STRATEGIC PLANNING OF AGRICULTURAL LAND INFORMATION SYSTEMS IN SOUTH AFRICA

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Declaration

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: 22 December 2008

ABSTRACT

The planning processes involved in the design and development of strategic land information systems in a semantic context require a logical approach. An array of efficacy problems associated with the relevance of the information required and the data to be provided must be dealt with in terms of this logical approach so that wise decisions can be made about future land resource use options.

This study applies the aforementioned statement to strategic decision-making regarding information management in the provision of accurate and relevant information about the characteristics of the land resource for use by both the public and private sectors in South Africa.

With ever evolving human needs that increase pressure on the limited land resource, the need for accurate and relevant information for strategic purposes is increasing. However, even at the present time, land information systems design and development is characterised by a technical design orientation and a narrow cost-efficiency focus, with a lack of strategic envisioning. Strategic decisions require effective choices regarding what data should be collected and how this should be stored and processed to support land-resource-use decisions in the future. Information systems can, however, not cater for too many variables due to cost implications. Hence, strategic choices in generating only the required information and data for storage and processing become necessary.

In the above context, methodologies with a future-oriented outlook are identified as being essential for enhancing effectiveness in the design and development of land information systems. This study employs these methodologies in applying a systems approach that

utilises semantic information modelling techniques, mind mapping and a workbook to information systems development processes. Such a systems approach assists in determining and narrowing down the critical processes and entities required in collecting and storing data for use in both the present and the future.

Three phases were utilised to implement this approach within the context of food security in South Africa. The first phase involved a review of economic and strategic principles and the application thereof in developing land information systems. The second phase, through meetings and workshops, utilised the expert opinions of information systems developers. During this phase, systems analysis was used as an analytical tool for selecting relevant dimensions and data sets. The third phase applied the workbook principle to show a possible future scenario. This scenario comprises particular dimensions, identified through systems analysis, to emphasise the importance of including them when collecting data in the present so that they are available when needed in the future.

The systems analysis approach advocated in this study suggests that a chosen strategy for enhancing information management with respect to a specific sector of the economy, must involve a conscious and deliberate understanding of the processes involved in the establishment of the system. Such a strategy must comprehend not only past decisions but also potential future alternatives. This approach is intended to serve as a reference point for specific applications that are more focused and subject-matter oriented.

OPSOMMING

Die ontwerp en ontwikkeling van strategiese land inligtingstelsels verg ‘n logiese proses. Hierdie logiese proses moet oorwegings akkommodeer, soos die relevansie van die inligting benodig en die ooreenkomstige data wat voorsien moet word, sodat sinvolle landbou hulpbronbenutting keuses gemaak kan word.

Hierdie ondersoek pas bogenoemde uitgangspunt toe op strategiese besluitneming ten opsigte van inligtingsbestuur by die voorsiening van akkurate en ter sake inligting oor die eienskappe van landbouhulpbronne vir gebruik deur die openbare en privaat sektore in Suid-Afrika.

Toenemende druk op landbouhulpbronne skep groter behoefte aan akkurate en ter sake inligting vir strategiese beplanning. Land inligtingstelsel ontwerp en ontwikkeling word tans egter gekenmerk deur ‘n tegniese ontwerpgerigtheid en ‘n enger koste doeltreffendheid fokus, met gevolglike gebrek aan strategiese gerigtheid. Strategiese besluite verg effektiewe keuses van data wat versamel moet word en hoe dit geberg en verwerk moet word om toekomstige landbouhulpbron gebruiksbesluite te kan ondersteun. Inligtingstelsels kan weens koste-oorwegings nie ‘n onbeperkte getal aanwysers akkommodeer nie. Strategiese keuses van die mees ter sake inligting en meegaande data wat versamel moet word, word dus benodig.

Die ondersoek het metodieke geïdentifiseer wat noodsaaklik is vir die effektiewe ontwerp en ontwikkeling van land inligting stelsels. Hierdie metodieke is toegepas in terme van ‘n

stelselsbenadering en het ingesluit semantiese inligting modellering tegnieke, denk kartering en ‘n werksdokument wat ter sake strategiese tendense toon. Hierdie stelselsbenadering het bygedra tot die vasstelling en afbakening van kritieke prosesse en entiteite wat benodig word by die versameling en berging van data vir huidige en toekomstige gebruik.

Die stelselsbenadering is toegepas op die voedselsekerheidsprobleem en is in drie fases geïmplementeer. Die eerste fase het die oorsig en toepassing van ter sake ekonomiese en strategiese beginsels by die ontwerp van land inligtingstelsels behels. Die tweede fase het eksperts se opinies deur middel van werksessies bekom ten opsigte van land inligtingstelsel ontwikkeling. Tydens hierdie werksessies is stelselanalise gebruik om ter sake dimensies van die problem en datastelle te identifiseer. Die derde fase het die gebruik van die werkdokument behels om ‘n scenario te ontwikkel met dimensies waaroor data ingesamel moet word vir toekomstige gebruik.

Die stelselsbenadering wat voorgestaan word in hierdie ondersoek verg die keuse van ‘n strategie om inligtingbestuur vir ‘n spesifieke sektor van die ekonomie te bevorder. Dit verg verder ‘n bewussyn van die prosesse betrokke by die vestiging van ‘n stelsel. So ‘n strategie moet ruimte gee vir bestaande en toekomstige alternatiewe hulpbrongebruik. patrone. Hierdie benadering het ten doel om ‘n vertrekpunt te verskaf vir meer gefokusde, spesifieke hulpbrongebruik toepassings.

“Change is itself constantly changing”
(Russell L. Ackoff)

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LIST OF ACRONYMS:

AGIS:	Agricultural Geo-reference Information System
BCA:	Benefit Cost Analysis
BIM:	Business Information Modelling
BPM:	Business Process Modelling
CAB	Technical Assistance to Commonwealth Agricultural Bureaux
CIA:	Central Intelligence Unit
CSIR:	Council for Scientific and Industrial Research
CSSSDM:	Comprehensive Social Security System and Disaster Management
CTA	Technical Centre for Agricultural and Rural Cooperation
DFD:	Data Flow Diagram
DoH:	Department of Health
DoTI:	Department of Trade and Industry
EA:	Entity Aggregation
ER:	Entity Relationship
E-RM:	Entity Relationship Modelling
E-RD:	Entity Relationship Diagram
FAO:	Food and Agricultural Organisation
FIVIMS-RSA:	Food Insecurity and Vulnerability Information Mapping System – Republic of South Africa
FSICP:	Food Security and Communications Program
FSWG:	Food Security Working Group
GDP:	Gross Domestic Product
GEAR:	Growth, Employment and Redistribution
GIS:	Geographic Information systems
GJMC:	Great Johannesburg Metropolitan Council
IFPRI:	Integrated Food Policy Research Institute
IFSS:	Integrated Food Security Strategy
IM:	Information Management
INSP:	Integrated Nutrition and Safety Program
IS:	Information Systems
IT:	Information Technology
ITU:	International Telecommunication Union
IAALD:	International Association of Agricultural Information
LIS:	Land Information Systems
NDA:	National Department of Agriculture
NSIF:	National Spatial Information Framework
OECD:	Organisation for Economic Co-operation and Development
PC:	Personal Computer
QUEST:	Quick Environmental Scanning Techniques
RDP:	Reconstruction and Development Program
RIEP:	Research Institute for Education and Manpower
RSA:	Republic of South Africa
SA:	Systems Analysis
SADC:	Southern African Development Community

S&T:	Science and Technology
SDSS:	Spatial Decision Support System
SDLC	Systems Development Lifecycle
SIM:	Semantic Information Modelling
SP:	Strategic Planning
SPFS:	Special Program for Food Security
UML:	Unified Modelling Language
UNDP:	United Nations Development Program
US:	United States
USD:	United States Dollar
URISA:	Urban and Regional Information Systems Association

STRATEGIC PLANNING OF AGRICULTURAL LAND INFORMATION SYSTEMS IN SOUTH AFRICA

CHAPTER 1: SPECIFYING THE PROBLEM

1.1 Introduction

In order to make wise decisions about land as a resource, good quality data is required. Over the years, tools with spatial and temporal data and mapping capabilities in the form of land information systems (LIS) have been developed to support such resource use planning. LIS involves the continual collection of spatial resource data to allow resource-use planning from the short to the long term. The efficacy of LIS at any point in the future in terms of relevant and appropriate accurate information will depend on the accuracy of data captured in the present. Data collection is time consuming and costly; therefore it is important to include only relevant data. Specific tools used for these purposes include geographic information systems (GIS), and airplane and satellite remote sensing. These are powerful tools that are constantly increasing in capability, due to technological progress. They are widely applicable but are costly in terms of the highly skilled personnel required to operate them in terms of data acquisition and processing. This implies that the decision regarding what data should be included in the present depends on one's ability to anticipate information needs in the future. Also, data collection for every parameter included in an LIS increases costs; hence, one cannot simply compensate for a lack of foresight by adding more and more parameters. Strategic thinking and planning are thus paramount to cost savings, reliability and accuracy of information needs in the present and in the future.

1.2 Problem statement and important assumptions

The central problem statement is that *current LIS planning lacks strategic orientation and coherence*. The underlying generic question to be addressed here therefore is “how can the agricultural sector in South Africa achieve and increase efficacy in LIS design and development, given the nation's resource endowment; current and future land use patterns for agriculture, forestry and tourism; and current and strategic information needs?" The underlying assumption here is that systems currently in use are ineffective, because of a lack of clear guidelines for the design and evaluation of LIS and because the input-output relationship for GIS and LIS applications in a resource-functional context are generally not well understood. The reason for this is that most systems have been established with an incorrect conceptualisation or ill-definition of the problem to be addressed by LIS. Limited funding, especially in developing nations, also sets limits on data quantity and quality, and thus information diversity, by prescribing the level of human and technological sophistication that can be afforded.

The problem statement prompts the following two research questions:

a) What key factors or relevant considerations need to be taken into account in the design and development of an effective LIS?

b) What is or should the role of government be in accomplishing effectiveness in LIS design and development?

The problem statement as deconstructed above is predicated on effective decisions regarding land use by both the private and public sectors, which require relevant and accurate information on the characteristics of land resources. In this context, the dissertation focuses on strategic information management for a specific sector of the economy as opposed to developing systems development lifecycle (SDLC) procedures for a modern LIS design. This information on what, how much, and where will eventually be used to show various land-use possibilities. Typically, strategic decisions requiring effective choices regarding what data should be collected and how this should be stored and processed to support resource-use decisions in the future is essential. Should LIS users therefore anticipate possible land use options for a particular area over the longer term in order to guide them in what data should be collected in the present and to serve and support land-use decisions in the future? LIS, however, cannot cater for too many variables, due to cost implications. Hence strategic choices in generating information are necessary. As will be shown further on, there has traditionally been a too narrow cost-efficiency focus on the usefulness of LIS – a cost-benefit trade-off – based on the benefit cost analysis (BCA), which gives unsatisfactory results. There is also rigidity in these information systems, implying a high cost of change. This brings us to the classical search for a modus operandi in order to facilitate more effective information system designs aimed at ensuring more effective land use decisions.

The recent developments in South Africa, described in Section 1.5, imply the need for information diversity and differentiated content in order to satisfy the information needs of agricultural land users, who at times have a conflicting understanding and conflicting goals relating to agriculture. These conditions require a rethinking of the adequacy and capacity of current information systems in providing for prevailing information needs and a framework that will ensure effective decision-making, if agriculture is to be competitive. Specific challenges include (i) clarifying the various outcomes of the LIS (what it should be used for), which assumes that the strategic positioning of the agricultural sector must be sound within a local, regional and global context, and (ii) assessing the structural coherence and strategic orientation of LIS components (How should the different components of LIS be related to enhance effectiveness).

1.3 A lack of strategic planning and coherent structure in LIS design and development

Brynjolfsson and Hitt (1996: 541), found that LIS design and development shows limited cost-effectiveness. Various explanations for this indicate an initial dominance of technical and later economic efficiency considerations and a lack of strategic planning. Though technical and economic efficiency considerations still have a role to play, they must form part of a coherent framework that adheres to effectiveness and efficiency in support of agricultural resource-use planning. Coherence is an important factor, particularly when LIS products are to be applied to food security, which is the core theme of this dissertation. This is because, by nature, food security or insecurity is a result of many factors that include growth of the macro economy, price fluctuations (purchases against production) and household income (social grants, salaries and remittances), all of which are directly and/or indirectly linked.

In addition to efficiency and effectiveness considerations, most LISs found within provincial governments are relatively sophisticated and have been developed within the context of a particular discipline. They are therefore often ‘one man horses’, the sustainability of which is highly vulnerable to staff changes. Those who implement LISs also have their own perceptions about their functioning and purpose. A classic example of this can be seen in the Early Warning System of South Africa, where for example, the Agricultural Risk Management and Crop Forecasting Committees are only focused on vulnerability within the agricultural sector, while the Disaster Management Committee is focused only on saving lives and not livelihoods (FVIMS-ZA, unpublished presentation at the Advisory Panel). There is therefore a general lack of a coherent overarching structure that serves as a basis for integrating the various components of collecting data and providing information. An ideal system though should be one which is simple enough to be understood and used by most, yet has enough content and context to address the information needs of agricultural land users. Given the high costs associated with these tools and budget constraints, a feature common to most developing nations, planning that assists in determining the content and the level of sophistication of spatial-based systems is needed. These issues are addressed in Chapter 5 using an entity relationship process, which utilises systems analysis to provide a logical structure for showing which issues (components/dimensions) of food security are relevant to the past, present and future, and how these are related to one another.

Challenges for now and in the future (Watkins, 2007: 20) include;

i) institutional failures – structural alignment, corporate anorexic strategies and cost cutting driven strategies.

ii) ability to sustain institutional growth.

iii) ability to deal with increasing complexity, data volumes and data relevance.

iv) moving from the data and technology focus to a value proposition where the goal is solving societies problems and providing opportunities for growth.

In the above context, there is need to understand that spatial information is not a stand alone but part of a broader e-government information environment (Williams, 2007: 6). Hence the need to focus on business processes with people and the business (i.e., users), having ownership of the envisaged LIS and ensure that business objectives have a spatial identifier (Thompson, 2007: 61).

1. 4 Identifying relevant parameters for strategic planning of LIS

Section 1.1 and 1.2 highlighted some fundamental issues in LIS planning. The fundamental task in this study is to develop some guiding principles, which are necessary to facilitate the planning process. To address this challenge, use will be made of policy documents and workshops that utilises the input of past and current key planners in the field of LIS development. Crucially important first, though, is to have a clear image of the system's application or purpose and the organisation for which it is planned. This will be achieved by making a comprehensive analysis of the current status of LIS in the context of South Africa's agricultural sector's internal processes and external environment, and this is the topic of Chapter 5. As indicated in Section 1.2, the systems analysis concept, which utilises entity relationship diagrams (E-RD), will form the basis for providing a criterion for the selection and logical structuring of relevant issues/components and their relationships to one another.

1.5 Relevance of research in the context of South Africa's agricultural sector

The problems of coherence and integration within information systems in South Africa were highlighted in Section 1.3. The current and future problems relating to the availability of agricultural information in South Africa have been the subject of discussion for some time, as evidenced by a study on vegetable farmers (Bullock *et al*., 1995: 9). What has been particularly emphasised is the need for making available necessary information under a free-market and competitive South African agricultural sector. On the latter, there are essentially four reasons why, based on the need for efficiency and competitiveness, this study is relevant to the South African agricultural sector in particular and developing nations in general.

The first reason why this study is relevant is related to trade policy reforms since early 1980, in particular the marketing deregulation of agricultural products, price control liberalisation, the abolition of tax breaks, and the tariffication of farm products. This has affected the quality of agricultural information (specifically marketing information) provided by the public sector, as described in studies by Madikizela and Groenewald (1999: 249). These processes have also exposed the sector to global competition that had not hitherto been experienced. It also though accords the sector the opportunity to produce specific agricultural products that fill certain gaps within global markets, and hence the necessity to identify specific land areas suitable for particular crops.

The second reason for this study's relevance is related to increased pressure on agricultural land. This is largely due to population growth being estimated at about three percent per annum; the change in the political environment as of 1994, which allowed for new entrants into agriculture; and agricultural production that can no longer be increased by horizontal expansion because most of the land suitable for agriculture has already been used up, and of the 13 percent of surface area that can be used for crop production, only 22 percent is of high potential (www.new.agric.co.uk/99-2/contryp.html). Hence, together with water availability, land availability is placing absolute limits on agricultural expansion, though given market liberalisation and globalisation; physical limits are less relevant than availability and suitability of land for new or niche applications.

The dualistic nature of the agricultural sector, which is characterised by capital-intensive commercial farms and a growing number of small subsistence farms, implies conflicting production-planning goals and varying views and levels of understanding of agriculture. This situation results in a diversity of information needs, which forms the third reason for this study's relevance. The aforementioned circumstances require a fundamental restructuring of the agricultural sector, particularly within the socio-economic and political-institutional arena.

In a global context, more fundamental events specific to agriculture and relevant to both South Africa and elsewhere drive the need to strategically rethink the appropriateness and effectiveness of current LISs, and this constitutes to the fourth reason for this study's relevance. The events referred to above are those relating to the advent of niche markets, globalisation, and the growth in value-added food that has changed the structure of the agricultural sector. The shift in consumer preferences towards specific food characteristics has resulted in a change in the structure of agriculture towards fragmented, smaller, and diverse niche markets requiring very detailed specifications and exacting standards. Under these conditions, commodity market prices, on which current LISs are founded, fail to give the level of detail that is required by niche markets (Bonnen and Harsh, 1995: 610).

The cumulative effects of the above circumstances necessitate questioning the adequacy of current information sources in addressing prevailing information/data needs and the ability of LISs to effectively and efficiently exploit agricultural land resources. Also to be questioned is the adequacy of existing LIS design and development strategies, which define appropriateness, effectiveness and the cost-value trade-off in providing land resource information. These effects also compel the creation of new coherent and integrated agricultural spatial resource data and information for the South African agricultural sector.

1.6 Objectives of the study

The main objective of this study is to derive a set of guiding principles for the design of LIS that can effectively and efficiently support the planning of resource usage, particularly, although not exclusively, in South Africa. Food security is used to illustrate the central statement regarding the lack of coherence and strategic orientation in the design and development of LIS. In order to achieve this objective, it is necessary to:

i) investigate experiences of LIS implementation, focusing on the modus operandi followed in order to identify/determine relevant issues that must be considered in developing an effective LIS. This will facilitate incorporating effectivity and efficiency considerations via the strategic planning of goals, structures and processes;

ii) consult various theoretical schools of thought which are expected to illuminate dimensions of LIS design and development;

iii) use the information obtained from empirical investigations of existing LIS and theories as a basis for deriving principles and procedures for designing LIS that can effectively and efficiently support resource planning in the general and particularly in South Africa

1.7 Modus operandi

i) The first part of this dissertation identifies conceptual gaps that define the research problem from a philosophical perspective. It is concluded, based on a literature study, by deriving generic theoretical guidelines that specify components and procedures that should be included in the development of an appropriate LIS.

ii) Following (i) above, economic principles, especially BCA and public choice theories relevant to LIS design and evaluation are used to develop an understanding of the conceptual problems and guidelines identified.

iii) Use is then made of Systems Analysis (SA), which provides a logical structure for identifying relevant parameters in designing LIS, and the Entity Relationship Modelling (E-RM) approach to lay a foundation for the design of an information system, using food security in South Africa as a theme. Food security business processes are used to identify current and future data and information required to be kept in an LIS.

iv) A framework for South Africa's LIS design is developed in terms of:

- strategic thinking and planning in identifying data and information needs for decision-making concerning agricultural land resource usage
- the content of the LIS, based on input-output relationships (goal, structure, process and their link with agricultural strategy)
- the authorities or levels of government that should be responsible for designing and developing LIS
- the nature of involvement of the various authorities in order to facilitate effectiveness in terms of both the design and functioning of LIS
- detailed provisions regarding the proposed processes that should apply to this framework.

v) Based on (i) to (iv) above, conclusions are drawn for each chapter.

1.8 Chapter layout

The fundamental question remains, "How effective is current LIS in providing for wise decisions about current and future land resource use options?" To address this question, the dissertation is divided into six chapters and one annexure. Chapter 1 is aimed at exploring this fundamental question further by defining the problem and presenting key questions and assumptions relevant to the study. It is based on the hypothesis that current LIS are ineffective because of a lack of strategic orientation in their design and development and because a design procedure is required if LIS effectiveness is to be enhanced.

In order to understand the nature of the problem as it relates to efficiency, effectivity and strategic orientation, it is important to look at the historical development of LIS/GIS. This issue is addressed in Chapter 2, where the theoretical concepts underlying LIS and the current interest in LIS effectiveness are addressed. It is important to note that in Chapter 2 strategic planning per se is not treated as a new concept; however, its application in generating principles and procedures in the design and development of an effective LIS is treated as a new concept.

In most countries, the provision of information as a public good to support the wise use of the land resource in a global, regional or local context is the responsibility of the government. The reason for this is to assist land users, who are consistently faced with the problem of having to decide on how best to use their land resource in the present and how to better position themselves to use their land resource in the future. The result of this approach would be spatial and strategic positioning with regard to both current and future demand patterns for agricultural products and the use of agricultural land as an amenity.

Resource economics provides classical concepts on wise resource use. Examples of these are highest and best use, which focuses on the most profitable and competitive use to which a land parcel can be put, and land use capacity which focuses on resource quality and accessibility. These concepts remain relevant in making decisions, for example, on where a particular crop can be produced for a niche market or for which area a particular product would be best suited.

Classical concepts are also relevant in terms of selecting areas for a particular economic activity from different needs perspectives, such as areas that are suited to tourism rather than agriculture. The latter concept is one of the subjects of discussion in Chapter 3, which looks at, among other matters, the functional concept of land resource use. This concept implies that any form of resource is an attribute of the environment, appraised by man for the purpose of obtaining prescribed goals, and that *resource* per se has no meaning independent of spatial location with regard to needs, local culture and indigenous knowledge.

The objective of Chapter 4, based on the findings of Chapters 2 and 3, is to relate strategic planning and thinking processes to the process of developing LIS in an effort to enhance effectiveness.

One could argue that the decisions stated above should be left to private persons and that the market mechanism will drive private decisions towards optimal resource use. However, due to the location specificity of agricultural resources and changes in needs over time, market regimes require good quality spatial and temporal information. This is because over time the resource base may change, for example, due to land degradation and new possibilities that may be recognised, which could influence the current and future use of a given land parcel. Hence, there is a continual need for effective and efficient resource use planning at a micro level (i.e., at farm level for crop selection) and at a macro level (i.e., for infrastructure planning). Time, therefore, becomes a critical factor in determining current and future land resource use options and patterns.

The importance of time as a determining factor in resource use planning is the topic of Chapter 5, as it relates to systems analysis and business processes in information and data generation relevant to agriculture and food security. Apart from showing how components of a given area of interest, such as food security, are related, systems analysis also provides a logical structure to show which issues relating to these components – business processes – are relevant to the past, present and future, and this augments the reasoning in previous chapters.

To support the systems analysis concept, a workbook is provided as an annexure, aimed at creating a picture of the future to emphasise the importance of including particular dimensions (identified during systems analysis) to be included in data collected so that these dimensions will be available when needed. The workbook assists in focusing attention on the most important parameters that should be incorporated in data collected and stored in an LIS, thus helping enhance LIS relevance and efficiency.

Chapter 6 is a synthesis of ideas captured in previous chapters and is therefore a distillation of the essence of the dissertation.

CHAPTER 2:EFFECTIVENESS ASPECTS RELATING TO LIS DEVELOPMENT

2.1 Introduction

This chapter aims to review some of the theoretical concepts relating to LIS effectiveness. It establishes the need to focus more attention on LIS effectiveness, compared with historical efforts that aimed predominantly at LIS efficiency. Particular attention is given to the evolution of LIS and the impact of this on organisational effectiveness. To address the need to focus more attention on LIS effectiveness, an attempt is made to clearly define what constitutes effectiveness in LIS functioning, which calls for the need to think strategically about information management.

Information as an aid to decision-making is important, as is LIS as a tool for providing such information. To this end, systems of varying capabilities, sophistication and cost have been developed, particularly for circumstances in Europe and North America (Craglia, 1992: 544). Concerns are, however, that these systems were developed with technical efficiency and accounting evaluating processes based on traditional benefit-cost analyses (BCA) as priorities (Dos Santos and Sussman, 2000: 431; Silk, 1990: 186), with little consideration for effectiveness.

As a result, these systems have fallen short of delivering value and are unable to measure effectiveness benefits, as has been noted by Brynjolfsson and Hitt (1996: 541), and Dehning and Richardson (2002: 7). This has been called the *productivity paradox*. A shift in focus from technical efficiency to a more strategic approach is needed to add value. This would involve a strategic systems planning process that translates planning needs into information-technology-based solutions. In turn, this would facilitate managing information as a resource and challenging the value and contribution of Information Systems (IS) from a business, rather than a technical/accounting perspective (Ward et al., 1996: 215; Grimshaw, 1994: 115; Serafeimidis and Smithson, 2000: 95). This change in focus is in line with the evolution of LIS towards organisational effectiveness and competitiveness, which has impacted on strategic systems planning in LIS/GIS design and development.

Strategic systems' planning is not a new concept, as is shown, for example, in the works of Porter (1991), MacFarlan (1991); Porter and Millar (1985: 149). However, this rationale is increasingly becoming critical for ensuring effective macro planning, allocating scarce resources, forecasting resource requirements, and controlling information processes. These new applications have arisen because of the strategic opportunities afforded by advances in IT and the alignment of LIS with organisational goals.

Strategic systems' planning is thus new with regards to LIS design. It is within this latter context that the South African agricultural sector is used in this study to develop a framework for enhancing the effectiveness of LIS, given this country's resource endowments, current and future agricultural land use optimisation and patterns, forestry and tourism development requirements, as well as other current and future strategic information needs.

2.2 Issues relating to LIS effectiveness

Effectiveness is defined as a measure of impact on performance (Worrall 1994: 548) or, in the context of this study, changes in, for example, land use activities or information use as a result of the implementation of LIS. An effective LIS function is concerned with the impact of the information provided in helping users do their jobs. It follows that effectiveness is concerned with 'doing the right things', whereas efficiency entails 'doing things right' (Bay-Petersen, 1996: 89). A distinction between efficiency and effectiveness in the use of information technology is also given by Cane (1992: 1730).

From an organisational viewpoint, a system's effectiveness can therefore best be defined as a measure of the extent to which organisational goals and objectives are fulfilled with the aid of an LIS (Grimshaw, 1994: 128). In this context, the value of the benefits of effectiveness resulting from a given system should invariably depend on the effect that the changed output has on each user, assuming that output has value when it causes changes in behaviour. However, an LIS has both direct and indirect impacts which cumulatively determine the overall performance of the sector (Figure 2.1). The direct effects are easy to identify and quantify. It is the indirect effects however that have become the subject of considerable debate (Smith and Tomlinson, 1992: 248-252; Worrall, 1994: 552, 556) in terms of measurement and determining overall impact. The debate over LIS effectiveness has arisen because of the limited impact of their performance in organisations in which these information technology/systems have been implemented.

