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SPATIAL MODELLING AND DECISION SUPPORT FOR NEW LINEAR DEVELOPMENTS

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SPATIAL MODELLING AND DECISION SUPPORT FOR NEW LINEAR DEVELOPMENTS

by

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Abstract

SPATIAL MODELLING AND DECISION SUPPORT FOR NEW LINEAR DEVELOPMENTS

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Eskom, the South African electrical utility, is committed to sustainable environmental development. Eskom Transmission has formalised their environmental planning of linear developments into guidelines, which supports the pending environmental legislation in South Africa. When new transmission lines are built, environmental impact assessments are used to determine the optimum corridors for these new developments. This decision making process includes determining corridor alternatives, their evaluation and comparison, and choosing the best environmental option.

Features of the environment that needs to be considered in this decision making process can either be issues where the line potentially impacts on the environment, or issues where the environment potentially impacts on the line. These issues are identified per project, mapped and assessed to determine the potential significance of their impact. To determine and compare corridor alternatives, the spatial location of these issues, their spatial relation to each other and the potential significance of their impact needs to be considered.

Spatial decision support systems are uniquely suited to assist in the environmental planning of new proposed developments. The conceptual design of a spatial decision support system was developed to complement the Transmission Guidelines for Environmental Planning of Linear Developments. This system's concept is referred to as CORDS, short for corridor decision support.

As part of the functional design of the model base in CORDS, a holistic allocation model for linear features was developed using a cartographic modelling language. The use of such a language makes the implementation of modelling extremely powerful, easy to implement and flexible to change in future.

The methodology followed for the systems analysis and design is based on a soft systems approach. A soft approach to systems planning also considers the human and organisational environment of the new system, and does not merely focus on the technology of a solution. This approach has proven especially relevant to the design of spatial decision support systems and resulted in this case in a conceptual design seen by its users as applicable and suited to their task.

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DISCLAIMER

The results presented in this thesis are based on my own research in the Department of Environmental and Geographical Sciences, Manchester Metropolitan University. All assistance received from other individuals and organisations has been acknowledged and full reference is made to all published and unpublished sources used.

This thesis has not been submitted previously for a degree at any Institution.

Signed:

S.E. van der Merwe

15th May 1997, Johannesburg, South Africa

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I would like to express my appreciation to Eskom for the bursary granted to do this work and for allowing me to have worked on this project. A special word of thanks goes to the people in Transmission Land Survey for their participation in the project and especially to the environmental planners for their faith in the system. May the outcome of this work be very useful and may you reap the fruits of it.

Thank you to Prof. Dr. Henk Scholten for putting in many hours to review my thesis, for all the long distance calls and for coming to South Africa to give advice. The encouragement and direction have been greatly appreciated. The UNIGIS office in Amsterdam has also put in lots of trouble. Thank you Mathilde for your excellent administration and assistance.

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Fanie, your love, support and encouragement have carried me through many days. Thank you for standing on my side and believing in me. I love you tremendously.

Above all else, I am eternally grateful to my Father who has led me to this path, who has walked with me, and who are teaching me more important things that these.

GLOSSARY

CAD	Computer Aided Drafting package
CORDS	SDSS for **cor**ridor **d**ecision **s**upport on linear developments
CSDM	Collaborative spatial decision making
DB	Database
DDE	Dynamic data exchange
DELPHI	A process for participative decision making
DSS	Decision support system
EDSS	Environmental decision support system
EIA	Environmental impact assessment
EIMP	Environmental impact management plan
EIR	Environmental impact report
GIS	Geographical information system
IAP	Interested and affected parties
IEM	Integrated environmental management
IT	Information technology
MTS	Main transmission system
NCGIA	National Centre for Geographic Information and Analysis
NIMBY	Not in my back yard
RAD	Rapid application development
RDP	Reconstruction and development program
ReGIS	Relational geographical information system
ReSPAN	Spatial analysis module of ReGIS
SADM	Systems analysis and design methodology
SDSS	Spatial decision support system
SSA	Soft-systems analysis
TLCADD	Transmission Line Computer Aided Design and Drafting **-** a program to optimise transmission tower locations based on engineering and economic viability

C h a p t e r   1

ORIENTATION AND PROBLEM STATEMENT

1. BRIEF PROBLEM STATEMENT

1.1 Research Problem Definition

To investigate and design an appropriate system to support decision making for the environmental planning of new linear developments.

- Understand the environmental planning problem and the respective decision to be made;
- investigate spatial decision support systems to solve this problem;
- through the integration of GIS and spatial modelling techniques;
- do the analysis and design of this system based on a soft-systems methodology;
- design a system that is seen by its intended users as relevant and appropriate.

1.2 Business Problem Definition

Setting: Environmental Planners in Transmission Land Survey, Eskom, South Africa

Background: Environmental legislation is about to be introduced in South Africa whereby a certain procedure needs to be followed for any environmental impact assessments. The environmental planners in Transmission Land Survey have developed detailed guidelines that spells out the steps to follow for the environmental planning of new linear developments.

Required: A spatial decision support system is needed to assist the environmental planners in the corridor selection of new transmission lines. This system should facilitate the implementation of the guidelines and specifically consider the spatial nature of the problem and the decision.

2. ORGANISATIONAL SETTING

2.1 Eskom as an Electricity Utility

In South Africa Eskom is a household name and synonymous with electricity as it is the largest electricity utility in the country. Eskom supplies more than half of the electricity consumed in Africa and is classed among the top five electricity utilities in the world. The total power line network is 241 802 kilometres in length. (Eskom, 1995, p.1)

Eskom consists of three primary business units, namely Generation, Transmission and Distribution. Electricity is generated primarily by coal-fired power stations situated in Mpumalanga, the former Eastern Transvaal region. From there the electricity is conducted along a network of transmission lines to the rest of the country. Distribution and electrification have historically been the task of the Distribution Group, but due to recent changes in the country each local authority now has the right to take over this function if it chooses to do so.

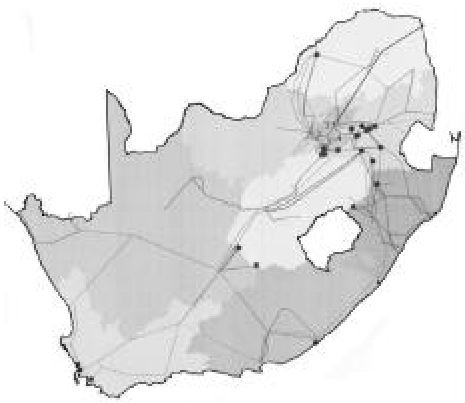


Figure 1 - The Power Stations and Main Transmission Network in South Africa

The stated mission of Eskom is to provide the world's lowest-cost electricity for growth and prosperity. The South African Government has an extensive Reconstruction and Development Programme, for the purpose of uplifting the previously underprivileged communities. This programme is commonly referred to as the RDP. Among Eskom's many RDP commitments is the electrification of 1 750 000 additional homes between 1994 and the year 2000 (Eskom, 1995, p.32). This will improve the lives of approximately 11 million South Africans who currently rely on paraffin and wood for their daily energy needs.

In Eskom's pursuit of its goal to provide the world's lowest-cost electricity, it is essential to advance the business through research, applicable technologies and environmental resources. It is necessary to constantly examine what one is doing, how one is doing it and what else can be done to improve service, reduce cost and result in a return on investment.

Recently doors of opportunity have also opened to compete in the global market for projects across our borders into Africa. Eskom is in a favourable position to understand African conditions and has a good track record. Eskom has always had the monopoly in South Africa. Looking into Africa, Eskom has suddenly become one of many players in a field where the best price, the best service and the best product count.

2.2 Eskom and the Environment

South Africa's environmental awareness has only recently been awakened. Major companies such as Eskom have been proactive in ensuring that environmental policies and programmes would be put in place. But only recently has participative decision-making on environmental issues in South Africa received significant participation from the general public.

Eskom's commitment to the environment is to limit the adverse environmental impact of its activities, to contribute to the enhancement of the quality of life of citizens, and to contribute to sustainable development (Eskom, 1995, p.1). The company adopted the Integrated Environmental Management Procedure, commonly referred to as IEM, to serve as a guideline in this matter. The Department of Environmental Affairs designed IEM "*to ensure that the environmental consequences of development proposals are understood and adequately considered in the planning process*" (Department of Environmental Affairs, 1992, p.5).

This procedure has been compiled in such a way that it can be adopted as a policy by the Government. Although the legislation has not been passed yet, it is merely a matter of time and of finalising participation in the process. Eskom is actively involved in refining the process and in certain areas has enhanced the process considerably.

International funding normally plays a major role in projects into the rest of Africa. It has become clear that environmental impact assessments (EIAs) and environmental management plans (EMPs) must be in place for all these projects before funding can be secured. The environmental planners in Eskom will play a major role in setting the standard in this regard throughout the rest of Africa.

2.3 The Planning of new Power Lines

To electrify an additional 1.75 million houses an extensive infrastructure will be needed. Current electricity networks need to be strengthened and smarter methods need to be found in order to conduct more power through the existing network. Upgrading or expansion of the existing network invariably has an adverse effect on the environment.

Power lines crossing the South African landscape are typically affecting various ecosystems along the vast distances they traverse. This spatial variation in the environment needs to be understood and adequately considered in the planning of new lines.

The Environmental Section of Eskom's Transmission Land Survey Department has developed Guidelines for Environmental Planning of Linear Developments. These guidelines are based on the IEM procedure. It has more prescriptive details than the procedure and overall it is more encompassing as well. The team of environmental planners received countrywide recognition for the process developed and were awarded several trophies for their contribution to sustainable development.

If we refer to the planning of a new power line as a project, it is safe to assume that various projects will have various levels of complexity. At the outset of a project a scoping exercise is done. Scoping is defined by the guidelines as the identification of potentially significant issues in the earliest possible stage of planning (Eskom, 1996, p.21). These issues can normally be mapped out as one or more features of the environment. The number and types of issues should give an indication of the level of complexity of the environment, and therefore the complexity of that project. The Guidelines for Environmental Planning of Linear Developments are comprehensive and are based on a worst-case scenario to cater for all projects, irrespective of complexity.

From Eskom’s side, the people involved in the environmental planning of a new line project are a multidisciplinary team that is formed for every new project. The members of this team will typically come from the environmental section, the GIS section, the surveyors and the drawing office, and will include a public relations and a farm liaison officer as well as a negotiator. For the purpose of this discussion the main area of responsibility revolves around the completion of an environmental impact assessment, including public participation, and the final route selection.

3. THE AIM OF AND REASON FOR THIS STUDY

3.1 Purpose and Objectives

The purpose of technology is to simplify and enhance our daily tasks. There are several tools that the planning teams can use to help them produce better EIAs. Depending on the level of complexity of a project, the planning team can choose the method or planning tool it wants to use on that project. Table 1 summarises various methods and the implications of their use.

TOOL	DESCRIPTION OF THE METHOD	APPROPRIATE PROJECTS	BENEFITS OF THE APPROACH
Maps	Features are manually drawn on maps or transparencies to be overlaid. 'Light-table method'	Projects done in the past. Projects done on the run. As part of an initial scoping exercise. Projects that do not require EIAs.	Quick, but dirty. Simple visualisation. Method is understood by most people.
CAD	Features are captured in a CAD system as drawings. Can be plotted as maps or on transparencies for overlays.	Projects that due to complexity or lack of time or expertise, need not or cannot be done on a GIS.	More detailed data can be used than with the manual method. Professional map output.
GIS	Features are classified into a GIS with or without attribute data attached.	All projects requiring EIAs and whose issues identified during the scoping exercise are not significant or cumulative.	In addition to the above: Almost any digital data can be used, including remotely sensed data. Easy integration of data from various sources. Toolbox of functionality available for data manipulation and reports on alternatives. Effective visualisation of input data as well as corridor alternatives.

TOOL	DESCRIPTION OF THE METHOD	APPROPRIATE PROJECTS	BENEFITS OF THE APPROACH
CORDS	In addition to the above: Use of a GIS application specifically developed to complement the process for EIAs on new linear developments. More appropriate for the task at hand - application-specific and specific to the organisational context.	All projects requiring EIAs and whose issues are significant.	In addition to the above: The approach complements a well-defined process, which supports the IEM procedure. The method is comprehensive, catering for projects of various levels of complexity. The logic behind feature assessments as prescribed by the process is programmed into the system. The method or steps in the process can be demonstrated. It hides the underlying complexity of a generic toolbox from non-GIS experts. It allows DELPHI-type participative decision-making. The output is tailored to the specific application.

Table 1 - A Comparison of the Planning Tools Available for EIA Projects

The aim of this study is to develop a model for a decision support system that can facilitate in the selection and comparison of alternative corridors for new linear developments. The system name selected by the end users is *CORDS*, which stands for *cor*ridor *d*ecision *s*upport. The comparison of the tools in Table 1 is based on the way in which the new system is to be developed.

A definition of the system as envisaged by the users reads as follows: CORDS is a spatial decision support system utilised by a multidisciplinary planning team, designed to facilitate decision-making in selecting power line corridors within the constraints of data availability. This system should provide Eskom with the tools to remain proactive and environmentally competitive.

The following business objectives should be achieved:

- To have a system that would complement the pending environmental legislation;
- and facilitate the implementation of the Transmission Guidelines for Environmental Planning of Linear Features.

- To develop a user-friendly application which is perceived by its main customers, the multidisciplinary planning team, to be relevant and to add value to their business.
- The system should be flexible enough to be used by GIS experts and novices alike.

3.2 Problem Statement

The problem to be addressed can be said to be threefold. Firstly CORDS should be an enabling technology. Secondly a soft-systems approach should be used in the analysis and design methodology. Finally, the spatial analysis in the system should be written in a cartographic modelling language.

Both geographical information systems (GIS) and specifically spatial decision support systems (SDSS) can be labelled as enabling technologies. An enabling technology is one which makes it possible, or provides the means or opportunity, to perform a certain task better. Such a technology can only truly fulfil its role if the intended users of the system perceive the application as accessible and useful.

In developing CORDS as a system which enables decision support, its perceived accessibility by the professionals in the planning team should be ensured. The underlying complexity of the system should remain hidden from the users, while simultaneously making power and flexibility available in a user-friendly interactive decision support environment.

It is therefor important to involve the users of the system in a vital and real way right from its conception, analysis and design phases, and through to its development and implementation phases. They should see themselves as the driving force behind the system and the ones that determine what goes into it. This can be achieved by following a methodology that would foster such ownership and involvement.

Traditionally systems development has been undertaken by information system technologists. Such systems invariably reflect the information technologist's interpretation of the solution, according to the way in which he/she understood the problem. These technocentric systems have led to dissatisfied users and often to a loss of faith in technology. The approach followed for such systems became known as the hard or reductionist approach, a scientific way of problem-solving which is objective and technocratic.

Recently a change in emphasis resulted when soft issues such as people, their opinions and specific sociological needs were identified as part of the problem that needs to be addressed. Soft-systems analysis (SSA) was born and the emphasis in computer systems shifted from technocentric to sociotechnical solutions. A sociotechnical solution is realised when a balance is sought between social and technical issues. This soft or systemic approach to problem-solving is pragmatic and often subjective, and is based on the social sciences.

The systems analysis and design methodology that will be followed for CORDS is a soft-systems approach, called the multiperspective eclectic methodology as explained by Bell and Wood-Harper (1992, p.21). The methodology is eclectic because it makes use of a wide range of tools from both the hard- and the soft-systems environments, and multiperspective because it views the problem from a number of different directions.

A SDSS such as CORDS makes extensive use of spatial analysis in the computation of results. The cartographic modelling language developed by C. Dana Tomlin has recently been implemented by various raster GIS packages. This language is becoming a new standard for the implementation of modelling, and more specifically the computation of models. The use of this modelling language, or map algebra as it is also referred to, not only simplifies the development of complex spatial analysis algorithms, but is also very powerful in its implementation and simplifies maintenance on code.

The CORDS model will be implemented by using the cartographic modelling language as developed by AutoDesk Development Africa in their yet to be released GIS suite of software. The functionality is currently implemented in ReSPAN, a module of ReGIS[1] - Relational Geographical Information System - a GIS developed in South Africa.

3.3 Research Questions

During this study the following questions needs to be addressed:

1. To design an environmental decision support system in such a way that it assists environmental professionals to adhere to planning procedures.
2. To develop a holistic allocation model for linear features through the use of a cartographic modelling language.
3. To determine whether soft-systems analysis is an appropriate system analysis and design methodology for spatial decision support systems.

4. To recommend any modifications to an existing soft systems methodology for it to be applied to GIS application development

4. STRUCTURE AND LOGICAL DESIGN OF THE STUDY

4.1 Research Design

The research approach to be used for this study will be action research. Bell and Wood-Harper explained the place of action research on the research methodologies' continuum as opposite to a conceptual study - see Figure 2. Action research implies that the researcher (or systems analyst in the context of information systems development) is part of the problem context, being a part of the organisation for which the system is to be developed. This approach to systems solutions requires an active involvement from the users. (Bell & Wood-Harper, 1992, pp.14-23)

Perceptions
Meaning
Personal view of reality

Technical facts
Objective meaning

8	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Action research	Phenom-enological research	Case studies	Surveys (opinion research)	Field experiments	Laboratory experiments	Mathema-tical modelling	Conceptual study
Less control Subjective Eductive Quantitative		Participative research		Non-participative research		Objective Inductive Control Quantitative	

Figure 2 - Research Methodologies' Continuum

The study will be conducted in four parts. First the real world problem will be sketched, then tools and methods for solving the problem will be discussed, a solution to the problem will be formulated and finally the outcome will be evaluated. Figure 3 illustrates the four logical parts of the study while the numbers indicate the six chapters.

[1] AutoDesk bought the ReGIS source code in 1995 and is planning to release a GIS based on ReGIS in the middle of 1997 under the name Autodesk World.

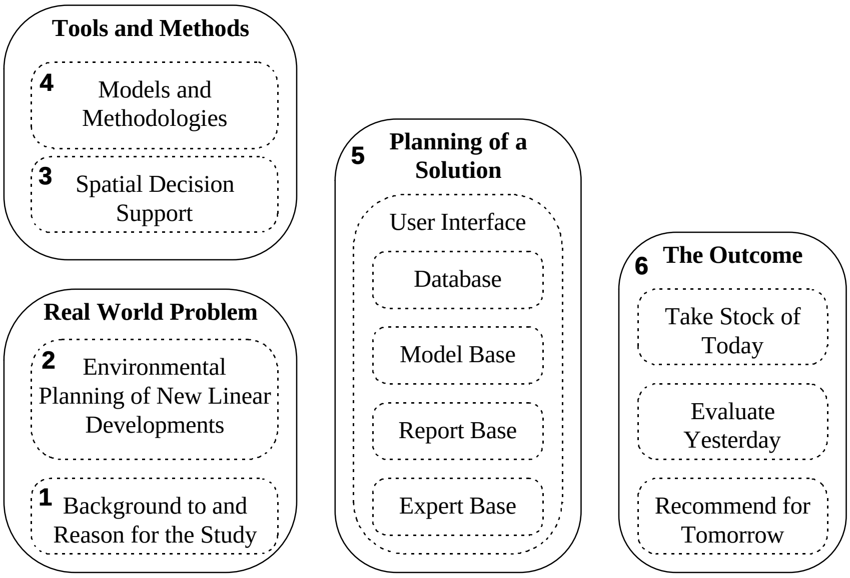


Figure 3 - Logical Design of the Study

Apart from this introduction and background, the first part sketches some real world requirements of environmental management and outlines the Guidelines for Environmental Planning of New Linear Developments in the South African and Eskom context. An understanding of the spatial nature of the problem will be pursued.

In the second part, the tools that will be used to solve this environmental planning problem will be discussed. They include GIS, SDSS and cartographic modelling. The various components that will be required in CORDS will also be introduced. This part further discusses soft-systems analysis, with specific emphasis on the multiperspective, eclectic methodology that will be used for the analysis and design of CORDS.

The main part of this work covers the analysis and design of CORDS. The sections of this chapter are the steps prescribed by the methodology, with slight modifications made where the specific application dictates.

Finally an evaluation of the process as well as of the outcome of the process will be done, with recommendations for future research and development.

4.2 Contents of Chapters

Chapter 2

NEW LINEAR DEVELOPMENTS AND THE ENVIRONMENT

1. ENVIRONMENTAL MANAGEMENT

The term environment is used in several different contexts. When we refer to environmental management, the word environment is used to describe the interrelationship between people and nature (Fuggle, 1994, p.4). Environmental management is a management problem rather than an environmental problem.

Fuggle defined two basic aims for environmental management. The first is a commitment to sustainable living, and the second is the responsibility for the integration of conservation and development. Sustainable living seeks harmony with other people and with nature. Development enables people to enjoy long, healthy and fulfilling lives, while conservation attempts to keep our actions within the earth's capacity (1994, pp.2-3).

An organisation that is managed according to sound environmental management principles therefore manages with the goal of building a sustainable society. On a macro level environmental management manages man's activities within the planet's environmental carrying capacity.

1.1 Environmental Management in South Africa

Environmental concerns do not have a strong electoral base in South Africa. As a result of this, development agencies are under no statutory obligation to be environmentally responsible as yet.

Before environmental concerns can be integrated with public policy, one must have a wide disclosure of information and an informed citizenry. South Africa is a less-developed country and is lacking in these aspects. The national goals are economic growth and development, which are seen as far more important than the conservation of resources. Many forms of conservation are seen as a denial of the basic human right to make use of resources.

