geographical and spatial attributes of impact prediction in detail. MacEachren (1998, 1999) has explored the interface between cartography, geographical information systems (GIS) and EIA, and there are opportunities to further develop the integration of these disciplines. It is likely that the conventional format for the EIS – documents presented as bound paper volumes – will no longer be appropriate as the specific spatial characteristics of impacts are presented graphically. Examples of these approaches may include the World-Within-World multi dimensional plots referred to in **Table 5.1**. In this case, a high dimensional surface is mapped to a local area, and dynamic viewing, filtering, rotating and scaling is facilitated by proprietary software. The format and interface of an EIS prepared in accordance with such approaches could be radically different to that described in the EPA guidance and advice notes (CAAS 2002, 2003).

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APPENDIX 1 LIST OF ENVIRONMENTAL IMPACTS BY ENVIRONMENTAL ASPECT
(CAAS 2002, 2003)

Human Beings

number, population, type and location of persons or communities affected

changes in overall population and their activities

changes in patterns of employment, land use and economic activity

consequences of change, referring to indirect, secondary and cumulative impacts

potential for interaction with other impacts

worst case for human beings if all mitigation measures fail

(CAAS 2003)

Typical significant impacts scheduled in the Advice Notes relate to:

Employment

Accommodation

Power generation

Pollution impacts (noise, dust or other emissions)

Leakage hazard through accident or external event (eg earthquake)

Cross-site transfers of radioactive waste

Fire hazard or explosion hazard

Dust and air emission effects on health

Health impacts to workers and the general population

Light nuisance.

Fauna

describe the number/ population, type and location of organisms affected

describe changes in species diversity; – describe any impacts for the maintenance of the regenerative capacity of the ecosystem-system

describe the consequences of change to the larger population, referring to indirect, secondary and cumulative impacts

describe the results on fauna of changes in the vegetation, e.g. animal dispersal and movement

describe the potential for interaction with other impacts, for example those on soil, water, humans

distinguish temporary and permanent impacts where possible
describe the worst case for fauna if all mitigation measures fail

(ibid)

Typical significant impacts scheduled in the Advice Notes include affects on:

Site disturbance during construction or operation
On-site habitat loss
Food chain effects of released toxins
Impacts due to liquid effluent
Dust impacts
Disturbance due to on-site activity
Spillage/ other hazard risks
Contaminated deposition and run-off
New water bodies
Contamination of food chains
Impacts on agricultural stock.

Flora

describe the location, area and type of plant communities directly affected
describe changes in species diversity, paying particular attention to sensitive species
describe any impacts on the maintenance of the regenerative capacity of the ecosystem-system
describe any changes to the vegetation that will arise from impacts to fauna, e.g. reproduction, grazing
describe indirect and long term effects brought about by changes in environmental factors including soil disturbance
distinguish between temporary and permanent impacts
describe the worst case for flora if all mitigation measures fail

(ibid)

Typical significant impacts scheduled in the Advice Notes relate to:

Site clearance and works
Impacts due to atmospheric emissions
Impacts due to liquid effluent (pre and post closure)
Habitat loss (marine and terrestrial)
Phtyotoxic substances in air and water

Spillages/ other hazard risks

Contaminated deposition and run-off

Take-up of contaminated discharges

Water discharges (especially regarding temperature)

Quarrying impacts

Impacts on pasture and tillage.

Soils and Geology

describe the potential for interaction with other impacts

describe the worst case scenario if all mitigation measures fail

(ibid)

Typical significant impacts scheduled in the Advice Notes relate to:

Soils obliteration

Soils for waste disposal site coverings

Soil erosion by wind

Soils for bunding

Excavation and removal of soil and rock

Stability

Soils acidification from atmospheric accretions

Effects of any shore works on sediment movement.

Water

describe the location and extent of any waters likely to be affected

describe the character and significance of any changes in water quality or flows

describe any impacts for the maintenance of the reproductive capacity of the ecosystem-system

describe the consequences of change, referring to indirect, secondary and cumulative impacts

describe the potential for interaction with other impacts

describe the worst case for water if all mitigation measures fail

(ibid)

Typical significant impacts scheduled in the Advice Notes relate to:

Impacts on surface and groundwater

Pollution (physical, chemical or biological) during construction

Impact of effluent

Rainwater/ surface water management systems

Fuel leakages

On-site drainage impacts

Effects on drainage and run-off due to introduction of large impervious area

Dissolution of airborne emissions

Surface or groundwater abstraction

Contaminated deposition and run-off

Impacts of damming watercourses

Planned and unplanned marine discharges

Long-term and cumulative discharges to groundwater

Turbulence impacts due to shipping.