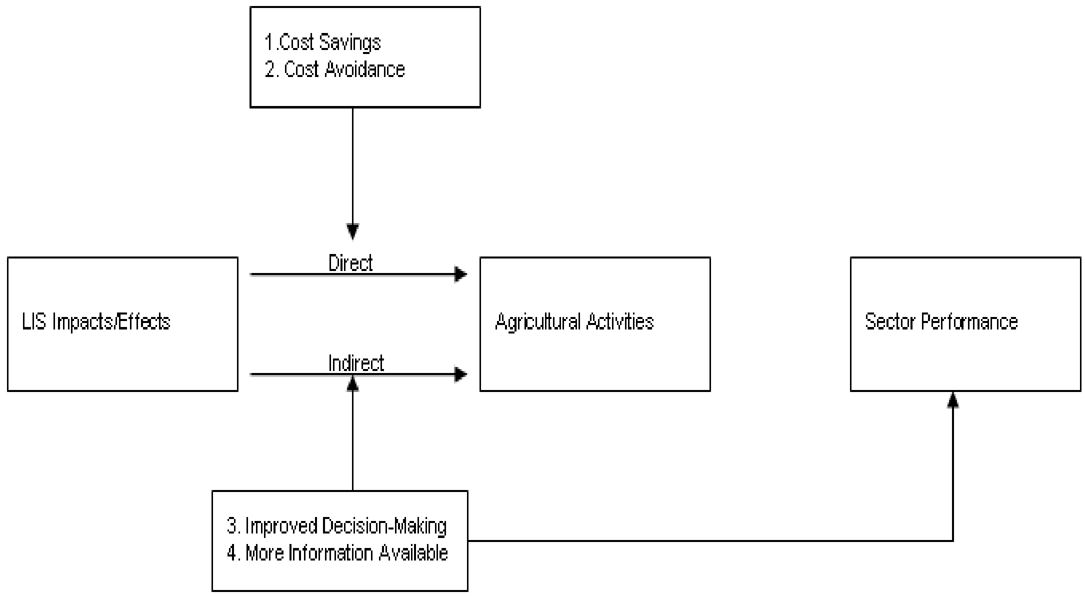

Figure 2.1: Direct and indirect impacts of LIS on agricultural resource use planning (adapted from Richardson, 2002)

This was indicated in various studies that took place in the early 1990s, which found either no relationship or a slightly negative relationship between investment in IT/IS and organisational performance (Strassmann, 1996: 542; Brynjolfsson, 1996: 542; Kraemer and Dedrick, 1994: 1924). However, in studies starting in the late 1990s, positive returns on investment in IT were found (Dewan and Min 1997: 1663; Brynjolfsson and Hitt, 1996: 557).

Several reasons have been put forward for this inconsistency. Some attributed this paradox to "a failure in strategic thinking and to management resistance to change" (Dos Santos and Sussman, 2000: 431-33). Others, however, have seen this as being a 'conceptual failure' to realise that information systems are complex socio-technical systems, inseparable from the organisational context they operate within and interact with (Serafeimidis and Smithson, 2000: 94). In a review of studies of the productivity paradox, it was concluded that this was mainly due to a measurement problem (i.e., input/output distortions, with inflation overestimated and real output underestimated), lags in benefit realisation, and redistribution and mismanagement of resources (Brynjolfsson, 1996: 543). As shown, various reasons have been put forward in support of the productivity paradox, yet with no definitive explanation for the failure of organisations to attain effectiveness from their investments in IT/IS.

What is apparent though is that often organisations design and use IT/IS applications to improve what is currently done, rather than thinking about these applications as opportunities for re-engineering/redefining their organisations, i.e., a strategic orientation towards organisational effectiveness. It is important to determine what it is that constitutes or, rather, enhances effectiveness in LIS implementation. To this effect, some authors have called for more research into *what* actually determines success and *how* IT/IS can be made more effective (Brynjolfsson and Hitt, 1996: 557). The need for a better understanding of the process of adoption of GIS technology and the impact of such technologies on organisations has been reiterated (Goodchild, 1992: 40).

Three conditions for effective implementation of GIS have been suggested (Masser and Campbell, 1991: 63). These are (1) the need for an information management strategy and thus the need for strategic planning, (2) commitment to and participation in the implementation of any form of IT by individuals at all levels of the organisation, resulting in coherence and integration, and (3) organisational and environmental stability, continuity and evolvement.

Hence, issues relating to IT/IS and LIS effectiveness, in particular, are still of major concern and open to debate. While issues pertaining to understanding the opportunities and impacts of investment in IT/IS are still of concern, more emphasis is now being placed on “taking the responsibility to improve performance" (Peters, 1990: 205).

2.3 Evolution of LIS research activities

Three generic LIS research activities, namely, theory, technology and application can be identified (Muller, 1993: 293). To these, two more research activities, namely, investment appraisal and management, and planning are added from literature inferences (Dickinson and Calkins, 1988: 307-327; Campbell, 1992: 531-541; Smith and Tomlinson, 1992: 246-256; Worrall, 1994: 546-565; Ward *et al.*, 1996: 214-225).

These research activities, as well as changes in research thrust, in an evolutionary context are shown in Figure 2.2. They proceed from theoretical issues that emphasise data analysis/collection to systems management and planning that emphasise effectiveness.

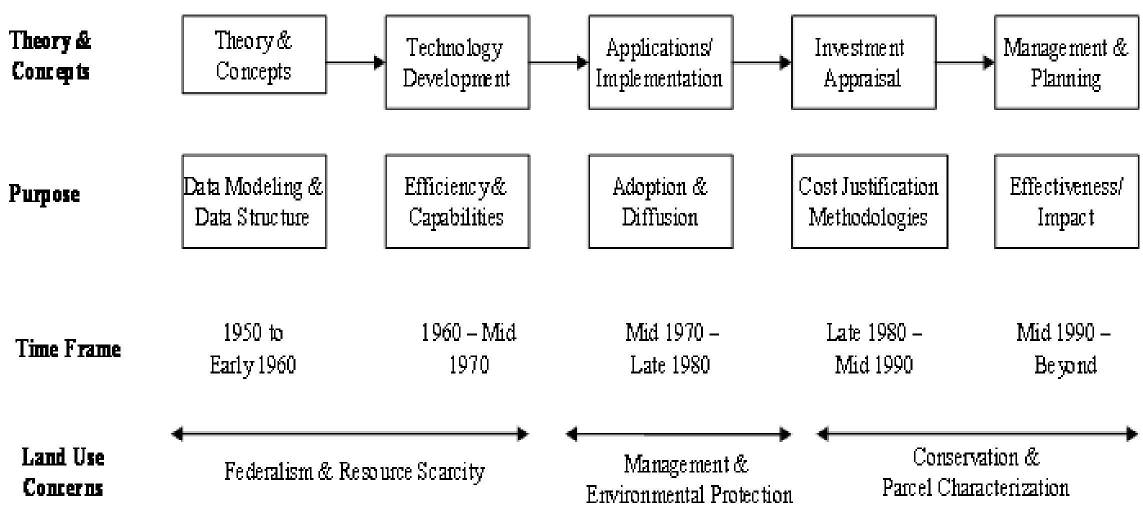

Figure 2.2: Shifts in GIS/LIS research purpose and land use concerns

Early research (theoretical and technological) was mainly concerned with enhancing technical know-how in handling geographic information (i.e., data modelling, data structure, and technological efficiency and capability).

To a large extent, both the theoretical and technological aspects of LIS have adequately been addressed, as witnessed by the drop in hardware and software costs and increases in technical efficiency overtime. However, effective utilisation of GIS depends not only on the development of the necessary technology but also on relating it to the organisational, personal and environmental context in which it is implemented (Bellamey, 1996: 49; Jan and Tsai, 2002: 72). Therefore, applications, investment appraisals, and management and planning are still of prime importance to both developed and developing nations. These are dealt with in more detail in the following subsections.

2.4 Measuring the impact of LIS on organisational performance

It is difficult at the start of an LIS project to assess the eventual impact of LIS on an organisation, and how acquired information will trigger organisational change and development. This is attributed to the difficulty in envisaging the uncertainties, risks and contextual dependencies concerning the value of GIS and its products to organisations that, quite often, are undergoing considerable changes. Several research approaches, shown in Figure 2.3, have been developed that either directly measure the overall impact of LIS on the sector (Route 1) or do so indirectly through their impact on processes (Route 2 and 3).

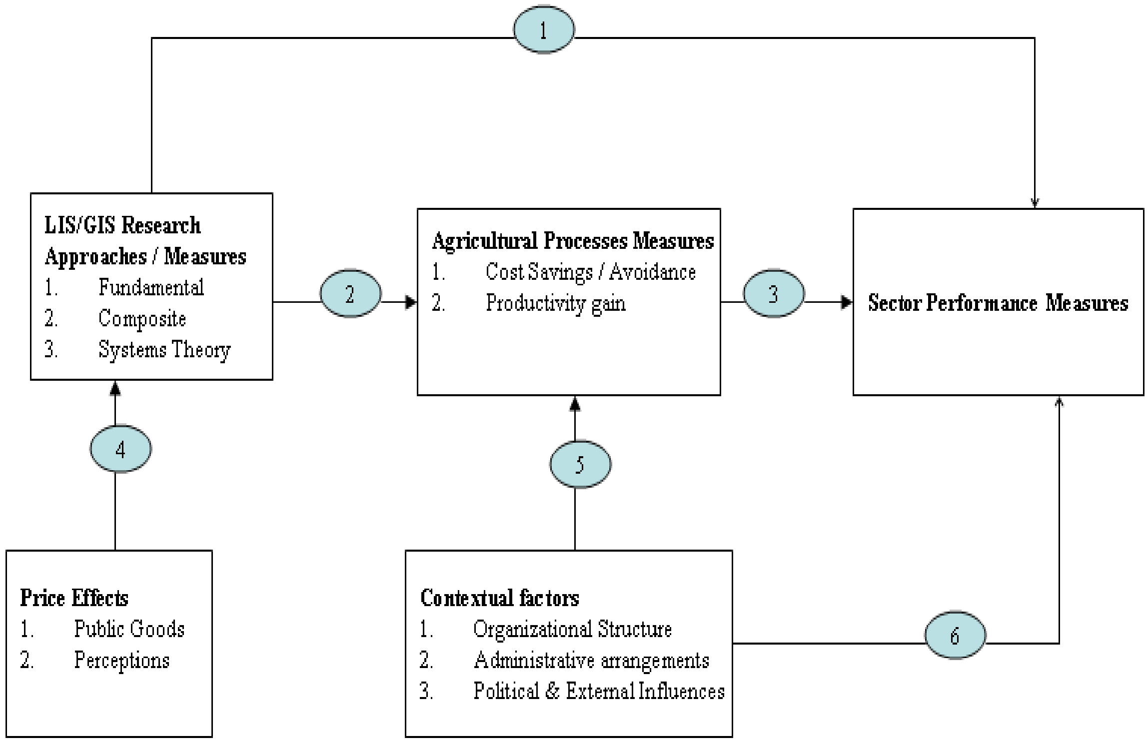

Figure 2.3: Impact of LIS/GIS on agricultural processes and sector performance as measured by researchers

Contextual factors provide the background against which LIS usage takes place. The manner in which these factors interact with LIS determines the processes that influence the development of LIS and their effectiveness. LIS should thus be designed to take cognisance of contextual factors.

Techniques for measuring the impact of LIS on organisational performance, however, have largely been based on the concept of benefit-cost analysis (BCA). By definition, BCA is a technique for enumerating, evaluating and comparing the benefits and costs that stem from the utilisation of a productive resource base (O'Riordan, 1971: 33). In terms of social welfare, this implies attempting to maximise net social benefits so that benefits accruing to any one set of consumers cannot further be increased without benefit losses being incurred by another set of consumers (a pareto optimal equilibrium).

Attempts to apply BCA to justify investment in LIS were initially undertaken by Dickinson and Calkins (1988: 307-327) and Demers and Fisher (1991: 469-485). These have since been followed by an array of applications and discussions on mainly methodological issues, notably by Wilcox (1990: 203-221); Worrall (1994: 546-565); Ward *et al*., (1996: 214-225).

The greatest shortcoming of BCA is its underlying assumption that all impacts can be financially quantified, and thus it places undue importance on economic efficiency without taking into account other important factors such as social equity or performance effectiveness (Rourk, 2000: 2-42). In the past, BCA focused on efficiency at the expense of effective planning. To employ effectiveness considerations, however, it is necessary to have a strategic planning orientation. There is also broad agreement in the literature that BCA when applied to LIS investment is limited by an array of conceptual and practical problems (Sassone, 1988: 82; Silk, 1990: 186), some of which are discussed in the subsequent sections. The problem, however, does not lie within BCA per se but in expectations of BCA, which, in terms of its design, it cannot meet. It is equally important to emphasise that the cost benefit considerations for information is a general question for information and not limited to spatial information as is the case with LIS

2.5 Conclusions

It is apparent that the difficulty in measuring the effectiveness of LIS has an historic bearing, with most efforts having been directed towards measuring efficiency. The lack of a measure for effectiveness has also made it difficult to justify investment in LIS design and development.

Concentrating on BCA as an analytical tool has also set limits to accounting for all LIS benefits, as some of them cannot be assessed in monetary terms. Deliberations in Sections 2.1 to 2.3 indicate that limited effort has also gone into the strategic planning processes that link the effectiveness of LIS to organisational goals. Yet, several scholars have called for a change in the way LIS benefits are measured and for LIS products to be linked to organisational goals, thus allowing for a strategic orientation in systems design and development.

An important conclusion of Chapter 2 therefore is that, besides efficiency considerations, applications, investment appraisals, and management and planning of LIS are still of major importance to both developed and developing nations. Invariably, information, which has a poor cost-benefit ratio, should be considered as being of poor quality and should not be collected

To address these economic components, economic theories and applications relevant to LIS design and development are explored in Chapter 3. A considerable focus of Chapter 3 is the use of literature and economic principles to identify gaps that need to be bridged in order to make LIS more relevant and effective as a tool for aiding land-resource-use planning.

CHAPTER 3: THE APPLICATION OF ECONOMIC PRINCIPLES IN THE CONTEXT OF LIS

3.1 Introduction

The information economy theory, of which information is a critical input and the basis for competition and economic growth, is not sufficiently developed. Apart from being characterised by an array of uncertainties and complexities that make the selection of appropriate research methodologies difficult, the field of information systems (IS) also lacks solid economic theory.

The rationale behind investment in IS in general can usually not be described by specific economic theorems, but rather by a conglomerate of theories. The most suitable economic theory – with a technological dimension as well as a development abstract that seems to be applicable to geographic/land information systems (LIS) and the impact of information in general – is the economic growth theory. This theory has its origins in the writings of Domar (1946: 137-147); Harrod (1948) and, in particular, Solow (1956: 65-99). Of particular relevance are the 'endogenous' growth models of Romer (1986: 343-356); Jones (1995: 495-525) which, among other things, define an exogenously given economic growth rate for technological progress.

One assumption described in these growth models is that an increase in the level of knowledge in society has a positive externality on the productivity of a given firm, owing to the non-rivalry of intellectual resources, as opposed to the competition among most physical resources. By design, LIS development increases knowledge concerning natural and human resources and thereby increases the potential to exploit these resources in a more effective and efficient manner to enhance economic growth.

This positive externality comes from the development of human capital, due to new knowledge being acquired in the LIS development processes and resulting from the products of LIS in general.

The problem however is that, according to standard microeconomics theory, when the provision of a good or service results in positive externalities, market participants do not have the incentive to invest in research and development for such a commodity, as others would invariably benefit from their investment without paying. For the same latter reason, market forces may not produce an efficient level of what causes the positive externality. Hence, in these circumstances there is an incentive for government intervention to enhance investment in research and development of LIS. This would be necessary if efficiency and effectiveness in the provision of land resource information, and thus land resource use in general, is to be achieved.

Because of this lack of a specific theory to address concerns relating to LIS issues *per se*, this chapter aims to identify applicable economic concepts that can be used to explain LIS functioning. Its primary goal is to identify conceptual gaps that determine LIS effectiveness as a function of system appropriateness. To achieve this aim, a large portion of the chapter is devoted to the application of resource economics to LIS functioning, as a way of introducing effectiveness into IS processes in general. The difficulty in applying economic concepts to information as a product of LIS is also highlighted at the end of the chapter.

3.2 Land characteristics as a source of competitive advantage

Theories in resource economics and agricultural land resource use in particular date back to the 18th century and can predominantly be linked to the writings of Thomas Malthus (1766–1834), David Ricardo (1772–1823); John Stuart Mill (1806–1873). Such theorists subscribed to the laissez-faire doctrine that government intervention in the individual's use of resources should be kept to a minimum.

The shift from a laissez-faire view and individual interest towards a greater emphasis on the economy as a whole, with proper allocation of national resources, came predominantly from Karl Marx (1818–1883); Alfred Marshal (1842–1924); Arthur Pigou (1920), Zimmermann (1951); John M. Keynes (1936) (see Edwin and Bezung 1975: 29-31). This group emphasised the need to link the acts of individuals using resources to the effects of their actions on society as a whole. Governments are thus expected to play a major role in resource allocation.

In both paradigms however, economic growth was seen as a function of resource availability, and this played a major role in comparative advantage. Optimum resource utilisation was therefore seen as a function of competition for the so-called factors of production (i.e., land, labour, and capital) that drove factor comparative advantage within and between nations.

With advances in technology however, many nations (China, Japan, and Korea) have since defied the odds by being world leaders in those industries for which they have limited production factors. In the context of the above, statement, the advent of technology has thus reduced the importance of access to abundant factors of production and has shifted the emphasis from resource scarcity to technological efficiency, capabilities, and skills in defining competitive edge.

However, with global accessibility to technology, technology per se is now less of a distinguishing factor than are resources in their respective context. More emphasis is once again being placed on the contribution of the particular resource characteristics necessary to fill a certain need within global markets.

Within the agricultural arena, for example, the establishment of niche markets requires the identification of suitable land characteristics for certain crops that can satisfy particular consumer preferences in national and global markets. Therefore, countries or locations with land resources that possess the required specific characteristic will have a competitive advantage for producing certain crops. In the context of this study and agriculture in particular, the fundamental questions therefore are the following: (1) Can the prevailing LIS adequately provide this kind of specific information? and (2) At what level of LIS investment would it be optimal to do so, given a country's resource endowments, current and expected future land uses, and information needs for specified purposes?

3.3 The functional concept of *resources*

The term *natural resource* has no meaning independent of the spatial location of needs, the location of resources to match end-uses, local culture, and indigenous knowledge (Yapa, 1991: 52; O'Riordan, 1971: 3). The term is therefore space specific and LIS, as a tool for spatial and regional analysis, can assist in implementing the space-specific logic of end-use rationality in the resource functional relationship originally defined by Zimmerman (1971: 3).

By definition, a *resource- functional* relationship implies that any form of resource is an attribute of the environment, appraised by people for the purpose of obtaining prescribed goals within the constraints imposed by their social, political, economic, and institutional framework (O'Riordan, 1971: 3). Hence, a tripartite relationship exists between people's ability, the environment, and people's needs and desires (Figure 3.1). In this sense the value and meaning of a resource is determined by the function that the planning agent prescribes. This relationship assists not only in the classification, but also in the understanding of resource and information needs. The functional relationship thus gives a frame of reference and emphasises the necessity of supporting well-informed decisions.

In a functional context, the term *resource* is therefore a highly relative one in that its meaning will change according to the planning agent's, objectives, understanding of the environment, technological progress, and existing social-institutional arrangements. In this context, both space and time become important factors in defining the use(s) of a given land parcel. As stated above, the functional concept of *resource* is thus an important one in that it gives purpose and value to land as a resource and thus defines information needs and issues to be addressed by an LIS in the form of strategic goals on the part of the planning agent.

This means that where needs/goals are not given, LIS can help determine these based on resource-use possibilities, such as via scenario development. The issue here, however, is not to make a detailed functional analysis of land as a natural resource, but rather to use the functional concept to establish a trade-off between the cost of providing land resource information and the quality, quantity, and diversity of the information required to enhance effectiveness in the use of the agricultural land resource.

The application of LIS at each of the three stages of the functional relationship Figure 3.1) therefore becomes vital. Besides being complementary, each stage of application will be unique in terms of objectives and resource requirements, thus defining differentiated input/output relationships.

3.3.1 *Application of the resource-functional relationship concept in the context of LIS*

In a *resource-functional* context, LIS application is aimed mostly at addressing resource-environment issues that provide answers to the questions, 'what is' and 'where are' in a form which can be depicted as shown in Figure 3.1. Hence, the application of and investment in LIS/GIS will differ at each stage of the functional relationship, due mainly to the differences in information required at each functional stage.

Application 1 in Figure 3.1 relates to LIS/GIS viewed as a technological aid to support planning**.**

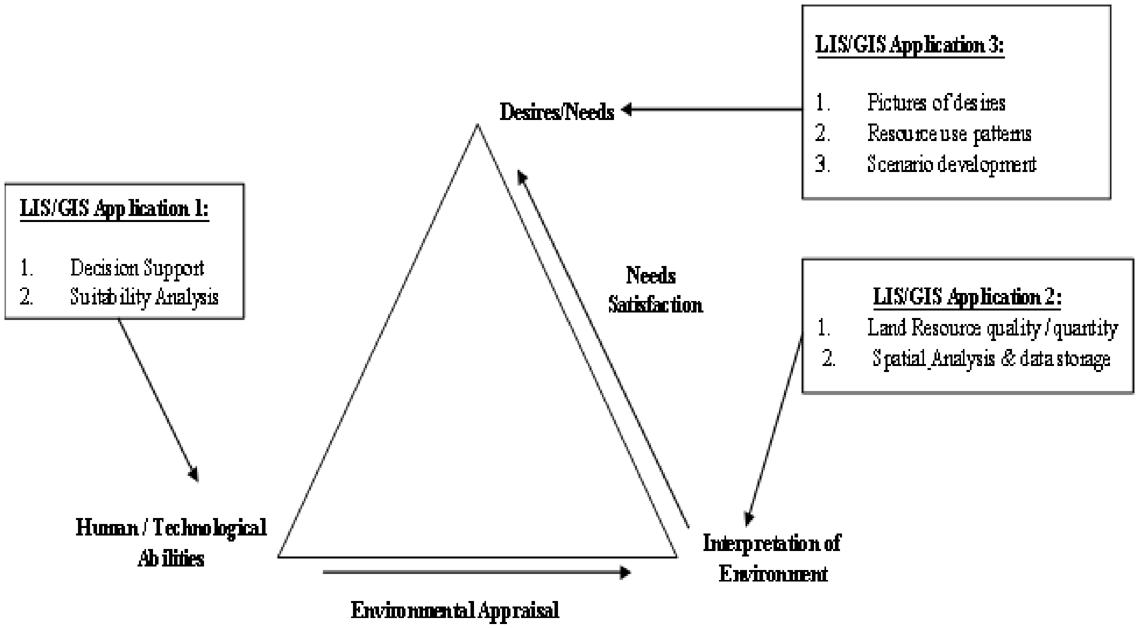

Figure 3.1: Application of GIS/LIS in a resource functional relationship context

At the level of people's ability, LIS/GIS can be used as a technological aid to support planning. It can do this by e.g., identifying suitable areas for a given crop that satisfies a certain need within global markets. Therefore, systems (e.g., spatial decision support systems (SDSS) and expert systems) capable of providing such information are crucial for enhancing people's ability, which then translates into resource-use efficiency and sector-competitive advantage. Therefore, the relevant questions are the following: (1) Are current systems capable of delivering such detailed and specific information? and (2) What specific information in terms of structure, processes, and resources is needed, not only for the development but also for the long-term sustainability of the system?

At the next level (i.e., Application 2), LIS is viewed as a system for storing, capturing, and displaying information**.** At this level, referred to here as the level of environmental interpretation, LIS can be used to capture, store, and display large amounts of resource information in a spatial format that allows for a more complete understanding of quantity, quality, and location of the land resource. A lot has been achieved at this level as witnessed by technologies for remote sensing and the availability of software for use in varied land/soil inventories.

The third application in Figure 3.1 (Application 3) refers to LIS viewed as a system for shaping people's images of desired land resource-use patterns or spatial images of desired land-use projections and scenario development. This is one area where there is limited research and information on the structure, processes, and content necessary for the development of systems capable of providing such information.

To this end, systems have been developed that are capable of enhancing planning ability and quantifying environmental scenarios, but in general, the research literature still lacks theoretical and empirical contributions on GIS use and on the narrow topic of spatial decision-making. Hence, the technology transfer demonstrated by the implementation process must be followed by applications that demonstrate the utility and benefits to be derived from LIS, given specific areas of application.

3.3.2 *The need for well-defined organisational goals*

At each stage of the functional relationship, systems will vary in terms of resource requirements (i.e., financial and human) and information and data products. For example, systems destined to support planning will require different data and data interpretation from those destined for scenario development and images of desired land-use projections.

Therefore, the application of LIS in a *functional-relationship* context of the nature depicted in Figure 3.1 requires that national goals on spatial land use be well defined.

Organisational goals are of particular importance as they are designed to generate the questions to be addressed by an LIS. Many organisations however, especially local authorities and service departments, have not formally defined their aims and objectives, and as such, the link between organisational planning and LIS planning is usually tenuous (Worrall, 1994: 551). Also, though planning of LIS is central to ensuring systems appropriateness and effectiveness, many organisations do not adequately plan for their information systems, and neglect to incorporate competitive considerations into their planning efforts (Galliers, 1991: 55).

If national strategic goals are ambiguous about what is required, it will be difficult to decide how much to invest and for what type(s) of information. Information is thus needed to decide on the content of LIS, based on the input-output relationship at each level of the functional definition.

3.4 Concepts of *supply* and *demand* as applied to LIS/GIS

Complementary to issues of organisational environment and goals are the economic concepts of *supply and demand*, as applied to the area of information generation and provision.

On the supply side, the concern is with the quality and quantity of land resource information that is, or can be, made available for people's use. On the demand side, the concern is with the factors that affect the growing need for land resource information and information products, and with the ability to provide for these needs. When applied to LIS, these concepts imply that systems differ in terms of their purpose; the quality, quantity, and diversity of information they provide; and in terms of the data needs and resources (human, technology, and financial) required for availing this information.

The data quality, quantity, diversity, and interpretation are functions of both human and technological sophistication. Thus, deciding on the level of system sophistication implies dealing with a trade-off between the costs of providing the information (supply side) and the quality/quantity and diversity of information required (demand side). However, determining the optimal level of information to be supplied has not received much attention in the literature pertaining to LIS; neither has the differentiation in resource requirements for systems destined for varied purposes. Therefore, the LIS community needs to rethink the organisational setup necessary to involve not just the technical aspects, but also the economic and social aspects through a strategic planning approach that focuses on applications.

3.4.1 *Uncertainties in assessing LIS products*

There are several uncertainties that make understanding the supply-demand relationship in providing information difficult in the context of LIS and the environment within which it operates. These include the following:

- uncertainties about the environment which they are employed (De Man, 1988: 247);
- the difficulty in establishing the true monetary value of certain (intangible) costs and benefits (Litecky, 1981: 15; Silk, 1990: 186; Smith and Tomlinson, 1992: 249; Worrall, 1994: 552; Obermeyer and Pinto, 1994: 93);
- price effects, such as interest rates for discounting costs and benefits (Smith and Tomlinson, 1992: 249);
- exchange rates; and
- minimum wages and the public good nature of information (Rhind, 1992: 16).

In the public sector, where corporate *LISs a*re predominant, transaction costs that occur between and within departments are usually not budgeted for and are thus difficult to ascertain. Also difficult to quantify is available public information on the social welfare function (SWF) of societies with different cultures and resource endowments (Ciborra, 1987: 270). Other related factors include the following:

- systems development methodologies that concentrate on what organisations should be doing with respect to IS planning practices, which does not facilitate an understanding of what organisations are doing (Hann and Weber, 1996: 1043);
- institutions involved in system design; and
- narrowly focused goal setting and analysis of assumptions.