Fuggle (1994, p.749) suggested a different approach to environmental legislation in South Africa than that of the developed countries, which concentrates only on the negative impacts of development. The approach should instead encourage decision-makers to formulate an appropriate compromise, with the emphasis on identifying options and facilitating a choice between those options.

In 1984 the Council for the Environment, now called the Department of Environmental Affairs, started drawing up a recommended national strategy to ensure the integration of environmental concerns with development actions. This process is called integrated environmental management (IEM).

Due to a lack of prescriptive legislation, IEM procedures are undertaken on a voluntary basis. The Environmental Conservation Act, 73 of 1989, provides for the effective protection and sustainable utilisation of the environment, but no regulations have been promulgated under the Act as yet.

For the first time ever the new constitution, which was announced in the middle of 1996, introduced the possibility of a legally enforceable environmental right. The Bill of Rights in the new constitution states the following on the environment:

Everyone has the right -

- *to an environment that is not harmful to their health or well-being;*
- *to have their environment protected through reasonable legislative and other measures designed to -*
    - *prevent pollution and ecological degradation;*
    - *promote conservation; and*
    - *secure sustainable development and use of natural resources.*

The natural evolutionary process will continue to introduce sound environmental management into the South African agenda.

1.2 Integrated Environmental Management

IEM aims to ensure that negative impacts of development proposals are mitigated and positive aspects are enhanced, in such a way that the social benefits outweigh the social costs (Preston, 1993). If the IEM principles are followed, it could enable a developer and a community to plan a win-win situation. Developments could thus become assets to the community as well as more attractive propositions to the developer.

The principles underpinning IEM are in brief:

- informed decision-making;
- accountability for information on which decisions are taken;
- accountability for decisions taken;
- a broad meaning given to the term *environment* (i.e. one that includes physical, biological, social, economic, cultural, historical and political components);
- an open, participatory approach in the planning of proposals;
- consultation with interested and affected parties;
- due consideration of alternative options;
- an attempt to ensure that the 'social cost' of development proposals (those borne by society, rather that the developers) be outweighed by the 'social benefits' (benefits to society as a result of the actions of the developers);
- the opportunity for public and specialist input in the decision-making process.

IEM is an excellent tool to integrate the investigation, determination, evaluation and communication of the potential environmental impacts associated with development (Nel, 1993). Weaver (1992) commented that IEM is in fact the SA system for EIAs.

Although IEM has received criticism from various quarters as not being a comprehensive environmental management strategy (Nell, 1993; Quinlan, 1993; and Ridl, 1994), it is well positioned as a planning and decision-making tool.

1.3 Eskom's Response to Environmental Impact Assessments for New Linear Developments

Eskom recognises that the implications of its actions could lead to environmental problems and has committed itself to sound environmental practices. This commitment is empowered through corporate policies and directives. In response to these policies, the Environmental Section of the Land Survey Department in the Transmission Group has adopted a multidisciplinary planning policy and procedure. The approach is similar to the Integrated Environmental Management (IEM) procedure proposed by the environmental authority of the country (Department of Environment Affairs, 1992).

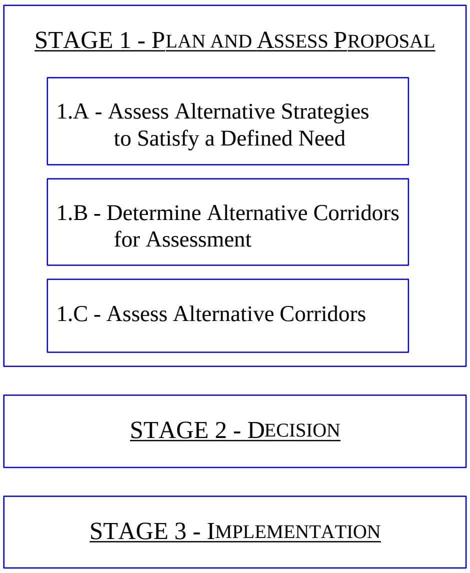


Figure 4 - An Outline of the Environmental Planning Guidelines

The procedure has recently been formalised in the form of a document referred to as the Transmission Guidelines for Environmental Planning - Linear Developments. The approach calls for environmental impact assessments and environmental impact management plans to be developed to assist decision-makers in the decision-making process. The process entails public involvement in the process and transparency in the decision-making process.

The main stages of this procedure as outlined in Figure 4 are similar to those suggested by the IEM procedure.

2. POWER LINE PLANNING

2.1 Need and Justification of New Power Lines

Eskom supplies 96% of the electricity used in South Africa and more than 50% of the electricity used on the entire African continent. For economic reasons the generation of electricity is concentrated on the Mpumalanga Highveld, which has vast coal deposits. From there the power needs to be transmitted over long distances to load centres in different parts of the country; for example from Johannesburg to Cape Town (1 200 km) and from Johannesburg to Durban (600 km), as well as from remote stations in the Northern Province such as Matimba (300 km).

In the light of the South African Government's RDP project and Eskom's related electrification drive, an additional 1 750 000 homes need to be supplied with electricity between 1994 and the year 2000. An extensive infrastructure needs to be in place to support this initiative.

Eskom's main transmission system (MTS) is tightly meshed in Gauteng and Mpumalanga, where power generation is concentrated, and needs to supply every potential customer throughout the rest of the country, including the Transkei (see Figure 1). Based on plans for an African grid, Eskom is also involved in several international connections. Major projects at present in progress include expansion into Namibia, Mozambique and Swaziland.

Forecasts in an Integrated Electricity Planning document drawn up by Eskom in 1994 included the following:

- Between 1994 and the year 2000, the maximum demand for electricity is expected to increase by more than 6 000 megawatts (which is equivalent to two large power stations).
- Between 1994 and the year 2000 the energy consumption is expected to increase by 40 terawatt hours per year (which is equivalent to 20 megatons of coal).

Eskom has plans on the table to influence as well as meet this demand, and those plans include the strengthening of the transmission network. A Report on Transmission Expansion Planning, produced by Eskom in July 1996, gives the a summary of new transmission lines to be built over the next ten years - see Table 2.

Reasons contributing to the need for additional power transfer capacity include:

- the addition of new generating capacity,
- the decommissioning or mothballing of generating plant,
- increased load at existing supply points,
- new loads, and
- improvements to the existing system.

VOLTAGE (kV)	**765**	**400**	**275**	**132**	**TOTAL (km)**
1996	0	2	21	0	23

1997	0	505	185	0	690
1998	0	307	229	195	731
1999	283	795	42	0	1120
2000	0	374	196	0	597
2001	0	210	0	0	210
2002	0	455	1	0	456
2003	0	20	110	0	130
2004	350	135	75	0	560
2005	0	174	138	0	312
2006	0	258	66	0	324
Total	633	3235	1060	195	5123

Table 2 - Transmission Line Lengths and Year of Commissioning

2.2 The Impact of New Power Lines

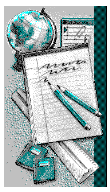
Upgrading the existing transmission network will inevitably have an adverse effect on the environment. Someone once remarked that there is no good place to put a power line, but only a least bad place (Anon).

An environmental problem can be defined as any unfavourable relationship between human beings and their natural environment. Power line planning as an environmental problem can be classified in the category of reversible biological and geophysical impacts (Fuggle, 1994, pp.4-5). In planning a new power line the challenge and responsibility therefore lies in bringing human action into harmony with natural processes.

Corridor selection for new linear developments presents specific challenges to environmental planners. The planning of power lines involves planning along linear lines over long distances. The successful planning of such projects calls for an integrated and multidisciplinary approach and thus the management of diversity.

2.3 Planning Considerations

One of the important aspects of linear assessments is the spatial variation in the environment being studied. The physical environment changes rapidly over a long linear distance, as do people's attitudes and priorities towards the environment. This spatial variation needs to be understood and adequately considered in the planning process.



The factors influencing transmission line route selection are technical and engineering requirements, environmental considerations, population density and public perceptions. As far as possible, transmission line routes are kept as short and straight as possible in order to minimise potential environmental impacts and construction costs.

For each new project environmental considerations are established from a list of concerns drawn up through interaction with the authorities, the public and specialists on the area, as well as from the past experience of environmental planners. Newspaper scans and desktop studies might also yield useful input. These concerns normally relate to environmental or social issues which need to be investigated for an accurate assessment of the situation and for the establishment of proper mitigation measures. They usually relate to environmental features on which a line can potentially have an impact.

Issues raised by the Eskom technical and environmental planning people might also be related to cost implications for the proposed development. These will typically be environmental features that can have an impact on the line, for example the occurrence of snow or frost, high incidence of lightning strikes, and terrain accessibility - each of these require specific design specifications, which will affect the cost of the towers.

Certain features in the study area might be regarded as no-go areas;- in other words, those areas should not be considered for power line placement at all. Identification as no-go areas may be due to either exceptional or irreversible environmental impacts or severe technical constraints.

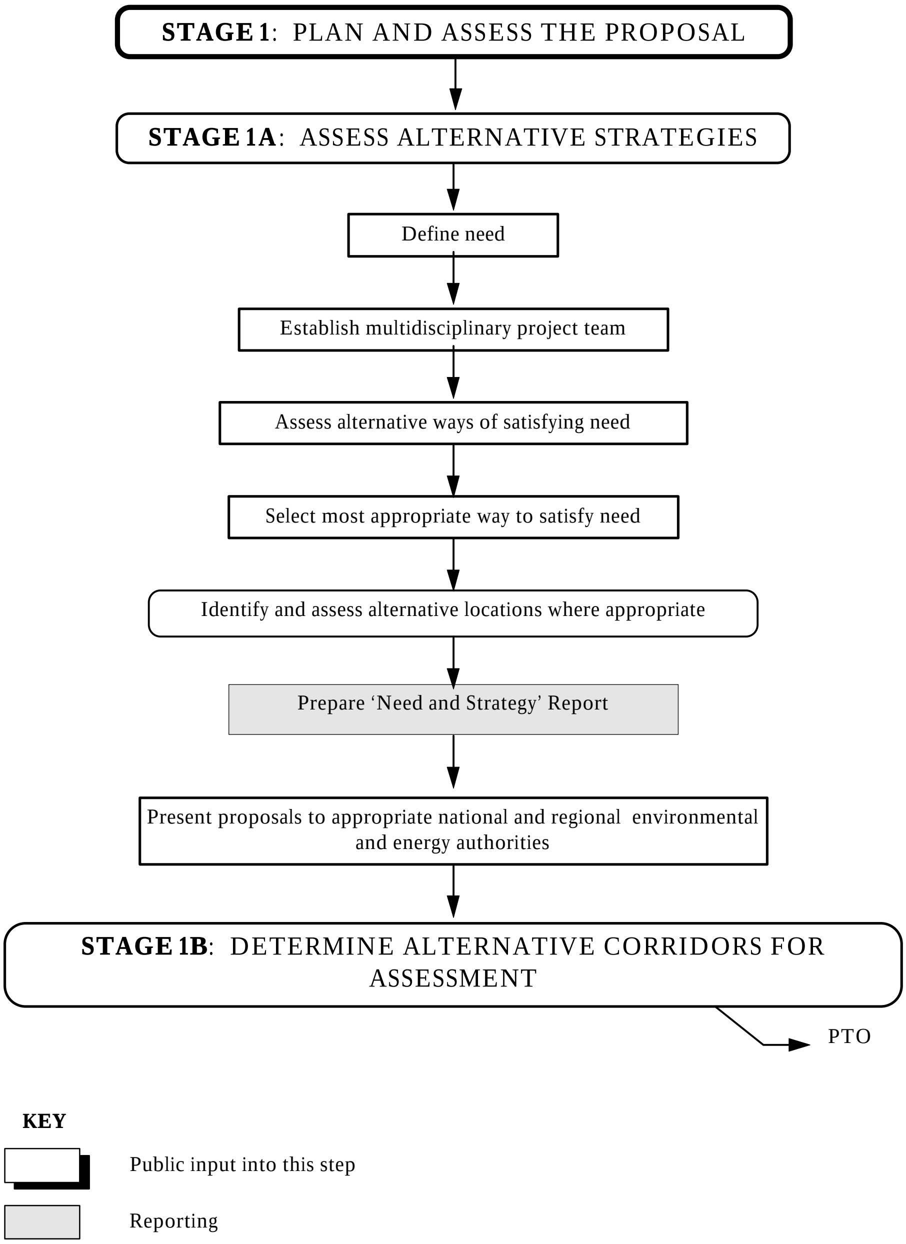
The engineering and technical considerations looked at in the analysis preceding the routeing of a transmission line include the line length, topography, geotechnical considerations, large water bodies, wetlands and population densities. River and road crossings are not a big problem, except for the angle of crossing if it is a large feature and the movement of construction equipment from the one side to the other.

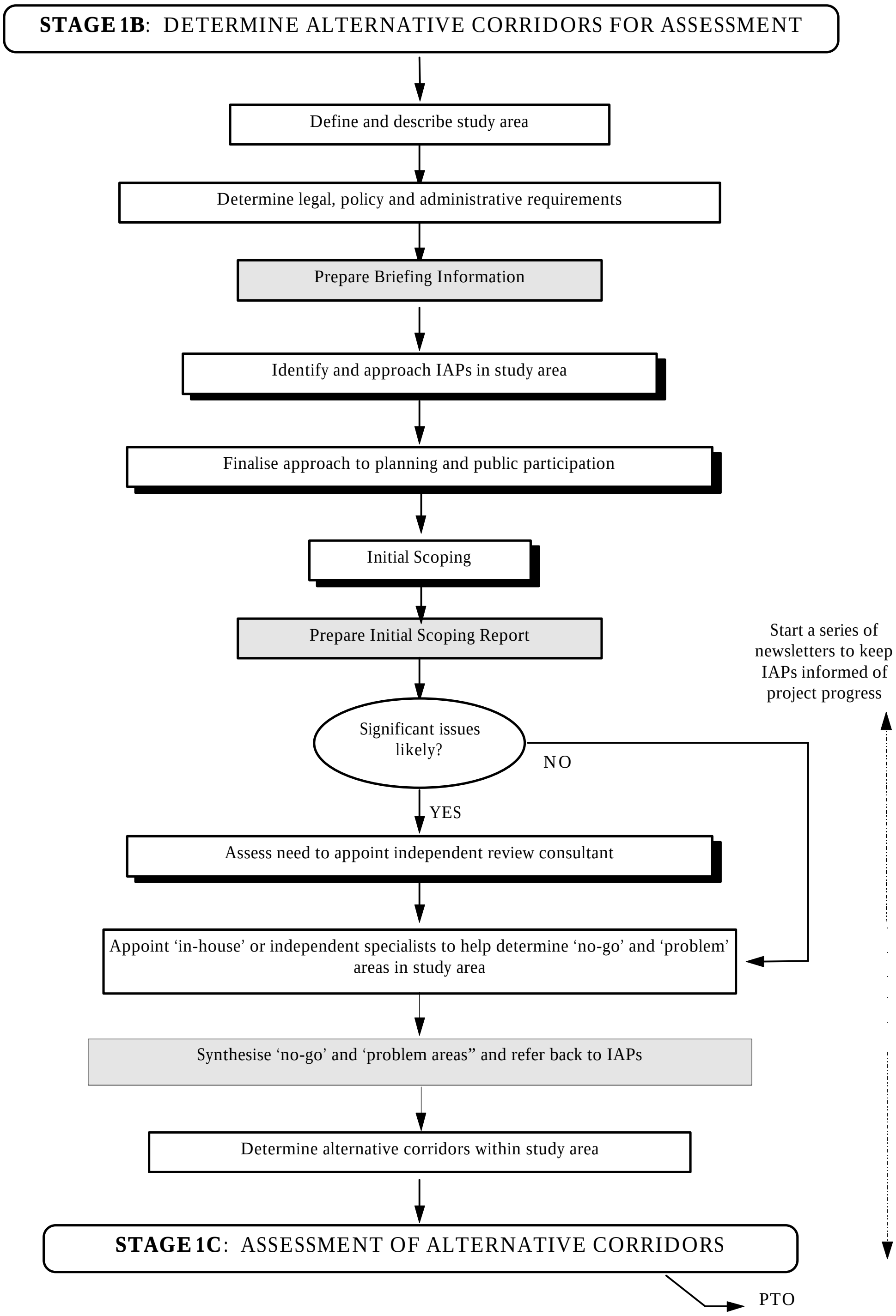
2.4 The Environmental Planning Process for Linear Developments

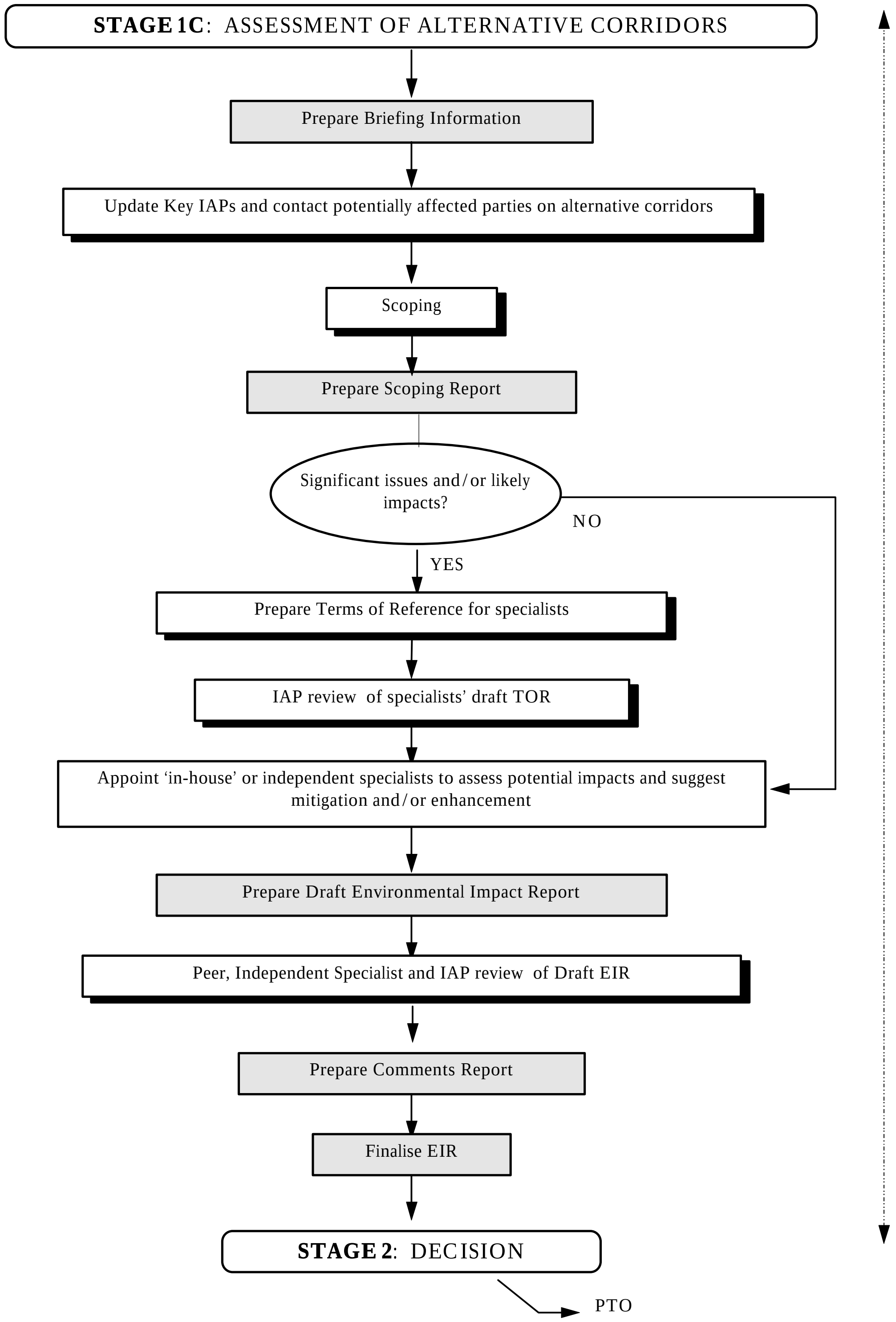
2.4.1 The Overall Planning Process

Environmental planning of the line takes place in three stages. Stage one is the planning and assessment of the proposal. The need for increased electricity supply and the different ways of satisfying that need are considered. When the most appropriate location for a transmission line has been established, alternative corridors that should be assessed in terms of their suitability to accommodate a transmission line are determined. During stage two an environmental impact report (EIR) is finalised, which will form the basis for deciding on the most appropriate corridor for the proposed transmission line. During stage three the decision is implemented, but audits will continue until the decommissioning of the line.