Air

Assess the adverse and beneficial impact in terms of the predicted changes in concentration of air pollutants and also with respect to absolute limits where appropriate. Take account of meteorological conditions as appropriate. Consider the impact on humans, vegetation and fauna where relevant. In the case of developments which themselves are sensitive to air quality, consider the impact of the existing air quality on the development itself.

(ibid)

Typical significant impacts scheduled in the Advice Notes relate to:

Atmospheric emissions of sulphur dioxide, hydrocarbons, dust and other pollutants

Aerial discharges leading to dioxin formation

Odours

Impact of unplanned or emergency releases

Airborne particles

Dust inside and outside the buildings

Unloading of raw materials

Loading finished products

Transportation dust containment

Dust during construction and from road traffic.

Noise

Assess the adverse or beneficial impacts on humans, and fauna where relevant, in terms of the change in noise level and also with respect to absolute limits where appropriate. Consider noise levels outdoors, and indoors. Take account of relevant time periods such as day, evening, night, weekends, as appropriate. Are there any special features, such as tonal noise, impact noise, or significant levels of low frequency noise? In the case of developments which themselves are noise-sensitive, such as dwellings, schools, hospitals, consider the impact of the existing noise environment on the development itself.

(ibid)

Typical significant impacts scheduled in the Advice Notes relate to:

Noise from refinery, shipping and road traffic

Noise from flares

Noise from PA systems

Vibration

Consider the adverse or beneficial impacts on humans, fauna and buildings where relevant. Describe the vibration levels, and character of the vibration to be expected at the receiver locations. Will the vibration be perceptible, or cause a nuisance? Will it manifest itself as audible sound within buildings? Will it result in detectable displacement of the ground and structures? Assess the scale of the impact according to relevant standards, in terms of annoyance to humans, interference with industrial facilities, and damage criteria for buildings. In the case of developments which themselves are vibration-sensitive, such as dwellings, schools, hospitals, consider the impact of the existing vibration environment on the development itself.

(ibid)

Vibration from trucks

Radiation

Consider the adverse or beneficial impacts on humans, and sensitive equipment where relevant. Determine the radiation doses, or in the case of visible light, the nuisance expected for the human population. Assess significance according to relevant standards. In the case of location of housing developments in areas of high background radiation, consider the radiation exposure of the human population in the development.

(ibid)

Typical significant impacts scheduled in the Advice Notes relate to:

Electromagnetic radiation

Climate

describe the climatic factors which will be affected stating to what extent change will occur
describe the consequences of change referring to indirect, secondary and cumulative impacts
describe the potential for interaction with other impacts
describe the worst case if all mitigation measures fail

(ibid)

Typical significant impacts scheduled in the Advice Notes relate to:
NO_2 or SO_2 contributions to acid deposition (with reference to international status)
Contribution to stratospheric ozone depletion (with reference to international status)
Global warming effects
Temperature effects in the immediate area, especially if there are warm water discharges
Installations for hydroelectric energy production
Industrial installation for production of electricity, steam or hot water.

The Landscape

describe the location and extent of areas affected
describe changes in character and visibility
describe any impacts for the maintenance of the reproductive capacity of the ecosystem-system
describe changes in patterns of land-use
describe the consequences of change, referring to indirect, secondary and cumulative impacts
describe the potential for interaction with other impacts

(ibid)

Typical significant impacts scheduled in the Advice Notes relate to:
Visual impact of new structures on site, such as buildings, cooling towers and power lines
Transportation loading/ unloading facilities and stockpiles
Access roads
Traffic
Parking
Visible atmospheric emissions (including flares)
Night lighting.

Material Assets, Including the Architectural and Archaeological Heritage and Cultural Heritage

describe the activities, areas, infrastructure and resources likely to be affected
describe changes in overall land-use
describe the consequences of change, referring to indirect, secondary and cumulative impacts
describe the potential for interaction with other impacts
describe the worst case for material assets if all mitigation measures fail

(ibid)

Typical significant impacts scheduled in the Advice Notes relate to:
Traffic impacts (including marine navigation if applicable)
Disposal sites for solid wastes
Power and water supply
Capacity of existing infrastructure
Property value
Sterilisation of natural resources
Implications for other potential land/ foreshore/ navigational users
Possible effect on radio navigational facilities of aircraft
On-site features or artefacts.

The Interaction of the Foregoing

existing land-use practices which sustain natural processes
existing plants which sustain significant fauna
existing soils which sustain significant flora and fauna
the quality, quantity or location of water can affect physical, biotic or chemical processes
existing air quality can sustain land-uses and natural processes

(ibid)