In implementing LIS, it is frequently assumed that all organisations have similar basic characteristics and are free from external pressures. However, a number of studies have considered this misleading, as it fails to take full account of social and political processes present within and outside the organisation (Hirschheim and Klein, 1989: 1201).

Another element of uncertainty is the nature of the good itself. Geographic information displays many features in common with the notion of *public good* in economics in that many individuals can share its benefits without it losing value, and it is not easy to exclude people from using it once released (Flowerdew and Whitehead, 1974: 14-15; Rhind, 1992: 16-17). Most significant though is that different types of information display different kinds of characteristics, with no obvious unit of measurement and, generally, an investment good aspect that entails consumption considerations. Unlike other commodities, information remains in the hands of the seller even after it has been sold, and its inherent leakiness makes exclusive ownership difficult.

These features have had important implications in defining property rights/rights of access to publicly held information. Typically, copyright statutes lag behind technological development (Rhind, 1992: 18), and this makes practical enforcement of licensing and, therefore, cost recovery strategies more difficult and bureaucratic. However, data costs (mainly conversion and maintenance costs) are quite substantial, accounting for approximately 65% to 70% of total GIS costs, and are expected to account for an increasing share of the cost associated with global projects (Worrall 1994: 556).

At any scale, the cost of data interpretation is many times the cost of IS acquisition. Hence, the imperative need to ensure that only the relevant and required data is collected and stored if costs are to be kept at a bare minimum. However, in the evolution of systems development, the criterion for storing only the relevant data has not received much attention from systems developers. Of fundamental importance is the question of who should decide, and on what basis, how much data to store and what information to generate from stored data. Also, at a national level, should this decision be made by small, large, rich or poor landowners? The relevance of answers to such questions is that the more data parameters are included, the higher the costs. The same applies to collecting and keeping/updating irrelevant data. These uncertainties, most of which are exogenous, form part of the environment within which a given LIS has to function.

3.4.2 *Sustainability in LIS funding, and staff retention*

A major challenge to most organisations in developing countries is the ability to attract funds and build the capacity for sustained GIS development. This may require the structuring of organisations so that they are able to attract higher levels of independent funding. A major complication within local governments is that most of them are highly departmentalised along rigid professional lines. As budgets are usually controlled departmentally, this makes funding of corporate projects highly problematic and results in cohesion and coordination difficulties, with duplication of effort in data collection and storage quite common.

Still, in the developing world and related to fund availability, there is difficulty in recruiting and retaining the required skills for data interpretation. Analytical and modelling abilities add the capability of structuring, analysing and interpreting data to the information system in relation to specific user applications (De Man, 1988: 252). However, needs assessment studies by CAB International and the Technical Centre for Agricultural and Rural Cooperation (CTA) led to the conclusion that developing nations lack the resources, equipment, and trained staff necessary to establish and sustain reliable agricultural information services.

Usually, inadequate resources are devoted to information provision (Ogbourne and Ison, 1996: 19). In practice, data analysis requires a deep understanding of the subject matter at hand (professional expertise) as well as technical skills (GIS expertise). However, most organisations have GIS experts and professional experts, but seldom is one person both a *GIS expert* and a *professional expert*. This creates a weak link within the data analysis process.

In a study in North America, Tomlinson (1987: 216) observed an increasing gap between the need for qualified staff in government agencies that have acquired GIS and the ability of the educational system to provide them. Also, a case study of GIS effectiveness in the British local government structures revealed that the more successful environments were those that had a collection of highly able individuals who possessed the full range of skills necessary to implement a GIS (Campbell, 1994: 319).

In developing nations, too, skills levels are a major constraint, with heavy reliance on foreign expertise and, as a result, increased long-term costs of GIS construction (World Bank, 1996). Training between the late 1980s and the early 1990s focused mainly on the development of specialised technical skills and less on database design and management, and organisational aspects. It is because of this that civil servants already in employment are unlikely to have had training in information use and management. There is also a brain drain from Africa to the developed world, mainly because remuneration in most African countries is not competitive in global markets.

3.5 Conclusions

The objective of Chapter 3 was to identify conceptual gaps that determine LIS effectiveness as a function of systems appropriateness. In general, published literature provides good advice on testing and conducting needs assessments for various information systems. However, the literature gives very little assistance on how to decide on the correct level of investment (low, medium, or high), and it offers little advice on the quantity, quality, and diversity of data and information, required in relation to particular applications and resource endowments.

Economic theory states that benefit yields are related to investment intensity and that, for each investment, there is a theoretical limit to how much benefit can be obtained. Yet, there appears to be a gap in GIS approaches to the economic assessment of investment tradeoffs, which define the quality, quantity, and diversity of information required for the various applications of land resource use.

Accounts from previous sections imply that the input-output relationship of LIS in their respective areas of application is not well understood. This is mainly because a lot of emphasis has been put on supply and less on demand in LIS development. Of particular concern is the long-term sustainability of capacity building efforts, which lag behind because of lack of involvement by the private sector in terms of its development of capacity. The non-participation of the private sector is the result of the absence of a well-functioning market that fully defines the business aspects of geographic information.

Implementation of LIS has also been largely performed in the absence of a coherent vision and strategic orientation, with most IS initiatives being technology/donor driven, and a few initiatives being oriented towards information management or users. The processes involved in generating information are also not well defined. How to decide, for instance, on what data is relevant (quantity, quality, and resolution) and what data should therefore be kept in an LIS differs from one system to another, resulting in duplication.

The cumulative effect of the above is the existence of costly and rigid systems, which have a limited positive impact on organisational performance and result in difficulty in adjusting to changes over time in order to stay relevant. There is therefore a need to look at the processes involved in generating information. An effort is also required to come up with an operating procedure that can assist in the coherent design and development of appropriate LIS/GIS's. Strategic planning processes that take cognisance of current and future data and information needs are a possible approach to addressing the above areas of potential improvement.

Such processes and their relevance in defining a logical structure for LIS development are addressed in Chapter 4. To facilitate a common understanding of this concept, a review has been made of the concept itself and how it can be used in principle to address LIS issues. The advantage of applying strategic planning principles to LIS is that they add a future orientation to thought processes and thus treat issues of uncertainty as endogenous to GISLIS.

CHAPTER 4: CONCEPTS IN THE STRATEGIC PLANNING OF LIS

4.1 Introduction

Chapters 2 and 3 highlighted several critical issues relating to the functioning of Land Information Systems (LIS). A conclusion of Chapter 3 however is that even though there is no specific economic theory applicable to the functioning of LIS, resource economics can be used to illuminate relevant information/data needs. For this to occur, land resource planning agents need to anticipate relevant current and future uses of the land resource or what images of desired land resource projections will be required given ever-changing and diverse national, regional and global human wants/needs.

This requires a strategic thinking orientation in LIS development that will provide the required information/data, not only today, but also in the future. Strategic planning of LIS implies looking at relevant future resource needs and critical issues/parameters that dictate what data should be stored in an LIS now in order to provide relevant data and information in the future. In general, any strategy must identify the current needs of the organisation as well as its future needs in order to decide how best to achieve future goals, given the alternative options and resources available.

A chosen strategy must also involve a conscious and deliberate understanding of the processes involved in the establishment of the system, which will help understand not only past decisions but also potential future alternatives (De Man, 1988: 253). To achieve this, a multiple-perspective approach is necessary that takes cognisance of social, economic, political-institutional, physical-biological and technological changes. This perspective must also consider how such changes relate to each other to form a mutually dependent whole in influencing agricultural/rural resource demand patterns and information needs over time. This is because, interactively, changes in these factors influence either the performance, purposefulness or effectiveness of the area of application, in this case, the agricultural sector. This also means assessing the impact of the way the agricultural land resource should be used in the present and in the future.

Invariably, such forces impact on the information needs of land users and thus on the design, development and functionality of LIS. Also, the future dimension of LIS (the ideal) is the result of an interaction of an array of variables that include manpower; computer capacity; institutional aspects; hardware and software; and operational costs, all of which will dictate how much data to store, where to store it, and on what level the data should be stored and managed. The ever-changing and complex environment in which the agricultural sector operates and in which an LIS has to function effectively therefore requires a process that is results- and future-oriented. These elements are the crux of the concept of strategic planning.

Hence, the major objective of Chapter 4 is to relate strategic planning and thinking processes to LIS development in an effort to enhance effectiveness. Use is made in this section of the experience of New Zealand concerning the practical application of strategic planning and thinking processes within local government. An attempt is subsequently made to highlight, in general terms, influences that will affect the supply and demand of information stored in an LIS. This assists in setting the stage for the search for a principle that will determine appropriate LIS developmental dimensions.

4.2 Concepts and nature of strategic planning

There are numerous definitions of and approaches to strategic planning. Most of these have a core emphasis on the need for organisations to better understand their operations and the reasons for their existence. Strategic planning, however, is about the future and thus involves accounting for uncertainties. Given alternative visions of the future, thinking about and attempting to control these are therefore important components of planning (Galliers, 1991: 68). In an analysis of strategic thinking, Mintzburg (2003: 1-8), identified three characteristics of strategic thinkers, which include seeing ahead and behind, seeing beside and beyond, and seeing above and below, where seeing above implies being able to see the true bigger picture.

In this context, strategic management becomes an issue of envisioning and realising the future (Roux and Du Toit, 2003: 1-5). The Strategic Planning (SP) Handbook (2006: 1) defines strategic planning as a tool for organising the present taking into account projections of the desired future. From all of these analyses, it is clear that the essence of strategic planning entails finding ways of changing mindsets so that managers or planners can anticipate futures and prepare for them; a process commonly referred to as strategic thinking.

4.2.1 *Strategic thinking as a prerequisite for strategic planning*

Strategic thinking means asking the question, "Are we doing the right thing?" It also requires a purposeful understanding of the environment and creativity. Strategic thinkers are those people with the ability to link past, present and future issues and make sense out of the gap between today's reality and intentions for the future.

To think strategically, key members of the organisation must be actively involved and committed to strategic planning. Their combined knowledge and reflections should drive their thinking into the future. Hence, Mintzburg (1994: 291) states that, "Such thinking must not only be informed by the moving details of action, but must also be driven by the presence of that action". Strategic thinking involves looking at each part of the organisation and the thinking process, "…not as the sum of its specific tasks, but as a contribution to a larger system that produces outcomes of value".

4.2.2 *The strategic planning process*

Strategic planning is visionary in that it seeks to anticipate a future that is both desirable and achievable for the organisation. It allows organisations to perceive what is going on in their environment, to think through what this means for them, and then to act on this new knowledge (Van der Heijden *et al*., 2002: 3). Strategic planning is about studying the future to ensure that the organisation takes the right action now in order to be successful in the future (Ringland, 1998: 51).

Strategic planning is, therefore, a cyclical and ongoing process that is information-driven, rather than a singular event. It is a process of asking and answering three basic questions about the organisation. Formalising the answers to these questions provides guiding principles for implementing future results. These three basic questions are:

i) *Where is the organisation today, and what is its operational environment?* This is the starting point for the strategic planning processes. It involves environmental scanning, which is done internally at the organisation. For emerging issues and to specify trends that describe these issues, it takes into account, first, the immediate area and region of the organisation's operations, second, the entire country in which it operates and, third, the world. In scanning, one is looking for trends and events that could have an immediate or future impact on the institution and its potential. The emphasis is on building the ability to recognise the signs of change that inevitably affect the organisation, an understanding of their significance and a strategy for how the organisation should react.

ii) *Where does the organisation want to be in the distant future*? This implies the need for a clear sense of direction, involving the scope of operation, a mission statement and specific goals and objectives. A crucial step in strategic planning is deciding on what question(s) need to be answered about the future. A useful starting point is exploring the understanding and perceptions of key management figures. Understanding their perceptions and unlocking their strategic thinking is key to strategic planning processes. Asking the right questions for a specific area of interest over the relevant time scale can help enhance their strategic thinking.

iii) *How will the organisation achieve its goals*? This involves developing specific organisational models for achieving specified goals and meeting resources needs, including making necessary allocation of doing this. Understanding flaws in thinking, such as group-thinking, personal/interpersonal conflicts, a predetermined thinking culture, and limited thinking or the inability to think out of the box, all of which act as barriers or bottlenecks to achieving goals, is an important part of continuous strategic planning processes.

4.2.3 *A strategic vision of the development of LIS*

A strategic vision is a common framework of reference within which information can be organised to enable managers to know what signals to look for, against the 'noisy' background of the organisational environment. Here, the concept of formulating a strategic vision is described as needing to satisfy three conditions, namely:

i) A clear and explicit rationale for LIS design and development must exist, focusing on building effectiveness by building a reservoir of potentialities.

ii) A system for dominance, expressed as a commitment to excellence in a number of capabilities (more than two, less than ten), perceived as such crucial factors for success that their importance tends to override everything else, is needed.

iii) Coalesced into a unique combination, the abovementioned are then expressed as a strategic vision of what LIS the organisation wants to develop.

An example of the processes of developing a strategic vision is provided here. It highlights how Land Information New Zealand in 2004 attempted to formulate its geo-spatial information as a strategic vision, in terms of the aforesaid conditions for formulating a strategic vision. In defining the principles and values for guiding the development of their geo-spatial information strategy, New Zealand specified five principles, which stipulate the following:

i) Geo-spatial information should be collected once and shared by many.

ii) The acquisition of geo-spatial information should be easy.

iii) Relating to its area of application, geo-spatial information should be easy to understand and interpret.

iv) It should be easy to combine geo-spatial information from different sources.

v) Geo-spatial information required by government should be readily available under conditions that do not require extensive coordinated effort

Based on these five principles, the vision for the New Zealand government's geo-spatial information requirements was described as needing to increase the availability, accessibility, shareability and usability of trusted geo-spatial data to ensure the following:

i) New Zealand's safety and security.

ii) The growth of an inclusive, innovative economy for the benefit of all.

iii) Protection and enhancement of the environment.

iv) Consideration of potential intervention options that would define the key geo-spatial building blocks for achieving the proposed vision. These included the existence of important data sets and the establishment of priorities, accessibility to exiting geospatial resources, the interoperability of geo-spatial information resources from various sources, and the coordination and governance of geospatial information.

The linkages between these building blocks are represented diagrammatically as shown in Figure 4.1 below.

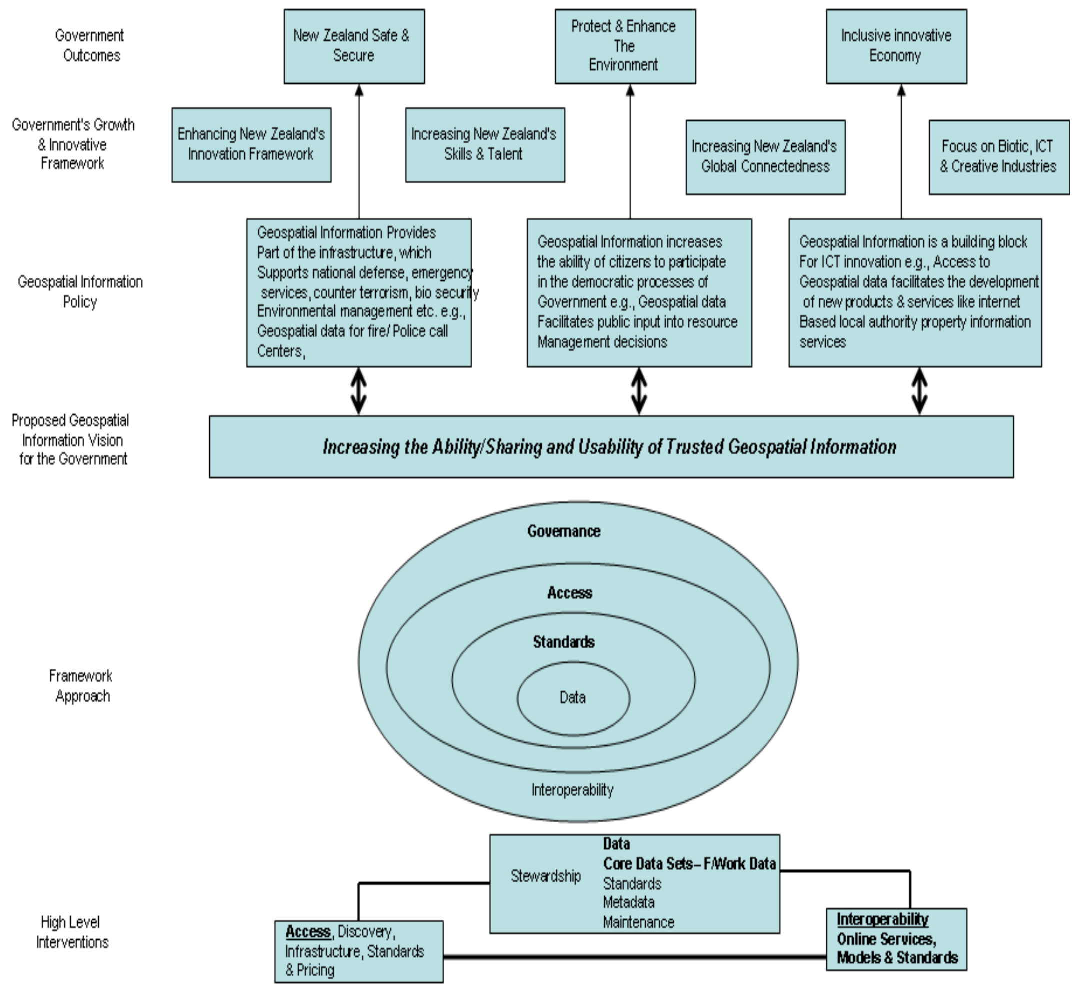

Figure 4.1: Linkages between proposed Geospatial Information Intervention and Government Outcomes
Source: Geospatial Strategy – Discussion Document, www.linz.gov.nz.geospatial

In countries such as South Africa, Thailand, India and Latin America, where a few agricultural research and development information systems have been put into operation, concerns about coordination and standardisation of content and access are still important. In developed countries, such as Germany, which have passed through the infrastructure and operational phases, coordination and control of information available in their LIS are still important issues.

4.3 Overview of important environmental forces that can influence the future development of LIS

Environmental forces that can influence the future development of LIS are those forces that will shape and push the supply of information and resource demand patterns over time. These forces, collectively or independently, have a direct or indirect influence (Figure 4.2) on the nature and quality of data to be stored to satisfy long-term information needs, and on the demand for information for resource use planning. Such forces can be classified as economic, social, political, legal-institutional, technological/physical-biological, depending on their origin and nature of influence (Figure 4.2). They can also be classified as being direct or indirect.

Direct and indirect influences that will affect the future development of LIS are given in Figure 4.2. In general, direct forces are influences that affect processes and can be identified and measured. They are usually linked to another set of indirect influences.

Indirect influences operate more diffusely, often by altering one or more direct influences, which in turn cause changes in the future demand for and supply of LIS services. Both types of forces can further be classified as either those that influence information supply or those that influence the derived demand for information.

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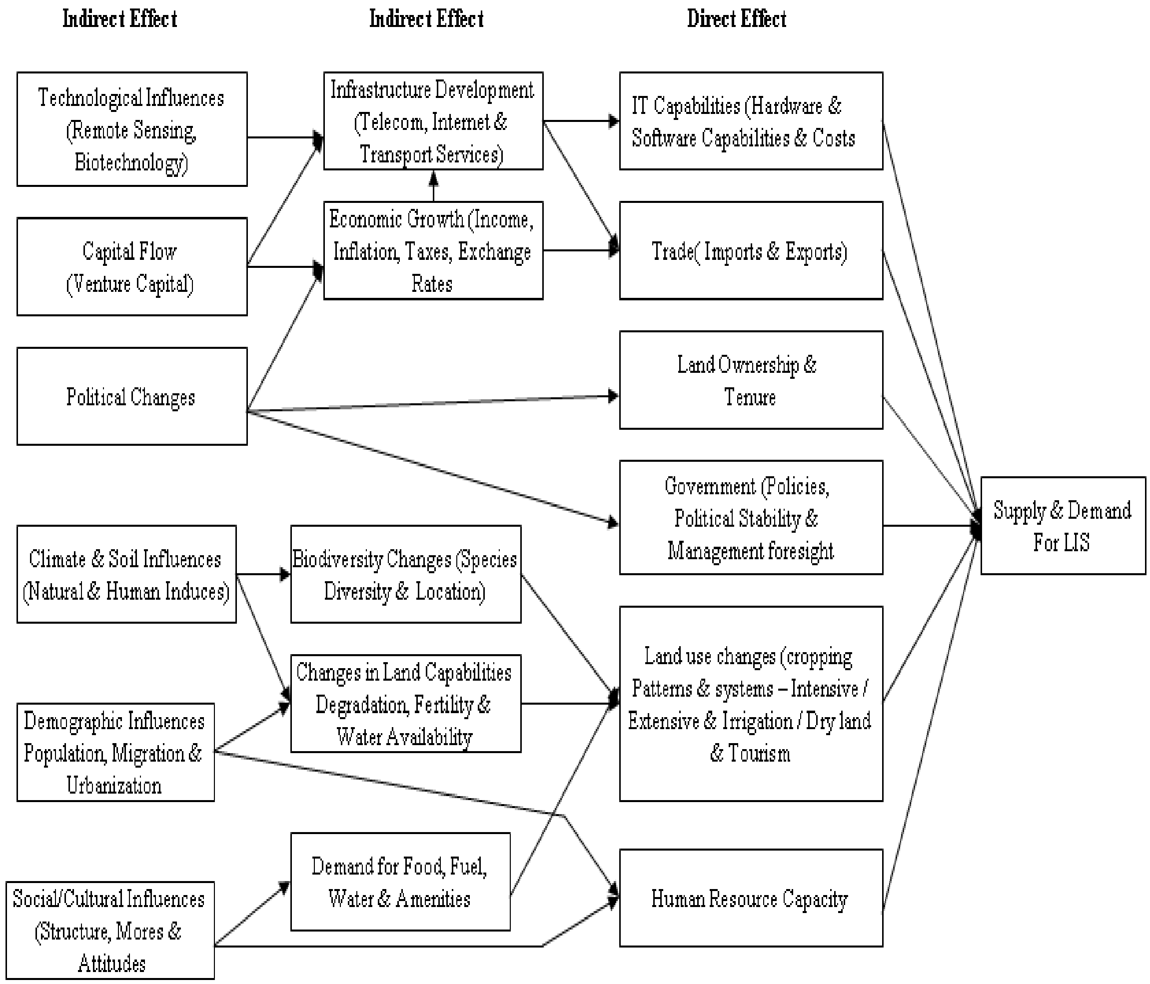

Figure 4.2: Direct and indirect forces that will influence future supply & demand of LIS services

4.3.1 *Influences that affect information supplied by an LIS*

Influences that affect the information and data to be supplied by an LIS define the quality, quantity and cost of this information and data. They also define the level of sophistication of a given LIS in terms of human resource requirements, including data interpretation abilities. Two broad-based influences of this nature are identified here as follows:

i) *Technology capabilities and costs*. Examples of these include advances in LIS hardware and software, remote sensing technologies, telecommunications, and weather monitoring technology. Advances in hardware and software capabilities that allow for increased storage capacity and data processing speed mean more data attributes can be stored and processed within a given bite at reduced processing time and cost. Improvements in telecommunications also improve interoperability and availability of data from various sources. Remote sensing equipment such as GPS, which is more accurate and specific, provides high quality spatial data. All these technological factors collectively define the overall future cost of information and data to be supplied by an LIS.

ii) *Human resource capabilities and costs:* The type and quality of LIS human resource skills (both providers and users) available have a direct influence on the quality, cost and level of LIS/GIS sophistication. Depending on the existing and future trends in levels and quantities of IT skills, an organisation will be inclined to develop an LIS of a given level of sophistication and cost. The availability of low-level skills would attract a relatively unsophisticated LIS that is less costly in terms of staff retention and remuneration and LIS software and hardware costs.

4.3.2 *Influences that affect the derived demand for LIS information*

This set of influences will affect the derived demand for information and data to be stored in an LIS for planning usage of the land resource by defining the data and information types, quantity, resolution, scale and location. Such influences include the following:

i) *Land use changes,* which include changes in land use (to alternative uses, e.g. a switch from use for livestock farming or cultivation to use for game farming or agri-tourism), cropping systems (intensive/extensive, irrigation/dry land) and cropping patterns switches in locations and production sites). Shifts in these factors will affect the type and amount of data to be kept in an LIS and the derived demand for information for, among other things, conservation planning purposes.

ii) *Land tenure and ownership.* Land tenure is the system of rights and institutions that govern access to and use of land. It is the principle factor determining the way in which resources are managed and has an influence on the intensity and level of investment for particular purposes. Hence providing security of tenure often implies intensified agricultural production and better natural resource management and sustainable development prompting for certain types of data acquisition and storage

iii) *Trade.* This includes aspects of, imports, exports, niche markets. Niche markets are increasingly becoming important a form of defining the competitive edge of a nation. Such markets requires a unique set of data and to maintain it competitive edge

iv) *Governance*, particularly good governance is a function of policies, political stability and management foresight. These form the basis within which aspects of land use, land tenure and trade (international, and regional) function.

It is important to note here that, the more attributes there are the more the overall cost of LIS development and functioning will be.

4.4 Conclusions

Chapter 4 focused specifically on the principle of strategic planning and how it applies to LIS processes. Strategic planners were defined as those individuals who can 'link past, present and future issues, and make sense out of the gap between today's reality and intentions for the future'. Emphasis was put on the need to formulate a strategic vision that would act as a benchmark for directing the thinking processes of LIS planners. Here, standardisation, coordination, and coherence in data and information collection and storage are still seen as important issues to be addressed in both developed and developing countries.

For an LIS to be effective, planners should emphasise identifying the most relevant areas of application for which data needs to be collected, determine the relationships between these areas of application, and then make sense out of these and what they mean to their organisation.

However, shortcomings in most information systems are a consequence of the isolated views held by planners regarding the issues and solutions at hand. One formal way of introducing strategic envisioning into LIS design thinking processes is through a method called systems analysis (SA). This methodology provides a clear logical model of perceived reality, or a part of the real world, and of why and how components of this perceived reality are related. An elaborate discussion of this concept and its application to LIS are given in Chapter 5.

CHAPTER 5:SYSTEMS ANALYSIS

5.1 Introduction

Chapter 4 identified issues of data standardisation, and coordination and coherence of information providers as major issues of concern in LIS effectiveness. These issues are further compounded by a lack of strategic vision among land use planners and LIS developers. This is because human beings are not able to identify complex systems and their interrelations without following a formal systems analysis process.

Hence, a major area of focus in Chapter 5 is the introduction of the systems analysis concept as one option for assisting in enhancing LIS effectiveness. Systems analysis achieves this by providing a logical framework for those issues that are relevant in the past, present and future, and by relating these to each other. In this study, a systems analysis concept that utilises entity relationship diagrams (E-RD) provides a point of departure from the use of environmental scanning which utilise the environmental hexagon and normally used in strategic planning processes.

Systems analysis is used here as an analytical tool for selecting relevant entities and data sets in developing an effective LIS. Key to this selection of entities and data sets is the use of a mind-mapping exercise that is similar in terms of features and structuring of entities to brain storming and the environmental hexagon respectively.

Mind mapping is a critical first step in systems analysis in that it encourages coordination and coherence, both by and among LIS information and data providers, thereby reducing isolated views and systems that are developed within departments along organisational lines. These solutions arose because of shortcomings in most information systems that originated with isolated views of the problems to be solved. With systems analyses, a logical structure showing which issues (components/ dimensions) are relevant in the past, present and future and how these are related to each other is provided. In particular, the modelling processes that utilise E-RD form a convenient way of visualising the relationships between the various entities of a given problem or goal. These E-RD modelling processes influence decision-making by employing a holistic approach to looking at processes and activities that solely or collectively define a given goal or problem.