The Transmission Guidelines for Environmental Planning of Linear Developments prescribes the following process:




STAGE 1B: DETERMINE ALTERNATIVE CORRIDORS FOR ASSESSMENT
Define and describe study area
Determine legal, policy and administrative requirements
Prepare Briefing Information
Identify and approach IAPs in study area
Finalise approach to planning and public participation
Initial Scoping
Prepare Initial Scoping Report
Start a series of newsletters to keep IAPs informed of project progress
Significant issues likely?
NO
YES
Assess need to appoint independent review consultant
Appoint 'in-house' or independent specialists to help determine 'no-go' and 'problem' areas in study area
Synthesise 'no-go' and 'problem areas" and refer back to IAPs
Determine alternative corridors within study area
STAGE 1C: ASSESSMENT OF ALTERNATIVE CORRIDORS
PTO


STAGE 1C: ASSESSMENT OF ALTERNATIVE CORRIDORS
Prepare Briefing Information
Update Key IAPs and contact potentially affected parties on alternative corridors
Scoping
Prepare Scoping Report
Significant issues and/or likely impacts?
NO
YES
Prepare Terms of Reference for specialists
IAP review of specialists' draft TOR
Appoint 'in-house' or independent specialists to assess potential impacts and suggest mitigation and/or enhancement
Prepare Draft Environmental Impact Report
Peer, Independent Specialist and IAP review of Draft EIR
Prepare Comments Report
Finalise EIR
STAGE 2: DECISION
PTO

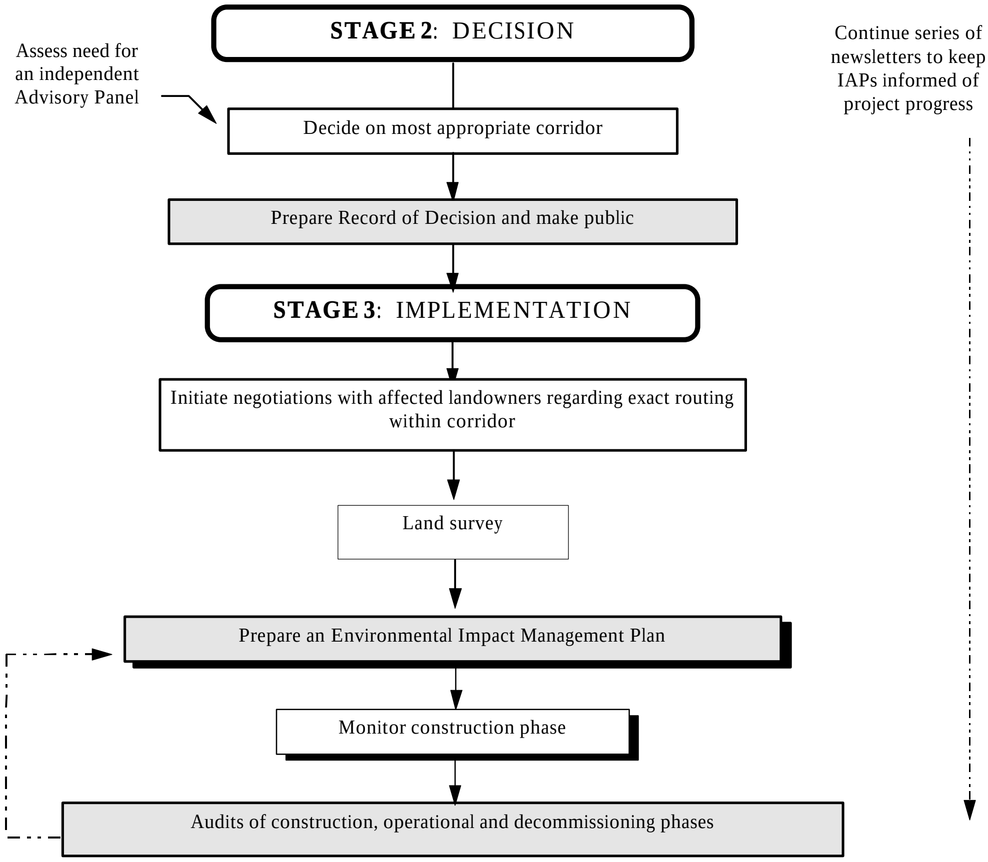


Figure 5 - The Planning Process

2.4.2 How Alternative Corridors are Determined

It is during stage 1B that alternative corridors for building a new power line are determined.

During the scoping exercise for each new line project, issues of concern in the study area based on past experience and feedback from interested and affected parties (IAPs) are identified. The Transmission Guidelines for Environmental Planning of Linear Developments gives examples of issues and their corresponding concerns, as set out in Table 3 (Eskom, 1996, p.21).

ISSUES	CONCERNS EMBRACED BY EACH ISSUE
Technical aspects	Erosion, access, topography, lightning, altitude
Infrastructure	Impacts on roads, railway lines, communication networks and systems, dams, irrigation systems, airfields, buildings, pipelines
Economics	Capital costs: length and technical complexity of line, compensation costs
Visual	Impacts on visual aspects, views: sky-lining, scenic routes and views
Historical and cultural	Impacts on historical and/or cultural sites or buildings
Archaeological	Impact on archaeological sites
Population density	Impacts associated with direct resettlement of people, numbers of people

	potentially affected
Tourism	Impacts on current and likely future tourism activities, routes and venues, as well as on character of area on which tourism is based
Intensive agriculture	Impacts on intensive agricultural activities: irrigation, aerial spraying, smallholdings, intensive stock/stud farming
Commercial afforestation	Impacts on productivity of commercial forest land
Priority flora	Impacts on threatened species and species important to nature conservation
Priority fauna	Impacts on threatened species and species important to nature conservation
Protected areas	Impacts on the integrity of proclaimed national parks, nature reserves, biosphere reserves, conservancies, natural heritage sites, sites of conservation significance
Wetlands	Impact on geohydrological system
Health and safety	Health impacts relating to electromagnetic fields, risk of electrocution. This will be in part dependent on population density near the line and projected population expansion into this area.
Security	Violence-torn areas where there could be a significant risk to safety of personnel involved in construction and/or maintenance of line
Privately owned/title deed land	The number of title deed/privately owned parcels of land which would need to be crossed: the more the parcels, the longer the likely negotiations will take, implying greater demands on cost and time
Reliability of supply	Impacts of veld/cane/forest fires, lightning, parallel lines, wind, particular land uses, man-induced damage to lines, sabotage

Table 3 - Examples of Issues

As an example, consider the nature of typical technical issues that need to be considered. Technical issues may include the need to construct access routes to be used during the construction phase; the topography of the study area may impose certain limitations during construction. River crossings may necessitate the removal of vegetation on the embankments which, in turn, may result in erosion. High altitudes are associated with steep slopes, remote access and topographical constraints, as well as technical limitations such as poor insulation, high incidence of lightning strikes and an impact on visual aesthetics due to skyline effects.

Based on the location of significant features, problem areas and no-go areas, alternative corridors are determined in the study area.

2.4.3 The Method for Feature Assessments

Each identified issue needs to be investigated in terms of its nature and the status of the impact of that issue, whether positive or negative. The issues need to be assessed in terms of the extent of the impact, the duration of the impact and the intensity of the impact.

A second-step criterion may include the probability of the impact, the potential of a cumulative effect with other impacts, the risk involved, and the reversibility of the impact. Potential mitigation measures as well as the possibility of implementing them need to be described for each issue.

Each identified issue should be assessed in terms of the impact it has, as explained in the impact and assessment criteria of the Transmission Guidelines and outlined in Table 4 (Eskom, 1996, p.34). In order to compare the various issues with one another, a definition of significance ratings has been compiled as part of the Transmission Guidelines, outlined below:

DESCRIPTION OF IMPACT	
Status	Positive or negative
Nature	What and who is affected, and how
ASSESSMENT CRITERIA	
FIRST-STEP CRITERIA	CATEGORIES
Extent or spatial influence of impact	Local or site-specific Regional National International
Magnitude of impact at that spatial scale	High: Natural and/or social functions and/or processes are severely altered Medium: Natural and/or social functions and/or processes are notably altered Low: Natural and/or social functions and/or processes are negligibly or minimally altered
Duration of impact	Short term: 0-5 years Medium term: 5-15 years Long term: 15+ years

SECOND-STEP CRITERIA	CATEGORIES
Risk associated with impact	Low High An impact is considered to be a high risk when: there is uncertainty, or a low level of confidence, in predicting the impact, AND the impact could be severe, irreversible and/or have severe cumulative effects
Reversibility of impact	Yes No An impact is considered to be irreversible if: it is permanent; ie it will not be reversed in time
Cumulative	Yes No An impact is considered to be cumulative if: the impact will have severe indirect and/or synergistic effects
Probability that impact will occur	Unlikely Possible Probable Definite

Table 4 - Description of Impact and Assessment Criteria

SIGNIFICANCE RATING	**FIRST-STEP CRITERIA: MAGNITUDE, EXTENT, DURATION**
VERY HIGH *Significance*	Impacts could: EITHER be of high magnitude at a national level in the medium to long term; OR have an impact at an international level
HIGH *Significance*	Impacts could be: EITHER of high magnitude at a regional level and endure in the medium to long term; OR of high magnitude at a national level in the short term; OR of medium magnitude at a national level in the medium to long term.
MEDIUM *Significance*	Impacts could be: EITHER of high magnitude at a local level and endure in the medium to long term; OR of medium magnitude at a regional level in the medium to long term; OR of high magnitude at a regional level in the short term; OR of low to medium magnitude at a national level in the short term;

	OR of low magnitude at a national level in the medium to long term.
LOW Significance	Impacts could be: EITHER of low magnitude at a regional level and endure in the medium to long term; OR of high magnitude at a local level and endure in the short term; OR of low to medium magnitude at a regional level in the short term; OR of medium magnitude at a local level and endure in the medium to long term.
VERY LOW Significance	Impacts could be: EITHER of low magnitude at a local level and endure in the medium to long term; OR of low magnitude at a regional level and endure in the short term. OR of low to medium magnitude at a local level and endure in the short term.

Table 5 - Definition of Significance Ratings

2.4.4 How Corridor Alternatives are Evaluated

The Transmission Guidelines define a corridor as a belt of land of variable width in which a transmission line could be routed (Eskom, 1996, p.14). For the purpose of this document, a corridor will refer to a line or an area. When specific emphasis needs to be placed on the variable width of a corridor, the term that will be used is a go area. The reason for this is technical and will become clear further in the document; but to explain in short: When a shortest path between two substations through a surface of corridor feasibility is determined, the outcome is a line and not an area. To obtain a true corridor, a go area can be generated based on the terrain of the corridor feasibility surface.

Environmental, socioeconomic and engineering design criteria that are geographically spread across a large study area must be simultaneously considered in the evaluation of corridor alternatives. A balance (or compromise) must be found between the socio-economic benefits of the proposed development and its projected costs - both economic and environmental.

Before a decision can be made, the corridor alternatives are evaluated in terms of three factors, namely:

- The potential significance of issues and related impacts, obtained by the feature assessments.
- The relative importance of these issues and related impacts to IAPs, obtained through public participation.
- The efficiency, equity and sustainability implications of using each alternative.

The efficiency, equity and sustainability are social welfare criteria by which a decision should be judged. These criteria are described in the Transmission Guidelines, as outlined in the following table (Eskom, 1996, p.46):

CRITERION	DESCRIPTION
Efficiency	A project is *efficient* if there are net social benefits, ie the total benefits exceed the total costs to society, so that gainers can compensate losers and still be better off.
Equity (or social justice)	A project is *equitable* if those who benefit also bear the costs, or if those who bear the costs can be fully compensated directly or indirectly by those who gain.
Sustainability	A project is regarded as *sustainable* if it does not have negative intergenerational effects, ie if the ability of future generations to meet their needs will not be compromised by the project. For example, if a project were to jeopardise life-support systems, irreversibly affect ecological processes, foreclose future land use options, or reduce biodiversity, the project would not be sustainable.

Table 6 - Social Welfare Criteria

2.5 The Stakeholders in the Process

2.5.1 Participative Decision-Making

Some of the basic principles underpinning IEM include an open, participatory approach in the planning of proposals and the opportunity for public and specialist input in the decision-making process (Department of Environmental Affairs, 1992).

The IEM procedure equate public participation to consultation and public review, which are far from adequate. Nel (1993) describes the function of IEM as a way to ensure that decision-making reform takes place by acting, among other things, to:

- introduce science into the decision-making process
- ensure informed decision-making
- facilitate rational decision theory and alternatives
- ensure responsible decision-making
- ensure accountable decision-making
- ensure participative decision-making.

Where true participative decision-making is incorporated in the process, it calls for transparency, participative management and informed decision-making, involving affected communities and all other interested and affected parties. This results in a demand for easily accessible information, objective judgement and presentable decision-making material. It also calls for a process by which decisions could be challenged, repeated or altered according to individual preferences.

2.5.2 Interested and Affected Parties

The interested and affected parties (IAP) that have to participate in the process are firstly the affected communities. It is important to note that for the purposes of building of a new power line, the affected community comprises not only the landowners affected directly by the servitude, or communities affected indirectly due to exposure to its effect on the visual aesthetics of a region, but also the beneficiary community who would receive electricity at the end of the production line. All too often the immediately affected community will shout louder than the beneficiary community. A balance needs to be sought.

Another group of IAPs includes governmental, regional and local authorities and institutions that need to be involved in negotiations and coordination. From the Transmission Guidelines in Figure 5 it is clear that these key IAPs will play a decisive role from a very early stage of the project life cycle .

Consultants and specialists add independent advice and credibility to the process. Finally, as an initiator of the RDP, as a developer and as a voice for the environment, Eskom is an IAP. Eskom is directly represented by the multidisciplinary planning team.

2.5.3 The Planning Team

For each new power line planning project, a multidisciplinary planning team is formed. Members of this team will typically come from the environmental section, the GIS section, the surveyors and the drawing office, and will also include a public relations and farm liaison officer, and a negotiator.

The responsibilities of the team members include the production of an environmental impact assessment in which public participation plays a decisive role, surveying of the route, and negotiations with the landowners in the acquisition of servitude rights. Back-office responsibilities include digital data acquisition, the manipulation and analysis of data, and map-making.

For the purpose of this discussion the main players in the team are the environmentalist and surveyor who work together from the scoping of the project, and the GIS specialist who would be responsible for any spatial information processing during this project’s life cycle.

3. CONCLUSIONS

The concept of environmental management is fairly new and under-utilised in South Africa. The Department of Environmental Affairs put a process called Integrated Environmental Management in place to ensure that the implications of development proposals are understood and adequately considered in the planning process. Eskom established its own Guidelines for Environmental Planning of Linear Developments to serve as a standardised and comprehensive approach to EIAs in respect of new power lines.

The transmission line network needs to be continually strengthened and several hundreds of kilometres of new lines are built annually. These power lines can have an impact on various features of the environment. An outline is given of the environmental planning guidelines. Main issues to be considered include environmental impacts, cost implications and the topography, as well as problem and no-go areas in the study area.

During the process of participative decision-making various stakeholders are involved in each project. The interested and affected parties include members of the public (both affected and beneficiary communities), specialists and experts used during the planning phase, and the in-house members of the multidisciplinary planning team.

Chapter 3

DECISION SUPPORT ON CORRIDOR ALTERNATIVES

1. SPATIAL DECISION SUPPORT SYSTEMS

1.1 Decision Support

Decisions are made based on people's understanding of a certain situation. Computers are normally fed by data - unprocessed, unintelligent lists of numbers and words. Computer systems are famed for their ability to take this data and process it into information. If required to make decisions, one needs to take the process one step further - this information needs to be turned into understanding on which decisions can be based.

According to Cleaves (1995) a good decision:

- accurately describes the problem and the criteria for solving it;
- uses available information;
- generates a wide range of alternatives to choose from;
- distinguishes between facts, myths, values and unknowns;
- describes the consequences associated with alternative problem solutions; and
- leads to choices that are consistent with personal, organisational, stakeholder or other important values.

Hargrove (1996) note that *"Decisions, by definition, are based on insufficient data; if enough information was available, the correct answer would become obvious and no decision would be required."* Sociologists classified conflict (or the need for a decision) in four basic categories based on facts and values. This classification has been incorporated in Figure 6.

One can build on this classification by distinguishing between the nature of a problem and the type of knowledge needed for problem-solving. Thus you would need a data-processing system to solve computational problems, an expert system to solve legal problems, a decision support system to solve political problems and a human expert to solve cultural problems.

PROBLEM-SOLVING TECHNIQUES					
	CONFLICTS MATRIX				
Human expert	*Inspire*	CULTURAL Facts: Disagree Values: Disagree	POLITICAL Facts: Agree Values: Disagree	*Persuade*	*Decision support system*
Expert system	*Verify*	LEGAL Facts: Disagree Values: Agree	COMPUTATIONAL Facts: Agree Values: Agree	*Solve*	*Data processing system*
		Facts: Known to be true	*Values: Regarded as Desirable*		

Figure 6 - Sources of Conflict and Problem-Solving Techniques

Conger described that a system that supports decision-making *seeks to identify and solve problems*. The users of decision support systems (DSS) are typically professionals and managers and it can be used to perform what-if analysis, identify trends, or perform mathematical / statistical analysis of data to solve unstructured problems. (Conger, 1994, p.20)

Based on Cleaves' description of a good decision, one can deduce that a decision support system facilitates the creation of alternative choices as well as report comparisons between these alternatives. Decision-makers should be more than just choosers of options - they need to be involved in the analytical reasoning which produced those options in the first place. It is important that the users of a decision support system understand and trust the methodology and operation of a system. To paraphrase the words of Professor Robert Woolsey of the Colorado School of Mines, *"Managers would rather live with a problem they can't solve than apply a solution they don't understand."*

1.2 The Use of GIS in Decision Support

Geographical information systems *use computers and geography to help people better understand the world we live in, and solve problems* (ESRI, 1996). GIS enables us to see a model representation of the world, with everything one chooses to include forming part of it, through a bird's eye view which allows you to look at the world with new eyes (or insight).

A GIS only provides rudimentary support for decision-making, but when you start to combined it with the relevant data, spatial modelling tools and appropriate interfaces to decision makers, more sophisticated decision support can be achieved. The ability to integrate information and support decision-making is the true power of a GIS. Petch (1993) explained on geography in decision-making that there are certain management decisions for which spatial information, analysis and cognition are essential and that the use of maps influences how we look at or conceive things and therefore what we decide.

According to Gallo, the integration of GIS and decision support software:

- promotes collaborative GIS;
- promotes joint intellectual efforts;
- facilitates the understanding of each other's concerns;
- focuses problem-solving efforts; and
- establishes and maintains an alignment between personal and group goals - in a controlled and moderate setting (1995).

There is a definite trend to investigate the use of GIS to facilitate group decision-making. Due to the complex nature of spatial problems, a multidisciplinary team normally needs to be involved in the decision-making. The NCGIA, who has contributed significantly to research on SDSS, recognised the need to move its focus from individuals to groups. They are currently developing models for supporting collaborative spatial decision-making (CSDM), which will certainly be very useful where participative decision-making is a requirement.

> *Collaborative efforts serve a number of purposes. They seek to accommodate different interests by including them in the decision process; this may lead to contention rather than cooperation. They seek through consensus to bind diverse parties (often subordinates) to an agreed conclusion. They seek through collective review to avoid egregious mistakes. Most of the gains … involve capturing from diverse participants the benefits of wider experience and varied personalities and outlooks. (Harris, 1995)*

Group decision support systems (GDSS) provide a historical memory of the decision process in support of groups of decision makers (Conger, 1994, p.20). GDSS focus more on the group interaction process where pure DSS focus more on data modelling or statistical analysis.

In one of his Beyond Mapping columns Berry wrote about the topic of GIS and participative decision-making (Berry, 1995a):

> *This final step is where GIS is used as a decision support system. Within this context the GIS isn't used to provide answers, but is used in participatory decision making. Consensus building and conflict resolution among interested parties are the focus. The GIS is used as a means to respond to a series of 'what if' scenarios in which any single map solution isn't important. It is how maps change as different perspectives are tried that becomes the information to make a decision. That develops an understanding of the sensitivities of the decision. Also, it involves decision makers in the analysis process instead of just choosing among a set of tacit decisions produced by detached analysis. Using GIS in this manner is a radical departure from current spatial reasoning and dialogue methodologies. When you reach this plateau, you and your high-powered GIS are ready for the races.*

The efficient analysis and visualisation of information during decision-making offer managers and professionals greater productivity and timesaving, which in turn saves cost. The power and functionality of GIS help people around the world to make more informed decisions by providing a simplified view of this complex world we live in.

1.3 Decision Support during Environmental Planning

Environmental management problems are increasing in complexity. On a daily basis it is getting more important to find suitable and sustainable solutions to these problems. There is therefor an increasing need to apply the information management potential of computing technology to help environmental decision makers with the difficult choices facing them (Frysinger, 1995).

According to Batty and Densham (1996), technology is naturally evolving and being adapted to the kind of decisions and management functions that lie at the heart of the environmental planning process. Environmental management and environmental planning are being affected daily through better techniques and approaches, bigger processing power, cheaper computer memory, more accurate and available data - the list goes on. This trend is accompanied by an emphasis on informal decision-making using computers interactively.

Frysinger defines environmental decision support systems (EDSS) as computer systems that help humans make environmental management decisions. EDSS both consider the crucial spatial context of environmental management decisions and support the dynamics of environmental systems. These systems are focused on a particular decision problem and decision maker to offer them everything the need to make the decision at hand - but only those things. This allows these systems to be particularly tailored to the problem facing the analyst, and offer a user interface that is optimised for this problem. It is therefor very different from the general purpose GIS.

One of the questions that can be addressed through a GIS is 'what if?'. Because a GIS is an abstract model of the world, one can play with various scenarios and ask, for example, what would happen if a new transmission line was built along a specific route. By simply moving the line on the GIS to another location and asking the same question, the implications of each could be compared. This process is referred to as modelling. Mann (1996) investigated the use of spatial process modelling for regional environmental decision-making and made the following statement:

> *If serious attempts are to be made to manage the environment then appropriate information must be available as to the consequences of any actions. Because most environmental action is irreversible, modelling provides a powerful way of non-destructively testing actions and outcomes.*

Frysinger noted that the EDSS designer must endeavor to understand the decision problem and all of the factors that must be considered in solving it (1995). A lot of the foundations for understanding the decision problem has already been laid in the previous chapter. The next section will now translate this problem into the information necessary to achieve corridor decision support.