In this study, food security serves as a theme to illustrate the central statement that LIS lacks coherence and a strategic orientation. As a specific instance of this, South Africa is used here as a case study for prescribing trends that should be highlighted in food security processes. While mind mapping is used here to give a picture of food security as the central theme of this study, business process modelling (defined later) is central to entity and attribute identification. It is also important to add the time dimension as a factor that is critical to all identified attributes and entities. This is done to emphasise the fact that, by nature, all entities and their attributes may change over time.

While systems analysis has been selected here as an analytical tool, there are various other ways of representing information models, for instance, EXPRESS-g (Schenck and Wilson, 2003: 33), Unified Modelling Language (UML) (Booch *et al*., 2003: 38), Entity-

Relationship (ER) (Chen, 2003: 9), DAPLEX (Shipman, 2003: 38) and Nijssen's Information Analysis (Nijssen and Haplin, 2003: 38). Others include the IDEFO, IDEFI, IDEFIX and IDEF3 - (Lin *et al.,* 2002: 22). These can be divided into graphical (e.g. ER, IDEFI, IDEFIX, EXPRESS-G, and UML) and lexical (e.g. DAPLEX) techniques. The strength of the graphical techniques lies in their ability to visually display the structure of the model. The ER, IDEFI and IDEFIX information modelling techniques, for instance, all apply entity-relationship diagrams to identify:

i) the information collected, stored and managed by an organisation;

ii) the rules governing the management of information;

iii) local relationships within organisations reflected in the information; and

iv) problems resulting from lack of good information management.

5.2 Some features critical to the application of systems analysis

The relationship between data, information, knowledge and decision-making needs some explanation in order to differentiate data sets from entities and attributes in utilising systems analysis for identifying relevant issues. This is the subject of Section 5.2.1. There is also the need to have a clear understanding of what is involved in information management systems processes, which is a topic of Section 5.2.2. Familiarity with this concept will foster a clear understanding of what an LIS would need to communicate to system users. Section 5.2.3 utilises the background given in Sections 5.2.1 and 5.2.2 to show the relevance of looking at information processes, using South Africa as a case study.

5.2.1 *The relationship between data, information, knowledge and decision-making*

Figure 5.1 illustrates the relationship between, data, information, knowledge and decision-making. This relationship is important in making decisions regarding what data to collect, store, and process in order to address a particular problem or goal. Collecting and storing unnecessary data will increase an Information System's (IS) operating and development costs. Data is defined as symbols or signs that, based on the rules of interpretation, can represent information (Kjellberg, 2003: 33; Schenck and Wilson, 2003: 33). Data is therefore merely a representation of a concept, and it is the concept that brings meaning to data.

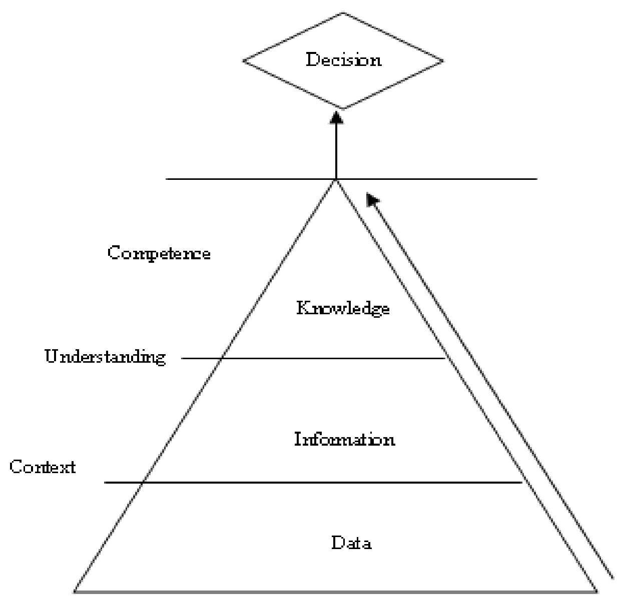

Figure 5.1: The relationship between data, information, knowledge and competence
Source: Nielsen, 2003:35

Information is interpreted from data that has a particular relevance to the receiver; knowledge, on the other hand is a perspective relating to information (Hicks *et al.,* 2003: 33). The ability to use acquired knowledge and information to make appropriate decisions and take certain actions requires competence and the will and drive to make a change (Nielsen, 2003: 35).

Appropriate data, that is, data of the right quality, quantity and resolution is needed as the basis for generating information and knowledge. Where there are no formal rules for interpreting and coordinating data, the same data can be interpreted differently by various disciplines or organisations, even where it is meant to address the same problem or goal. Coordination and a set of rules are therefore absolutely necessary if the interpretation of similar data sets has to yield the same information and knowledge for users of varying levels of understanding or from different disciplines.

A third element introduced in Figure 5.1 is that of competence, which is embedded within the concept of human skills. Competence requires that individuals involved in interpreting data and generating information and knowledge possess a particularly high level of interpretive ability. Human resource development, therefore, becomes a key connecting factor in generating information and knowledge for appropriate decision-making. This was identified in previous sections as one of the limiting factors in the effectiveness of LIS, and it is an issue of concern in both developed and developing nations

5.2.2 *The need for information modelling in communication*

Communication deals with how best to exchange information and thus relates to the interaction between people within and between organisations. Communication therefore relies largely on personal communication skills. However, not knowing what to communicate and where to find the information to communicate may complicate information management.

By nature, information modelling helps to make complex systems more understandable. Modelling the information needs for food security planning is an example of addressing such a complex systemic problem. This is because the data and information used in the communication and planning processes of the various activities for achieving food security, for example, usually come from different disciplines, and quite often this data and information differs in terms of terminology and concept, and the manner in which it has been processed.

In an interface between, for instance, food availability and the attainment of food security, the planning process would entail dealing with problems relating to managing information regarding, for example, domestic agricultural production, imports, commodity price trends, input/output resource needs, and distribution processes. This would result in complexities in data collection, storage interoperability and interpretation.

These issues can be addressed if there is a good understanding of: (i) the activities involved, (ii) the data needs for the different activities, and (iii) processes governing how information within and between activities are related. Information models provide a formal way of defining both the concepts and terminology for such a purpose and thus help address communication and complexity problems. This is done by creating a common understanding of the way data and information should be used by various disciplines within and between organisations.

5.2.3 *Information management systems processes*

As indicated in Section 5.2.2, information models provide a formal way of defining concepts and terminology for the processes and activities involved in solving a given problem. In general, the processes involved in an information management system can be represented as in Figure 5.2 below, subject to the interpretations of Section 5.2.1. It is necessary to indicate right at the beginning that, as one moves from data to wisdom the complexity in information management processes also evolves from low to high in terms of both technological and personnel needs.

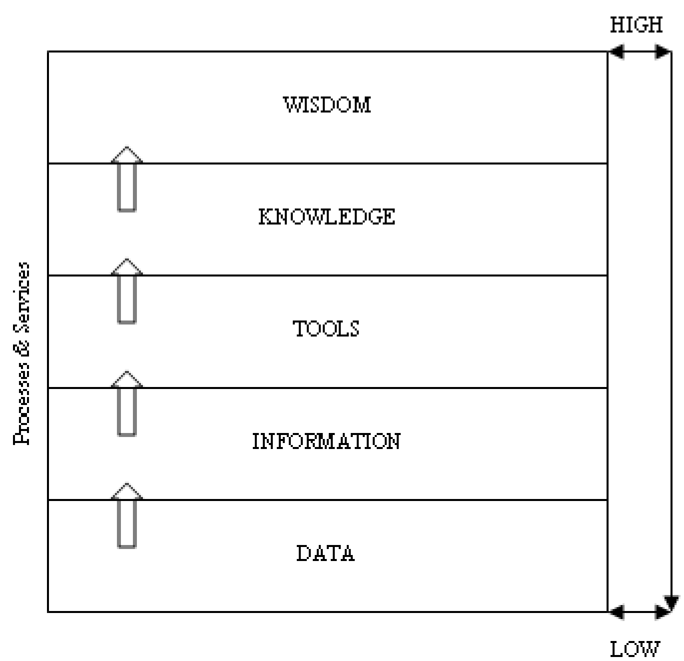

Figure 5.2: Processes in Information Management

This is because, *Data* tells us what is, where and how much of it there is. *Information* is analysed data (value adding) that expresses for instance a trend in the form of a downward or upward, normal or linear distribution, *Tool* refers to the analytical artefact or mechanism used for developing scenarios, e.g., what the result of the continuation of a particular trend will be. Here, one develops 'What if?' questions. *Knowledge* implies the ability to do certain things and thus indicates perspectives on information. These are the 'How to?', or the 'So what?' questions. For example, given certain scenarios, what do these findings mean in terms of organisational goals or strategies for the future of the country as these pertain to natural resource management? *Wisdom* refers to making decisions once the organisation understands the 'So what?' questions, i.e., "What does the organisation have to do now, given all these scenarios?" Moving from one level to the next (as shown in Figure 5.2) requires certain processes and services, which need to be described, and this description is generally lacking as an aspect of information management and LIS development in South Africa.

5.2.4 ***The need for information process modelling in South Africa***

The inference from Section 5.2.3 is that there is generally a lack of description of processes and activities as one moves from data to information, and from there to knowledge and wisdom. There is a need to have a description not only of the content of the data but also of the processes involved. There also needs to be a common thinking process in the transformation of data from one level to the next.

A workshop for GIS professionals, hosted by the CSIR in collaboration with the University of Stellenbosch, which was held on the 26^{th} February 2005, revealed that South Africa still has a great distance to go with regard to describing the processes involved in information management (IM). While cohesive information management and, storage and manipulation for national, regional, and continental planning purposes, is the domain of the National Spatial Information Framework (NSIF), in reality this mandate is not being fulfilled. Instead, the NSIF has been addressing data issues by describing where certain data is currently located, but it has not been describing the processes involved, for example, how the data is going to be used or interpreted and who is going to be utilizing the information. Also, a description of the methodology involved or the questions that need to be posed in order to obtain additional data/information does not exist in the current NSIF database.

Therefore, what is also lacking in terms of land information management strategies is the framework for asking questions such as, "Is the data currently being collected going to be able to generate sufficient information to answer questions in 20 years time?"; "What needs to be added to this database to allow for future uses?"; and, "Is there a component that could be lacking that would enable users to predict certain things in 20 years time?" A framework or plans to design a framework to enable the posing of these crucial sorts of questions is lacking within NSIF structures.

Therefore, there exists a need in South Africa to begin thinking about what data and processes should link into the metadata system of NSIF framework, as well as what value adding processes would be required to answer certain hypothetical questions about the future. However, it is important to note that such a description of the interactions and processes involved, though critical, is difficult to capture. Semantic Information

Modelling (SIM), referred to here as systems analysis, is used, which delivers a relatively abstract model of a description of the reality of what an LIS is dealing with. The SIM allows for all the objects and data attributes to be identified, bearing in mind that what really changes in the long run are the data attributes.

Another example of a lack of process description in South Africa is related to the Food Insecurity and Vulnerability Information Mapping System- Republic of South Africa (FIVIMS-RSA). FIVIMS-RSA is a tool and information source (computer storage system) that assists with national and subnational food security interventions and is meant to provide a *light* monitoring system that complements existing early warning systems. It is embedded in the Agricultural Geo-reference Information System (AGIS), whose mandate is, among other functions, to co-ordinate GIS activities and facilitate ease of access to spatial information in South Africa.

A one-day meeting with AGIS and FIVIMS-RSA officials on the 16th November 2006 indicated that both institutions have achieved a lot in terms of providing the necessary information and data for decision-making within the agricultural sector and for food security (particularly FIVIMS-RSA on the latter). However, the two groups acknowledge that there is a "greater reliance by the majority of South Africans on purchased food as apposed to own food production, which exposes households and individuals to price fluctuations". To this end, a lot of data and information has been collected using various methodologies. Both groups also acknowledge that several approaches have been tried in addressing data collection issues; however, a formal question framework applicable across disciplines was still lacking within the National Department of Agriculture (NDA), with rigidity and disconnectedness being a common practice. Other information obtained from the meeting includes the following:

i) **FIVIMS-RSA question framework**

In order to achieve its mandate, FIVIMS-RSA must address a number of questions, which include the following:

- Who are the food insecure, and where do they live?
- What is the nature, frequency and degree of their food insecurity?
- What is the nature of their livelihood systems, and what kinds of constraints are they experiencing?
- Who are the vulnerable and where are they located?
- What is the nature of the coping strategies of the vulnerable in response to these risks, and how effective are these coping strategies?

These questions are quite relevant and offer a good description of the prevailing food security issues, but they lack strategic orientation. Answers to these questions relate to some of the issues indicated in the mind mapping and E-RDs in this chapter; however, these will not show trends and the future implications of the changes suggested in the latter part of this chapter. Answers to these questions will also not show the relationships between influences.

A price fluctuation, for example, is just one element of access to food, which is a complex phenomenon that comprises numerous other elements, such as, poverty, income, and infrastructure development. The magnitude of the individual effects of these factors on access to food will also differ and may not all occur at the same time. In order to fully address food security issues now and in the distant future, a strategy-oriented question framework is needed, as is illustrated later in Chapter 5.

ii) **Integrated food security and nutrition program**

The 1997 discussion document of the Food Security Working Group illustrates the food security challenges in South Africa and gives a good representation of important issues to food security in general (Food Security Working Group: A discussion document 1997: 18-20). Major factors in food security identified here include; nutrition and food safety, food production and trading, social safety and food emergency. These are also highlighted in the mind mapping and E-RD concept in this chapter.

These issues are usually addressed by different organisations, for example, nutrition and food safety is the responsibility of the health department, while food production is the responsibility of the agricultural department. Within the food production and trading sector, there are both internal and external factors with short- and long-term perspectives. There is currently a lack of coherence between the various entities involved in food security, and hence this indicates an important need for the existence of the FIVIMS-RSA programme.

Though all these entities affect food security in one way or the other, the program does not indicate the interactions and dependencies of these parties. This is important in that action taken by one may have spill-over effects on the other or may require that certain facets have to be in place before action in relation to another can be taken. The issue of capacity building is a precondition for matters such as information management and food production.

5.3 The principles of meta-information and semantic-information modelling

The ultimate goal of information modelling is to formulate descriptions of real world information so that it may be processed and communicated effectively, without the necessity of knowledge concerning its source and without the need to make any assumptions (Schenck and Wilson, 2003: 38). Hence, in an organisation such as the NDA, it is important that individuals or groups of individuals create the same knowledge from the same data and information. This is possible only if these individuals or groups of individuals have a common pre-existing understanding of the informational elements (i.e., structure, context, measure, and rules of interpretation).

By definition, an information model provides a formal way of presenting these informational elements, as it defines the data that *represents* the information, the relationship between data sets, and the rules for interpreting the data (Nielsen, 2003: 7). Information modelling thus facilitates a common understanding of the processes involved in the transformation of data into information and related knowledge for achieving set goals. Organisational functions, the activities a business undertakes, and the kind of information it needs to successfully engage in these activities can be defined in a process called business process modelling (BPM).

With semantic information modelling, which utilises E-RD modelling techniques, business processes are defined. Information modelling is understood to be one of the functions of the food security programs within the NDA. Such a process-oriented view recognises the fact that organisational functioning are often closely connected to the interrelatedness of decision-making and business flows (Kätsch, 2003: 11), and this facilitates the development of a coherent information system that avoids the problem of rigid function-related systems that have difficulty in adapting to changes over time. This is elaborated on in Sections 5.3.1 and 5.3.2.

5.3.1 *Business process modelling*

In this section, business processes should be understood as referring to a sequence of activities, functions or tasks that lead to a well defined operational goal. Time is therefore a critical factor, as each activity may occur at different times and the intended outcome of an activity may change in the way it influences the ultimate goal. Each activity may be viewed as a subprocess that utilises data, knowledge, information or material to achieve a specific goal. BPM is thus a discipline for defining business practices, processes, information flows, data stores and systems and is an important tool in understanding the activities a business undertakes and the kind of information it needs to successfully engage in these activities.

BPM applies E-RD modelling techniques to construct an ideal representation of interdependent entities that together form the business process in terms of either the current or future desired state. The object of BPM is to define entity relationships in terms of inputs, outputs, mechanisms and controls. Entities are the things, real or conceptual, that processes manage and manipulate. A process, however, is a specific ordering of work activities with clearly defined inputs and outputs – externally determined by user requirements.

A business process often begins when an internal or external 'thing' initiates an event to which the business or organisation has to respond determined by resource needs. The business process model then traces the actions performed (activities undertaken) in an effort to respond to that event (achievement of a goal i.e. the response). Data and information are needed in order to carry out these activities. Such a representation of activities assists in assessing the potential benefits of information technology to an organisation. For illustrative purposes, the terms *event*, *activity* and *response* are defined below (Nielsen, 2003: 29):

i) **An *event*** is something that happens instantaneously and has an effect on another thing, at a particular point in time, e.g., the incidence of famine in a given year and in a given country to a defined group of people.

ii) **An *activity*** describes what is done when an event occurs. It is a set of action that, over time, makes a change to the impact of an event, e.g., importing food when famine occurs.

iii) **A *response*** is the output produced when an activity is accomplished. It is a specific activity triggered by an event, e.g., food availability through imports in a famine-stricken country.

In this context, events, activities and responses form business processes whose locus can be traced in order to yield workflows, which need to be supported by the data and information stored in an LIS. The term business process, therefore, denotes any set of activities that together achieve some desired goal, in this case, food security, regardless of whether these processes are inside or outside of the organisation, in this case, the NDA-South Africa. Such activities generate and use data and information, which need to be identified, collected and stored in an LIS. Therefore, business processes defined in this context comprise networks of workflows that are in most cases interconnected.

Modelling each workflow, using business process modelling, can therefore assist in identifying bottlenecks, resources, commitments not being achieved, and possible means of optimising processes. To describe the business under consideration from an information perspective, it must be scientifically broken down into its fundamental functions and transactional components in a process called business information modelling (BIM).

5.3.2 *Business information modelling*

Business information modeling is a way of defining the major business functions of an organization which is often divided into primary and support functions. It therefore serves as a framework for documenting organisational business processes which are quite often associated with the definition of the data, or metadata, that the organization needs to execute the business processes, and the data that is produced by these processes for use by others.

In this context, BIM describes the important entities needed to define a study area in a business perspective. It is based on information engineering techniques, and provides a structure for describing the business under consideration from an information perspective. It seeks to improve information systems development processes and effectiveness by scientifically breaking a business down into its fundamental functions and transactional components, thereby enhancing accuracy in the identification of information processing requirements. BIM therefore provides an understanding of the flows of information into, out of, and within the organisation, thus depicting business functions and information needs in the context of its environment. Once the business processes and supporting information requirements have been identified, Data Flow Diagrams (DFDs) can be used to represent data acquisition, transformation and storage, and the information delivery processes within an information system. DFDs make use of External Entities, Data Flows, Process and Data Stores to achieve this.

5.4 The use of business process modelling and business information modelling in identifying data and information needs for LIS development

The starting point for BPM and BIM is to define the business process of the organisation for which the Information System (IS) is to be developed (Kätsch, 2003: 11). In doing this, one should first aim for a relatively high level of abstraction of the information model for which the logical structure is to be described (Figure 5.3). This implies stating as much detail as possible regarding the problem to be addressed to allow for individual functioning and data model development. To avoid complexity, and to ensure flexibility in a system's application, the model is usually designed at different levels of abstraction. In principle, these models serve as task and flow supports and to describe organisation-related aspects. As with entity-relationship diagrams (Chen, 2003: 9), such a representation forms a convenient way of visually depicting the objects and their relationships within the model.

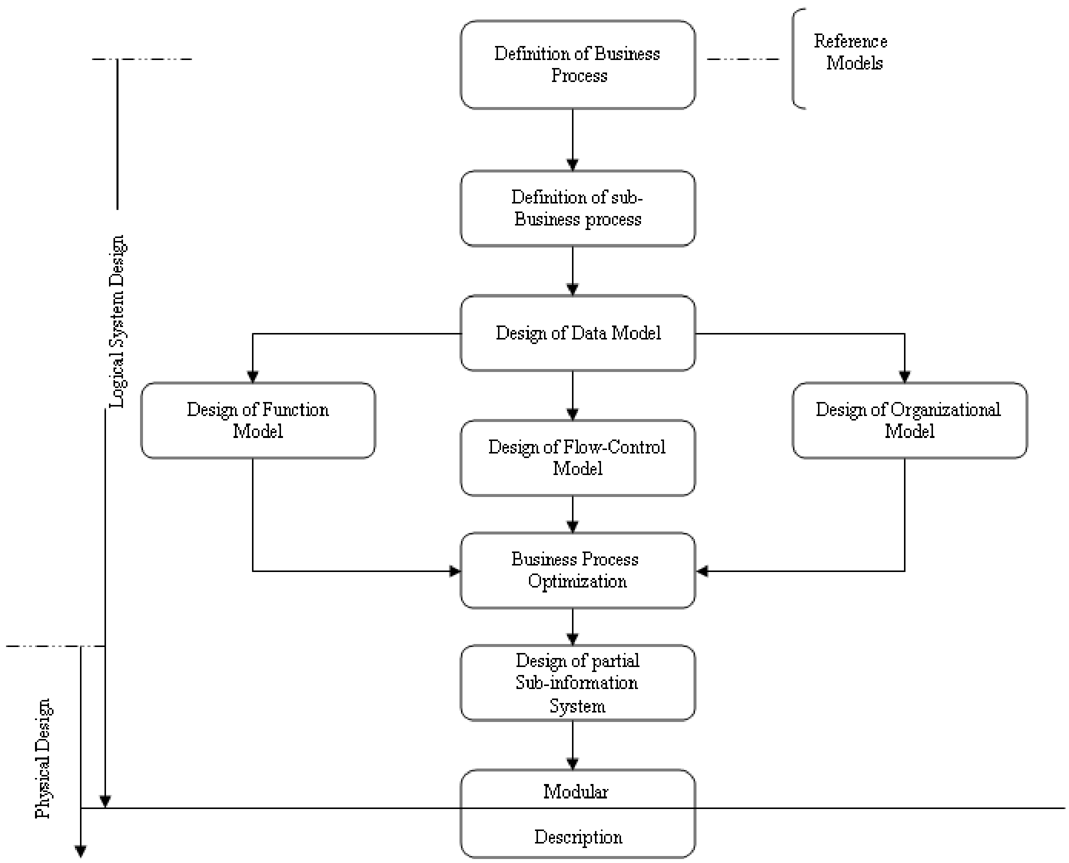

Figure 5.3: The process-oriented design of forestry information system, Kätsch, 2003:.12

Each aspect forms a process-related model whose interrelations can be combined to form flow control models represented by means of procedure chain diagrams (Figure 5.4, below).

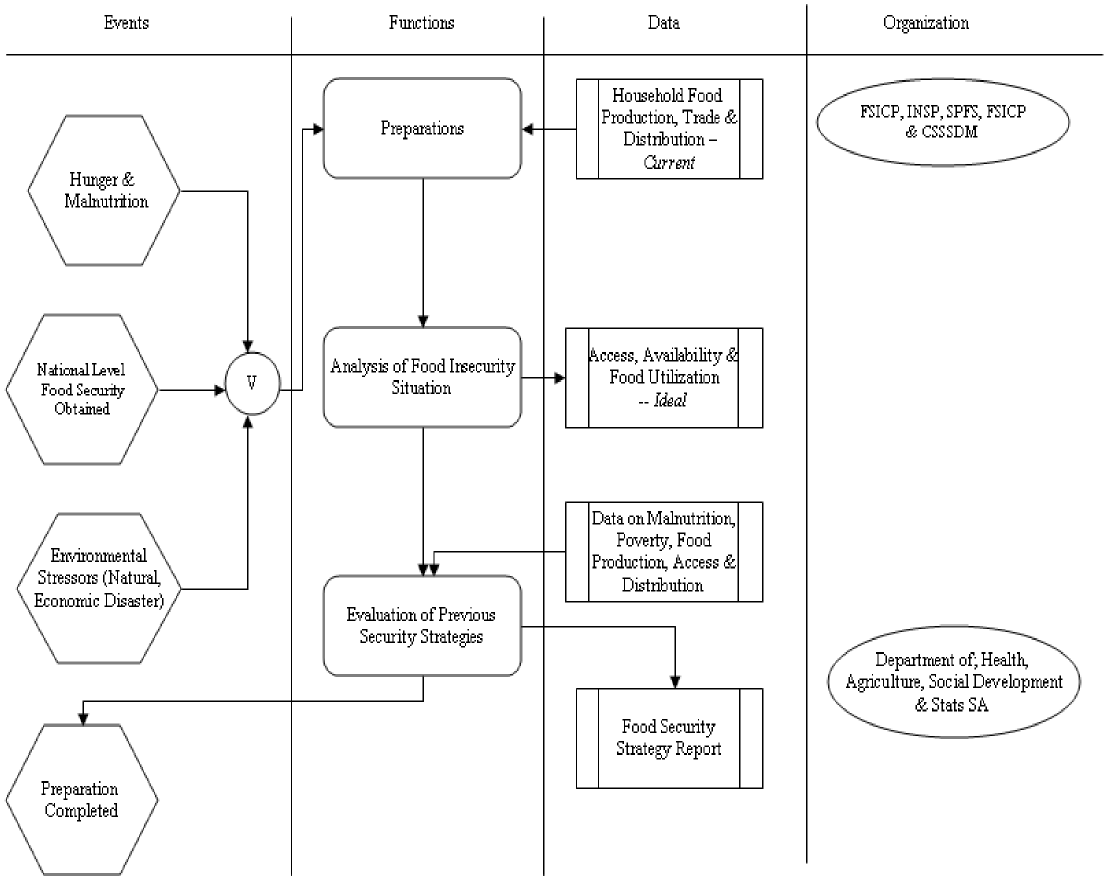

Figure 5.4: Procedure chain diagram representing the business process "Improved Household Food Production, Trade and Distribution". Adapted from Kätsch, 2003:13, unpublished paper.
Note: FSICP = Food Security Information & Communication Program, INSP = Integrated Nutrition & Safety Program, SPFS = Special Program for Food Security, FSICP = Food Security Information & Communication Program, CSSSDM = Comprehensive Social Security System& Disaster Management

The procedure chain diagrams form a platform for showing how the triggering events are related to data needs, as well as for how the organisation needs to perform certain functions. The database for such diagrams can be modelled in what is commonly known as Entity-Relationship Modelling (E-RM).

5.5 Entity-relationship modelling

Relationship modelling is a very popular method for designing databases (Edmond 2001: 241). The starting point for E-RM is describing 'a relevant part of reality' in terms of entity types (major things/issues) that are related to one another. It is important to note that what one person may see as an entity in its own right may be seen by another as an attribute. In general, if there is a need to collect information about a 'thing', this makes it an entity. In semantical data modelling however, each object of the real or imaginary world would become an entity even if no data are stored for it.

Entities can be further refined to show associated attributes. In the agricultural sector, for example, entity types might be farmers, farms, crops, and agricultural land. Relationships that exist between these entities may be described as follows:

i) Farmers own farms.

ii) Farmers grow crops.

iii) Crops are grown on farms.

iv) Farms are located on agricultural land.

5.5.1 *Entity types*

In semantical data modelling, each object of the real or imaginary world would become an entity even if no data are store for it. However, in simplistic terms and for clarity purposes, an entity type can be defined as an object on which one wishes to store data. In an accounting application, for example, one would commonly wish to store data on customers, suppliers, products, invoices and payments. Each of these would then be classified as entity types. The decision relating to which entity types are to be included in an E-R diagram therefore depends on the application for which the diagram is to be used.

In E-RM, however, it is important to identify the most important features that comprise entities. The name of the entity type is singular, as this represents one type. An entity is simply one member, example, or element of the entity type. These are usually enclosed in a rectangle, as shown in Figure 5.5, for an agricultural-related entity.

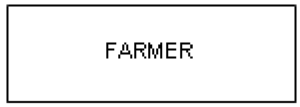

Figure 5.5: The farmer entity type

Another example of an entity in the agricultural sector would be farms (Figure 5.6).

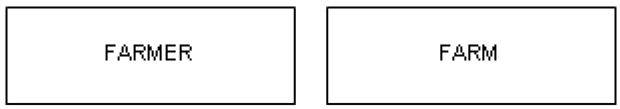

Figure 5.6: Farmer and farm as entity types

5.5.2 *Relationship types*

While in sementical information modelling relationship specifies the link between two entities, in logical data modelling, it defines links between data tables. Relationship types here therefore refer specifically to the link between two entities. In this context, an E-RD therefore consists of a network of entity types and connecting relationship types. To describe the relationship adequately, one needs to state the name of the relationship type and its inverse, the degree of the relationship type that links the entities, as well as the number of entity types involved.

A relationship type (which can be one-one, one-many or many-many i.e., *cardinality*) specifies the association between entity types. There are three symbols to show cardinality. A circle means zero, a line means one, and a crow's foot means many (Figure 5.7). A one-one relationship implies that each occurrence (a single instance of an entity) of entity A is associated with one and only one occurrence of entity B, and each occurrence of entity B is associated with only one occurrence of entity A. Entities displaying such cardinality can easily be merged as they are usually the same.

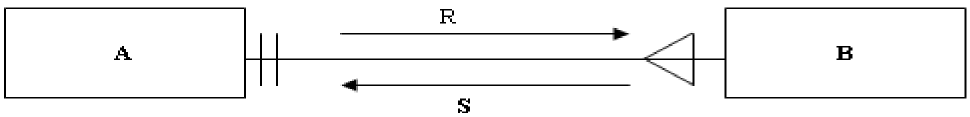

Figure 5.7: Relationship between entities **A** and **B** showing cardinality

Note: **R** relates each **A** to one or more **B**'s
S relates each **B** to one **A** and **S** is the inverse of **B**
R is one : many relationship
S is many : one relationship
R is optional
S is mandatory

A one-many relationship implies that each occurrence of entity A is associated with one or more occurrences of entity B, but each occurrence of entity B is associated with only one occurrence of entity A. These are the most stable relationships and are commonly used in E-RD. With a many-many relationship, each occurrence of entity A is associated with one or more occurrences of entity B**,** and each occurrence of entity B is associated with one or more occurrences of entity A. This type of relationship illustrates how two entities share information in the database structure. An entity relationship data model therefore views the real world as a set of objects (entities) and relationships among these objects.

An important aspect of entity relationships is cardinality. In the previous example (Figure 5.6), a third entity could be a crop (Figure 5.8). The relationship (enclosed in the diamond shape) between entity *farmer* and entity *crop* is shown (Figure 5.8) This figure shows that one (1) farmer can grow many (M) crops and one crop can be grown by many (M) farmers.

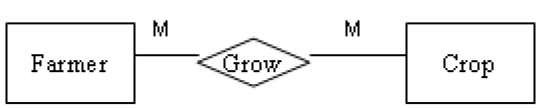

Figure 5.8: Farmers can grow many crops and one crop can be grown by many farmers – displaying many- many relationship

The cardinality of the relationship is represented by the many-to-many (M:N) notation. This relationship between farmer, farm and crop can be shown as in Figure 5.9. However, many-many relationships are not advisable and should be converted to one-many relationships by splitting and forming new entity types from original entities

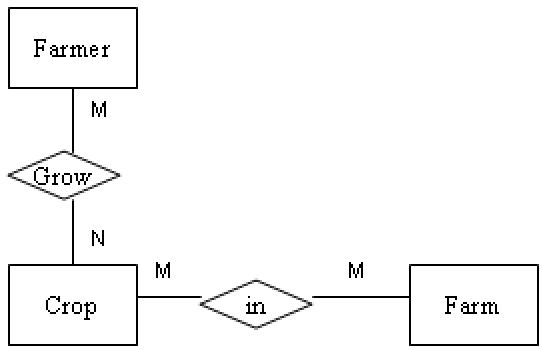

Figure 5.9: The relationship between farmer, farm and crop

.The maximum cardinality of the relationship is indicated by a number (1) or a letter (N, M). It is also important to note that at times some entities can be self-linked. Such a relationship is referred to as being recursive. A recursive relationship, the most difficult to master, relates to situations where entity occurrences have direct relationships with other entities of the same type (such relationships can be 1:M, 1,1 or M:N). A typical example is where organisational units report to other organisational units (Figure 5.10) or in academic institutions, where one course is a prerequisite for another course.

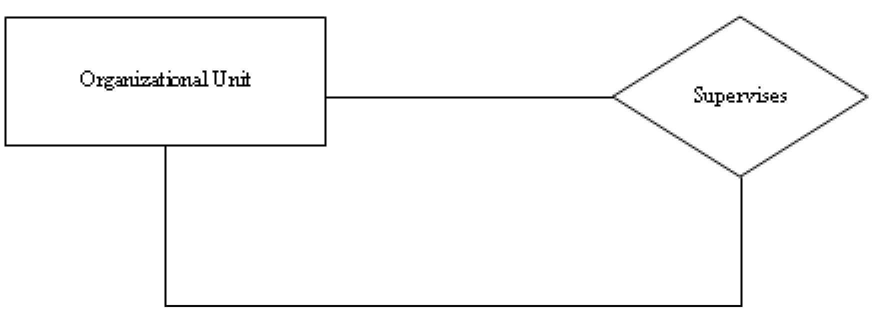

Figure 5.10: An organizational unit supervising another unit displays recursive relationship

The E-R approach, as described above, encourages decision makers to start with the more important issues and to establish their relationships before refining them into related attributes. As stated previously, these relationships can be many-to-many, one-to-many or one-to-one. The different facets or data sets for an entity and its relationship types are described by attributes.

5.5.3 *Attributes*

Attributes can be divided into three types; simple, composite and set-valued (Edmond, 2001: 246). They show different facets details of the entity and relationship types and comprise the data that one may want to keep about each entity within an entity type. Attributes depict the qualities of the entities whose values are stored in the database. These are usually shown as an oval that encircles the attribute for each given entity (Figure 5.11, below). Each farm therefore has a particular name, location and soil class. This is the data about an entity that can subsequently be stored in an LIS.

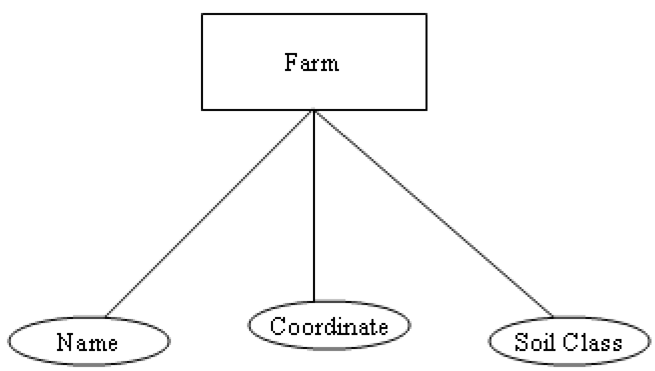

Figure 5.11: Farm attributes

Generalisation: Two or more entities can be summarised under a general term (Figure 5.12). In the context of crop production, wheat, maize, and sorghum, can be referred to as crops or cereals.

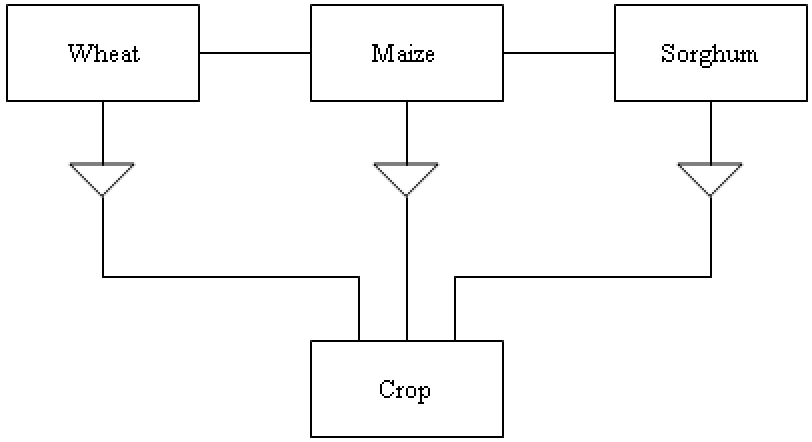

Figure 5.12: Generalization of entities

Entity Aggregation (EA**):** EA is a very important concept for E-RM and information management in general. This is because in many instances (www.msdn.mcrosoft.com/en-us/library/ms978573.aspx);

i) there may be multiple systems of record for the same entity

ii) semantic dissonance exists between data values represented within the same entity

iii) applications may need logical subsets of the data elements tat may not be available in a single repository

In the above context, EA therefore relates to a requirement for integration of information present in different systems or repositories (Figure 5.13a). Automating processes between systems by utilising the EA concept allows for a single consistent representation of key entities which are logical groups of related data elements such as entity type *food availability* (Figure 5.13b). It therefore allows for data that is redundantly distributed across multiple repositories to be effectively maintained by applications as integrated information. This is achieved by introducing an EA layer (*food availability*) that provides a logical representation of the entities (domestic production, demand patterns, and support systems (Figure 5.13 b)

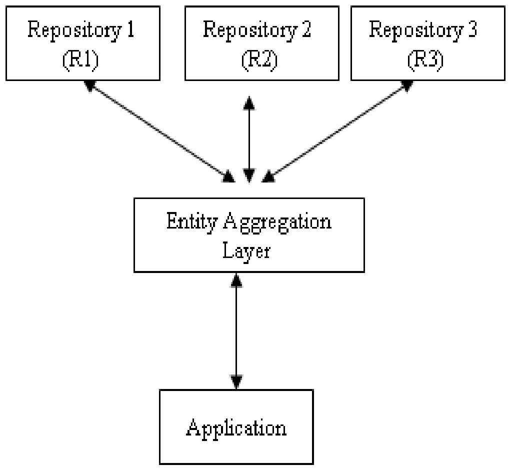

Figure 5.13a: Entity aggregation – repositories
Source: www.msdn.microsoft.com/en-us/library/ms978573.aspx.

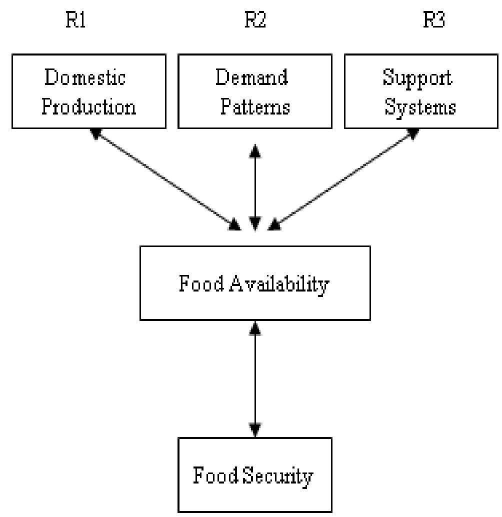

Figure 5.13b. Entity aggregation – food availability

The two concepts of *aggregation* and *generalisation* are important for simplifying complex diagrams.

Database design and data modelling: The data model is the product of a database design process that aims at identifying and organising the required data logically and physically. A data model defines the information needs of the database. The issue of how such information should be used also defines the relationship between items contained in the database. Hence, each entity type gets a relational database table, and each attribute forms one of the fields (columns) within the database table.

5.6 Application of the business process model in developing an entity-relationship diagram for food security in South Africa

As indicated in Section 5.1 there are many other approaches to information modelling, including workflow and enterprise modelling. However, the business process modelling that utilises the E-RM approach is used here because of its process orientation and graphical representation of entities, as illustrated in Section 5.3 and 5.4. Also, the object of this dissertation is to use food security as a means of showing the application of systems analysis in identifying relevant entities for given processes. These define what data and information should be kept in an LIS for it to be effective. By definition, the E-RM can serve this purpose. A simplified illustration of the E-RM in the form of an Entity Relationship Diagram (E-RD), is given further on in Figure 5.18.

Food security is used here as a case study because of the legislative emphasis put on it by the South African government, as well as the challenges it poses for the agricultural sector. The right of *access* to sufficient food (a key component of food security) is enshrined in Section 27 of the South African Constitution, which obliges the State to provide legislation and other supporting measures to ensure that all citizens are able to meet their basic food needs (Integrated Food Security Strategy for South Africa: July 2002: 11).

In response to this, the National Department of Agriculture's (NDA) Integrated Food Security Strategy (IFSS), adopted as its guiding vision, "*the attainment of universal physical, social, and economic access to sufficient, safe, nutritious food for all South Africans to meet their dietary requirements,*" with the overall goal of eradicating hunger, malnutrition and food insecurity by 2015 (Statistics South Africa, 2005).

Household and individual food insecurity however, do exist, mainly due to the inequality in income distribution. About 24% of the population is income poor, with 75% of the poor living in rural areas (UNDP Human Resource report, 2003). Hence it is mainly individual and household food security that are important in the context of South Africa.

5.6.1 *Defining entities, entity relationships and attributes for food security in South Africa*

As stated in the previous section, the starting point in information modelling is a definition of entities and business processes (Kätsch 2003: 11), in this case applying to food security as a goal for the South African NDA. Hence, it is important to look for important features before examining them in detail. To this end, South African policy and food security documents are analysed and used here to illustrate this process. Information from these documents is also used in a mind-mapping exercise (Figure 5.17), which forms the basis for the entity-relationship and event-control diagrams, using specific examples (Figure 5.18).

As defined in Section 5.4.1, entities are the 'things', or objects we seek information on, and these can either be concrete (e.g., person or book) or abstract (e.g., concepts or processes). Some entities are referred to as weak entities. Weak entities are those that are dependent on others for their existence. Therefore, because food security is a concept, entities here are considered abstract, rather than concrete, while weak entities are also featured. There are four interrelated components of food security that apply to South Africa (IFSS 2002: 15) and the FAO's definition of food security. These are (i) food availability, (ii) food accessibility, (iii) food utilisation, and (iv) food distribution. Each of these components of food security is discussed below.

i) Food Availability, which is the responsibility of the Special Programme for Food Security, National Department of Agriculture (NDA): Food availability is dependent on domestic food production, international importation and efficiency of food distribution (Food Security Working Group, 1997: 4). In this context, food availability is affected by input and output market conditions, as well as the production capabilities of the agricultural sector. It thus relates directly to the effective supply and demand of agricultural commodities. To illustrate the latter statement, Table 5.1 compares the 1997 demand for major commodities to the projected demand of the same commodities between 2000 and 2020.

Table 5.1: Growth in food demand for major agricultural commodities in South Africa, 2000–2020 (%)

Year	Wheat	Maize	Mutton
2000	>30	10	20
2010	>50	15	40
2020	90	40	70

Source: Adapted from FSWG, 1997:14 & IFSS, July, 2002:20

Projections for 2020 indicate that South Africa will have to increase current levels of production in order to match projected future demand. This will require a range of policies and support systems, such as technological innovation, managerial upgrading and sustainable farm production (FSWG 1997: 20).

The above account identifies the following four key elements of food availability:

- domestic production (supply capacity)
- market conditions (imports and commodity prices)
- food requirements (demand patterns)
- support systems (policies and distribution systems)

ii) Food Accessibility, which is the responsibility of the Community Development Programme, Department of Public Works (DoPW) and the Department of Trade and Industry (DoTI): This relates to the ability of households to obtain sufficient food for all members at all times, either through production or through exchange (FSWG 1997: 4). It thus relates to effective demand as influenced by purchasing power, consumption behaviour, marketable skills and poverty.

iii) Food Utilisation, which is the responsibility of the Integrated Nutrition and Food Safety Programme, Department of Health (DoH): This concerns the ability to consume safe and nutritious food, It is influenced by intra-household factors (e.g., control over resources, the authority to make decisions , urbanisation, educational levels, marketing skills, norms and beliefs, health care, and behaviour).

iv) *Food distribution*: This is a spatiotemporal element that relates to the equitable provision of food where there is demand.

In their abstract form, food availability, food access, food utilisation and food sustainability, in the context of food security in South Africa, constitute the broad-based *entities types* of food security (Figure 5.14).

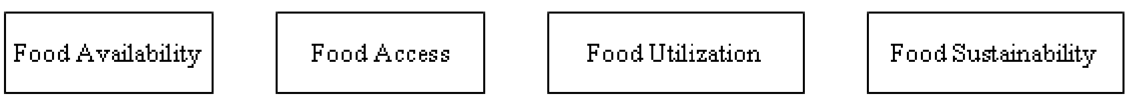

Figure 5.14: Four broad-based entities of food security

In terms of the definition of *business processes,* as discussed in Section 5.2.1, these are also considered processes, as individually they constitute the activities necessary to achieve food security.

Refining Entities: From the explanation given in Section 5.5, the entity type *food availability* is a typical aggregated entity that can therefore further be broken down into weak entities that include domestic production capabilities, market conditions, demand patterns, and support systems, collectively referred to here as the second level of broad-based entity types. Such a subdivision is shown in Figure 5.15.

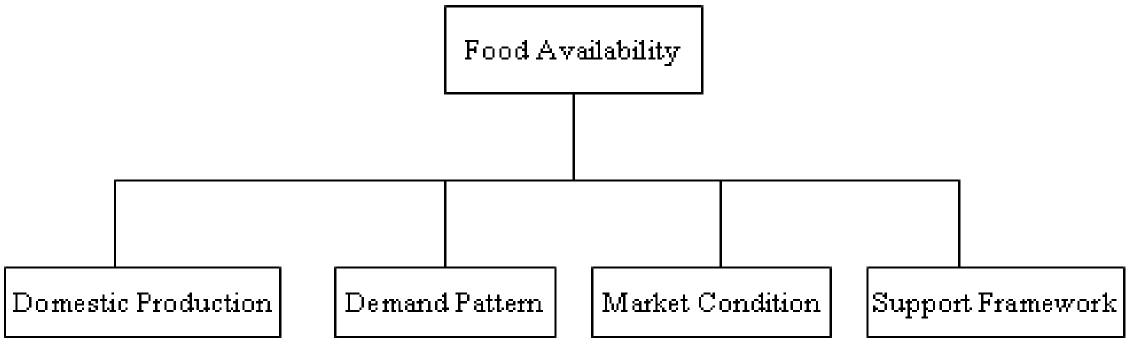

Figure 5.15: Second level Broad-based entity types for food availability

Another set of entity types can be derived by subdividing any one of the above second-level entity types. The entity type *domestic production capabilities,* for example, can be divided into: production factors, investment in research and extension, and infrastructure development (Figure 5.16).

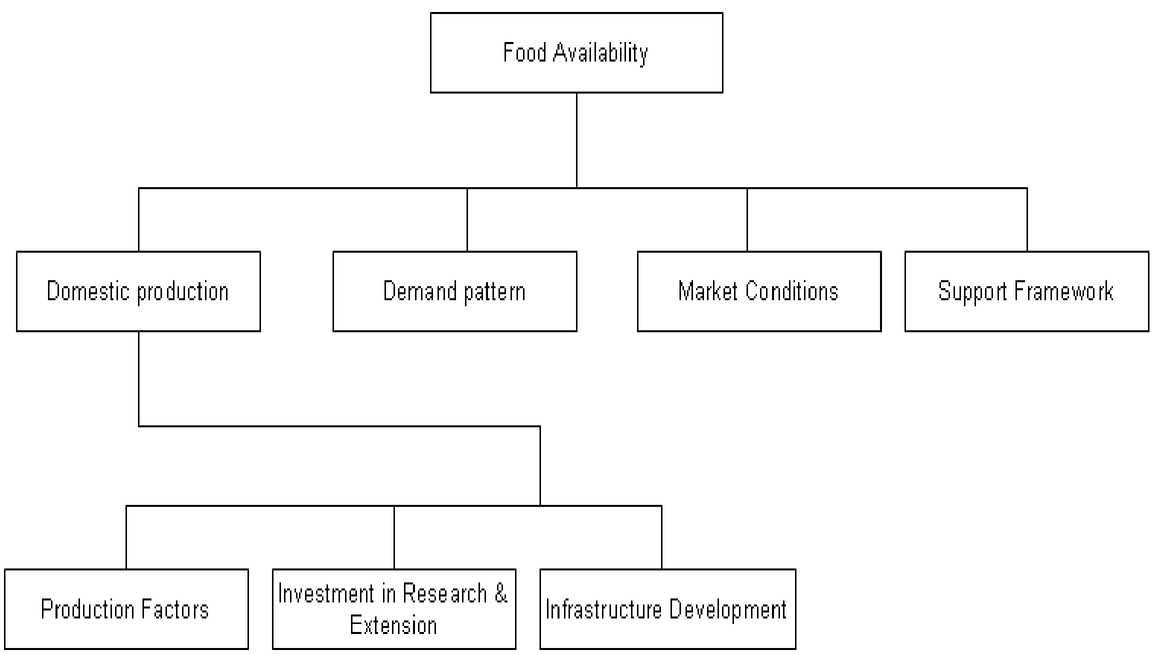

Figure 5.16: Second level broad-based entities

The exercise described above for the *food availability* entity type, is applicable to other broad-based entity types (i.e. food access, food utilisation and food distribution). The next step involves identifying and displaying the relationships between these entities. As illustrated in Figures 5.18 and 5.19, the entity relationship is enclosed in a diamond shape, as described in Section 5.4.2. Before the exercise in Section 5.6.3 is undertaken, it is important that a mind-mapping exercise be performed.

5.6.2 *Mind-mapping exercise*

The mind-mapping exercise of Figure 5.17 is a very important prerequisite in developing entity relationship diagrams and related steps. It is the first step in modelling complex issues or systems and should be performed before the start of the E-RM process. Similar to conventional brain-storming exercises, it does not recognise any relationship(s) between the influences. It does, however, give a broad-based picture of the complex nature of the problem at hand and possible entities that may later be used in the entity relationship diagrams.

In the mind-mapping diagram, it is important to identify entries that are as similar to reality as possible. This can be made possible through interviews, discussions or informal talks with key decision-making individuals, or through accessing policy documents. Previous job experience with the different facets of the problem at hand also serves as a key component of ensuring relevance of the entities considered.

Figure 5.17 is a mind-mapping exercise for food security in general, with particular relevance to South Africa. In this case, key decision-making persons within the organisations indicated in Section 5.6.1 (i.e. NDA, DoTI, and DoH,) should serve as sounding boards to verify the authenticity of the information generated. In the process, policy documents were used as valuable sources of information at national, regional and international levels. Useful sources of information were obtained from IFPRI, FAO, Global Environment Food Security Working Group, and IFSS documents that deal directly with food security issues at various levels.

Rather than only one individual performing a mind-mapping exercise, it is advisable for several people within the different sections of the organisation to produce their own mind maps, which can then be harmonised into one working document for the whole organisation.

From the mind-mapping exercise, factors that will influence current and future food security can be grouped into the following four internal and external categories:

i) **Physical, biological and chemical influences** comprising agricultural land resource, domestic agricultural supply, investments in agricultural research, distribution network development, availability and access to appropriate technologies, conservation and sustainable use of the land resource, land availability and suitability, natural and human induced environmental stressors, and human health and nutrition.

ii) **Economic influences** comprising inflation trends, commodity and food price trends, access to financial capital and credit, income-earning opportunities, market access, assets and wealth accumulation, and the productivity status of resources.

iii) **Socio-political influences,** which include international and national policy regulatory frameworks for food, agriculture, fisheries, and forestry; availability of food aids and food imports; equitable access to natural and economic resources and social services; property rights regimes; coherent social capital; livelihood opportunities; knowledge of food, agriculture, fisheries and forestry; level of vulnerability; cultural preferences; and access to nutritious and safe food.

iv) **Domestic influences** including population pressure, age distribution, gender distribution, rural infrastructure development, and migration patterns.

Through its designated purpose, the mind-mapping exercise enhances coordination and coherence within and between organisations. It also offers new perspectives on issues so that different disciplines, departments, and organisations can select the relevant issues that need to be addressed with regards to the problem or goal at hand. However, it does not show how such issues are related, and hence, there may be a need to delve further by using this information to develop entity-relationship diagrams.

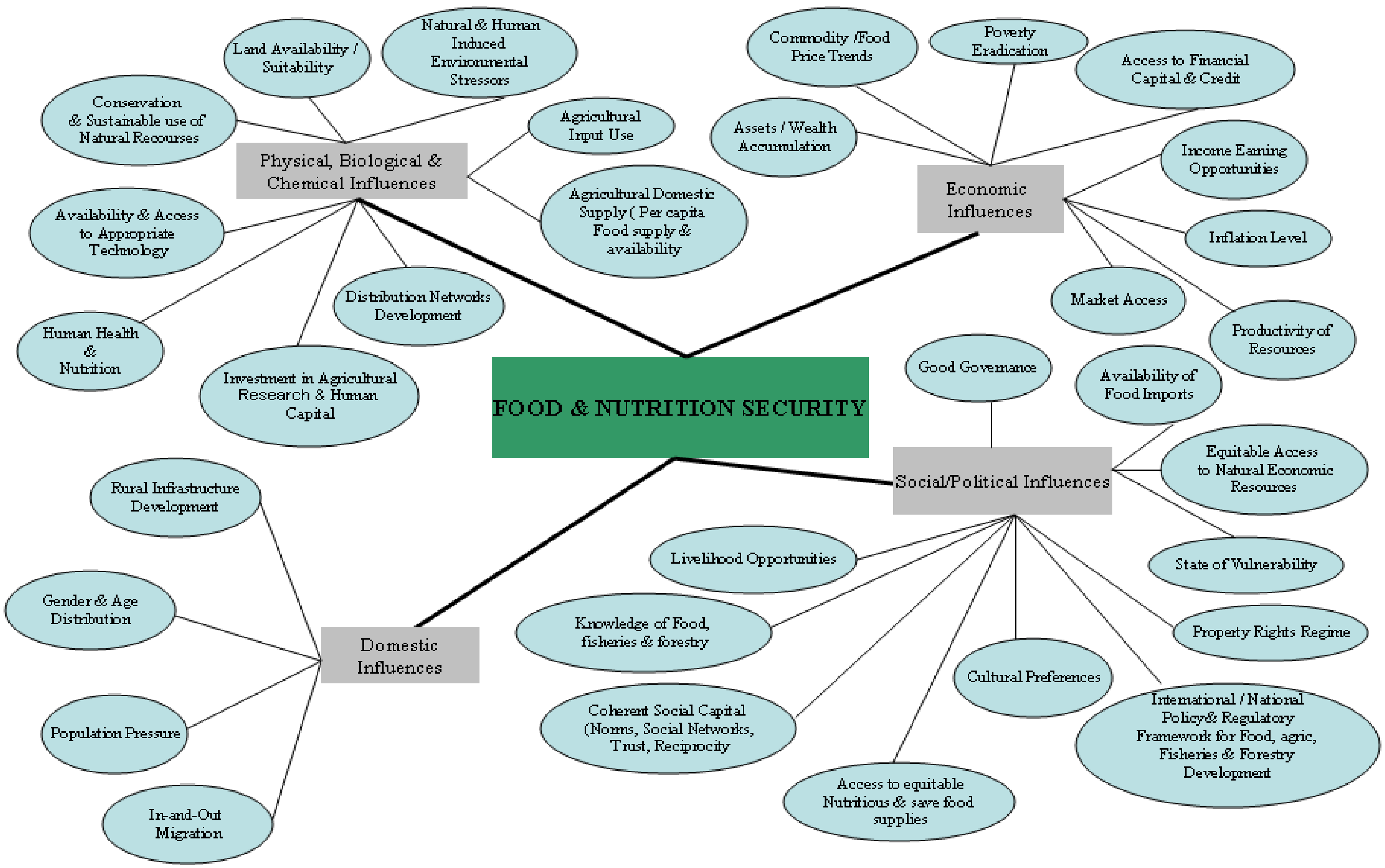

Figure 5.17: Mind Mapping Diagram for Food and Nutrition relevant to South Africa

5.6.3 *Entity-relationship diagram (E-RD) for food security in South Africa, showing broad-based entities*

Once the mind-mapping exercise is complete, the E-R Diagram (Figure 5.18) forms the starting point for the entire modelling procedure, using information from the mind-mapping exercise as a starting point. The E-RD is a useful tool for highlighting information and data needs. Following the same principle as outlined in Section 5.4, an elaborate E-RD for food security in South Africa is shown in Figure 5.18.