2. CORRIDOR DECISION SUPPORT

2.1 From Planning Requirements to Information Needs

Issues of concern that needs to be considered during the planning of new power lines can be categorised into two main categories. The first category is of issues where the new line will potentially impact on the environment, the other is where these issues will have potential cost implications on the proposed development. These will be respectively referred to as issues with an environmental impact and issues with a cost implication.

An extremely sensitive issue can be categorised as a no-go area irrespective of the category it originates from. Examples of no-go areas might include densely populated urban areas, protected areas or nature reserves. For each new project the project team should assess the need to appoint specialists to determine the no-go areas.

Another feature of the environment that might be considered on its own merits is the topography of the study area. Although certain terrain is easier and cheaper to build towers on, the engineers designing the transmission towers profess that they can design a tower to stand almost anywhere. Due to the vast distances that need to be connected as well as the often mountainous areas, the topography in a study area might play a decisive role in the selection of a new corridor.

Public participation needs to be actively sought throughout the project life cycle to incorporate their issues of concern, their value judgements of the relative importance of these issues, and their input in the final evaluation of the alternatives.

Negotiations with land owners can be eased if the corridor follows an existing structure, either a farm boundary, a road or an existing power line. For environmental or purely practical reasons this situation is not always desirable, but such structures might be considered to obtain the final corridor after a go-area has been identified.

The extent of these projects requires a vast amount of information to be analysed and interpreted. This information then needs to be presented in a clear and understandable manner to facilitate the decisions on the most appropriate corridors, as well as to effectively communicate these records of decision.

Monetary comparisons of the line alternatives are already possible given that survey data of the proposed lines can be provided. The transmission line and tower engineers have perfected a program, called TLCADD, that works out the templating for a new transmission line to place the optimum combination of towers taking tower design types, cost, clearances and tower spans into account.

The input into this system is cross sections from a digital terrain model of the proposed route and the proposed tower designs for that line. As this program has been tried and tested and works very efficiently, actual costs on the corridor alternatives can be obtained. These costs can be used in addition to the comparisons that would be possible from the environmental planning considerations as addressed in this model.

2.2 The Environmental Planning Guidelines and Decision Support

The Guidelines for Environmental Planning of Linear Developments were written for a generic worst-case scenario. To recapitulate on the three different stages of the process (Figure 4) taken from the IEM procedure, they are: Stage One - planning and assessing the proposal; Stage Two - decision-making; and Stage Three - implementation.

Decision support is required during stage one. Decision support in the environmental planning of linear features can be divided into stages One B and One C, that are ‘Determine alternative corridors for assessment’ and ‘Assessment of alternative corridors’.

A decision support system to complement this process will influence the process significantly due to the implications of using such a tool. Advantages of decision support technology that will influence the process include the processing speed, the large volumes of data that can be incorporated in the equation, and the number of alternatives that can be automatically generated for consideration.

In looking at the process an assessment of features is made only after the corridor alternatives have been identified. The assessment is quite a lengthy and complex process if made manually, therefore making it only in respect of corridors will hopefully narrow down the list of issues to be assessed. Utilising computers makes it possible to make an assessment of the total study area and to base the selection of corridors on the results of the assessment. Scenarios could even be created where different issues may be included, using

Decision Making Process — Potential Feedback Loops

Describe Real World
- Study area.
- Identify issues for each of the four building blocks.

  Build Model of Real World
  - Map issues for each of the building blocks.

    Analysis of Modelled Issues
    - Make assessment of issues.
    - Determine relationships between building blocks.

      Modelling of Alternatives
      - Corridor alternatives.
      - Scenario alternatives.

        Evaluation of Alternatives
        - Comparison of corridors.
        - Comparison of scenarios.
        - Individual reporting.

          Decision and Implementation
          - Identify optimum corridor.
          - Review.
          - Final decision.
          - Negotiations and survey.
          - Implementation.

Figure 7 - The Decision Making Process

different sources of input for the assessment, or different relative significance of potential environmental impacts versus cost implications can be tried at the push of a button.

The decision-making process in a DSS can be visualised as shown in Figure 7. The four building blocks refer to issues with an environmental impact, with a cost implication, no-go areas and the features of the terrain.

Due to the nature of the environmental planning process for new transmission lines, a lot of value can be added to the process through the use of an SDSS. In the following section the conceptual components of such a system are introduced.

2.3 Criteria for a Useful SDSS

The following list of criteria for a useful SDSS which is relevant to CORDS, has been adapted from Mann (1996),

- Visual: The users, while computer literate and professionals in their own right, will not be GIS specialists. The system must be easy to use and should appear simple to the users. A graphical user interface is a necessity for the finished product.
- Interactive: The user must be able to develop scenarios interactively.
- Customised solution: A model which support the specific application should be interactively developed and then implemented for ease of use.
- Spatial: Environmental assessments are spatially defined. The support of environmental decisions therefor requires the ability to do spatial manipulation and presentation.
- Database of scenarios: A database is needed to keep track of the scenario, both during it's development and in recording a history for analysis (as distinct from the spatial data).
- Generic: The system should be generic - that is, any environmental planning team on any linear project should be able to use it.
- Links with other programs: With the emphasis on decision making the system should be capable of linking with other programs such as word processing or spreadsheets for report generation and should be capable of normal management functions (copy, paste, save, print, etc).

In the following section the conceptual components of such a system is introduced.

3. CONCEPTUAL COMPONENTS FOR CORRIDOR DECISION SUPPORT

Conceptually the SDSS that will facilitate decision-making in selecting transmission corridors (CORDS - Corridor Decision Support) can be broken up into various components, ie a database, a model base, an expert base, a report base and a user interface. Although these components will be introduced separately, they will form part of an integrated whole. A holistic approach should also be taken during the analysis and design of the system as *'the whole is more than the sum of the parts'* (Reeve, 1994).

3.1 Database

The data needed in CORDS will be from various sources and of different types. Alphanumeric data will contain information about projects, scenarios, issues and feature assessments. Geographic data will be both vector and raster-based. Most issues will be mapped as vector data, but raster and TIN data will also be allowed as input - given that an intelligent interpretation or reclassification of that data can be provided by one of the users of the system, or that it was previously added to the expert base. All the interim steps and results of the model will be raster-based. The alternative corridors will probably be vector data.

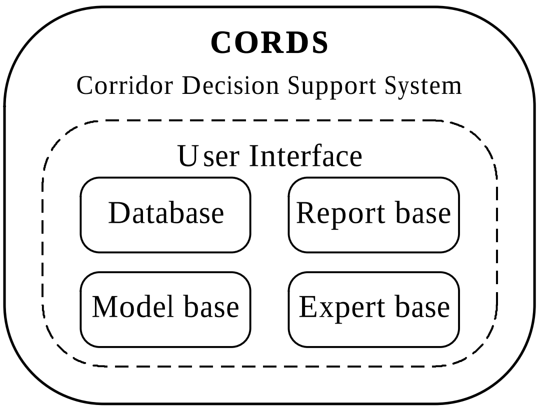


Figure 8 - Conceptual Components of the System

A database for the input, management and manipulation of all these various types of data can only be provided by sophisticated geographical information systems. CORDS will be developed as third-party software on top of a commercial GIS.

3.2 Model Base

Cornelius and Heywood (1995, p.4) defined a model as an idealised or simplified representation of reality, and modelling as the process of designing and constructing a model. Modelling allows planners and decision-makers to create different scenarios and to compare different 'what-ifs' with one another.

CORDS will model the effect and implications of new transmission lines on their environment. A model base needs to be developed that will take those aspects of the real world which are seen as issues of concern and, through modelling techniques, interpret them in such a way that one can base one's decisions on the modelled results.

3.3 Expert Base

An expert base refers to a usable collection of expert knowledge that would be required to interpret something or to get results from a system or process. An expert base should be developed in CORDS to standardise feature assessments and to teach the system how to interpret or classify raster and TIN input data to make it ready for use in the model base.

3.4 Report Base

A report base in an SDSS serves as an evaluation interface to the decision-maker and encompasses the traditional textual reports as well as the visualisation of spatial information. The presentation of the output should be clear and easily interpretable in order to support decision-making.

Reporting done in CORDS will focus primarily on the comparison of alternative corridors or the implications of selecting a specific alternative. These reports will be based either on the modelled results, or on the issues of concern and other features of the environment in the alternative corridors.

3.5 User Interface

Any system should be evaluated in terms of its suitability for a task and an audience. A user-friendly user interface is crucial for the successful utilisation of an SDSS. In an organisation such systems are typically utilised by professionals and managers who do not have time to battle with a system that is supposed to increase their effectiveness.

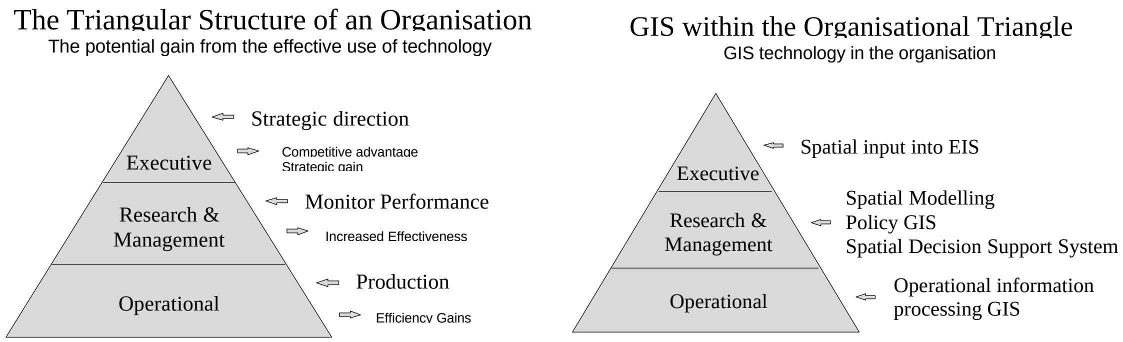


Figure 9 - GIS Usage in an Organisation

The user interface in CORDS should be intuitive, so that minimal training is required for the members of the environmental planning team to use the application. At the same time it should not prevent the GIS experts from taking the model base further than the basic system, allowing them to tap into the power and functionality of the underlying GIS modelling engine.

In the next chapter the analysis and design of CORDS will be discussed. The design of the CORDS database and model base will form part of information modelling, while the expert base, report base and user interface will form part of the human-computer interface design.

4. CONCLUSIONS

Due to rapid advances in research and technology, decision support systems are increasingly used to facilitate all kinds of decision-making. New models and modelling techniques continue to influence environmental planning. Environmental management is facilitated by these techniques and will continue to rely on decision support systems to attain scientifically verifiable decisions.

The ideas and concepts behind a corridor decision support system is further explained in terms of feasibility, benefits and those criteria that would make such a system useful.

The conceptual components of a decision support system for the environmental planning process of transmission lines have been identified and briefly introduced.

The following chapter will expand on models and modelling techniques used in decision support systems, as well as appropriate methodologies for the analysis and design of such systems.

Chapter 4

ABOUT MODELS & METHODOLOGIES

1. INTRODUCTION

In considering man's approach to spatial problems and spatial reasoning over time, it is clear that man first tried to understand spatial relationships by making physical abstracts of the real world in the form of maps. With the introduction of computers, these maps evolved into graphical inventories linking 'features to attributes' and describing the character, content and condition of mapped entities. Recently man started looking at the potential of GIS and 'mapematical modelling' in decision support. (Berry, 1995b, p.11)

Mapematical modelling or mapematics is a specific type of spatial analysis. The term spatial analysis is widely used, but in the strict sense it refers to operations in which the result depends on the spatial location of the data. Mapematics is also synonymous with map algebra or cartographic modelling.

To a large extent the decision support provided through CORDS will be based on spatial modelling. This chapter will develop a foundation for understanding models, it will explain how decision support models can be developed and cartographic modelling will be discussed.

Before setting out to the analysis and design of the SDSS, soft-systems analysis and design methodologies are introduced, with specific emphasis on the multiperspective eclectic methodology, which will be followed for CORDS.

2. MODELS AND MODELLING

Modelling facilitates the prediction of an outcome. The visualisation of modelled results often brings home the reality of a decision, or allows the decision-makers to understand the implications of their proposal or intended development more clearly.

During a modelling workshop interested and affected parties can participate in the process and reasoning which facilitate a decision. Mann (1996) suggests that the key benefits of such an approach are the atmosphere of ownership of the problem as well as the solution, the critical appraisal of available information and the mutual understanding of the capabilities and limitations of the model applied.

It is through the process of modelling that new information or new knowledge is produced. Any model requires certain data as input, but by applying the model to that data an outcome consisting of data that did not exist before is normally obtained. This is the added value of a GIS - the ability to create and visualise that which did not exist before.

The modelling techniques that can be utilised depend on one's specific application and are classified into descriptive and prescriptive modelling. Descriptive modelling answers questions such as ‘what is’ or ‘what could be’, whereas prescriptive modelling solves problems such as ‘what should be’. According to Tomlin (1990, pp.168-169), descriptive modelling techniques represent facts, simulate processes, express judgement and provide for the effective description of geographic phenomena. This is accomplished through the analysis and synthesis of cartographic data. Prescriptive modelling techniques, on the other hand, are used to select locations which satisfy stated objectives, also referred to as cartographic allocation. Prescriptive modelling is interactive and seldom fully automated, but *‘computation can greatly enhance our human ability to generate and evaluate alternative solutions to problems’* (Tomlin, 1990, p.199).

Prescriptive models will typically contain descriptive as well as prescriptive parts. At the beginning of the modelling process descriptive techniques are used that are relatively passive; later there is a shift to more active inquiry where prescriptive techniques are utilised to achieve an intention. Due to the prescriptive nature of cartographic allocation models, their use in spatial decision support systems does not come as a surprise.

2.1 Modelling Process for Decision Support

There is a generic process that one can follow in the development of a model for decision support. The process shown in Figure 10 has been adapted from Winston’s simulation process (1994, p.1224). The process consist of two phases being the construction of the model and the decision support using the model.

The initial stage in any scientific study is a statement of the objectives. This should include the performance criteria of the model, model parameters and the identification and definition of any variables that will be used.

The next two steps of development of the model and collection of the data goes hand in hand. The one might depend on the other, but both are determined by the objectives of the model. The detail, quality and accuracy of the data to be collected might depend on availability, feasibility and budget, but should primarily depend on the requirements set by the performance criteria of the model.

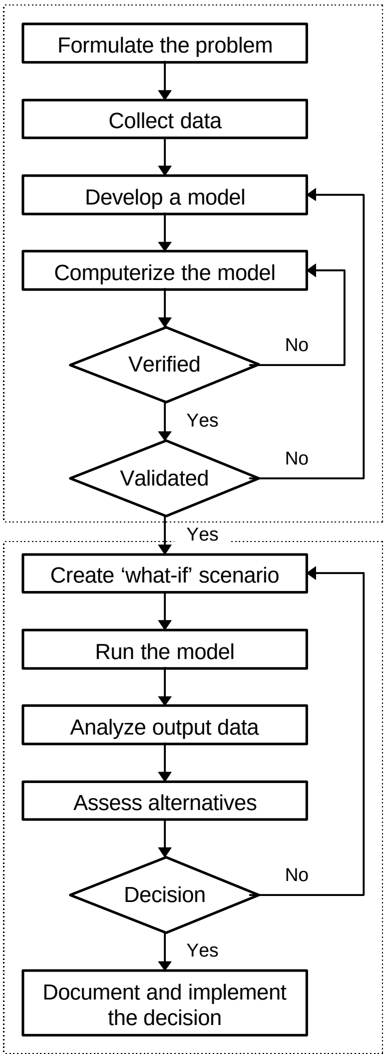


Figure 10 - The Modelling Process for Decision Support

Several simplifications and assumptions needs to be made to portray a real world system as an analytical model. This model will be but a representation of reality and will be limited in accuracy. The development of the model is a process through which you represent the essential features of the system under study by mathematical or logical relations. Winston reckon this process to be as much an art as a science (1994, p.1223).

After the model has been developed, a computer program should be developed that can execute the model. A critical success factor of this development phase is the computer language selected to implement the model with. The use of special modelling languages is advisable to speed the process and ease the future maintenance of the program. In the application at hand a cartographic modelling language will be used to implement the model with.

During the verification step the computer program developed is tested and debugged to determine if it is working the way it is suppose to be. During the validation step one determine whether the model realistically represents the system being analysed and whether the results from the model will be reliable.

Once the performance of the model is satisfactory it can be used for decision support on the specific application at hand. Through its use, further refinements to the model might be desired.

The main emphasis of this study is to develop a generic model for spatial decision support on the corridors for new linear developments. The process to be followed will therefor be slightly different from what has just been outlined. The first and primary focus will be on the development of the model and thereafter the model will be implemented in a decision support application that will be used in the environmental planning of new transmission lines. Once the application exists only data collection and decision support will need to be done on new projects.

2.2 Cartographic Modelling

Any problem that relates to spatial location can be addressed through some form of spatial analysis. Spatial analysis solutions are therefor central to any SDSS. The way in which these solutions are incorporated into application specific SDSS determine the flexibility of these systems for development and future modifications.

Most GIS systems provide some form of development tools through which third-party developments can be developed on those GIS platforms. Theses spatial analysis solutions can then be programmed into SDSS. The problem comes in when the users suggest a conceptual change to the model implemented. Extensive knowledge of the original application development is normally required in order to affect these changes. For complex SDSS the effort to do these change modifications can be so far reaching that the people involved choose to rather continue using the unmodified system than to go to all that trouble.

Recently the introduction of cartographic modelling languages for spatial analysis of geographic data has changed this picture considerably. Cartographic modelling provides a structured approach to the design of a GIS model by establishing a generic algebraic notation and natural language means of referring to the methods, spatial variables and spatial operations used to develop a GIS model (Cornelius and Heywood, 1995, pp.83-93).

In a few simple English structured sentences a model can be implemented today which previously required multiple complex programs. Because of the power, yet simplicity, of these modelling statements, future change modifications are comfortably achieved. C. Dana Tomlin, who is seen by many as the father of cartographic modelling, portrayed this emerging field as follows (1990, p.*xii*):

Cartographic modelling is a game of only several pieces and a few basic rules but unlimited possibilities… What the game does require, (however,) is an eye for both spatial and logical structure… This is a field whose basic foundations are just now beginning to settle, a field whose full potential has certainly not yet been explored.

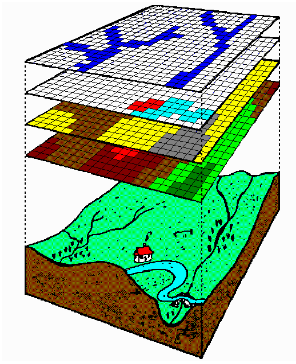


Figure 11 - A Raster Representation of the World

A cartographic modelling language provides a consistent way of writing spatial algebra statements in a vendor-independent format. The power and capability of such a language lie in the various operations available for data interpretation and manipulation. These operations can be classified into four basic classes, namely focal functions, incremental functions, local functions and zonal functions, explained in more detail in Table 7.

In order to define terminology, consider a raster representation of the real world. A theme is a single map layer of information - in the example given in Figure 11 rivers constitute a single theme, height above sea level another theme, etc. The individual building blocks are cells, or pixels, and rows and columns of these constitute a theme. Because the use of the terminology for a theme might be seen as software specific, it will be referred to as a surface in the text. An example of a surface is then the slopes from a digital terrain model or the cost implications of a proposed development.

There are two types of cartographic allocation models, namely an atomistic and a holistic allocation. An atomistic allocation problem is one that can be addressed on a location-by-location basis, while a holistic allocation problem treats groups of locations as integrated wholes. A prescriptive model for corridor decision support solves a holistic allocation problem.

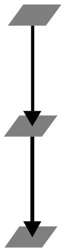
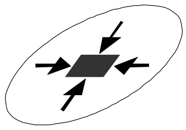
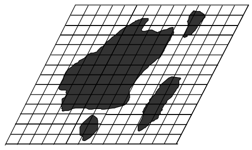
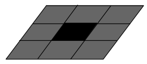
Local Functions	**Focal Functions**	**Zonal Functions**	**Incremental Functions**
 Local operations characterise *individual locations*. Commands from local functions work in a cell-to-cell manner to produce a new value for the resultant cell at the same location in the new theme.	 Focal operations characterise *locations within neighbourhoods*. Focal functions derive each cell value for the resultant theme by using the values within a specified neighbourhood, determined by values, distances or directions of neighbouring locations.	 Zonal operations characterise *locations within zones*. Each zonal function produces a new theme in which every cell is set to a value computed according to a selected map algebra function that associates the values from one theme with cells in a specified region or zone in another theme.	 These functions address the geometry of cartographic forms by giving greater consideration to *neighbourhood focuses* of immediate neighbourhoods. Cartographic forms may be punctual, lineal, aerial, or superficial. (Tomlin, 1990, pp. 64, 104, 154, 228-241)

Table 7 - Cartographic Modelling Operations

3. SOFT-SYSTEMS ANALYSIS AND DESIGN METHODOLOGIES

Several systems analyses and design methodologies are available to plan an information system. Some of these are very neat - reductionist, refutable and repeatable, *"but taken by itself it tends to lack realism in the complexity, risk and uncertainty of much of daily life"* (Bell and Wood-Harper, 1992, p.186). Such methodologies can be categorised as 'hard' - a scientific approach to problem-solving that is objective and technocratic. On the other hand, 'soft' methodologies (an approach to problem-solving that is based upon the social sciences - pragmatic and often subjective) also consider the human or social aspects and implications in systems planning.

Systemic is the direct opposite of reductionist, originating from systems thinking and relating to social philosophy. Systemicists are involved in the necessarily subjective world of real human activity (Bell and Wood-Harper, 1992, p.19). Solutions developed under 'hard' methods normally centre around technology, while systems developed by using 'softer' methods result in sociotechnical solutions.