The diagram describes all entities comprising the abstract entity *food security*. It is important from the outset to ensure that the relationships between the objects accurately reflect the real world. This can be achieved through consultations with key decision makers involved in food security policy formulation in South Africa.

As previously stated, a detailed narrative description of the relationship between entities is an absolute necessity, and this subsection is aimed at providing this. Based on the background given in Section 5.5, it is assumed here that the agricultural sector uses production factors in pursuing_its goal of national food security. In order to achieve this goal, programs such as FSICP, INFSP**,** SPFS, CSSDM, and IFSS (Figure 5.4 for definitions of these acronyms) define special projects that address national food requirements relative to the current food security status.

Such national food requirements are largely determined by food management and coordination strategies; domestic production and trade regimes; and institutional capacity building, especially in the rural areas where the majority (75% of South Africans) of the poor, and most vulnerable, and the fewest educated people reside. In meeting national food requirements, production factors (which include agricultural land capabilities, input/output markets, management practices, and technological/capital investments) and food distribution systems are used, and these define the choice of farm operations (intensive/extensive, commercial/subsistence) and enterprise types that make available the agricultural products demanded by households and individuals.

Household and individual preferences; health; population growth; migration; and income levels and distribution define the types and trends of demand for agricultural products. In the absence of government intervention, and with greater market liberalisation, market forces will in future determine the quality and quantities of agricultural products to be produced. In this context, domestic and international commodity prices will largely determine farm income, which will in turn affect the choices (type and quantity) concerning which agricultural products will be produced by farmers in South Africa.

To facilitate the optimal use of production factors, favourable policies and regulatory frameworks, a developed infrastructure, information management strategies, and an investment in research and extension are needed. Good governance, which invariably translates into favourable policy and regulatory frameworks; development of infrastructure; and investment into research and extension are critical in determining the types and sustainability of livelihood strategies and social capital selected. The value of social capital is critical to the preservation and use of natural resources. It is also central to mitigating the negative impact of global environmental change and to the development of policy and interventions at all scales. Conservation of the natural resource base is central to the future availability_of production factors and various resource use options (e.g., agriculture, tourism or amenities).

The above account reflects the graphic representation in Figure 5.18, below. It is important however to ensure that what is described portrays the current and/or future reality of the problem or goal at hand. In this exercise, much of the description relates to the processes involved in food availability, as described in the previous sections.

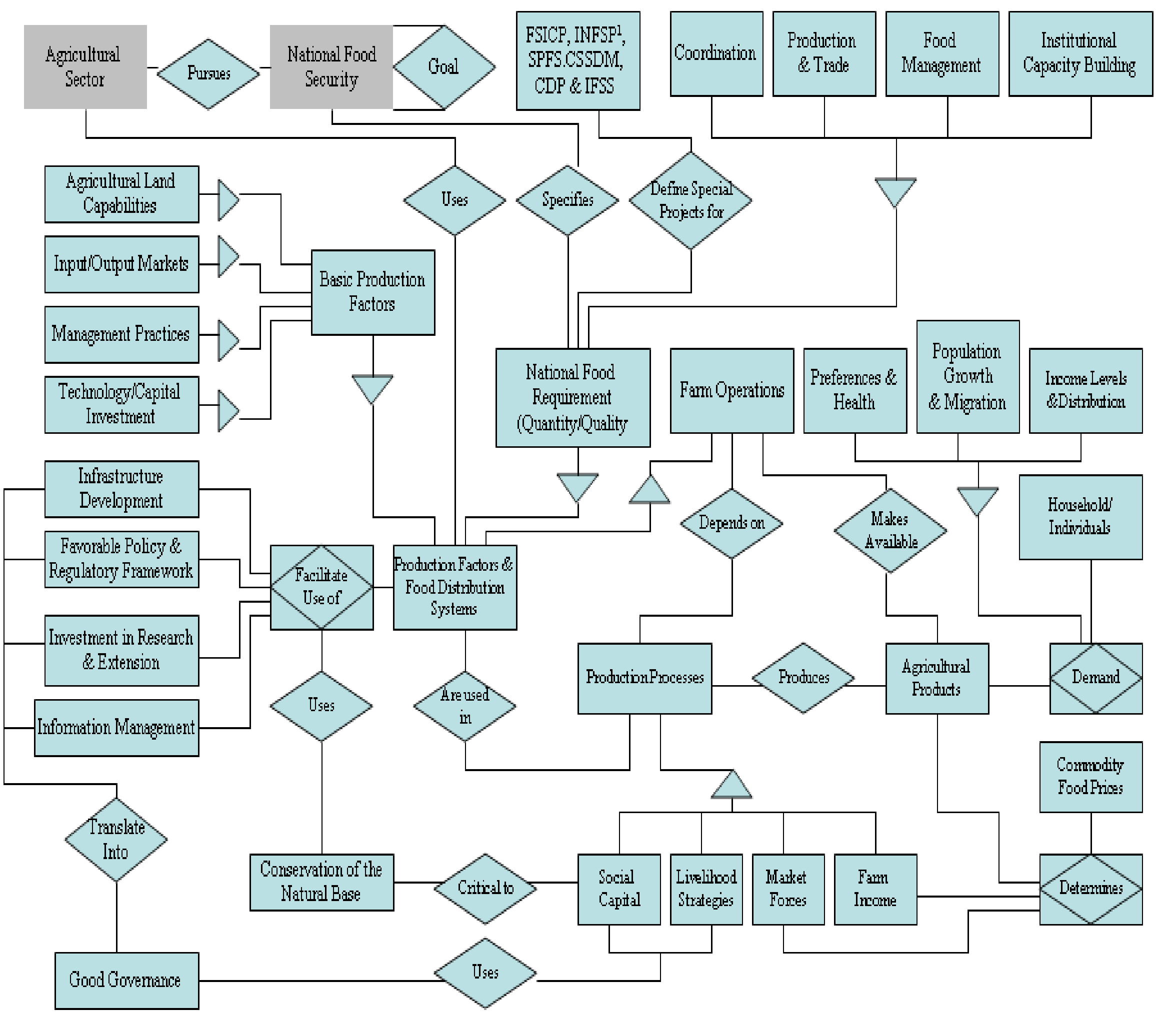

Figure 5.18: Entity Relationship Diagram for the Agricultural Sector with food security as a goal and food availability as an objective
Note/[1]: Acronyms in this box are the same as those explained in Figure 5.4 except for IFSS which stands for Integrated Food Security Strategy

The relationship between entities is important in creating awareness among decision makers of the interdependence and interaction of the various activities involved in the food security concept. Such activities may be performed by more than one department or organisation, and thus the need for coordination becomes apparent. Hence, addressing one type or group of activities might have a spillover effect on others, demanding that such activities be addressed in a holistic manner.

Such a representation is also useful in highlighting information and data needs. Each of the processes described in the previous and following figures (in rectangles), can be divided into their respective functional, data-logical and organisation-related aspects, such as those shown in Figure 5.18. Individual process-related models, in the form of procedure-chain diagrams, can subsequently also be developed for each aspect mentioned (Figure 5.10). After completing the entity-relationship model, it should be tested by checking it against a comprehensive set of queries that addresses database needs for collecting and storing information in an IS (Figure 5.19). In reading Figure 5.19 below, reference should be made to Figures 5.7–5.10 which illustrate on the notions discussed. Checking the validity of an E-RD can be achieved by stating the pathway that each process will take. Figure 5.19, above, illustrates and expands on of Figure 5.18, which shows relationships and pathways for a variety of entity relationships. The relationship between input/supplier and farm input order, for example, implies that the minimum number of agricultural input orders sent by an input supplier is one. The relationship between farm operations and agricultural inputs implies that each farm operation uses one or more agricultural inputs. Navigation between entity types requires the development of queries leading to pathways.

This requires a deep understanding of what is required of each entity, and thus, human resource capabilities become an important component of the process.

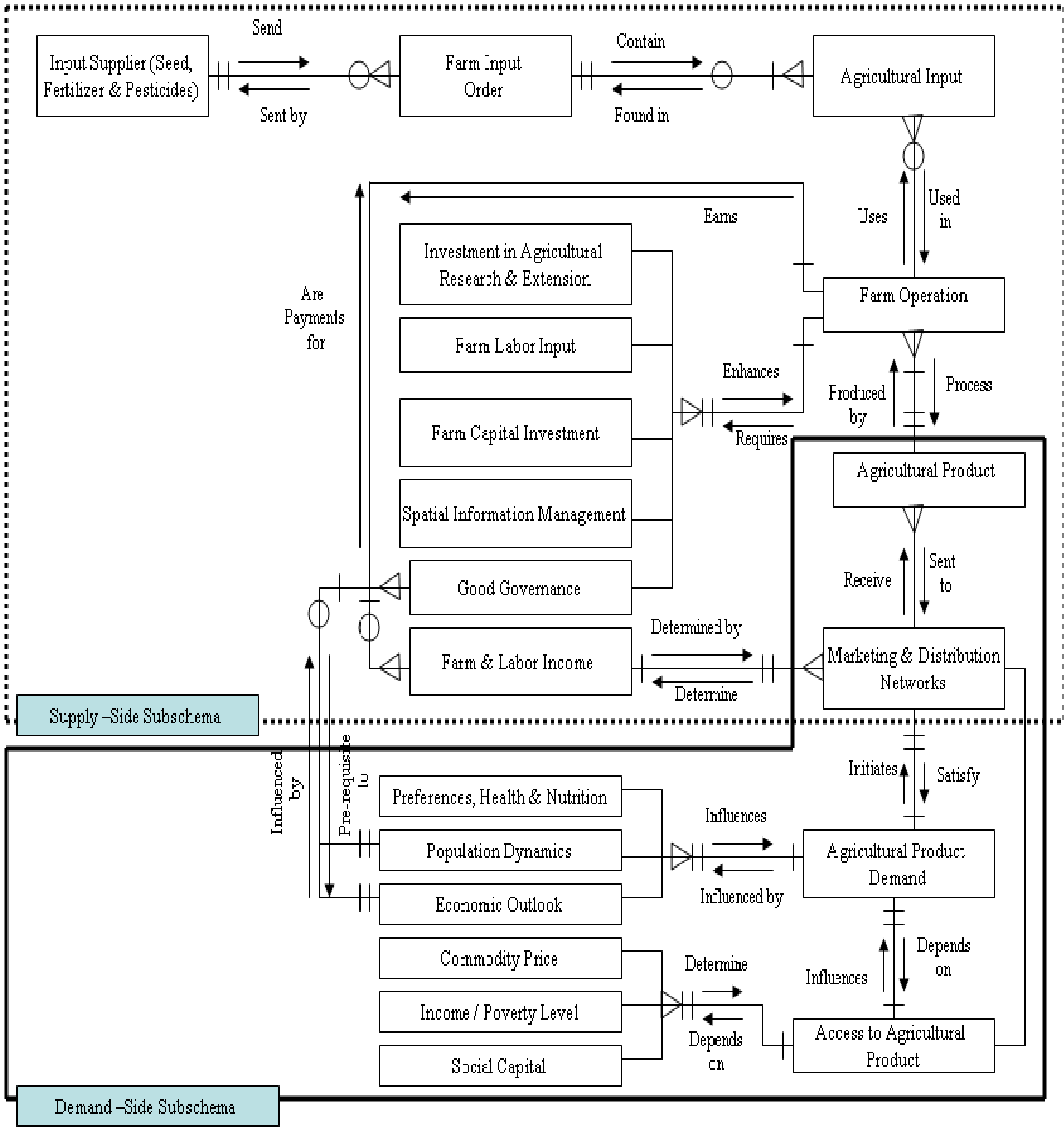

Figure 5.19: Navigating the entity-relationship diagram – and illustration

It is best to start off with what is already known about the query. This is only possible when all the attributes for each entity are known together with the relationships' names and meanings.

5.6.4 *Business processes and related entities relevant to food security in South Africa that must be supported by an information system.*

As has already been indicated in Section 5.5, food security as a concept and an *abstract entity* has five basic processes. These business processes include increasing household productivity; increasing food trade and distribution; increasing income earning opportunities; an improving nutritional status; and the enhancement of institutional support networks. These processes are also seen as food security priority areas in South Africa (IFSS 2002: 27).

Some of the key business processes for food security in South Africa, and related entities, are shown in Table 5.2.

Table 5.2: Business-process and related entities relevant to food security in South Africa

Business processes	Entities requiring LIS support
Increasing food production and trade (a *food availability process)*	Land capabilities, investment in research and extension, conservation, and sustainable use of the natural resource base, input/output market regimes
Increasing income earning opportunities (an *accessibility process*)	Livelihood strategies, market forces
Improving nutritional and health status (a *food utilisation process)*	Poverty, social capital, livelihood strategies
Enhancing institutional support networks (a *food accessibility and distribution process*)	Policy and regulatory frameworks, information management, governance, institutional capacity building, coordination
An *early warning process*	Preparedness and prevention
A *fast response process*	Risk analysis, mitigation, preparedness, rehabilitation, and reconstruction
Monitoring, evaluation and prediction processes	Risk analysis, policy impacts, poverty interventions and agricultural practices, and resource usage

Not all entities have been identified. Only those which are perceived as being critical have been used for the purpose of illustration. However, in the real world situation, all important entities for each business process should be identified, described, and verified with the relevant authorities. A description of the entities found in Table 5.2 follows to illustrate the process of entity identification.

i) *Land capability*

The entity type *land capability* is important in South Africa, especially where production needs to be expanded to the former homelands, with the entry of new farmers in certain land areas. There is a need to identify which land areas are suitable for which types of production (intensive, extensive) and which crop types (farm operations) should be cultivated to create a scenario of sustainable, optimal use (agriculture, tourism etc.). Technological innovation is also needed, and this calls for a certain level of investment in research and extension in order to be effective. Sustainable funding for agricultural research and extension leads to increased productivity, which in turn boosts farm output and lowers consumer food prices.

ii) *Conservation and enhancing sustainable use of the natural base*

This relates to issues of land degradation, water scarcity, pollution and sanitation, destruction of forest land, over-exploitation of resources, the greenhouse effect, and loss of genetic biodiversity. As competition for scarce resources intensifies, due to increasing pressure from a growing population, it is increasingly necessary to consider various options, solutions, including the multiple potential alternative uses of agricultural land resources, with the goal of conservation.

Land degradation and water scarcity, for example, lead directly to reduced agricultural land productivity. Policies supported by data and information are therefore needed to ensure both sustainability and conservation of water resources and genetic diversity at a national, regional and local level.

iii) *Livelihood strategies*

People everywhere pursue a range of livelihood strategies (i.e., capabilities, assets and activities required to earn a living) in an attempt to increase their income and assets (accumulation strategies), spread or reduce risk (adaptive strategies), mitigate the impact of shocks (coping strategies), and ensure survival (survival strategies). Some of the livelihood strategies include decreased expenditure on essential goods and services, (education, staple foods, health care, agriculture and livestock inputs), in-and-out-migration, and the sale of assets (Misselhorn 2005: 9). Many of these issues feed back to further exacerbate the vulnerability of the community to food insecurity. Capacity strengthening, by guiding the choices of agricultural practices, technologies, and support services, is therefore necessary to reduce vulnerability and enhance resilience.

iv) *Good governance*

High-level political commitment (associated with good governance) has consistently proven essential in improving the welfare of farm households. Political and economic instability and conflict, together with poor financial resources and poverty, frequently lead to withdrawal from family activities by younger generations. Good governance translates directly into a favourable policy environment and budget allocations to agricultural support institutions and related infrastructure.

v) *Social capital*

There are numerous forms of social capital. These include relations of trust, reciprocity, common rules, norms and sanctions (institutions), social connectedness, and social networks and groups (Adger 2005: 10,). All of these are potential human resources in the building of food security. The value of social capital is critical to the preservation and use of resources, and central to mitigating the negative impact of the processes of global environmental change, food insecurity and vulnerability. It fosters the development of policy and interventions at all scales (Berkes, 2005: 10).

vi) *Safety nets*

Safety nets are necessary to ensure access to sufficient, safe and nutritionally adequate food. National food insecurity and vulnerability information and mapping systems are required for this to occur (Corporate Strategies, www.fao.org///dorep/x355leo3.htm). This is because a growing population, a rise in income levels, health considerations, and changes in preferences may lead to increased demand for food.

vii) *Poverty levels*

Poverty is a product of poor resource endowments; the vagaries of climate, which could, for example, result in massive droughts and floods; and geographical location, e.g., extreme remoteness. But it could also be the result of unfavourable trade policies, external debt burdens, and a lack of investment in social services and infrastructure, all of which hinder development (Rosegrant *et al*., 2005: 05). The drivers of poverty, e.g., conflict, HIV/AIDS and associated human health issues, are linked to decreasing social coherence and social capital, the latter being a fundamental determinant of the escalating vulnerability across the Southern African region (Misselhorn, 2005: 10).

Poverty eradication should theoretically lead to food security. This includes increasing individual opportunities and resource productivity as a means of raising rural incomes and improving access to food (Corporate Strategies, www.fao.org///dorep/x355leo3.htm)

viii) *Institutional capacity building and coordination*

This is important, particularly in rural areas where 75% of the poorer population of South Africa reside. This is also where there is a significant lack of training, representation and institutions for effective delivery of food security initiatives.

The above account implies that there is a need for data and information to be collected, stored, and processed for the various entities to support effective decision-making on key business processes relating to food security. Appropriate information systems that support these initiatives therefore need to be developed. It is also important to note that there are several key role players (government organisations) whose aim is to address individual, national, and household food security issues. Coordination of activities (including the interpretation of related data), therefore, becomes a very important and complex challenge. This requires a common procedure that can be used as a guide to show the relationships between organisational activities and the effects of these.

5.6.5 *The general process model for food security in South Africa in a spatial context*

As pointed out previously, Figure 5.18 presents the overall E-RM, showing all entities involved in the food security issue. The spatial context approach is followed here because this dissertation focuses on agricultural land resource use. However, the procedure followed is applicable to any other discipline or area of interest, such as forestry, infrastructure (roads, rail, and telecommunication services), and fisheries. It is advisable that before this step is undertaken, practitioners be absolutely certain that the overall E-RM diagram is the final one that truly represents the reality of the issue at hand. It is also important to ensure that there is a link between the overall E-RM, the mind-mapping diagram, and the general process model.

After ensuring that the above criteria have all been met, and after the general process model has been developed, one has to consider the direction that development of the semantic information system must take, i.e., a more technical orientation, or a more conceptual-political one. A technical approach would entail looking at aspects such as the actual development of the information system, which includes software and hardware requirements.

A conceptual-political approach implies focusing on the logic and procedure required in developing an information system, and excludes the technical requirements. The former is the approach undertaken here, as the main goal of this dissertation is to establish a strategic spatial planning procedure that allows for technical issues to be dealt with at a later stage, in accordance with this approach.

5.6.5.1 *Processes modelling for food security in South Africa*

A process is a specific ordering of work or sequence of activities, functions or tasks across time and space, with clearly defined inputs and outputs, or resource needs. (Wynn *et al.*, 2003: 383; **www.ftp.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-**

75/files/REBPS_05pdf). With this definition in mind, food security processes in South Africa can be grouped into five broad-based business processes as follows (also see Table 5.2 and IFSS July, 2002: 24-32):

i) *Improving household food production, trade and distribution* – a food availability process. This can be achieved by, among other ways, increasing the participation of food-insecure households in productive agricultural activities and reducing unfair competition.

ii) *Increasing income and job opportunities* – a food accessibility process. This can be achieved by supporting measures that create a labour-intensive and diversified agricultural sector with strong links to other economic sectors.

iii) *Improving nutrition and food safety* – a food utilisation process. This can be addressed by enhancing public education and improving monitoring methods relating to health and nutrition.

iv) *Enhancing safety nets and food emergency management systems* – a food distribution process. This can be achieved by strengthening public goods such as infrastructure, information, research and extension, and technology development.

v) *Institutional arrangements and interaction processes.*

Because of the diverse nature of food security as a concept, it is not easy to have a clear-cut logical relationship within and between processes. Hence, a multi-pronged approach such as that shown in Figure 5.20 and as used by the IFSS (2002: 27) is adopted here.

Each of these processes can be divided into their functional, data-logical and organisation-related aspects, according to the standards of information modelling (Kätsch, 2003: 8, 11).

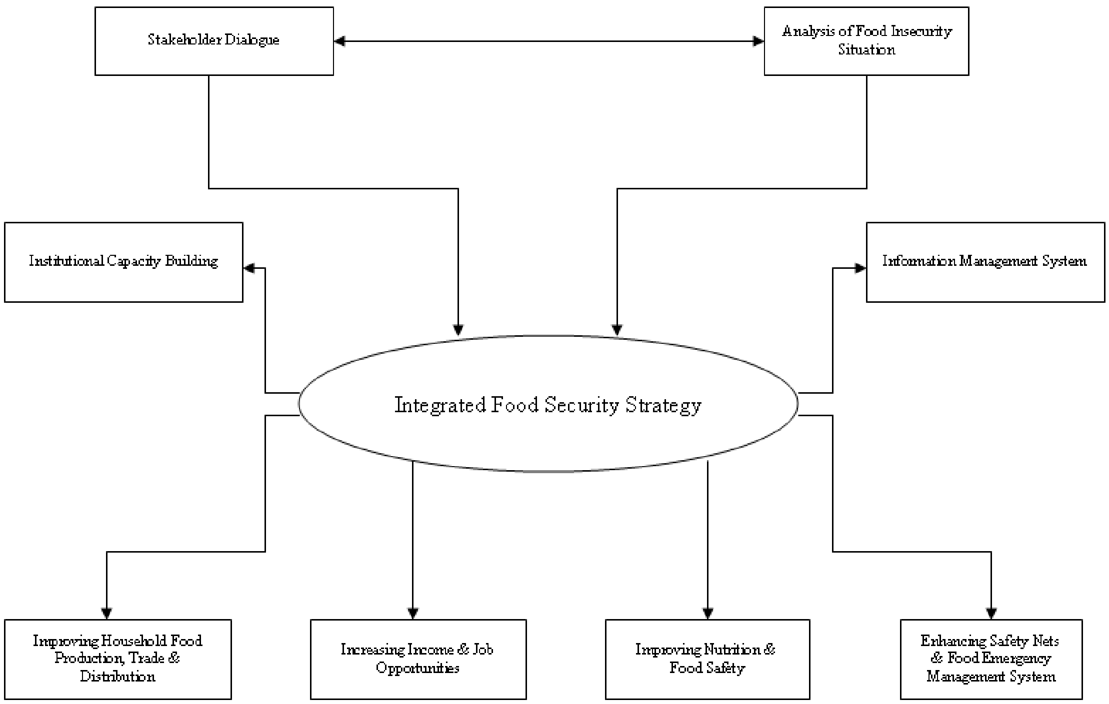

Figure 5.20: Program and Processes that will yield the highest social returns in achieving food security in South Africa
Source: IFSS 2000:27

Of relevance to the agricultural sector and to this dissertation is the *food availability process,* with particular emphasis on improving domestic food production for the purpose of achieving household and individual food security in the long term. Hence, Figure 5.21 is a procedure-chain diagram for the internal business process of domestic food production. A long-term perspective is taken here, and based on information presented in Section 5.5.4, it is assumed that the triggering events for this process will include domestic food supply and related imbalances; population pressure and dynamics; economic outlook; and natural and man-made environmental changes, among other event groupings. Any one or combination of these events will trigger the formulation of domestic production policy and support systems, or programmes, within the NDA. The current domestic production plan (NDA strategic plan) is therefore utilised as an information objective.

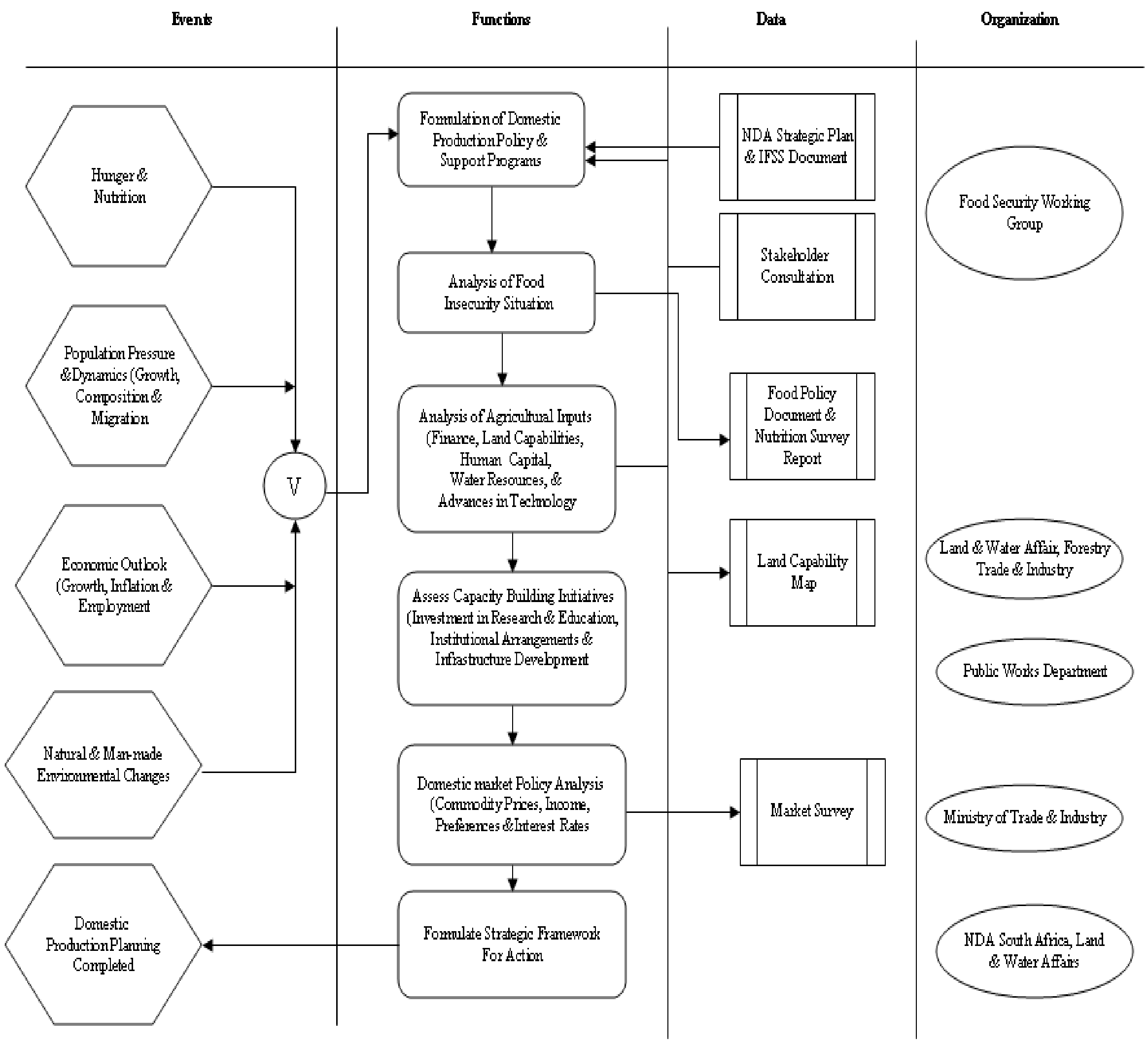

Figure 5.21: Procedure chain diagram showing business process "Domestic Food Production", by NDA South Africa

In order to bring the various sectors together, whose goals and objectives usually overlap, stakeholder consultation is necessary, and is thus also utilised here as input data. Once the policies and programs have been formulated, an analysis of the food supply and demand situation (and the food insecurity situation) is required specifically to identify areas of risk in terms of food production, access and use. In terms of production, information on agricultural inputs (land capabilities, water resources, and human capital) should be sought at both local and national levels.

With a long-term perspective of food production, information is also sought regarding the ability of regions and the nation at large to develop the necessary production capacity. The whole process terminates with the formulation of a strategic framework for action. It is worth noting that each of these functions will have sub-functions in their respective sectors, which may also manifest as individual procedure-chain diagrams of their own that need to be documented. It is important at all stages to bear in mind the links between processes and functions.

5.6.5.2 *The transition from information modelling to operational information system*

The transition from information modelling to an operational information system is signified by the subdivision of the functions and their assignments to logically related job sectors (Kätsch, 2003: 13). Use should be made of the identified business processes and related entities and data needs. This step implies assigning the functions of each sector to sub-information systems which can then be modelled in detail in terms of their logical structure.

Figure 5.22, below, illustrates the subdivisions of envisaged integrated food security information management systems. Theoretically, based on policy documents (particularly

IFSS South Africa, 2002), a food security information management system could be based on six interlinked sub-information systems (Figure 5.22). Each of these sub-information systems would use the same database and would require close coordination in the course of daily food security businesses processes. The *monitoring and evaluation system* would provide information on food supply and demand situations in different parts of the country, and this information could be used to identify risk areas with respect to food access and usage (IFSS, 2002: 1). It should also provide information on the impacts of policies, poverty interventions, and agricultural practices, which include remote sensing and resource use efficiency. This information system should be linked to a disaster management information system (floods and drought), poverty and health information systems (which will give information on trends in malnutrition and health matters, such as the prevalence of HIV/AIDS), and the early-warning system. The proposed information and communication system would also maintain a register of food-insecure households.

The information, communication and knowledge system should be aimed at improving agricultural knowledge on environment-friendly agricultural practices (especially in rural areas) that will ensure sustainable and efficient use of resources. The system should consist of sources of knowledge, methods of communication, and behaviour concerning agricultural and food security processes.

The disaster management information system should provide two sets of data, baseline and real time, derived from two sets of activities being pre-disaster and post-disaster, which should include triggering events. Pre-disaster implies risk analysis, prevention, mitigation, and preparedness, and thus should provide baseline data aimed at improving existing knowledge.

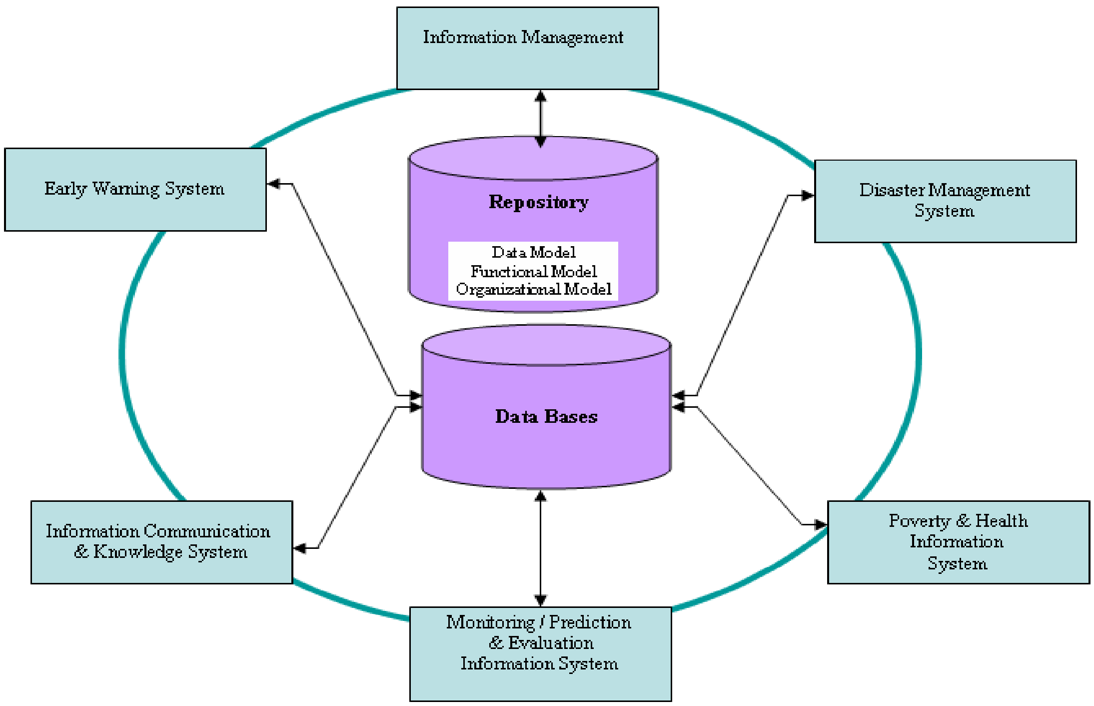

Figure 5.22: Components of a food security information management system
Source: Adapted from Kätsch, 2003:14

Post-disaster includes response, rehabilitation and reconstruction, and relates to the impact of the disaster (such as famine) on the community. The integrated structure of the system is usually administered by the centralised repository, which contains the logical information model and auxiliary aids for the administration and improvement of the model.

5.7 Conclusions

The theme of Chapter 5 is food security in South Africa. This chapter combines strategic planning processes with the concept of systems analysis to show how the two can be used in identifying relevant parameters and data sets to be stored in an LIS. The two concepts entail issues of coordination, coherence and foresight, which are essential aspects of developing an effective LIS. The theme was necessitated by the opinion that a question framework that has a future outlook (for instance 20 years ahead) remains a challenge within South Africa's National Spatial Information Framework (NSIF). In particular, human resource development – for providing the competence necessary for the transformation of data into information and, later, knowledge – is lacking. Hence, Chapter 5 places emphasis on business processes that constitute information generation and data acquisition in both the short and long term.

Through a mind-mapping exercise that assists in identifying general issues relating to food security and an E-RD process that shows linkages between identified parameters, processes in food security were identified. A key issue highlighted in Chapter 5 and necessary for LIS effectiveness is the importance of getting all concerned individuals/departments/organisations to contribute towards the mind-mapping exercise before any further steps are taken. This is important in enhancing coherence and coordination and in reducing the development of a discipline-centred LIS.

The E-RD and procedure chain diagrams developed should also resemble reality as closely as possible and should be validated by individuals with adequate competence in the problem or goal at hand. At the end of the exercise there should be a clear understanding of the relationships that exist between the business processes and entities to ensure that only the relevant data and information is stored. A major conclusion of Chapter 5 is the transition from logical modelling that shows business processes and related information needs to an operational information system that shows the various systems – including how these are interlinked – necessary to support these business processes.

It is these systems that will aid in decision-making concerning the agricultural land resource, and their link to identified parameters is of critical importance for effectiveness in decision-making now and in the future.

It is important to point out, however, that in systems analysis, at some stage, one has to decide on the level of detail required (e.g., one has to decide whether to go to the extent of soil types in terms of land resource use). The more one goes into fine detail, the more complex it becomes, as is shown in the tree diagram in Figure 5.18. Also, as one breaks a problem down to reflect more particular attributes, one tends to discover more about the real business processes. The appropriate level at which to stop, therefore, requires consultation and interaction with the relevant people involved in the operation in question, who in this case, are those involved in food security and LIS planning in South Africa.

Combining the strategic thinking principle and the systems analysis concepts requires the development of a workbook such as that provided in Annexure A. The workbook is a tool composed mainly of carefully selected relevant parameters identified during the systems analysis exercise and is meant to support the systems analyses**.** It provides future trends for the identified parameters and thus defines a basis of relevance for the data and information to be collected and stored. One classic example of the use of a workbook to support strategic planning is provided for in a PhD dissertation by Laubscher (1988), where it is applied to the deciduous fruit industry in South Africa.

In this dissertation, the workbook is applied to the theme of food security. It shows a variety of trends aimed at sensitising participants from various disciplines regarding various states of socio-political, economic, biophysical, and technological phenomena and informing their perceptions of these phenomena. It promotes alignment of these states projected into the future and motivates the inclusion of certain parameters in the systems analysis and data capturing of these in the LIS. The projections included in the workbook provide the magnitude of the prospective circumstances over the long term.

As the workbook is about the circumstances and because there is a critical mass of data and information set by cost implications that can be collected and stored in an LIS, careful selection of parameters to be included is critical. Concerned organisations therefore have to think carefully about the interpretations of envisaged parameters, as the ability to do so will determine the design and development of an effective LIS in terms of human and technological sophistication. As part of a screening process, one needs to avoid those parameters where data sets are not current. A useful practice is to work within the context of the mind-mapping diagram, as it helps focus attention on key parameters relating to the issue at hand and those that are relevant to potential LIS users.

CHAPTER 6: CONCLUSIONS AND SUMMARY

The objective of this chapter is to synthesise the ideas captured in previous chapters. It is therefore a distillation of the essence of this dissertation, beginning with a statement of the problem addressed and ending with a summary of the major findings.

6.1 Conclusions

The argument put forth at the beginning of this dissertation is that the design and development processes of current Land Information Systems (LIS) lack foresight and a question framework for defining business processes and data needs. This has resulted in systems that are not effective in providing the information necessary for making decisions about future land resource use options. The determination of an effective enhancement strategy is not new in the field of economics: however, it is clearly needed in the GIS field, where there has been no forward movement from benefit-cost analysis thinking.

This dissertation is aimed at making a contribution to the field of effective LIS design with regards to agricultural land resource use. Therefore, the focus is neither on the LIS dimension, nor on the interactive planning per se, as these have already been studied and applied discretely elsewhere. This study is aimed at bringing these two worlds together and providing the motivation to improve strategic orientation in LIS design by focusing on strategic information management that is supported by systems analysis. This was necessitated because a review of the literature clearly showed a lack of strategic planning skills in the LIS sector. It also showed that early LIS design was geared towards the life sciences, agronomy, engineering, and the soil sciences, with limited vision of future land resource planning needs derived from social issues like food security. Even today, LIS development is characterised by technical design and benefit-cost analysis, with a lack of strategic visioning.

A review of existing LIS also revealed that LIS developed by a particular government department focuses on specific uses and therefore includes only specific data parameters, e.g., the department of agriculture, generally focuses on agricultural use and therefore only includes agricultural data parameters. This means that the data gathered ignores other issues, such as agri-tourism and urban use of the same resource base, which for planning purposes would require other parameters besides those related to agriculture. Such institutional fragmentation does not allow recognition of the multiple uses of the resource base, including its evolution from agricultural to other uses.

The evolution and application of LIS follows a similar trend, with little emphasis put on using LIS for shaping peoples images of desired land resource use patterns by creating spatial images of desired land use projections. These flaws in thinking create a short-term view and a narrow technical approach in the planning processes and use of LIS.

With current trends towards globalisation, where countries need to position themselves strategically in order to gain a competitive edge in the long term, LIS applications that accommodated a long-term view and a multi-contextual perspective in decision-making are in effect critically needed. In light of this, the resource *per se* is no longer crucial in determining a competitive edge, as are the characteristics of the resource that make it unique to a particular use option, which will define a country's competitive edge in the long term. This implies that a long-term view (strategic orientation) in LIS development and thus strategic information management, is needed, and thorough investigation is necessary to complement what is already known about the effectiveness of LIS.

Strategic information management implies making choices now regarding which data to include in an LIS. The challenge lies in understanding and managing change and the complex processes associated with this change, and knowing how LIS applications can remain relevant in aiding decision-making in general and land resource use in particular. A basic principle in meeting this challenge involves acquiring knowledge about the future, dissecting it into its logical dimensions, and ensuring that there is a good understanding of the relationships comprising this knowledge about the future. This is where systems analysis has an advantage over other techniques used in strategic planning exercises.

The advantage that systems analysis has over other strategic planning techniques is that it is about:

i) understanding the underlying structure responsible for the patterns of behaviour of a given situation,
ii) the nature of the event or problem at hand,
iii) the role this event plays within a society,
iv) activities necessary to address this situation, and how they are interrelated,

v) thinking about the processes necessary to achieve the intended results.

Thinking along these lines implies seeing time and space as one reality. Altogether, systems analysis provides a clear, logical model of reality or a part of the real world. Unlike, for example, forecast-based planning methodologies, systems analysis, through mind mapping, allows participants to debate strategic issues in an objective manner, thereby facilitating organisational learning by means of a formal procedure for assessing current and evolving business processes. This is why it is important that the entries in the mind-mapping diagram are well debated by all concerned and are periodically reviewed so that they remain relevant with changing circumstances.

It is equally important that entries in the Entity-Relationship Diagram (E-RD) are validated as a true reflection of the real world situation by those knowledgeable in the subject at hand. In this dissertation, LIS experts within AGIS and FIVMS-RSA provided the necessary validation of the E-RD diagrams through workshops and meetings. The purpose of such an E-RD is to clearly indicate relationships between entities. It should be clear from the semantic descriptions that result from this process what kind of relationships exist. After the validation exercise and the semantic descriptions, the reasons pertaining to how things are related should also be very clear in the minds of all concerned. To stay relevant, dimensions in the E-RD should always be derived directly from the mind-mapping diagram.

Mind-mapping diagrams are far-reaching, non-linear, graphical representations of ideas, notes and information. In this dissertation, the mind-mapping diagram is hypothetical and is used to create a graphical summary of key thought processes relating to food security dimensions as a central theme. The value of such a diagram is that, because related ideas are grouped together, important patterns in the field data emerge, and synergies among all levels, divisions, and sections of the organisational hierarchy are revealed. This creates an aligning of the thinking processes of all those affected by/affecting food security concerns so that they have a shared vision of the current and future functioning of their envisaged LIS, even before development starts. The entity relationships and business processes define the relationships between organisations and the sequence of activities that need to occur in dealing with a known event (positive or negative). This facilitates the outlining of a locus from whence data can be derived and the identification of institutions that are likely to become involved. Going through this process is analogous to defining the LIS dimensions in terms of what institutions need in effect to interact and in what areas of interest they should become involved.

The actual data to be kept in the LIS for those dimensions that have been identified needs to be defined. As indicated earlier, a common practice in achieving this is the use of environmental scanning techniques, such as Quick Environmental Scanning Techniques (QUEST), which utilise the environmental hexagon. In the past, LIS design was mainly undertaken by soil scientists, resulting in a bias toward soil-related dimensions.

In this dissertation, a workbook that utilises a strategic-orientation approach is used. The workbook following this section takes a long-term perspective (ten to twenty years) using a select number of dimensions identified in the systems analysis exercise and provides images of the likely pathways these dimension will take. Its main purpose is to sensitise LIS planning participants, who may have varied academic backgrounds (e.g., hard/natural sciences and social sciences), to the various phenomena of strategic importance. The themes covered in the workbook are therefore meant to stimulate discussion among participants on the implications of these phenomena for the particular LIS that they are planning.

In this way, a strategic thinking approach that is far-reaching is introduced into the data processes and information needs of an LIS. A combination of the workbook, mind mapping, and the definition of business processes, as applied to LIS in this instance, reduces the thinking flaws inherent in organisations and among LIS developers and greatly enhances LIS effectiveness. This, however, needs to be complemented by government effort aimed at addressing issues of coherence, coordination and human resource capacity building.

Due to the public-good nature of information, its provision has always been and still is largely the responsibility of central government. Hence, government institutions such as AGIS, NSIF, and FIVMS-RSA dominate the design and development of LIS as well as the provision of most data and information within South Africa's agricultural sector. Major difficulties within these institutions have been caused by a lack of coherence, limited coordination in data collection and storage, and resistance to change, with the majority of such systems developed along departmental/discipline lines.

Generally, these factors, collectively or individually, impact negatively on LIS effectiveness. A major role of government is seen here as that of enhancing coordination and coherence by setting up policies and programmes that promote consultation and data sharing among information custodians. This will reduce duplication in data collection and overall LIS development and, hence, running costs. To some extent, AGIS is playing this role but demonstrates capacity limitations. The overriding difficultly lies in defining processes, which supposedly is currently being undertaken by NSIF, and in the lack in South Africa of strategically oriented guiding principles for LIS design, which this dissertation addresses.

Another role of government should be that of developing appropriate technical skills through the education system. This implies addressing issues of matriculation in the sciences, the ‘brain drain’, and designing appropriate systems for building capacity and staff retention within the LIS sector. These functions of government are currently not being performed in South Africa. Government participation in LIS development by assuming these functions would enhance data interpretation capacity and thus define the human and technical sophistication necessary for LIS effectiveness, starting from the short term to the long term.

Accounts in this dissertation are by design of necessity, generic, and socially oriented. Applying these principles would, however, involve further distillation by subject-matter specialists within various disciplines for them to be fully appreciated as an alternative to the usual environmental scanning techniques. Their use is at present limited to providing a basis for influencing the mind-sets of LIS practitioners towards adopting principles/procedures that promote 'systems thinking capabilities'. They also allow for detailed descriptions of activities necessary for achieving organisational visions, missions, goals, and objectives in using LIS applications, other than limited to the development of an LIS *per se*. They are aimed at helping LIS practitioners understand the importance of this line of thinking in enhancing LIS effectiveness and thus information management. The actual design and development is therefore left to LIS specialists.

6.2 Summary

The essence of this dissertation is informed by the philosophical belief that effective decisions in both the private and public sectors need to be based on strategic choices about what data to collect now and how this should be stored and processed in an LIS to support land resource use options, starting now and continuing into the distant future. Against this background, a central hypothesis was formulated to the effect that '*LIS planning lacks coherence and strategic orientation'*, and that systems currently in use are ineffective due to a lack of clear guidelines for the design and evaluation of LIS. Also, the business processes for LIS applications in a resource-functional context are generally not well understood. This results in most of these systems being established under an erroneous conceptualisation (or ill-definition) of the problem that is to be addressed by the LIS. This dissertation assumes the above statement to be true and hence aims to address the classical problem of a search for a *modus operandi* for enhancing effectiveness in strategic information management that will deliver on effective decision-making about various land resource use options. Effectiveness in strategic information management is here defined in terms of the extent to which organisational goals and objectives about land resource use in both short and long term are fulfilled with the aid of an LIS.

To expound on the above line of thinking, this dissertation has been subdivided into six chapters and one annexure. Chapter 1 dissects the above-stated fundamental question into study components and formulates key questions and assumptions that are subsequently addressed in the study. The chapter emphasises the need for strategic planning and thinking processes in the design and development of LIS in an effort to enhance LIS effectiveness.

In order to explore the issue of LIS ineffectiveness further, Chapter 2 reviews some of the theoretical concepts relating to LIS and establishes the need to focus more attention on LIS effectiveness against an historical background of concerted efforts towards LIS efficiency. Issues of resource use efficiency and benefit measurement, particularly the application of benefit-cost analysis (BCA) to measuring the impacts of LIS, are also addressed here. The assumption that all benefits can be measured in monetary terms is identified as a critical limitation to the use of BCA as a measure of LIS impact – in fact, LIS benefits, particularly effectiveness benefits, cannot easily be quantified. A major finding of Chapter 2 is that, besides efficiency considerations, applications; investment appraisal and management; and planning of LIS are still of prime importance to both developed and developing nations.

Chapter 3 utilises the literature reviewed and the economic principles identified in Chapter 2 to identify gaps that need to be addressed in order to make LIS more relevant and effective as a tool for aiding land resource use planning. A major gap identified here was the inadequacy of economic theories for assessing investment trade-offs that define the quality, quantity, and diversity of information required for various types of land resource use. The gaps that need to be addressed include a lack of a coherent vision and strategic orientation; a lack of understanding of the input/output aspects of LIS; resistance to change; and a lack of definition of the processes and specifications required for data and information that are to be stored in an LIS.

Chapter 4 looks specifically at the meaning of the principle of strategic planning and how it relates to LIS processes. Of particular importance is evidence that strategic thinking adds foresight to a strategic vision for LIS. This, in turn, acts as a benchmark for directing the thinking processes of LIS planners towards the future and possible alternative functioning of the LIS. Utilising evidence from the previous three chapters, a point of departure is established, which requires that LIS practitioners incorporate strategic planning and thinking processes in developing LIS in an effort to enhance effectiveness. To facilitate this, the concept of systems analysis was introduced as a formal procedure for utilising strategic visioning in the thinking processes involved in LIS design. Systems analysis was chosen on the basis that it provides a clear logical model of reality, or part of the real world, with regards to why/how things are related. An elaborate view of this principle and its application to LIS is given in Chapter 5.

Following an elaborate view of the systems analysis concept, an illustration is given in Chapter 5 of how this concept, particularly semantic information and business process modelling (SIM), which utilise mind-mapping and entity-relationship diagrams (E-RD) for describing business processes, can enhance LIS effectiveness. SIM was used here to dissect the chosen theme (food security) into its logical components, in order to determine which dimensions were relevant for collecting and storing data in an LIS.

The mind-mapping exercise is useful as a tool for identifying general parameters regarding food security. The E-RD process complements the illustrations by showing linkages between identified parameters and processes of food security, thereby aiding selection of only the important and relevant data sets to be stored in an LIS. This further augments coordination and assists in avoiding collecting and storing unnecessary data. A combination of SIM, E-RD, mind-mapping and the workbook further reduces the scope for ad hoc data collection and enhances foresight in the development of LIS.

The workbook, which is given in an annexure to this dissertation, is composed of parameters that create a picture of the future to emphasise the importance of including particular dimensions, identified during systems analysis, in collecting data now so that it is available when needed in the future. The workbook is useful in showing a variety of trends in order to sensitise participants from various disciplines regarding various states of socio-political, economic, biophysical, and technological phenomena, thereby updating their perceptions of these phenomena. It therefore encourages coherence between and within disciplines and adds foresight and thus a strategic dimension to LIS planning, while supporting systems analysis processes.

This Chapter (six) is a distillation of the entire dissertation. It ends with a summary of the major findings and conclusions of the previous chapters, as set forth above. It is important to note that the conclusions reached here are not unique to food security or agricultural land resource use, as the concepts used are applicable to other fields of study. Its application in a specific field of study, such as engineering or systems design, however, requires individuals with a thorough knowledge of their subject matter. Hence, this dissertation has simply provided an alternative philosophical approach to the environmental scanning process commonly used in strategic planning exercises, with a bias towards illuminating key social issues that need to be taken into consideration. The dissertation should, therefore, serve and be treated as a reference point for specific applications that are more focused and subject-matter oriented.

ANNEXURE A: THE WORKBOOK

1.0 Introduction

The workbook is a preparation tool for supporting the systems analysis processes. It serves to create a picture of the future, emphasising the importance of particular dimensions (identified during systems analysis) to be implemented in collecting data in the present so that it is available when needed in the future. The aim of the workbook is to sensitise participants in strategic planning sessions to possible future scenarios regarding the dimensions identified during these exercises. Its development should come immediately after the systems analysis has been performed and verified. For illustrative purposes, only a few themes have been selected and included in this dissertation's workbook.

In interpreting the identified parameters, the focus is placed mainly on sketching a picture of the future and the implications of this on the design and development of an effective LIS for food security. This is based on the assumption that, because of world uncertainty, it is both efficient and necessary for an organisation to invest up front in strategic thinking. For this purpose, an organisation needs to mobilise the intellectual power of its staff, utilising their networking and observational skills within the organisational environment. In this regard, use is made of Figures 5.17, 5.18 and 5.19 to derive the parameters that are to be included when developing an LIS.

To sustain focus, only a few relevant parameters have been included here for illustrative purposes. Because of the emphasis on food security as a theme of study, all parameters come from the *increased food production and trade* business processes of Table 5.2. Also, because emphasis here is placed on the resource characteristics necessary to enhance food security parameters, this business process falls within the *physical, biological and chemical* category of Figure 5.17. It is therefore important to note that it is the nature of the theme or study area that defines the business process and thus the data needs follow thereafter.

1.1 Role of the workbook

The role of the workbook is to show a possible future scenario comprising particular dimensions, identified through systems analysis, to emphasise the importance of including them when collection data in the present so that they are available when needed in the future. It is important to note that in this dissertation, only a few dimensions were chosen to illustrate the application of systems analysis and the workbook. It is equally important to note that the workbook presents only images, envisaged outcomes and ideals relating to each dimension under consideration and nothing factual about their future. However, it is the relationship between present and past business practices and processes governing life in general that makes it possible to accept these envisaged outcomes and ideals as possible outcomes.

A major role of the workbook in LIS design and development is that of shifting management thinking processes towards building an understanding of the processes, structures, and contingencies of change that will shape the future of a given theme. This process allows decision makers to think through what the plausible or ideal future is likely to be. In this way, LIS developers can start preparing now for that future so that stakeholders are ready when it becomes reality. Only by carefully thinking through the process of each dimension and the relationships between trends, such as those of poverty and population growth, how they occurred, and approaches toward addressing them – including information technology utilised for food security – will the ways that they affect each other be understood. This will immediately lead to coherence and coordinated efforts between concerned parties, who may or may not be part of the same organisation, when collecting data. In this context, a workbook that utilises systems analysis principles becomes a very useful tool for guiding strategic thinking processes, without necessitating going through an environmental scanning exercise. The systems analysis provides the criteria for selecting certain dimensions critical to a given theme, while the workbook provides the possible future occurrences of such dimensions that require data collection and storage in an LIS, thus aligning the LIS dimensions with a more strategic thinking-oriented approach to systems effectiveness.

2.0 Future occurrences of selected dimensions

As indicated previously, the dimensions referred to are those that were identified during systems analysis and derived particularly from the aforegoing mind-mapping and E-RD diagrams (i.e., Figure 5.17 and 5.18). An elaborate view of some of these dimensions is given in the following subsections.

2.1 Human resource dynamics

2.1.1 *Education*

Education determines the future human capital available in a country, thereby serving as a fundamental building block of social capital and economic progress. This is because, even though a country may have access to state-of-the-art technologies, if it does not have the right human skills and talent to operate these, it could fail to realise the full potential of these technologies. In this regard, Gordon (2003: 2-182) foresees that many jobs worldwide will go unfilled because people are not being educated for the real needs of the future workplace. In South Africa, a large proportion of the population is expected to fail to cope with the demands of economic and social change in the knowledge era. For example, the Research Institute for Education and Manpower (RIEP) projects that the average annual growth rate of learners who graduate from tertiary institutions will decrease by about 0.25 percent during the period 2001-2010. A poorly resourced workforce comprising limited human capital will result in increased unemployment, widening income gaps and escalating poverty.

The importance of unskilled, cheap labour and bountiful raw materials as a source of comparative advantage is declining in favour of skills and knowledge-based manufacturing. Longer-term trends in workforce requirements indicate a favouring of highly trained, well-paid, technology-literate professional employees over unskilled personnel. Knowledge investments therefore hold the key to economic growth (Buvton *et al*., 2003: 2-183), and as has been witnessed in the growth in numbers of the jobless within the South African economy, technological progress is weakening the relationship between economic growth and increased employment opportunities. The current shortage of highly skilled labour in South Africa, especially in the engineering, artisan and service industries, may thus affect the implementation of long-term development projects.