Soft-systems methodology, or SSM, is described by Checkland and Scholes (1990, p.xiii) as *"…one well-established way of intervening to improve problem situations… and (SSM) was developed expressly to cope with the more normal situation in which the people in a problem situation perceive and interpret the world in their own ways and make judgements about it using standards and values which may not be shared by others".*

SSM is particularly well suited to the creation of information systems. Checkland and Scholes continue to explain this process as follows:

> *Information systems are here described as being 'created', rather than simply 'designed', because the connotations of the 'design' activity are that what is required has been specified, and design is concerned with the question of how to realise the specification. Creating something implies a broader perspective (Checkland and Scholes, 1990, p.53).*

Creating an information system, as opposed to designing it, is particularly relevant to the GIS environment. By their very nature GIS applications are dynamic and grow with their users. If understanding their own system requirements is difficult for users of non-spatial information systems, it is even more so for users of GIS systems. Conger explains that the development life cycle of a DSS tends to be iterative with continuous identification of requirements (Conger, 1994, p.20). Growth should therefor be expected and flexibility planned for.

Reeve referred to soft-systems analysis as a *consultative process of enquiry* (1994, p.164). On previous GIS implementations it was reported that a people-oriented philosophy was the major factor in the success of the innovation (Koller, 1993). For these reasons and because of the importance of user interaction and people's perceptions of the effective utilisation of any SDSS, soft-systems analysis is a very appropriate development methodology in this problem context.

4. A MULTIPERSPECTIVE, ECLECTIC METHODOLOGY

The research methodology followed in this project is based on action research. This implies that the scientist is part of the problem context and therefore part of the research, and that he/she understands reality by linking theory and practice. Such an approach involves active assistance from the recipient community. This type of research is on the opposite side of the scale to a conceptual or mathematical study - on the action side - is less controlled and is subjective and eductive (Bell and Wood-Harper, 1992, p.16). Action research also ensures that the analyst understand the job being supported and can interpret what he/she observes during the analysis and design phase.

Before analysis and design can start on a new system, the analyst needs to choose a methodology to follow. The emphasis should move away from finding the 'right' methodology to selecting the right combination of methodological tools for any particular situation.

The methodology on which the analysis and design of this system will be based was developed by Bell and Wood-Harper and is a multiperspective and eclectic one. Eclectic refers to the wide range of tools used, and multiperspective refers to the attempt to perceive the problem confronting an information system from a number of different directions (Bell and Wood-Harper, 1992, pp.19-21). This is a soft-systems methodology; in other words, it also considers the 'human' aspects of business problems. The main idea behind this method is to incorporate the specific people and organisational environment the system analysis is done for, into the analysis of the information needs. A system solution is therefore specific to the paradigm of the people and the organisation involved. The method to be followed might differ slightly from the published methodology due to the implications of applying it to geographical information systems, which inherently differ from traditional information systems.

The multiperspective, eclectic methodology consists of five components or tools. The following figure, taken from Bell and Wood-Harper (1992, p.21) shows how four of those components relate to each other, while the fifth deals with the interface between the user and the computer itself - the human-computer interface. Two of the components are largely systemic and two reductionist, two tend to be concerned with the organisation in which the system is being developed and two are more centred on technology. The sequence of applying these tools is ① soft-systems methodology, ② information modelling, ③ analysis and design of social and technical aspects, ④ design of the human-computer interface and ⑤ design of the technical details.

During the information modelling phase the emphasis is on what the information system is actually going to do, and an outline system that is practical and workable should be produced. This phase therefore incorporates the analysis of the database, expert base and model base. The design of the human-computer interface, on the other hand, is the sensible place to discuss the design of the report base and the user interface. During the design of the technical details these conceptual components all come together as this

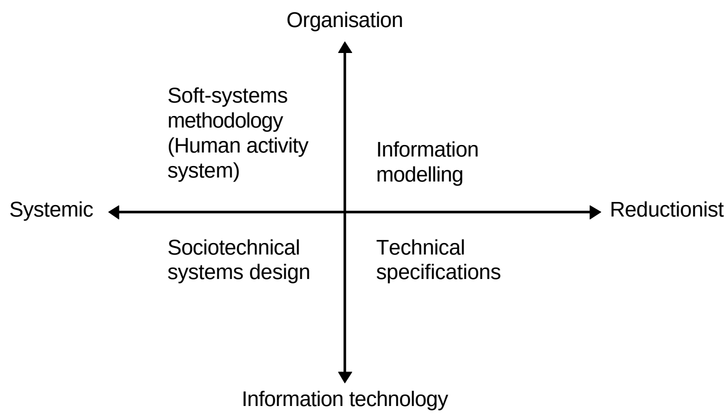


Figure 12 - Four of the Methodologies Used

phase focuses on applications, databases, retrieval, management, maintenance, monitoring, evaluation and putting everything together.

The application of this methodology, especially in GISs, appears to be extremely relevant due to the emphasis on first understanding the nature of the problem before a solution is produced. This understanding is achieved through the application of a soft-systems analysis, which gives explicit consideration to social concerns.

Through balancing the social and technical considerations an optimum solution is sought which will address the needs of a particular group of users in their organisation specifically. Prototyping plays an important part through addressing the users' expectations at their point of need. The human-computer interface stage is specifically relevant to GIS applications as not only the user interface, but also the appropriate presentation of spatial information can determine the usefulness of the application to the specific group of users.

5. CONCLUSIONS

A basic introduction to models, decision support model creation and specifically cartographic modelling, has been given. It has been shown that the CORDS model base will contain a prescriptive model to solve a holistic allocation problem.

Soft-systems methodologies not only look at technology to solve a problem, but also consider the total social impact and implications of introducing a new system into an organisational environment. Due to the complexities involved in the implementation of any GIS, the use of soft-systems methodologies is very appropriate.

The specific soft-systems methodology to be used for the analysis and design of CORDS is based on the multiperspective, eclectic methodology developed by Bell and Wood-Harper (1992, p.21). The following chapter deals with the way in which they introduced the basic methodology.

Chapter 5

ANALYSIS AND DESIGN OF A SOCIO-TECHNICAL SYSTEM

1. INTRODUCTION

This chapter contains the analysis of and design for CORDS, based on the multiperspective eclectic methodology explained in the previous chapter. The analysis now tells what must be done to solve the problem, while the design tells how the problem should be solved. A brief outline of the process is given in Figure 13.

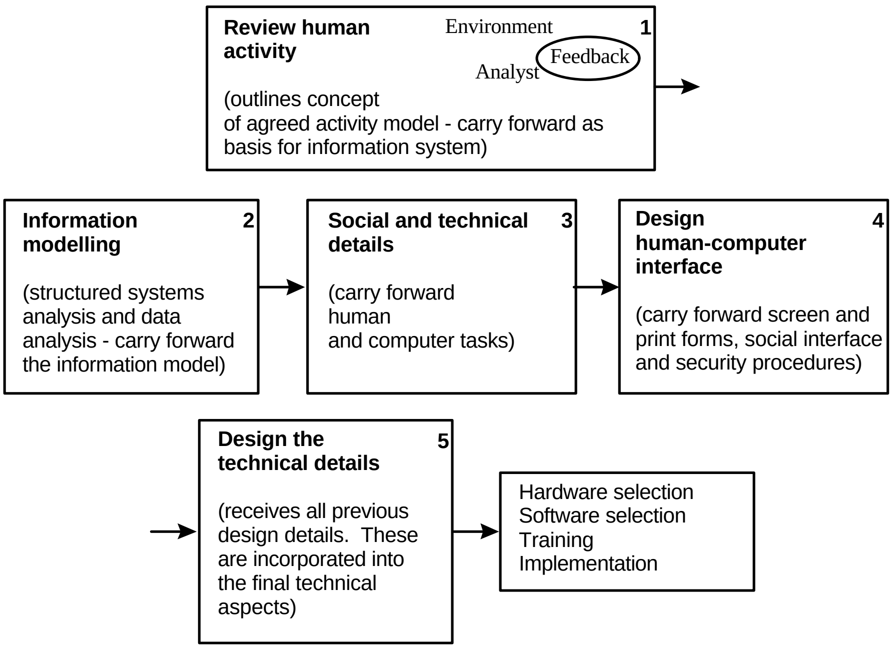


Figure 13 - The Multiperspective Eclectic Planning Methodology

The effectiveness of the implementation of an SDSS should be measured by looking not only at the technology utilised in the system, but also at the receptivity of the human and organisational set-up into which the system is introduced. Gunnar noticed that in many instances SDSS is implemented into agencies without serious consideration of its impacts on adoptive institutional structures or local capacities to sustain technology (1995). A holistic approach is crucial to the success of a SDSS. For this reason the analysis and design of CORDS will focus on social and technical considerations, which should be aligned throughout the process.

> *Through the design of more appropriate computer systems which address the needs of the users, such as managers and decision makers, the use of technology for spatial decision making can be taken from the technical domain into the general domain. This will empower people to utilise the technology to make decisions and better understand their environment (Carver, S.J., et.al., 1995).*

All the users of the new system should be involved in the analysis and design process on a regular basis. Conger noted that DSS are generally developed for people in jobs with a significant amount of discretion in what they do and how they do it. Therefore, observing or working with one or two people as representative may result in a biased view of the application requirements (1994, p.101). A group of people involved in producing a solution normally supports it.

2. THE HUMAN ACTIVITY SYSTEM

This first stage of analysis is to follow the soft-systems approach to define the perception of the problem situation and the resulting need for information, and agree on a view of the system and its context. The steps of the process are, briefly, to perceive the problem situation through rich pictures and root definitions, construct a conceptual system model and compare this model with reality in order to improve it further.

The outcome of this step of the process is a model of a human-activity system which will also be a refined definition of the situation. This definition helps the system analyst to understand the nature of the problem. The model of the human-activity system should also show senior management how this information system will further the aims of the organisation.

The terms of reference for the system at hand read as follows:
Develop a decision support system to support the *Transmission Environmental Planning Guidelines on Linear Developments* in order to increase the efficiency of environmental assessment projects.

Any problem exists within the context of a human-activity system. In this case the ‘problem’ is the need for a decision support system. In order to understand the context in which the system is to be introduced, one needs to draw a rich picture of the human-activity system, consisting of 'hard' and 'soft' structures and processes that might influence this system. The structures and processes have been identified as follows:

Hard Structures	**Processes**
The Department	
Transmission Environmental Manager	Oversees environmental management throughout Transmission.
Management team	Oversee all environmental projects, surveys and negotiations related to transmission structures; manage historical records.
Environmental Section	Environmental assessments of all Transmission projects, including lines; environmental policies and methodologies.
Surveyors	Part of multidisciplinary planning team on environmental projects; surveys on all transmission projects; supporting technologies.
GIS experts	GIS consultation service; spatial data management; spatial analysis; supporting technologies.
Drawing Office	Map-making; templating; maintaining historical records.
Public Liaison Section	Public relations; participative decision-making.
Negotiators	Negotiations with landowners.
Eskom	
Projects	Define new line requirements; determine budget and timing of all new projects.
Other survey and environmental teams	Also have a need for decision support on new lines; would like to learn from this department and use technology.
Other Eskom GIS users	No Eskom-wide standards.
Eskom Environmental Policy	Eskom's commitment to the environment has been formalised in the form of a policy that should be adhered to.
The World	
GIS software developers	Software currently used is being enhanced; will be shipped under a new name, look and feel - 1st quarter 1997.
GIS data providers	Need to obtain / provide appropriate data.
IAP	Interested and affected parties should be consulted and negotiated with throughout the process; need to understand the decision-making process and the visualisation of the results.
Landowners	Landowners whose land forms part of the final selected corridor need to be negotiated with for servitude rights.
Environmental legislation	The country's environmental guidelines should be adhered to and new legislation should continually be incorporated in the process.

Table 8 - Processes on Hard Structures

Soft Structures	Processes
The Department	
Other GIS interests	Different people see different priorities in GIS applications and development.
Roles and responsibilities	Shifting - only vaguely defined.
Organisational change	Move to process mode - change results in uncertainty.
Changing role of management	Management is uncertain - staff are frustrated.
Past GIS experience	Negative perceptions from past GIS experiences can still be carried over.
Eskom	
Possibility of privatisation	Future is uncertain - either a threat or an opportunity.
Projects	Pressure to deliver projects in good time and on budget, but otherwise no sympathy for environmental assessments.
Eskom's perceived environmental performance	There is a commitment and a drive to perform environmentally; but it is not supported consistently.
The World	
IAPs	They need to support Eskom's planning approach and Eskom needs to satisfy their expectations.
Data	Needs to be available, relevant and of appropriate quality.

Table 9 - Processes on Soft Structures

A rich picture is an attempt to incorporate these structures and processes in one drawing. Such a picture allows one to see all the various factors of potential influence for consideration at once. It also facilitates communication between the various stakeholders involved.

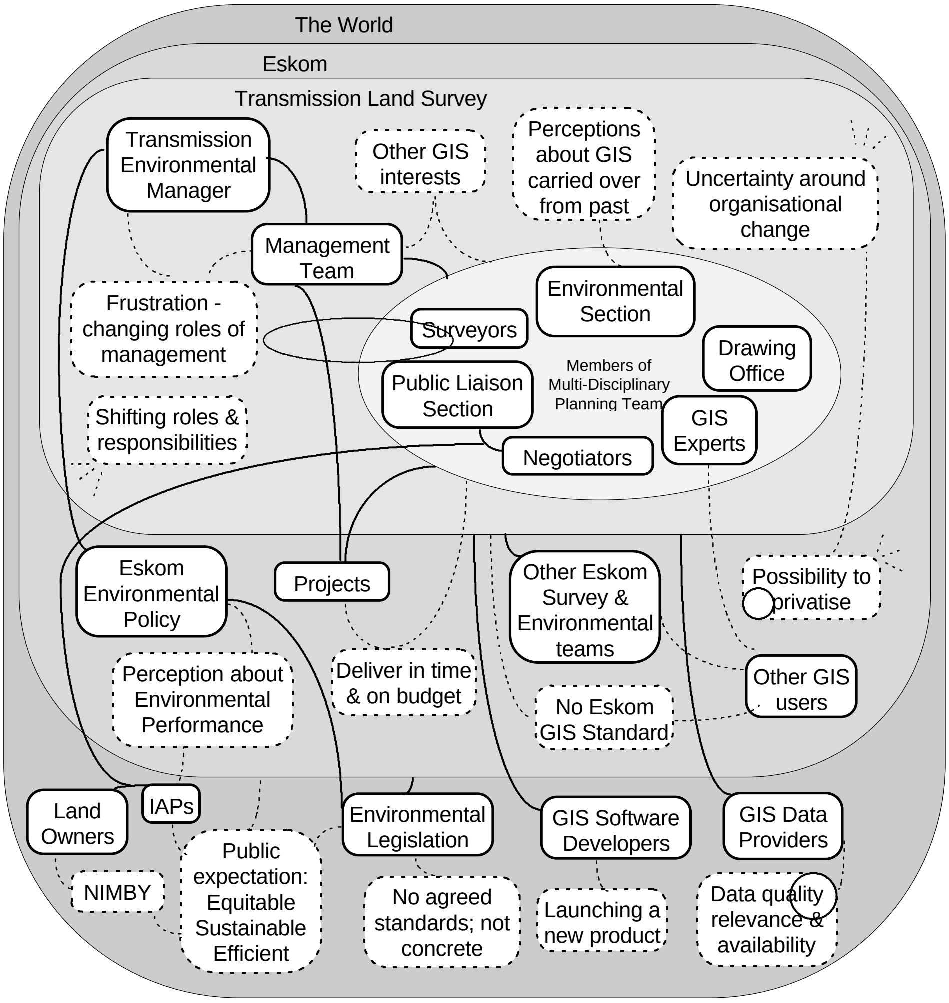


Figure 14 - A Rich Picture of the Human Activity System

The next step is to write down a root definition of the system to be developed and to build a conceptual model of the new system, representing the shared perceptions of the analyst and the major stakeholders.

A CATWOE breakdown of the root definition:

C*lient*	Transmission Land Survey
A*ctor*	GIS Analyst, GIS Specialists, Planning Team
T*ransformation*	Provide decision support on new linear developments
W*orld-view*	To facilitate decision-making
O*wner*	Planning Team / Transmission Land Survey
E*nvironment*	The Department.

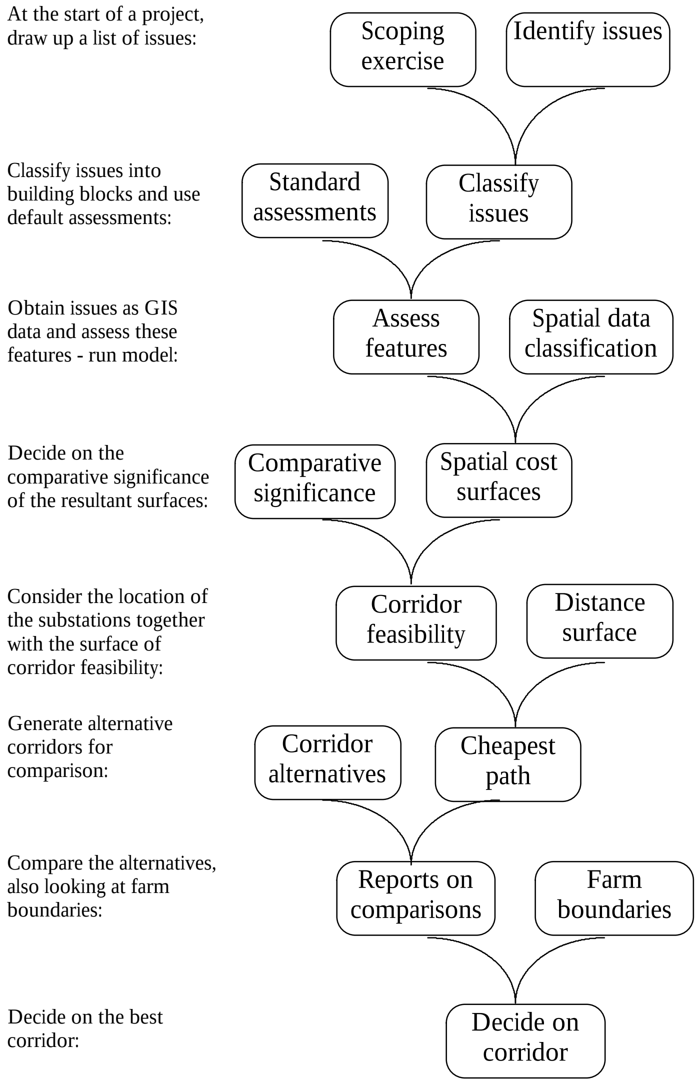


Figure 15 - A Conceptual Model of the Solution

<u>The CORDS root definition</u>:

CORDS is a spatial decision support system utilised by a multidisciplinary planning team, designed to facilitate decision-making in selecting transmission corridors within the constraints of data availability.

The conceptual model has been presented to the stakeholders and they agree on the principles contained in it.

3. INFORMATION MODELLING

This 'harder' stage of the methodology structures the conceptual model previously defined into a workable system. Information modelling is done starting from the root definition and conceptual model agreed upon in the first phase. These ideas are progressively decomposed into subsystems, which can be translated into data flow diagrams. Based on the analysis of the human activity, an entity model including the relevant entities and relations is developed. The emphasis is on producing an outline system that is practical and workable. At the end of this stage the information model is presented to the stakeholders in an understandable way. The conceptual model might need revision. Once consensus has been reached, we can proceed to the next stage.

Information modelling takes place in the database, model base and expert base of CORDS. Details of each are given below:

3.1 The Database

Entities (or things we wish to keep information about) need to be identified; attributes (or qualities) of entities need to be listed; and functions (or the jobs entities are involved in) and events (which trigger functions) need to be identified. In short, entities have attributes and carry out functions as a result of particular events.

As CORDS is a spatial system the entities we wish to keep information about are both spatial and relational. It is accepted that one needs good geographic data in order to make good decisions. Good data does not necessarily mean large volumes of data, but rather that subset of data that is significant and relevant to the decision at hand (Berry, 1995b, p.11). Data availability and relevance are issues of concern in undertaking any project, but should not be seen as a consideration in the design of this generic system.

The entities involved in such a generic SDSS are determined partly by the process to be supported and partly through knowledge of the spatial analysis required to deliver the outcome.

The CORDS spatial and relational data entity model is represented in Figure 17 at the end of this chapter. A data entity model normally shows all relationships between all the entities. Due to the complexity of the relationships between the spatial and relational entities, not every possible relationship is represented. This entity model should be interpreted as a generic representation of entities, and not as an example of what would happen inside one scenario.

Entities	**Default Issues**	**Project**	**Scenario**	**Study Area**
Attributes	Issue name	Initiation date	Description	Description

	Feature details Standard assessment Social welfare category	Project team Project name Spatial extent Projection Scenarios	Study site name Spatial extent Resolution	Spatial extent Theme name
Entities	No-go Areas	Terrain Model	Impact Issues	Cost Issues
Attributes	Description Spatial features	Slope theme name Height theme name Spatial DTM	Feature details Assessment results Significance Social welfare category Spatial features	Same as before
Entities	Mask	Construction Suitability	Impact Surface	Cost Surface
Attributes	Spatial Theme name Relative significance (0/1)	Spatial Theme name Relative significance (0..n)	Same as before	Same as before
Entities	Begin & End Points	Distance Cost Surface	Corridor Feasibility	Cheapest Path
Attributes	Description Spatial co-ordinates Sequence	Spatial Theme name Sequence	Spatial Theme name	Path name Spatial
Entities	Alternative Paths	Go areas		
Attributes	Path name Spatial	Spatial		

Table 10 - CORDS Entities and Attributes

A description of functions and events is given in Table 11. This logical flow of the process is also illustrated in Figure 18, followed by a process and data flow model in Figure 19, both at the end of this chapter. The numbers used in both these figures serve to facilitate comparison.

Events	**Functions**
New line project requires spatial decision support	Follow the Transmission Guidlines for Environmental Planning. Define and describe study area. Prepare geographical project and first scenario in GIS.
Scoping exercise	Do scoping. Identify issues and classify into types.

	Obtain and classify GIS data.
Feature assessment	Assess the features. Determine no-go areas. Run model to obtain shortest path: Aggregate significance's of various types of features. Assign relative importance to surfaces. Run weighted overlays.
Determine alternative corridors within the study area	Obtain cheapest path. *Optional*: Create another scenario and repeat the process with different input for different results. Add other alternative paths. *Optional*: Generate go areas around paths. *Optional*: Optimise these alternative paths along farm boundaries or similar structures.
Assessment of alternative corridors	Generate reports on alternatives. Assess alternatives. Repeat process if required.
Decision	Decide on the most appropriate corridor.

Table 11 - The CORDS Functions and Events

3.2 A Model Base

The modelling process for decision support that has been described in chapter 4 consists of two phases, being the creation of a model and the decision support using that model. During this phase of the analysis and design of CORDS, a model for decision support will be developed with an emphasis on user involvement. Unless the environmental planners understand the reasoning behind the solution they will not be able to trust its outcome on their projects.

3.2.1 Formulate the Problem

A prescriptive cartographic model should be developed to describe, assess and compare location alternatives for new linear developments. These alternatives should be based on minimal potential impact on the environment, acceptable cost implications for the developer and construction suitability, and should not impede on predefined no-go areas. The model should support a generic process that can be applied on all new projects.

3.2.2 Collect the Data

Spatial data sets required for this model will be determined for each project and will map the issues identified as concerns for that project's corridor selection. Specifically these data sets will map features with a potential impact on the environment, those with a potential cost implication for the developers, the topography of the study area and identified no-go areas. Human valuations or judgements are required at several stages to influence the outcome of the model results.

For the sake of testing the model, small test data sets have been compiled, but actual land cover data for one of the projects has also been used for testing purposes.

3.2.3 Develop a Model

The logic of moving from the required data to a solution is illustrated in Figure 18 at the end of this chapter. The numbers used in the figure, depicting the logical flow of the process, are repeated in the data / process flow model in Figure 19 to facilitate comparison. The model process is clearly interactive and iterative (as shown in Chapter 3, Section 2.2) and can be followed throughout the environmental planning process to evolve into the most suitable alternatives and eventually into the better decision. A prescriptive cartographic model to support the process is illustrated in Figure 20, also at the end of this chapter.

An interactive process of user involvement has been followed to derive this model. The author has to acknowledge that the model would have been far more complex if it had not been steered by the users in the way it has. It is noteworthy that team work resulted in a simpler model, but one that is accepted and understood by all. The users have remarked that the concept and logic on which the model is based are exactly what they need to allow them to be more efficient and to support their work.

3.2.4 Computerise the Model

Cartographic modelling statements will be used to computerise the model:

' *Have environmental impact and cost implication features rasterised with their respective significance ratings, no-go features, the study area and heights rasterised, as well as the location of the 2 substations*
' *x is the number of features with potential environmental impacts, y of potential cost implications, and z of no-go features*
' *m is the significance factor for environmental impacts, n for cost implications and p for construction suitability*

' *Compute The Corridor Feasibility*
PotentialEnvironmentalImpact = localmaximum of EnvIss1 and EnvIss2 and ... EnvIssx
PotentialCostImplication = localmaximum of CostIss1 and CostIss2 and ... CostIssy
Slopes = focalbearing of Heights
ConstructionSuitability = localrating of Slopes with 1 for 0..5 with 2 for 5..10 with 3 for 10..15 with 4 for 15..20 with 5 for 20..
SignificanceOfImpact = localproduct of PotentialEnvironmentalImpact with m

SignificanceOfCost = localproduct of PotentialCostImplication with n
ConstructionSignificance = localproduct of ConstructionSuitability with p
CorridorFeasibility = localsum of SignificanceOfImpact and SignificanceOfCost and ConstructionSignificance

' Compute The Final Cost Surface And The Shortest Path
No-goAreas = localsum of No-goIss1 and No-goIss2 and ... No-goIssz
Mask = localsum of No-goAreas and StudyArea
MaskLink = incrementallinkage of Mask
FinalCostSurface = focalproximity of Substation1 at ..Distance spreading in CorridorFeasibility throughlinkage MaskLink
'run the shortest path function from Substation2 to compute the shortest path between the 2 substations and rasterise that into ShortPath

' Generate A Go-Area Around This Path Alternative
' a and b are parameters which define the relationship between ConstructionSuitability and the buffer width of the go-area
Temp = localproduct of CorridorFeasibility and a
Bufwidth = localsum of Temp and b
Buffer = focalproximity of ShortPath at ..Distance
Temp = localdifference of BufWidth and Buffer
VarBuf = localrating of Temp with 1 for 0..
Go-Area = localproduct of Temp and VarBuf
'the result is a surface with a go-area with numerical values which indicate the construction suitability of each cell

3.2.5 Verify the Model

During the verification step, the cartographic modelling statements are tested and debugged to determine whether it is working the way it is supposed to be.

All functions used deliver the correct results except for complex focalproximity statements. This is a bug in the software and has been reported to the software developers. The algorithm comes up with the correct answer in most of the cells, but occasionally a wrong value has slipped through in the small test data sets. The software also had difficulty applying the complex focalproximity statement to the high resolution real data.

If you ignore the occasional wrong result in some cells and continue with the testing of the model, the rest of the functionality worked fine and delivered good results.

3.2.6 Validate the Model

It is one thing to have an answer, but is that answer valid? During the validation step one determine whether the model realistically represents the system being analysed and whether the results from the model will be reliable.

The approach taken from the beginning was to design a SDSS to facilitate the implementation of the Transmission Guidelines for Environmental Planning of Linear Developments. The guidelines effectively translate a complex problem situation into a manageable and reasonable step by step solution. But several assumptions and simplifications of the real world are made in the process. To then take the guidelines and implement it into a model for SDSS further implies that assumptions and simplifications are made.

Does this model realistically represent the system being analysed? If the systems context is that of the guidelines, the answer is yes - probably as realistic as the data used to map the various issues with. If the systems context is that of the real world problem of corridor selection, public resistance against a new line through their back yards, and so forth, then the answer depends on the overall approach and attitude to the specific project and the reasonableness of the interested and affected parties involved.

Are the results from the model reliable? According to the guidelines, during the assessment of issues, a significance rating is determined for each. This is all fine and well for making a formerly emotional decision into a scientific exercise. What is the definition of a cheapest path through such a cost surface?

Through a monetary cost surface, one can find the cheapest path. Which is the cheapest path through an impact surface? If going the one side past a no-go area will mean going through cells of value 0, 0 and 3 and going the other side through cells of value 1, 1 and 1, which is the best way to go? This is perhaps a matter of ethics in terms of the environmental impacts you are willing to accept in the process for an overall better option. Further investigations and perhaps other modelling alternatives need to be explored before a satisfactory answer can be given.

The shortest path algorithm used for testing purposes only looks at a range of one cells around it to find the next cheapest cell, etc. Ideally you need an algorithm on which you can set the range to be searched, as well as the risk it should accept to go along a worse route in the hope of finding a cheaper path beyond the next mountain. This needs to be further investigated and a better alternative found.

3.2.7 Conclusions

This model will form part of the SDSS and is therefore a piece of the puzzle that will fit into a bigger picture. Once the model is implemented in the SDSS, the system will allow for model exploration rather than the development of modelling *per se*. Some DSS allow you to develop your own models and apply modelling techniques to any problem at hand. Although the underlying GIS package on which the system is to be developed allows for modelling development, only this application specific model will form part of the SDSS.

3.3 An Expert Base

The CORDS expert base will contain information and/or interpretations previously given by experts during the process, which can again be used in the future. Such information will typically be the result of assessments done on issues, or the interpretation of raster or TIN data before it can be incorporated in the process.

The expert feature assessments have been incorporated in the database as a separate table. When an issue is included in a scenario and such issue has been identified before, its standard assessment should immediately show, although it can be changed.

TIN data should be converted into raster data before it can be incorporated in the process, while the interpretation of raster data requires the spatial data operation of reclassification. The parameters for executing the reclassification should be contained in separate cartographic modelling language statements saved in text files. A typical example of such a statement is the reclassification of the slopes derived from the elevation model to a surface of construction feasibility, or ease of construction. Some manual interaction might be required in converting TIN data into raster and in tying the correct map algebra statement with the correct raster file.

4. SOCIAL AND TECHNICAL DETAILS

This phase addresses how the system can be fitted into the working lives of the people in the organisation using it. People have the right to control their own destiny, and for this reason the intended users of the system are the major players during this phase of the process. This is a very crucial aspect that needs careful consideration. especially in large GIS implementations.

The social objectives of the system, which may include aspects such as morale and job satisfaction, need to be defined. These are combined with technical objectives such as improved timeliness and better, cheaper turn-around of deliverables. Options for system design are identified through a combination or ‘good fit’ of these social and technical objectives.

The result of this joint analysis and design phase is the people, organisational and computer requirements of the solution.

4.1 Predict the Future

The following factors could impact on the future of CORDS as well as on the human activity system around it:

- This tool will impact on the environmental planning process for linear features and might become a requirement for future projects.
- This SDSS might be required by other Eskom departments and outside companies.
- The model for selecting linear features can, in the future, easily be adapted to work on sites as well.
- The software on which CORDS is developed is undergoing a change. ReGIS has been bought by AutoDesk, and the next release of this software will be significantly different. CORDS will utilise more than just the basic modules of ReGIS and the first release of the AutoDesk World will not contain all these necessary modules. Until such time as CORDS can be developed in the World environment, the conceptual solution should be applied by GIS experts.
- Improvements or enhancements needed should be incorporated when the system is developed in the AutoDesk World product.

4.2 Social Objectives

The expectations of the stakeholders are social objectives, which should be adequately planned for during the analysis and design of the system. The following social objectives were identified at the beginning of the process, in consultation with the stakeholders:

<u>The team:</u>

- To spatially enable the planning team
- To improve the accuracy of their environmental analysis
- To improve efficiency and effectiveness
- To build trust in the team
- To facilitate decision-making
- To enable the team to make nonbiased decisions
- To become leaders in power line selection
- To put the team at the forefront of environmental analysis

The department:

- To provide support for the decision

Transmission:

- To assist in adhering to Eskom's environmental policy
- To advertise in a bid for other transmission line projects in sub-Saharan Africa

Eskom:

- To complement the pending environmental legislation
- To assist in attaining environmental objectives and legal requirements within resource constraints
- To demonstrate care for the environment and commitment to environmental protection
- To become world leaders in power line selection through improved capabilities
- To improve Eskom's image and boost the public's trust

4.3 Technical Objectives

Technical objectives refer to the primary tasks a system should undertake and the capacity of an organisation to react to key issues. The following technical objectives have been identified:

The planning team:

- To obtain cost-effective, environmentally sound power line routes
- To allow both vector and raster data input
- To have a flexible system that can be used by novices and experts alike
- To have a user-friendly application
- To concentrate efforts on *feasible* alternatives
- To save time
- To make better decisions, based on available data
- To assist in standardising the methodology of environmental analysis, which will streamline procedures and processes
- To improve the utilisation of resources

The department:

- To choose the best possible environmental option (BPEO) for a new servitude while bearing in mind the drive for cheaper electricity and Eskom's commitment to environmental protection
- To facilitate the communication of the decision to other Eskom departments
- To improve the environmental assessment *management* by producing better, quicker and cheaper environmental reports

Transmission:

- To provide business capability and improve business performance
- To ensure minimal environmental damage during construction and maintenance
- In order to ensure that the prices are kept down, the best routes must be obtained

Eskom:

- To use cost-effective and environmentally sound power line routes

4.4 Social and Technical Alternatives

The social alternatives for implementing the system have been listed in order of preference

- Planning team do projects on the system in collaboration with GIS experts from the department
- Planning team become GIS-competent and do projects on the system themselves
- Planning team consult external GIS experts to prepare projects and then run with those projects
- The system is given to consultants, who run the whole project on behalf of the planning team

The technical alternatives for system implementation in order of preference

- PCs together on one network with a shared Windows application
- Web application
- Stand-alone PC per project with Windows application

The preferred combination of social and technical alternatives is that option in which the planning team is assisted by GIS experts from the department to operate its projects on the system running as a shared network application in the Windows environment.

4.5 The Implementation Strategy

Due to the implications of the change in the software currently used in the department, a phased implementation strategy is needed. The end product in approximately two to three years from now should run on the new AutoDesk World product on a 32-bit architecture. But for the time being the conceptual solution should be applied and tested. Most of the functionality required should at least be available in a toolbox. Corridor decision support, with the assistance of GIS professionals, should be possible within a fairly short period of time.

A phased implementation strategy for CORDS is as follows:

a) First version of CORDS on ReGIS and ReSPAN:

- Finalising the logical design of what the system should do
- Identifying the most basic functionality required to identify and compare corridors
- Developing those functions not currently supported in ReGIS to have a toolbox of functions where corridor decision support is possible with the assistance of GIS professionals
- Applying the concept in practice with the available tools
- Refining the final results of the system with the stakeholders through evaluation and feedback until they are satisfied with the concept. This might require further development.

b) When the spatial analysis module becomes available in the AutoDesk GIS product, develop CORDS in this 32-bit environment:

- Re-evaluate and update the conceptual solution with the stakeholders
- Do the final physical design for CORDS
- Implement the design through prototyping.

4.6 An Outline of the Human and Computer Tasks

<u>People tasks</u>:

It is imperative for the success of any system implementation to adequately consider the various potential users and their requirements. People from various layers of a typical organisational structure need to work together in a co-ordinated way in order to ensure the success of the GIS.

User Profile	Function	CORDS Implementation

Project managers / co-ordinators (Work towards a GIS)	It is their job to ensure that projects are completed on time and within budget and according to adequate, agreed standards	<u>Who</u> Environmental GIS steering team and project teams <u>Management</u> Overall management of the system Management of an effective corridor comparison procedure <u>Training</u> Familiarisation with system's requirements
GIS analysts / programmers (Work towards a GIS)	It is their job to build the GIS so that 'real users' do not require costly technical training	<u>Who</u> People whose services are contracted in on a needs basis - for example for the development of CORDS <u>Management</u> Development process <u>Maintenance and Support</u> Put in place an effective corridor comparison procedure
GIS administrators / technicians (Work for a GIS)	These people monitor system performance, are responsible for new software installations, all hardware and peripherals as well as backups of data	<u>Who</u> People working in the department, overseeing all GIS applications <u>Management</u> System and its wellbeing <u>Training</u> Maintenance of peripherals System administration and management <u>Maintenance and Support</u> Network and computer maintenance
GIS specialists / processors (Work on a GIS)	People with the necessary GIS skills and expertise who can provide the application users with a support and consultant role. Also produce products from the GIS for specific purposes	<u>Who</u> GIS specialists working with the environmental section <u>Management</u> Metadata <u>Input and Output</u> Project and scenario preparation Running the model Report compilation <u>Training</u> Operations and support <u>Maintenance and Support</u>

		Support the GIS drafters / digitisers and application users
GIS drafters / digitisers (Work on a GIS)	Through digitising these people capture the data into the GIS and use their drafting skills to produce maps from the GIS	Who Drawing Office personnel Management Spatial data capture Spatial data accuracy Input and Output Spatial data input to the system Effective visualisation of results Training Use of the system Maintenance and Support Metadata maintenance
GIS application users (Work with a GIS)	In the decision support environment these are often professionals who have complex problems they need to solve. Systems given to professionals must be user-friendly and deliver the desired results in a way that is easily understood and effectively communicated. Once this is achieved, the professional will be enticed to pursue GIS technology further - but only to the extent to which this technology is flexible and can be discovered step by step. Learning to use the GIS should therefore be no more difficult than learning to use a word processor	Who Environmental team and other members from the multidisciplinary planning team Management Spatial data relevancy Input and Output List of features to be mapped from concerns raised Feature assessments Interpreting the output Training In the use of the system How to explain the process and interpretation of the outcome to IAPs

Table 12 - Various Types of Users Involved in CORDS

Computer tasks:

- The computer needs to be able to handle the following data structures:
  - Geographic project data
  - Alphanumeric project, scenario and feature data
  - TIN data

    - Raster theme data
    - Modelling language statements
    - Reports such as lists, graphs or maps

- All equipment necessary for a successful system is in place already, including networks, output devices, power standby equipment and backup devices.

5. HUMAN-COMPUTER INTERFACE DESIGN

The human-computer interface refers to the environment in which the user and the hardware come together to carry out the information system operations. It is necessary to define how the users can best relate to the computer in terms of operating it as well as using its output.

In the case of GIS systems the human-computer interface is much more than a normal user interface. Also, the way in which spatial results from the system are generated should be decided upon and refined to a degree suitable for the users. Users in this instance extend beyond the immediate users of the system, to all those people who will be exposed to this output.

5.1 Report Base

The CORDS report base is the channel where the decision-maker evaluates alternative corridors and then bases his final decision on this comparison. The report base is the window from the system to the hands-on users, but also to the public, as these reports will be used to communicate the implications of decisions to all concerned and will serve as a record of decisions. Reports will be either text, or graphs or the mapped visualisation of spatial information and should be clearly understandable and easily interpretable.

A text report on a corridor can be based either on a single line or on an area - the go area of the corridor. If the report is on a line, for instance, it should include the length of the corridor and a summary of all the issues regarding this corridor. For each issue information is required about the first-order and second-order significance, the primary social welfare category, the distance involved and what percentage of all the issues that issue represents along this corridor. A report based on area would be the same, except that the distance calculations would be replaced with area calculations.

A text report can also be compiled for each corridor on the basis of the modelled results obtained through CORDS. Information for this report would be obtained from the impact, cost, no-go and construction suitability themes as well as the final surface for corridor feasibility. Such a report will result in a quick and easy way of comparing two alternatives, but the results would not make sense to someone not familiar with the model and its operation.

A summarised text report can also be compiled on the basis of the primary social welfare criteria for each of the issues along a corridor. Such a report would simply list all the issues classified into equity, efficiency and sustainability and state whether each complies with the criteria or not.

Each of the text-based reports explained above can be replaced with graphs, which would simply portray the information contained in those reports in a more effective manner, i.e. visually.

The possibilities of visualising the information on which decisions are based by using maps are endless. A picture is worth a thousand words and where a picture consists of issues that map concerns, each with its own significance or implications, that picture becomes indispensable. It is not only a tool in the hands of the decision-maker to gain a better understanding of the implications of and options for the decision, but also a negotiation tool when servitude rights need to be obtained from the landowners.

In his book 'How to lie with maps' Monmonier (1991, p.35) gives the following advice concerning the design of the map output, *"Function dictates form, and a map more 'accurate' in the usual sense would not work as well"*. When he gives eleven rules for polishing the cartographic image of development maps, he makes the following observation, *"It would be a shame, after all, for the truly cynical land developer… not to take advantage of the public's graphic naïveté and appalling ignorance of maps."* (1991, pp.78-81). Nonetheless these maps should be clear and easily understandable to even non-literate people

5.2 User Interface

The user interface refers to the view that hands-on users will have of the computer, and specifically of the system at hand. This user interface should be such as to complement the users' level of expertise and expectations. DSS may be used infrequently, therefor the user interface must be intuitive and should not require extensive training just to use the system. Cogner explains that the interface should *chauffeur* and lead the user as much as possible (1994, p.604).

The Windows point-and-click interface is a must, with context-sensitive help available to guide the user in gaining an understanding of the system's operation as well as input from the user throughout the process. Initial thoughts on the interface for the final system produced a potential interface as illustrated in Figure 16, but obviously this idea will need to be revised once the final physical design commences.

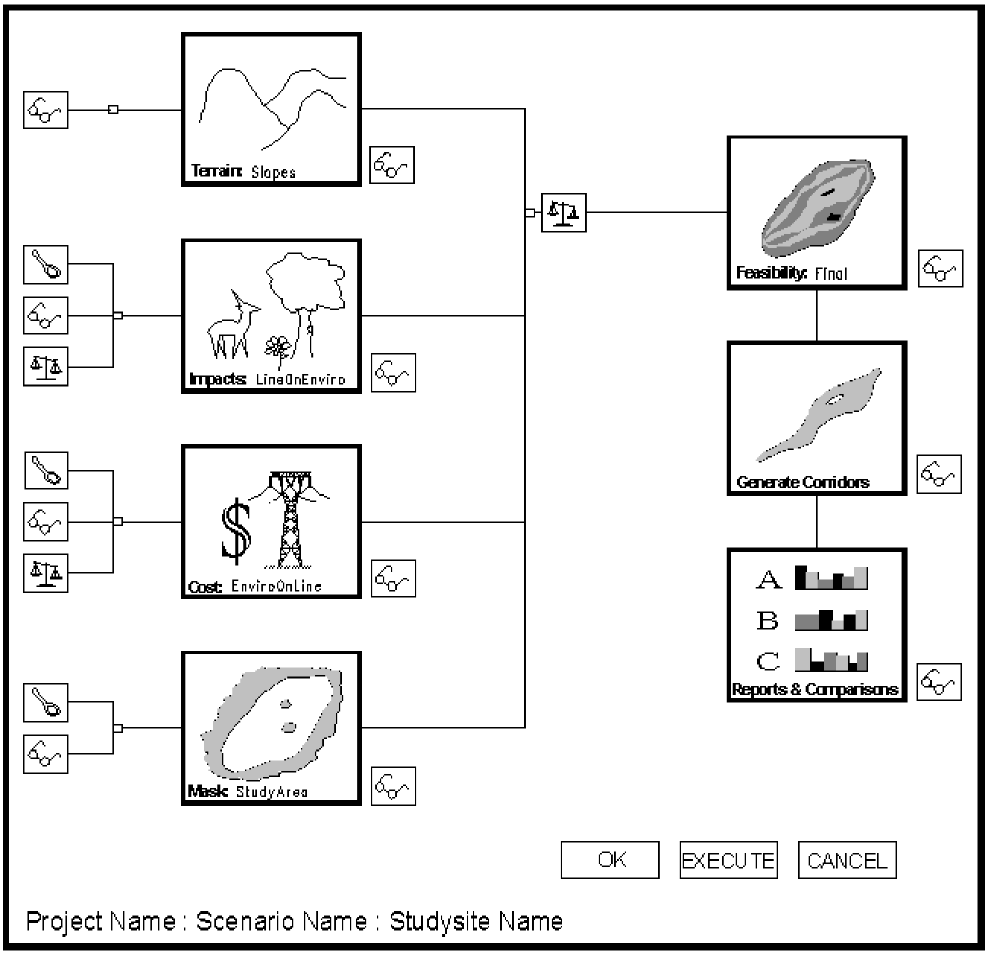


Figure 16 - A Proposed User Interface

6. DESIGN OF THE TECHNICAL DETAILS

The next phase in the planning process is the technical design of a system that will come close enough to meeting the identified requirements. The entity and process models of phase two and the interface requirements of phase four are used as input to this process. This last phase is primarily a technical exercise as all the social inputs have already been catered for through the process followed.

A comprehensive computer and people information system that should satisfy the requirements of the users is then developed. Six areas need to be focused on, i.e. applications, database, retrieval, management, maintenance and the monitoring and evaluation of the system.

Due to the phased implementation strategy of CORDS, this step can only be completed shortly before development and implementation. The previous phases will have to be revisited and updated before the technical design can be done.

7. CONCLUSIONS

The value judgement of the intended users of a system will determine the outcome of its implementation. If the intended users of a GIS system are not going to use it for the purpose it was developed for, a lot of money, effort and faith in GIS will be lost. It is critical to involve users in such a way that they know their opinions count and are considered during system planning and development. Soft-systems analysis provides a framework of involvement and ownership and appears to be crucial for any GIS application development.

A significant number of actual and potential barriers to the implementation and use of an SDSS can be eliminated beforehand by following a holistic approach that forces one to consider technical as well as social implications during analysis and design.

The results of this chapter should be seen primarily as a logical design. The physical design of the technical details can only be done once the concept has been refined through use and practice and the intended GIS software on which this application will be based has been explored. Thereafter the development can begin.

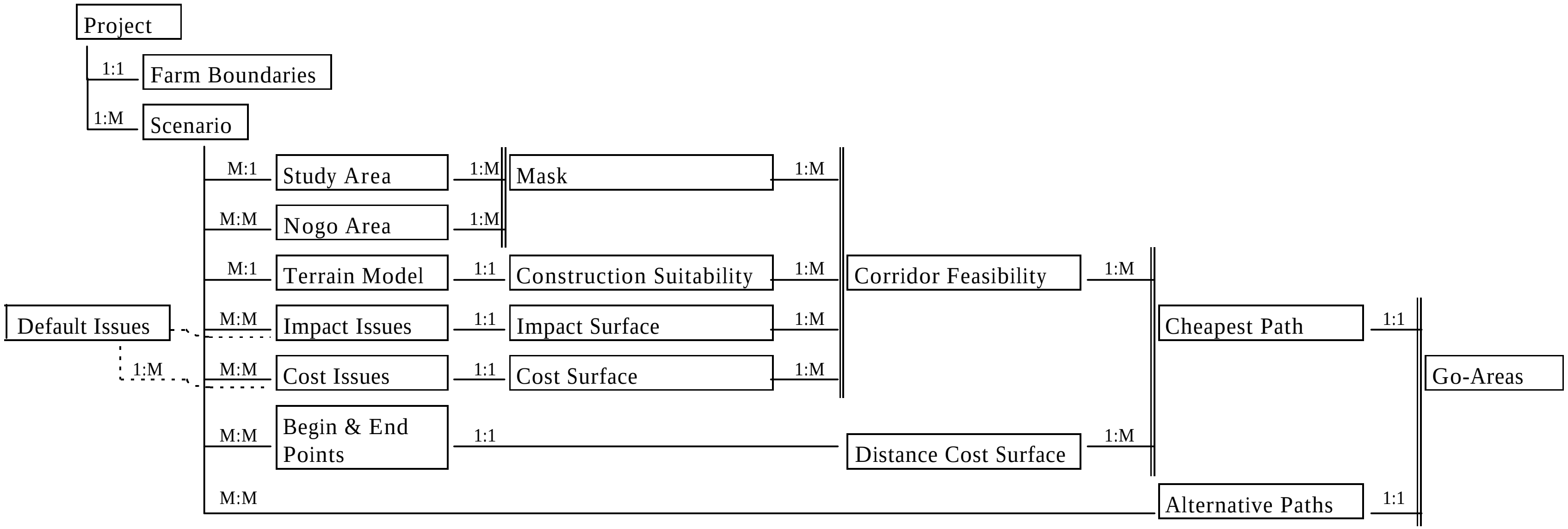


Figure 17 - A Spatial and Relational Data Entity Model

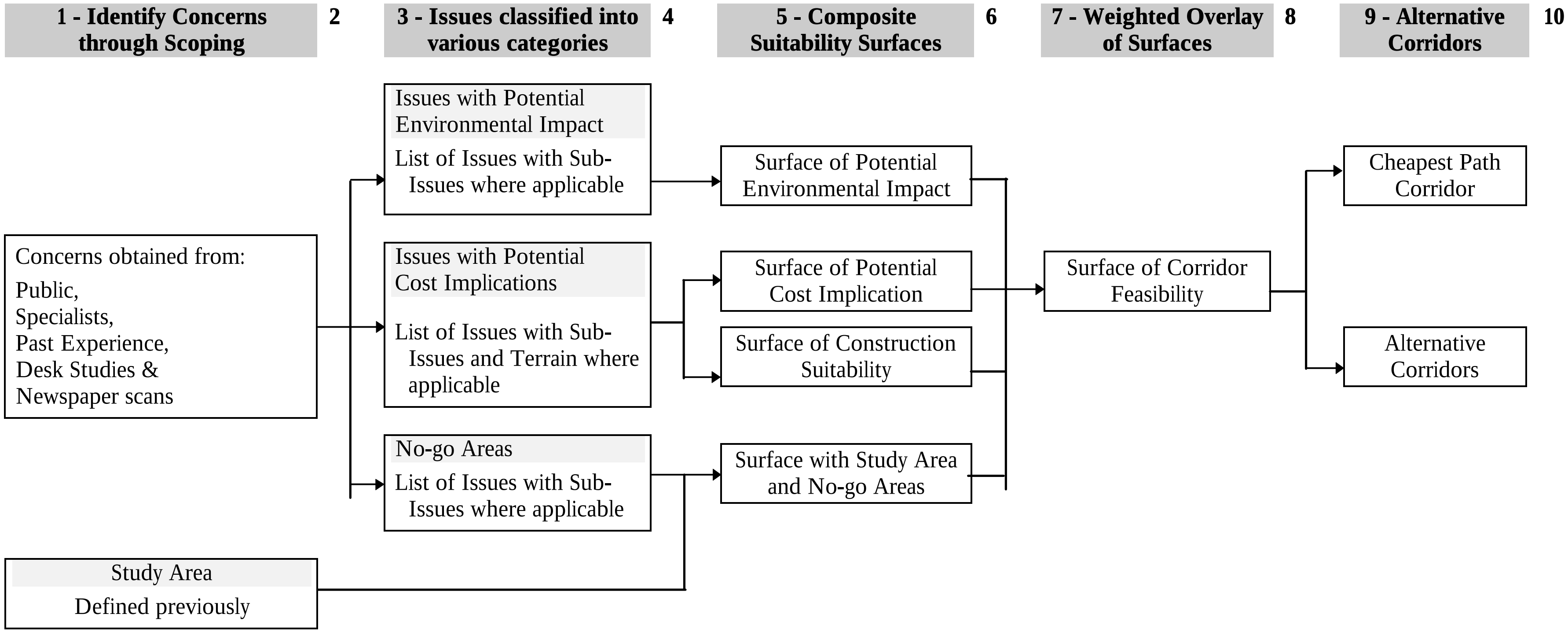


Figure 18 - Logical Flow of the Process

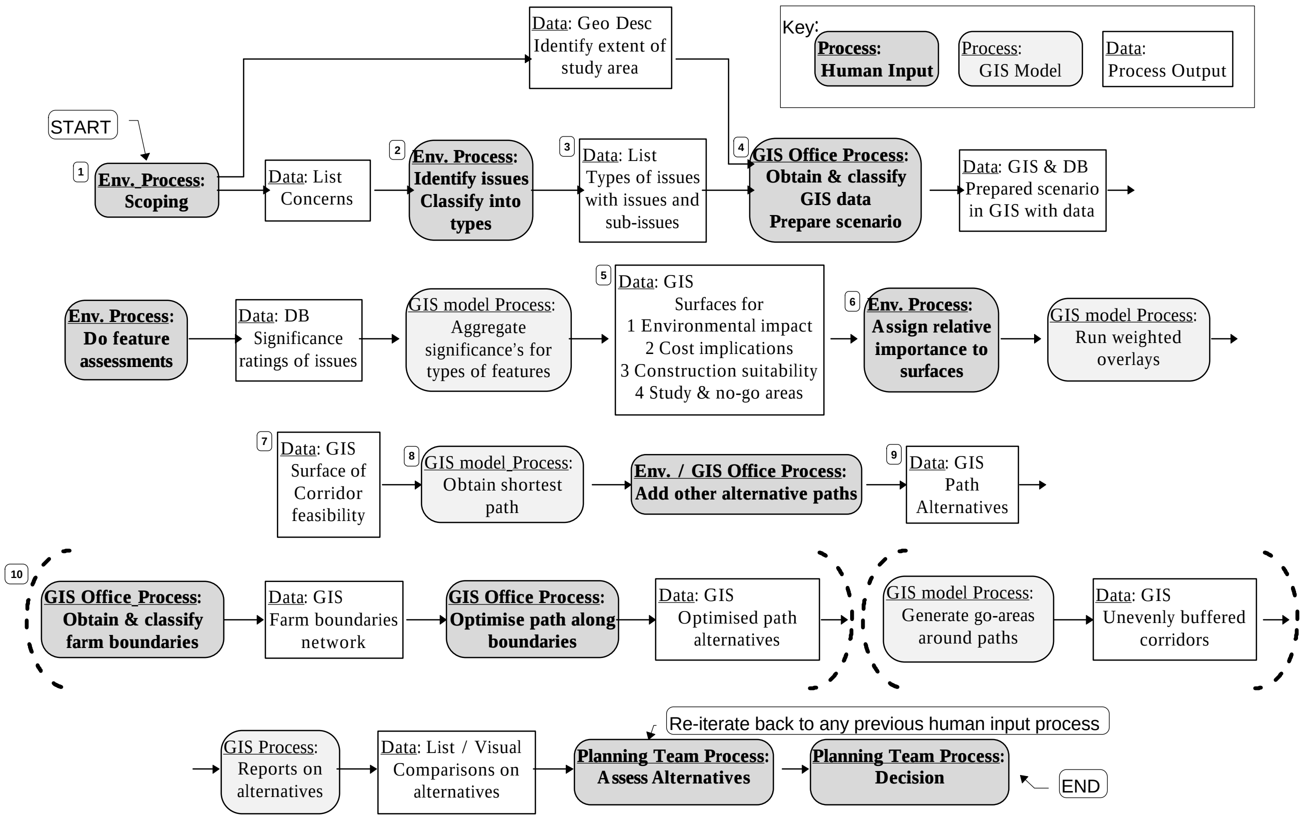


Figure 19 - A Data / Process Flow Model

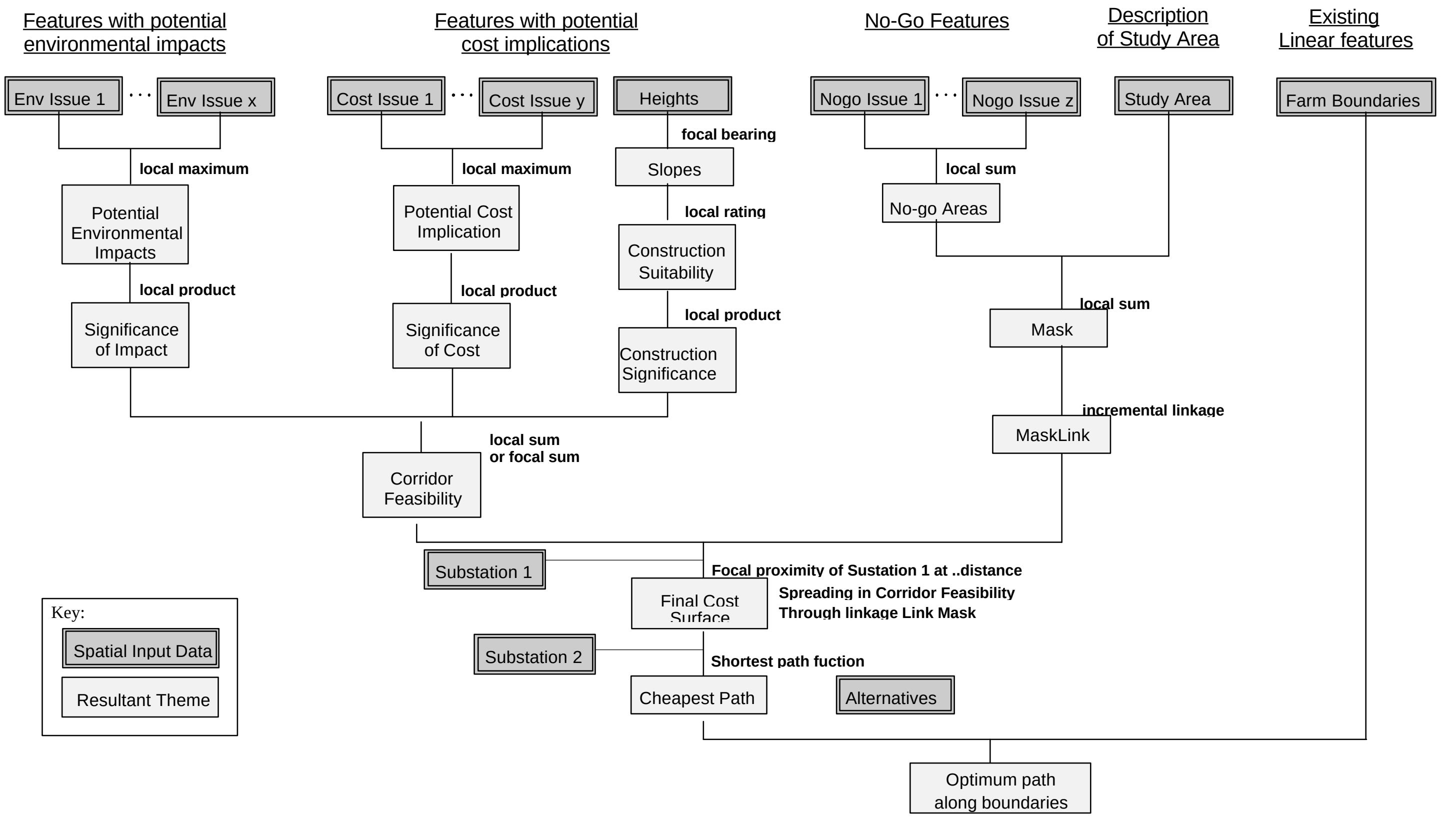


Figure 20 - A Cartographic Model to Support the Process

C h a p t e r   6

THE OUTCOME - YESTERDAY, TODAY AND TOMORROW

1. INTRODUCTION

The aim of this study was to develop a model for a decision support system which would facilitate the selection and comparison of alternative corridors for new linear developments. The following objectives were set for the system:

- a user-friendly application, perceived by the environmental planning team as adding value to its business;
- a system that would complement the pending environmental legislation;
- modelled around the Guidelines for Environmental Planning of Linear Developments;
- sufficiently flexible to be used by GIS experts and novices alike.

The purpose of this chapter is to assess and evaluate the outcome of this work and to determine whether these objectives have been met. Again, this requires a multiperspective view, but this time by looking at yesterday, today and tomorrow.

Yesterday certain lessons were learnt; today one is left with something that can be used; tomorrow there are recommendations that can be followed and further roads to be explored. Through the analysis and design phase a concept has been developed that can be applied today. Firstly that is taken stock off, and the practical steps to implement CORDS are briefly explained. As the current system is merely a first-phase implementation and further development will take place in the future, recommendations are made that should be considered in the next phase of implementation. But there are also recommendations for further research that would be necessary to improve the system of tomorrow. Finally one can look back on yesterday, to evaluate the process followed, the outcome, and the lessons learnt.

2. CORDS TODAY

2.1 What has been Accomplished?

At the outset of this study, the environmental planning of new linear features, and specifically that of new transmission lines, were investigated. This resulted in the information and processing requirements of a spatial decision support system to be used by the environmental planners responsible for the EIAs of new lines. The various components that would constitute such a system was also identified and considered individually.

The core of most SDSS consists of an integrated GIS and modelling component. In this case this model base were to be developed using a cartographic modelling language. Cartographic modelling has proven to be a very powerful and effective tool to implement spatial modelling with.

Before any new system can be developed, a systems analysis and systems design needs to be done to determine the detail specifications and operational requirements of this new system. Because no system functions in isolation, the human and organisational context where the system is to be introduced should be considered during the analysis and design as well. For this purpose a soft-systems methodology has been selected which looks at both ‘hard’ and ‘soft’ issues.

The outcome from this whole exercise is a decision support system’s concept which can be applied straight away during EIAs for new power lines, but also the promise of a system that will be developed with a user-friendly interface to be used by the environmental planners themselves.

Having to apply the system’s concept outside of a friendly user-interface for a while is a blessing in disguise. Any person from an information technology (IT) department will tell you that the users only know what the system was supposed to look like that they want by the time IT delivers the system they thought had been asked for. The ability to give the end users of CORDS the results from the system without giving them the system will give time for the concept to fully develop and mature into giving them what they think they require from it.

The next section briefly outlines the steps required to implement the system’s concept of CORDS on new line projects today.

2.2 Decision Support Using CORDS Today

In cases where a new line project requires spatial decision support, the CORDS process prescribes five phases, which may be repeated iteratively until a decision is made. These phases are scoping, feature assessment, determination of alternative corridors within the study area, assessment of alternative corridors, and finally the decision. The practical steps to follow in each phase in implementing the CORDS process have been outlined in Figure 21 and help us to visualise the process. Table 13 at the end of this chapter explains the various steps in more detail.

Please note that, for the sake of clarity, the topography is treated separately from other issues where the environment has an impact on the line, simply because the sources of the data are different. Construction suitability is definitely an issue with a cost implication, but features that map issues are normally vector data and a slope surface is raster data. That is the only reason for the distinction between the ways in which the data should be incorporated in the process. In the future, when the expert base module of CORDS will be developed to allow for other raster and TIN input as well, that type of data will most likely be treated in a similar manner to that in which topography is treated now.

A similar argument can be used for no-go areas. They will probably fall into one of the two categories of line impact on the environment, or vice versa. That data is treated differently simply because the way in which it is incorporated into the decision-making process is different.

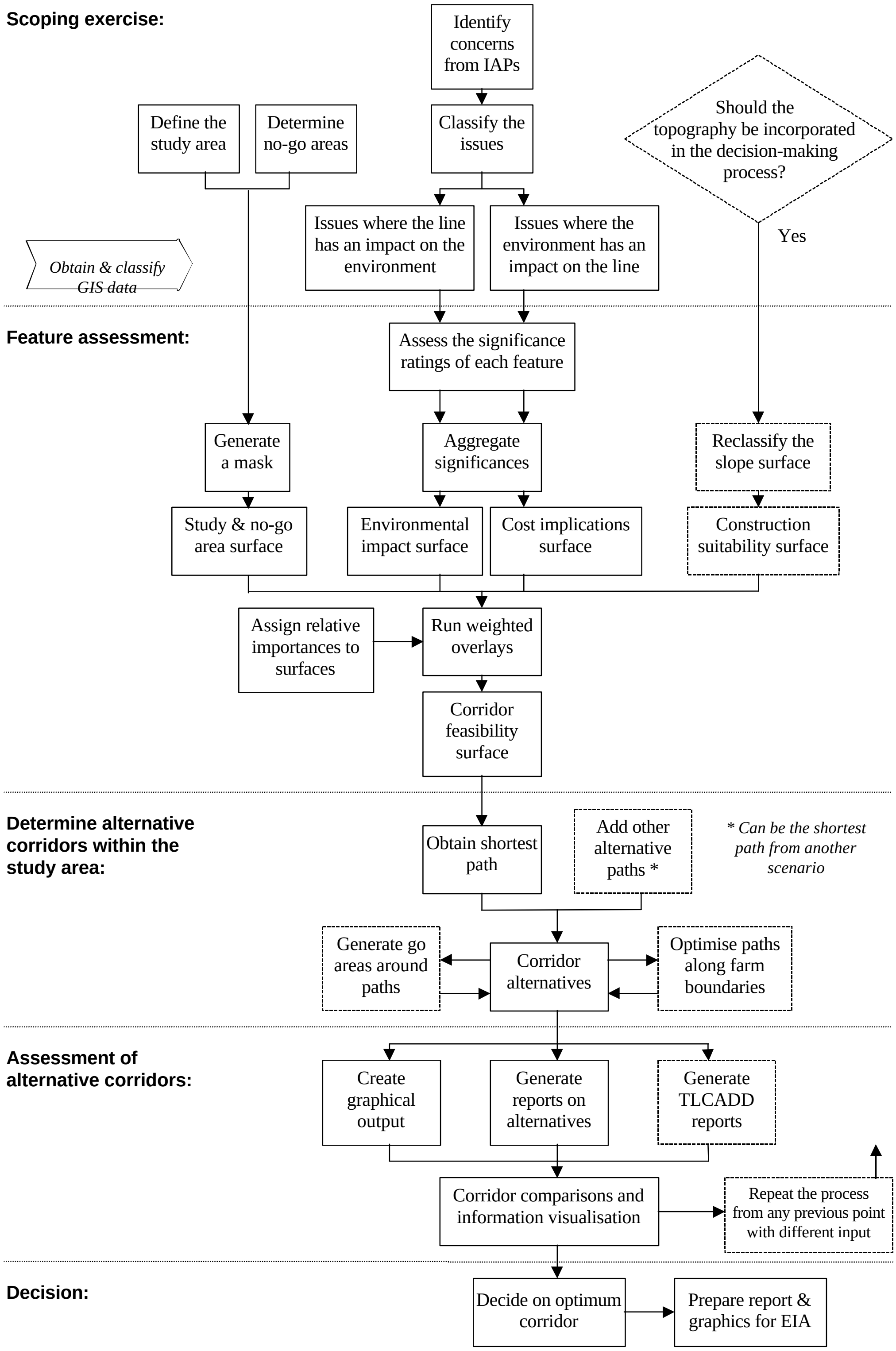


Figure 21 - The CORDS Process for Spatial Decision Support on New Line Projects

3. RECOMMENDATIONS FOR THE FUTURE

3.1 Further Research

The following are recommendations for further research specifically related to improving CORDS:

3.1.1 Reasoning behind the Model

The first and most important thing that requires further looking into is the reasoning behind the model. The validation of the cartographic model for decision support (Chapter 5, Section 3.2) has pointed out a conceptual problem in finding a shortest path through a surface of impacts.

This problem can be overcome by one of several ways. One suggestion is to also consider the cost of land, find a cheapest path through the study area and then investigate the impacts along this path. In other words the corridor is determined based on cost of land and not based on minimum environmental impact. Although this will technically give a solution, the answer might not be accepted by the environmental planners.

Another option is to assign a monetary value to each level of significance of impact, either once off or individually for each issue. Instead of computing a surface of impacts, one then gets a surface of actual costs. The cheapest path can then be determined through cost and not through impacts, and in this case the cost will be related to environmental impact and not to the developers expense as is the case previously.

Multi-criteria analysis can also be investigated for a solution. Perhaps the correct answer is not that far away and just needs some more deliberation.

3.1.2 Collaborative Spatial Decision Making

One of the areas of research that needs to be further exploited to improve the participative use of this environmental decision support system is the area of collaborative spatial decision-making. Carver, *et.al.* explained that CSDM systems should be used as a medium of communication which enable the understanding of the problem and of the analysis process to take place (1995).

Three focal areas for the NCGIA's research on CSDM are:

- how to encapsulate knowledge in SDSS to assist decision-makers in formulating alternative solutions to their problem;

- how to improve decision-makers' interaction with spatial analysis tools;
- how to provide decision-makers with mechanisms for evaluating alternative solutions to a problem (NCGIA, 1995).

CORDS should empower IAPs to make their opinions and input count in the decision-making process. Results from each of these focal areas will improve the collaborative use of CORDS. Besides for the design of the model itself, knowledge can be encapsulated in the proposed expert base of CORDS. The interaction between the decision-makers and CORDS primarily revolves around the tools that are made available to them through the user-interface. The report base should provide the mechanisms for the evaluation of corridor alternatives. All three these components of the system should be measured against the research results from this NCGIA initiative.

3.1.3 Update the Guidelines against the New Environmental Legislation

As soon as the South African environmental legislation is passed, an investigation needs to be launched to confirm the validity of the Guidelines for Environmental Planning of Linear Developments, as well as the spatial decision support model that has been developed here. Any changes or additional requirements needs to be incorporated where appropriate.

3.2 Implementation

The following are suggestions for the implementation phase of the conceptual model of CORDS that will ensure a better system in the long run. These recommendations can be divided into those relevant to the organisational environment into which CORDS is to be implemented, and those specific to the system:

3.2.1 Organisational Environment

- The Guidelines for Environmental Planning of Linear Developments were developed without any consideration of the effect of SDSS tools such as CORDS on the process. It has been shown that the application of such tools does influence the decision-making process considerably. The guidelines should therefore be adapted to incorporate the implications of the use of such a system on the process. The Environmental Section should also draw up a GIS policy to be followed during any future projects to ensure the successful operational life cycle of new projects.
- A project should be initiated to identify generic issues that will affect most new line projects throughout Southern Africa and compile a list of these issues. The data that maps these issues should then be

obtained at an agreed level of accuracy and scale (or at least the custodians of the various data sets should be identified). An assessment should be made in respect of all these issues and the results entered into the database. This will assist with the initial planning phase of all future projects. As soon as the initial scoping on a project needs to be done, the data and standard assessments will be at hand to deliver rapid results.

- It is essential to continue obtaining buy-in from all internal stakeholders in the project through appropriate participation. Keep them informed of the results obtained by means of CORDS on any project and involve them when the concept is refined further.
- Bear in mind that the success of this implementation will depend on the assistance the planning team receives to make CORDS work for them. None of the team members are GIS experts, yet they are keen to utilise the technology, provided it is made available to them in a way they can understand and feel comfortable with. An extra GIS support person should come on board and be trained to assist with the CORDS application.

3.2.2 System

The following points relate specifically to the system and it is recommended that they be investigated before development on the next phase of CORDS begins. The outcome of each point will be additional recommendations for development.

<u>Model Base</u>:

- The current cartographic model of CORDS can probably still be improved. Refine this model by comparing computer-based results with field checks and interactively verifying the results of real projects and the reasoning behind these results in open discussion panels.
- In determining the shortest path, the assumption is that the starting point and end point of this path are the two substations that need to be connected to the new line. It is nevertheless quite possible for the planners to require this new line to cross a specific point or to follow a predetermined path for some of the way. Work out a way of implementing the generation of a shortest path through any number of predetermined points.
- As a form of route optimisation, try the following: Once a cheapest path has been determined on the surface of corridor feasibility and a go area has been created for that path, try to run the cheapest path

algorithm again, but take the extent of the go area as the study area extent, to see whether the two paths differ. If there is a difference in these two paths, the latter should be the better option of the two.

Expert Base:

- The concept of an expert base should be tested through the incorporation of other raster data in the decision-making process in a manner similar to that in which topography is currently incorporated . Verify the implications of weighted overlays between this increasing number of themes versus incorporating those themes into the equation in exactly the same way as any other issue.

Report Base:

- CORDS should be able to compare corridors, go areas and scenarios with one another. Although some reporting criteria have already been suggested, these should be refined and relevant criteria should be determined for scenario comparisons.
- The question of relevant and appropriate maps for the visualisation of the results from the process is still left unsolved. It is suggested that research be done through interaction with the public to determine effective ways of communicating these results to the various public forums Eskom needs to deal with.

User Interface:

- The model allows the incorporation of people's perceptions in the decision-making process. A practical way of obtaining this input from IAPs should be worked out and documented as part of the public participation in implementing CORDS in a project.

3.3 Development

Before the next development in respect of CORDS begins, the analysis and design done here should be revisited and reviewed. The results of any analysis and design are based on the current understanding of the situation, the lessons learnt in the past and a knowledge of what works. In this case, where a soft-systems approach was used, the current organisational environment and the stakeholders also played a decisive role in the outcome of the process. Each of these things changes over time and although a lot of groundwork has been done, the analysis and design phase should not be seen as having been completed.

- The implementation phase of the conceptual design will probably be the single biggest source of input into the developments that are to follow. The people involved in this implementation should systematically record their recommendations for development.
- It is essential to ensure the continuous involvement of the various users and stakeholders during the next planning and development phase of the system. Through rapid application development techniques, a phased implementation strategy should be followed to make the system usable as soon as possible. In this way continuous feedback from the users to the developers is also guaranteed.
- A lesson the author learnt during previous GIS application developments is that the GIS software platform used as a basis for third-party development must, in practice, be known and understood by the analyst, systems designer and programmers involved. They should be familiar with the full power and functionality of the GIS in order to develop a hand-in-glove application that utilises all the strengths of the underlying software.
- After the review of the analysis and design phase, a logical design of the system should be drawn up and buy-in obtained from all internal stakeholders. A physical design will then follow, which will be used by the developers as the blueprint for the new system.

<u>Database</u>:

- A facility to manage different scenarios per project needs to be developed. This project-scenario management facility should also support the report comparisons between different scenarios and will logically form part of the database module of CORDS.

<u>Report Base</u>:

- Enhances reports on alternatives through innovative ways of presenting corridor comparisons, for example through the use of graphs, charts, tables and DTMs. This can be achieved, for instance, through the use of DDE links to existing word processing and presentation graphics software already in use in the organisation. (DDE stands for dynamic data exchange; one example of its use is to send data about corridor comparisons from the GIS to a spreadsheet package such as Excel in order to draw up graphs or charts with which to visualise the data.)

<u>User Interface</u>:

- From the beginning one of the aims of CORDS has been to serve as a user-friendly and intuitive system. This objective should be met during the development phase. Unless the intended users see a system as useful and usable, it will probably not be used. This is especially true when the users are professionals who may have a choice as to whether to use a tool or not.

- CORDS has been developed as a focused EDSS for specific decision makers and a specific decision problem. An environmental information system that supports these decision makers in their whole range of decision problems then constitutes several of these focused EDDSs, all sharing a common 'look and feel' user interface. CORDS might be one of many EDSSs to be developed for this office, therefor it is important to consider the user interface also with a wider application in mind.

Typically dynamic, changing and demanding problems are solved through a GIS. GIS solutions should therefore be developed to be flexible and to allow for rapid system improvements, even after development. As the user expectations and demands on the system mature, further development should be done on a priority-and-demand basis.

4. EVALUATION OF THE OUTCOME

As explained at the beginning of this study, the problem to be addressed is threefold. Firstly CORDS should be an enabling technology. Secondly a soft-systems approach should be used in the analysis and design methodology. Thirdly, the spatial analysis in the system should be written in a cartographic modelling language. As part of the evaluation of the outcome each of these areas will be briefly discussed together with the research questions posed in the first chapter.

In general the following comments can be made:

The quality and comprehensive nature of the system's concept that resulted from this study has shown again the importance of a thorough systems analysis and design phase. This forces one to consider various aspects that might impact on the system in future even before the system has been developed.

The importance of a systems analyst that knows the organisational set-up, systems context and requirements has been underlined again. It is crucial for the success of a new system that a trust relationship as well as a good working relationship exist between the systems analyst and the users. It is further recommended that true enabling spatial technologies can only come to be if the systems analyst balances information technology expertise with spatial technology expertise. With background in only the one or the other, too many compromises in systems quality will result.

4.1 CORDS - an Enabling Technology

To enable is to empower, provide the means, or make possible. In this case, technology refers to an information system, then the following definition is valid: An enabling technology is a system that empowers its users and provides them with the means to do or accomplish something that was not possible for them before.

Is CORDS an enabling technology, and has it been designed in such a way that it assists environmental professionals to adhere to planning procedures?

CORDS provides the means to do environmental planning on new transmission line corridors. On the one hand CORDS is the method through which planning should take place, and on the other hand it prescribes the supporting services that need to be in place in order to achieve that goal. During decision-making this system makes it possible to consider all available data for an objective judgement of the issues under consideration, for participative decision-making, and for a comprehensive approach to be followed on all new planning projects.

The philosophy behind CORDS is to empower environmental planners to utilise decision support technology in a familiar and non-threatening environment. At the same time the intention is to empower GIS experts to implement the model, utilising the strengths of the underlying GIS software to the full extent of their expertise. It therefore empowers them, without restricting them in their use of it.

4.2 The Soft-Systems Methodology Followed

One of the questions posed at the outset of this study was to determine whether soft-systems analysis is an appropriate systems analysis and design methodology for spatial decision support systems. A soft approach to planning information systems not only looks at technology to solve a problem, but also considers the people that will make use of the system and the organisational setting in which the system will be implemented. Reeve suggested that a soft-systems approach to systems planning may well prove to be a very appropriate vehicle to explore the need for GIS within organisations (1994, p.146). In this case the need and desirability of a specific application, in one part of the organisation, was determined in consultation with the users. Involving them in this manner has resulted in their sense of ownership in the outcome. Not only has Reeve's suggestion been confirmed, but a number of other observations were also made on the use of SSA for the analysis and design of GIS applications:

Social science is not an exact science. Working with people and their perceptions, feelings and environment takes time and patience. From the beginning a soft-systems approach was therefore expected to take longer than a traditional hard approach. This extra time should have been taken into account from the beginning, but the approach fortunately ensured that the stakeholders were involved in the system at all times and their buy-in was obtained in a very relevant manner. Although it is recommended that SSA is used for GIS and SDSS applications, more time should be allowed in the project schedule for the analysis and design than what would be necessary for conventional approaches.

The users of CORDS fit into the research and management level in the organisational triangle - Figure 22. The author believes that the success of a system at this level can, to a large degree, be measured by the perception of the users of that system. A user at the operational level can be told to make use of a system, but at the research and management level the users themselves will decide whether to use a system or not. Professionals at that level also do not have the time to bother with a system that is clumsy and does not allow intuitive use.

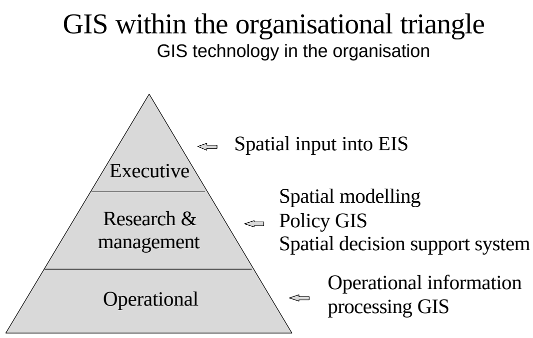


Figure 22 - SDSS Users in the Organisational Triangle

The solution to the problem was influenced a great deal by the extensive participation of the stakeholders. Having to obtain their participation and buy-in with respect to every level of the process has resulted in a solution very different from that which the analyst originally anticipated. This is very positive as the stakeholders now have a system they feel part of and, because they understand it, they trust it.

The implementation of a GIS is by no means an easy task. Normally one encounters many problems along the road that were never thought of during the conception phase of the project. The specific methodology followed prescribed a process of looking at technical as well as social matters. The social and technical details that had to be considered are especially relevant to the implementation of GIS systems. In a sense it forces you to spend time finding a solution to implementation related matters before your money is spend on expensive development. What has happened in the past is that money was spend on development, and when it came to implementation, much time was lost first having to sort out those implementation related integration problems.

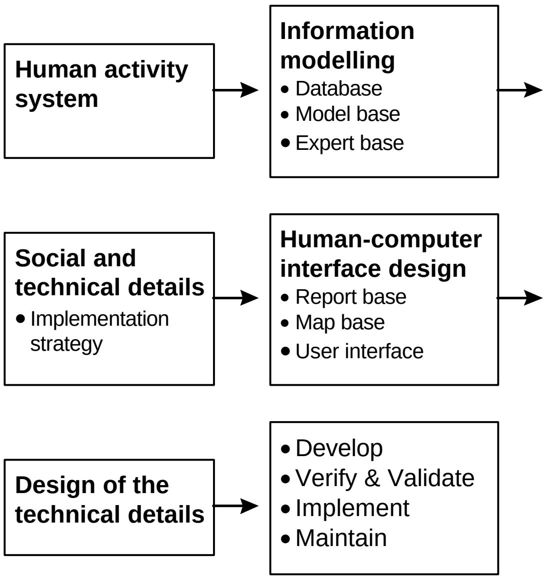


Figure 23 - A Proposed Soft-Systems Methodology for GIS Applications

As a GIS is considerably more than a normal information system, in the same way a GIS application is considerably different from a normal information systems application. The analysis and design of a GIS system should therefor consider and incorporate considerably more than what would normally be required. It has proofed to be relevant to first identify the various logical components the system comprises of, before the analysis and design phase was done. In that way those components could be dealt with individually under their logical headings as part of the analysis and design. The approach followed here, adapted from the multiperspective eclectic methodology, is put forward as a recommendation for future GIS application development. The only difference that might be considered is to treat reports and maps separately in future systems. In this case it was not deemed necessary.

All the steps prescribed in the original methodology can be followed, but in addition, regard the points mentioned in Figure 23 as separate headings.

A soft-systems methodology will not result in the most technically advanced *bells and whistles* system, but the outcome will be the system best suited to the users and their environment. The author strongly recommends the use of soft-systems methodologies for any GIS application development.

4.3 The Use of a Cartographic Modelling Language

Cartographic modelling is a specific geographic data-processing methodology that uses a high-level computational language. Through this cartographic modelling language, one tells a GIS in a quasi-English language how to manipulate spatial surfaces. This provides a very flexible and powerful platform to implement spatial models.

The implications of the use of such a modelling language for the implementation of the CORDS model have been phenomenal. Instead of concentrating on how to make such a system work in the GIS, the focus can be shifted to how to make this system work for the users. It was, furthermore, not necessary to write complex programs to test the ideas behind the model, as the use of the modelling language allowed various different approaches to solving problems with the push of a button.

In addition to the ease of the initial development of the model, the modelling language lends itself to very easy modifications in the future. Whole new concepts can be incorporated in the process without much difficulty.

The use of a cartographic modelling language in the development of the concepts behind CORDS has made the true power of geographic analysis available without allowing complexities to inhibit the process.

The last research question open for discussion, is at time of writing still open. To develop a holistic allocation model for linear features through the use of a cartographic modelling language. The model is indeed holistic as the whole study area is taken into consideration. It is indeed an allocation model for linear features as corridors can be suggested through the model. Although what is still open, is the validity of the model as discussed in Chapter 5, Section 3.2 and again in Section 3.1 of this chapter. A feasible solution will be determined though further research, debate and user interaction.

5. CONCLUSIONS

Having assessed the outcome of this project from the perspectives of yesterday, today and tomorrow, one can conclude that yesterday it was a learning exercise, today it is an accomplishment, and tomorrow it will have been a stepping stone to what is still to come.

The success of the development of this decision support concept can be contributed to the involvement and participation from the various role-players. The environmental planners understand and support the model up to date and are very keen to see it used on their own projects in the future.

Phases	Planning Team Function	GIS Function	Output / Deliverable
Scoping exercise	Define and describe study area.	Prepare a geographic project and a first scenario in GIS.	Geographic project in ReGIS with first scenario in ReSPAN as the whole study area
	Through a process of public participation, identify the concerns of the IAPs.		List of concerns
	From these concerns, identify the issues and classify them into issues where the line will have an impact on the environment and issues where the environment will have an impact on the line.		Issues in 2 categories
	Decide which concerns can be mapped and should be incorporated into the decision support model.	Obtain and capture GIS data.	Vector data captured in ReGIS
	Determine no-go areas.	Capture these areas into GIS.	No-go areas
	Decide whether the topography should be included in the decision-making process.	*Optional*: Obtain the DTM and generate a slope surface.	Slope surface in ReSPAN
Feature assessment	Assess the features based on the impact and assessment criteria and significance ratings as outlined in the guidelines.		Significance ratings of issues in the ReBASE database
		Aggregate significance's of various types of features; generate a surface of construction feasibility from slopes and generate a mask based on the CORDS cartographic model.	Surfaces for 1. Environmental impact 2. Cost implications 3. Construction feasibility4. Study and no-go areas (mask)
	Assign relative importance to surfaces.	Run weighted overlays.	Surface of corridor feasibility

Determine alternative corridors within the study area		Obtain the cheapest path through this cost surface of corridor feasibility.	Cheapest path for this scenario
	Define other alternative paths.	Capture these alternatives.	Alternative paths
	Optional: Create another scenario and repeat the process with different inputs for different results.	Provide assistance.	Different scenarios with their own cheapest path alternatives
	Optional: Optimise alternative paths along farm boundaries.	Capture farm boundaries and provide assistance with capture of new paths.	Optimised path alternatives
		Optional: Generate go areas around paths from corridor feasibility surface	Alternative go areas
Assessment of alternative corridors	Generate reports on alternatives.	Generate maps / graphs on alternatives	Reports and graphics for comparison
	Optional: Request TLCADD templating on the alternative corridors.		Monetary cost comparisons on alternatives
	Assess the alternatives.		
	Optional: Repeat the process if required.	Provide assistance.	
Decision	Decide on the most appropriate corridor.	Provide visualisation of final decision.	Reports and graphics for the EIA

Table 13 - The Steps for Implementation of the CORDS Process

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