It is estimated that Africa has already lost one third of its skilled professionals through emigration in the recent decade and has to replace them with expatriates from the West at a cost of $1.4 billion per year. The Southern African Development Community (SADC) countries, in particular, are experiencing two fundamental problems – a lack of computer skills and under-utilised systems, caused by the 'brain drain' of highly trained IT personnel and IT training not being placed at the top of teaching priorities (Esterhuyse and Cedras, 2003: 3-31). South Africa has been experiencing a serious brain drain (the highest in the world) of locally trained skilled and experienced labour for several years, reputedly costing the country some R2.5 billion per year, but the actual figure is estimated to be three times higher than the official figure. In 2002, South Africa experienced a net loss of 6 280 economically active people (incorporating a net loss of 2 113 professional, semi-professionals or technical personnel). Almost 17 000 science and technology (S&T) professionals, (i.e., about one percent of the total S&T workforce) left South Africa to seek employment abroad between 1994 and 2001 (Jones, 2004: 01). Therefore, in the long term, South Africa runs the risk of losing its expertise to foreign countries, thereby losing its competitive edge.

2.1.2 *Population growth*

Population growth, as measured by growth rates, is an important factor in determining the magnitude of the burden that will be imposed on a country by the changing needs of that country over time. The latest UN long-range population projections indicate that the world population will continue growing and will reach an estimated 9.7 billion by 2050, raising serious concerns about how food demand will be met. At the current rate, the world's population will reach 7 billion people soon after 2010, with the majority of the population residing in developing countries (89.9 % in 1980-90, 95 % in 1990-2000; 97.6% in 2000-2010 and 98.4% in 2010-2020 – http://ww2.unhabitata.org/habrdd/global.html). In sub-Saharan Africa, population growth in absolute terms is projected to more than double by 2020 (Figure A2.1) from 1990. Compared to developed countries, developing and less developed nations will still have greater than 2% population growth rates, putting even more pressure on agricultural land for intensive agricultural productivity. Given current trends of population growth rates of over 2% and an increase in productivity of less than 1%, developing nations will fail to feed their citizens (OECD/FAO 2006: 13). The World Bank estimates that by 2020, Africa alone will have a food shortage of 250 million tons, with poverty and malnutrition expected to follow the same trend. These food deficits will have to be met either through imports (prompting an import-debt-trap) and/or through increased local production, requiring intensive production systems.

Local food supplies may also have to be sourced from distant places, requiring infrastructural development (especially roads and rail). Population pressure on arable land also contributes towards land degradation, as more and more marginal land is then needed for cultivation to feed more and more people (Du Toit *et al*., 2003: 5-20).

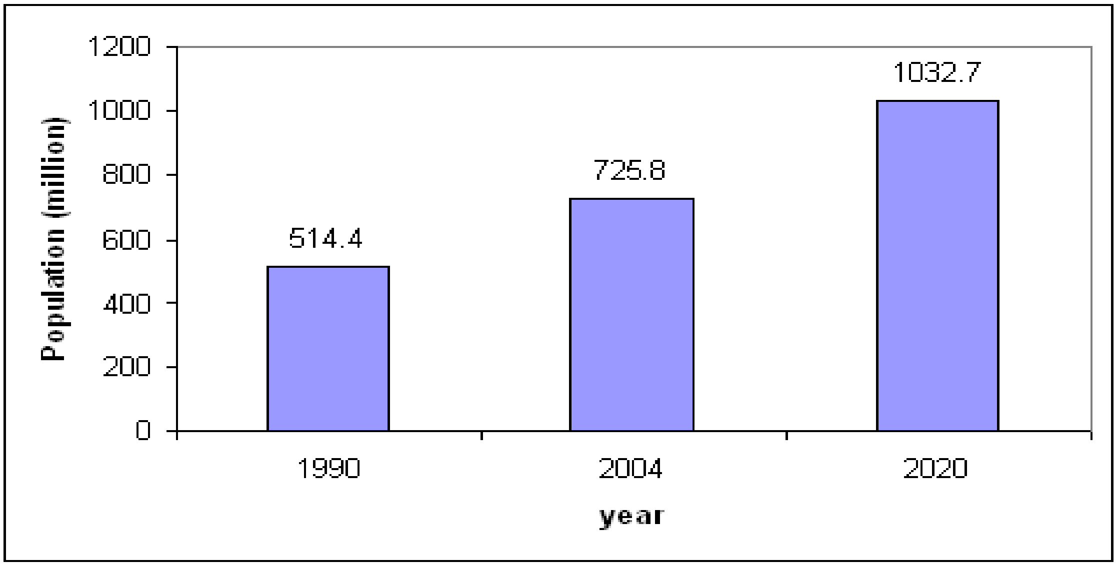

Figure A2.1: Population growth in Sub-Sahara Africa
Source: www.dedata.worldbank.org/wdi2006/contents/Table2_1htm

In South Africa, the population increased from 40 583 573 in 1996 to 44 819 778 in 2001, representing a 10.4% increase (Statistics South Africa, 1996 and 2003), with a July 2007 estimate of 43 997 828, i.e., a -0.46% growth rate (CIA World Fact Book, April 2007). According to the US Census Bureau (2003), the growth rate has declined from the 1980s to 1990s (Figure A2.2). This decline in population growth, specifically due to reduced fertility, the net migrant rate, and AIDS-related deaths has a negative impact on the availability of technical expertise, as it is the young generation that is mostly affected. South Africa is also a major exporter of food and beverages to neighbouring countries, such as Botswana, Namibia, Zimbabwe and Zambia.

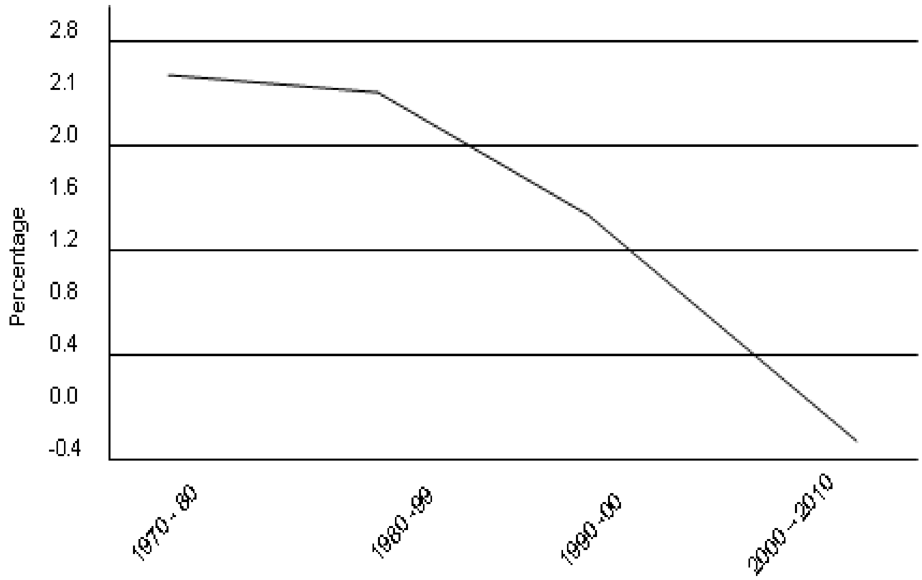

Figure A2.2: Population growth trends in South Africa, 1970 – 2010
Source: US Census Bureau, 2003. International Database. IDB Summary Demographic Data for South Africa www.census.gov/ipc adbsumm.html

Though the population of South Africa is expected to decline in the future, that of the sub-Saharan region is expected to increase (**www.earthtrends.wri.org/pdf_library/data_tables/pop2_2003.pdf**). This suggests a potential regional food insecurity scenario that will pose a challenge to South Africa. In order to satisfy the expanding demand in these neighbouring countries, South Africa will have to increase its agricultural productivity, most likely through vertical expansion. This demand will exert pressure on the land resource, prompting conservation issues and information needs from LIS. Normally, with increases in population, people leave agriculture and migrate to the cities, leading to a depletion of farm labour and possible changes in the general farming systems employed.

2.1.3 *Rural – urban migration*

A significant proportion of population increases in the developing world has been, and will continue to be, absorbed by urban areas (Figures A2.3 and A2.4). Recent estimates show urbanisation levels at 61.1% of the nation's total population for the year 2030. Yet, indications from Figure A2.3 and A2.4 are 93.4 percent of the global population is expected to live in cities by 2020, with over three-quarters of the world's population residing in developing nations.

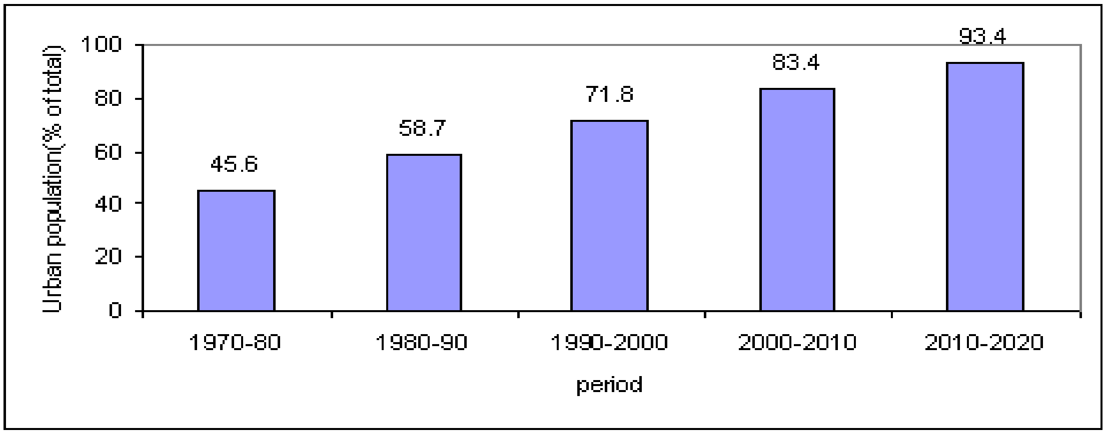

Figure A2.3: Urban population growth in developing countries
Source: http//:ww2.unhabitata.org/habrdd/global.html

Besides population growth, this transition is, and will be, driven by voluntary and involuntary migration, real and perceived employment, cultural expectations and changing consumption and production patterns. Experiences in developed countries show that industrialisation and urbanisation draw labour away from agricultural activities. Also, in the long-run, good agricultural land on the city periphery may be used for purposes other than agriculture, thereby compromising productivity growth. In poor developing countries, this may lead to (OECD-FAO, 2006: 26);

i) falling agricultural production if productivity growth is lagging,

ii) increased dependency on imports to satisfy domestic demand, and

iii) a shift in domestic production away from staple commodities (e.g., starchy staples), due to urban demand for high-value (protein-rich) foods.

All these factors are proxies for food insecurity, given that movement to urban centres does not guarantee sufficient employment to earn enough income to satisfy food and nutritional needs. This leads to increased poverty, malnutrition, ill-health and a possible demand for high-value food.

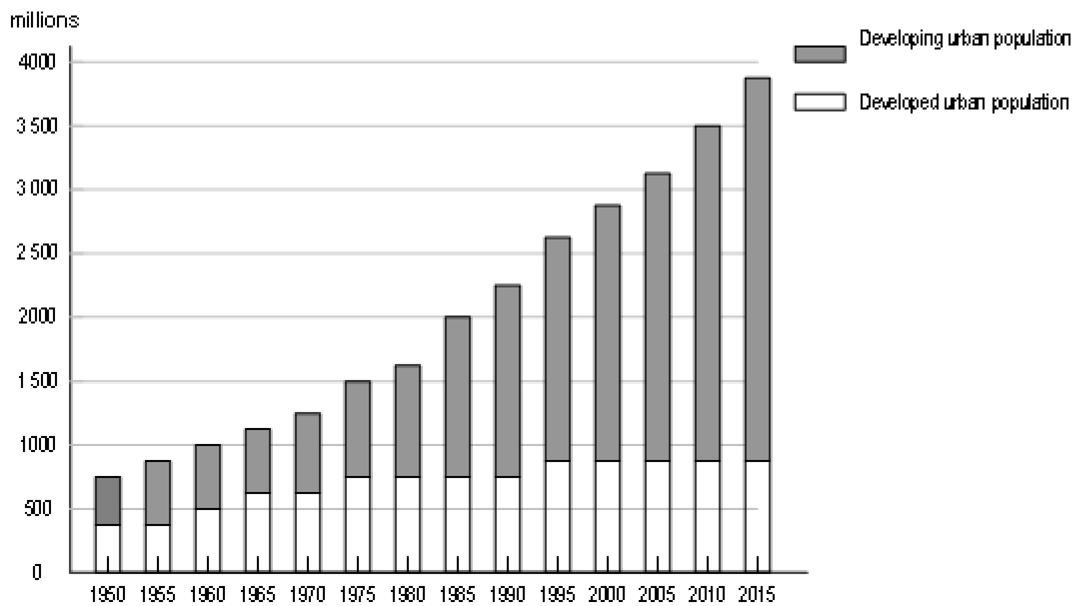

Figure A2.4: Urban population in developed and developing world, 1950 – 2015
Source: OECD/FAO 2006:25

The demand for high-value food may however promote the development of commercial agriculture and modernisation of the rural livelihood, provided such demographic shifts and resource re-allocations are complemented by modification, such as infrastructure development.

In South Africa, it is estimated that by 2011 the urbanisation rate will be about 1 million people per year (Spies, 1998: 2-24). Also, due to previous policies on settlements, South Africa is a special case in that urbanisation processes, exhibiting *oscillatory* migration (i.e., going back and forth) patterns, with migrants maintaining strong urban-rural ties.

Given this trend in urbanisation in developing countries, there will be increased demand placed on food supply and distribution systems to support urban dwellers, with increasing amounts of food being sourced from new and possibly distant production areas and more intensive production systems. This will demand greater efficiency from the food system, as well as enhanced agricultural productivity, while the issue of sustainability will also need to be taken into account (OECD-FAO 2006: 28). Additionally, to achieve a balance between world food needs (not demand), effective policies will be needed to curb population growth and slow down rural-urban migration, especially in sub-Saharan-Africa.

2.1.4 *Aging*

Population aging is a process whereby older individuals form a proportionately larger share of the total population. Over time, all countries are likely to face this problem, though in different magnitudes (UN, 2003: 2-66). It is estimated that by 2050 there will be more people over 60 years of age (about 30 %) in the world than those of less than 15 years of age (Buvton *et al*., 2003: 2-68). On a global level, the proportion of the population of at least 60 years of age was estimated at over 10 % in 2005. This is expected to rise to 12% in 2015 (OECD-FAO, 2006: 27). Figure A2.5, below, shows growth in population aging between 1950 and 2015 in developing countries. This is expected to reach 600 million by 2015.

In South Africa, the number of aged persons is projected to increase from 2.22 million in 2001 to 4.59 million by 2031, an increase of 107 percent. In contrast, the number of children aged 0-14 is projected to decline by about 38 percent from 14,37 million in 2001 to 8.98 million by 2031 (Buvton *et al*., 2003: 2-84).

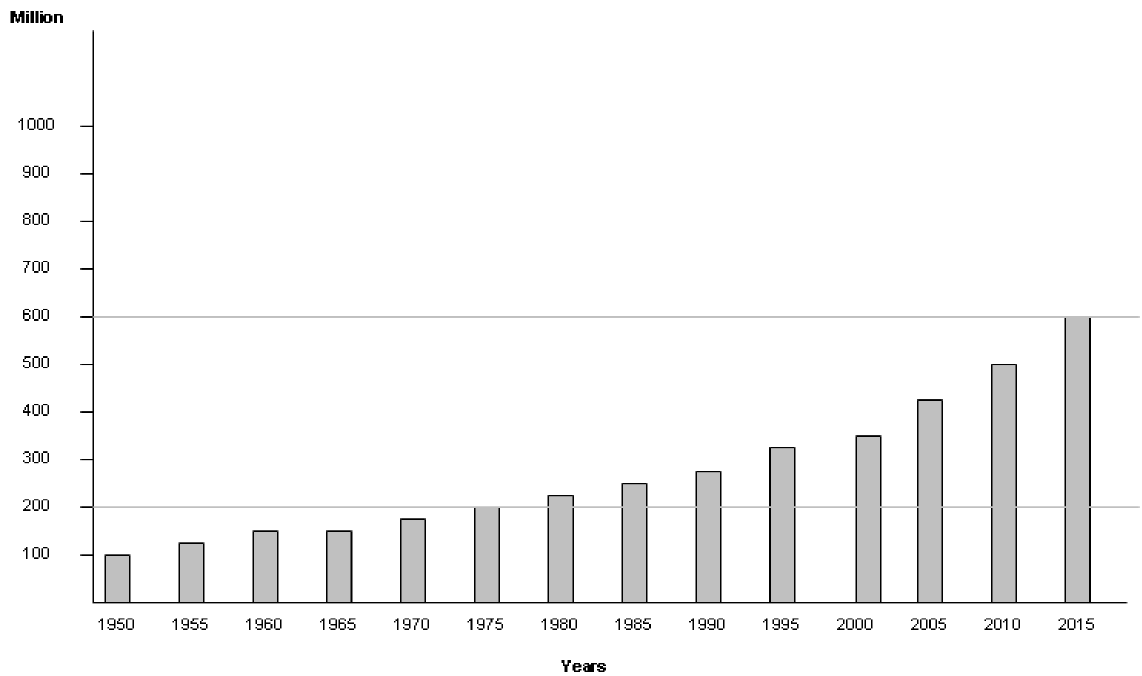

Figure A2.5: Population Aged 60 years plus in Developing Countries: 1950 – 2015
Source: Adapted from OECD – FAO Agricultural Outlook, 2006 – 2015 : 27

Table A2.1 shows some of these changes for the South African population structure.

Table A2.1: Actual (1996 – 2001) and projected (2011 – 2031) age distribution of South African population

Age Group	**Percentage of population**							
(Years)	**1996**	**2001**	**2006**	**2011**	**2016**	**2021**	**2026**	**2031**
1 - 4	34.3	31.39	29.3	27.2	23.7	20.9	18.5	16.9
15 - 64	60.8	63.4	66.1	68.2	71.1	73.1	74.3	74.5
65+	4.9	4.7	4.6	4.6	5.2	6.0	7.2	8.6

A major consequence of population aging is a severely impaired transfer of human capital from one generation to the next, due to a depletion of the replacement stock of skills and education that contributes towards an economy's potential. The volume and preferences for goods and services demanded by this group will also change, together with the production methods used. On a positive note, fewer younger people means that there is a possibility of better training for them, which is favourable for activities requiring higher skills such as those for LIS design and operation. These factors will have a major effect on the types of data to be collected and stored and the information that will need to be generated by LIS to satisfy future tastes and preferences.

An aging population has important implications for food demand, supply, and security, especially in rural areas. Elderly people normally consume more fresh fruits and vegetables and fewer animal products, with a reduced per-capita food demand. Further, production planning practices are likely to become more subsistence-oriented, leading to reduced adaptation to technological change, reduced investment in agricultural land, and ultimately reduced agricultural production. Generally, older people have higher income and accumulated wealth, more leisure time, and therefore more time to travel, implying an increased demand for tourist-oriented information.

When people living in towns get older, their need to spend time and money enjoying themselves outside the city environment increases. With the expected ageing of the South African population, there is going to be an increase in the demand for open air, beauty and outdoor leisure time. This increases the need to provide for aesthetic facilities and events in the city periphery or on nearby farms. The preservation of open grassland and plains therefore becomes vital to economic growth. Invariably this requires information on preferences, marketing and nature conservation, if a sustainable agri-tourism or eco-tourism approach is to be used. There is also a need to educate those running these agri-tourism farms on the best ways to run them, if they are to become competitive on a regional and international basis. In this regard, not only will LIS need to store agricultural-related information, but it will also need to generate the information necessary to run recreational places, facilities and events in a profitable and environmental-friendly manner, that is, in a manner more comparable to those found in countries and continents such as Kenya, Namibia, Botswana, and Asia. Conservation and management planning information required to protect resources from all forms of degradation is essential.

2.1.5 *Poverty*

Poverty is, and will remain, a major cause and consequence of environmental degradation (deforestation, soil degradation and desertification) and resource depletion, as the population increases and people strive to improve their standard of living. These scenarios can generally be linked to the many working definitions of *poverty*, with considerable ongoing debate occurring on how best to define the term. Income security, economic stability and the predictability of one's continuing ability to meet basic needs all serve as absolute indicators of poverty. Poverty may therefore be defined as the economic condition of lacking the predictable and stable means of meeting basic life needs, characterised by an inability of individuals, households and/or communities to attain sufficient resources and opportunities to enable them to lead a socially acceptable minimum standard of living (Wilkins, 1998: 5-7, unpublished summary report). The aforesaid circumstances may be a result of short-term shocks or long-term trends (macroeconomic trends and environmental degradation) that predispose vulnerable individuals and households to the vagaries of poverty and food insecurity.

Vulnerability to poverty is therefore a result of the inability to devise coping management strategies for dealing with such long- and short-term crises. Hence, by this definition, poverty is closely linked to economic growth, unemployment and human development. The major challenge is to specifically define what constitutes poverty and where exactly in the rural areas the poor are located. Defining the means to address poverty constitutes another challenge, as issues of accessibility (infrastructural development) and knowledge and education come into play.

Data on the long-term trends relating to poverty is not easily available because of the difficulty with measurement. A common measure of poverty is based on income or consumption and defines a poor person as one whose consumption or income falls below some minimum level (usually USD 1/day) necessary to meet basic needs.

Historically, there has been a progressive increase in poverty in sub-Saharan Africa, as measured by the proportion of people living on less than USD 1 per day. With increases in absolute numbers of population, this trend is likely to continue in the future. However, what is necessary to attain these basic needs varies across space and time, such that each country should use a measure that is consistent with its level of development, societal norms and values. Besides income-based measures, other social indicators of poverty include education, health, access to services, social capital and infrastructure, risk, vulnerability, and social exclusion.

2.1.5.1 *Trends in poverty over time*

On a global basis, substantial improvements in social indicators have been accompanied by growth in average incomes. For example, a report by the World Bank Group indicates that the proportion of the developing world's population living in extreme economic poverty has fallen from 28 percent in 1990 to 19 percent in 2002. Over the same period, the number of people living in developing countries grew 20 percent to more than 5 billion, leaving 1 billion people in extreme poverty. In sub-Saharan Africa, GDP per capita shrank by 14 percent, and extreme poverty increased from 41 percent in 1981 to 46 percent in 2001. Current projections are that in 2015 Africa's poverty rate will remain at over 38 percent – far above the 22.3 percent set for the UN Millennium Development Goals.

(**www.worldbank.org/WBSITE/EXTERNAL/TOPICSEXTPOVERTY/EXTPA/0**).

In South Africa, most of the poor, comprising 72% of the total population, live in rural areas. The poverty distribution can be defined in a spatial context, with the Eastern Cape, Northern Cape and North West comprising over 70% of the poor (Aging and Poverty in South Africa, 2003: 3). The poverty rates in South Africa are shown in Table A2.2 below. What is interesting in Table A2.2 is that the aged population is greater among the poor, and with a relatively aging population, vulnerability to poverty is expected to increase in the future.

Table A.2.2: Poverty rates (%) in South Africa by age group

Poverty Measures	Not Old	50 - 63	64 - 73	74 - 83	84+	Total
0.5 of poverty line	28.0	25.5	24.8	23.5	25.1	27.6
Poverty line	30.0	27.4	32.4	31.2	29.7	29.9
1.5of poverty line	14.2	13.7	13.7	14.0	13.4	14.2
Twice the poverty line	7.6	7.7	7.7	7.1	7.7	7.6
>Twice the poverty line	20.1	25.7	25.7	24.1	24.1	20.7

Source: Ageing and poverty in South Africa, 2003:3. www.un.org/esa/socdev/ageing/documents/workshops/Tanzania/South%250africa.pdf

2.1.5.2 *Unemployment*

Unemployment and total employment in an economy are broad indicators of economic activity, as reflected by the labour market, and have a direct influence on poverty and access to food. High and sustainable unemployment indicates serious inefficiencies in the allocation of labour resources. However, low unemployment rates can usually disguise substantial poverty in a country. In nations where there are well-developed safety nets, workers can, for example, remain unemployed until a suitable job arises.

Although the government in South Africa has put in place policy initiatives such as the Reconstruction and Development Programme (RDP) and the Growth, Employment and Redistribution (GEAR) strategy, there has not been much reduction in poverty, especially in rural areas, where unemployment is still high. South Africa has an increasingly high unemployment rate, estimated at 28.2% of the economically active population and growing at about 2% per annum (Statistics South Africa, 2005). Most of the unemployed also fall into the category of unskilled labour. In the World Bank GJMC report, for example, 95% of large firms in South Africa reported that they did not have any difficulty in finding unskilled labour. There has also been fluctuation in unemployment rates in South Africa, ranging from 26.2 to 30.4 % of total population (Statistics South Africa, 2005). Given the gross population of 47.39 million in mid-2006, these rates are considerably high. Employment in agriculture has also been declining over the years. With a current policy in agriculture of capital/labour substitution, resulting from falling commodity prices, increased population pressure, and the need for increased vertical productivity, this trend is expected to continue worsening the farm labour problem that already exists. As agriculture provides the main source of income in rural areas, this implies increased vulnerability to poverty and food insecurity.

South African poverty has a strong rural bias that is highly influenced by the nature of urban-rural interaction. This is because the main sources of income for rural people, other than from farm labour, comes from wages -52 %, social transfers -18%, and remittances -14%, mostly earned in urban areas.

2.1.6 *Human resource data needs*

AN LIS, by nature, contains data on resource characteristics in a spatial format, and as such, only data of this nature will generally be considered for all the variables under consideration. It is also worth noting that only a few data sets are included in this subsection for illustrative purposes and that an elaboration on these is given under the conclusion to the annexure. As indicated in the systems analysis section, data needs are specified by the attributes that define the characteristics of the issue under consideration. This is because, over time, it is these attributes that will change and thus influence the direction and magnitude of the effect of a given entity. In the case of human resource factors, it will therefore be necessary to keep data on the following:

i) population growth (absolute growth rates and distribution by age group and location), which will then define the magnitude of pressure exerted on other resources such as, land, food demand, and educational and health systems;

ii) rural-urban migration rates;

iii) unemployment/employment rates;

iv) poverty rates, vulnerability groups and their distribution over space and time; and

v) average annual growth rates relating to learners and emigration (particularly in engineering and among artisans).

2.2 Renewable resource characteristics (land, water and forestry)

Land resources are important, as human beings depend on them for their livelihoods, particularly in the developing world. Due to increases in population, pressure on the world's land resources has increased greatly, and the global landscape and land use patterns have changed profoundly. The most significant change has been the expansion of crop lands and the diminishing of forestry and grasslands, characterised by degradation, and a general loss of land productivity.

2.2.1 *Land degradation*

Land degradation may take a number of forms, such as the depletion of soil nutrients, salination and vegetative degradation (Table A2.3). Major causes of degradation include erosion, poor agricultural practices, such as, overgrazing, overcropping, and deforestation. Soil degradation caused by deforestation is a serious threat in Africa. Thirty-seven million hectares of forest and woodlands in Africa are said to be disappearing each year (FAO, 1986, in www.fao.org/docrep/X5318E/x5318e02.htm). The rangeland has also changed with many perennial grasses being replaced by nutritionally poor grasses. Africa and Asia seem to have the highest proportion of degraded agricultural land, with Asia having the highest proportion of degraded forest land (Figure A2.6). Various sources suggest that 5 to 10 million hectares are being lost annually to deforestation.

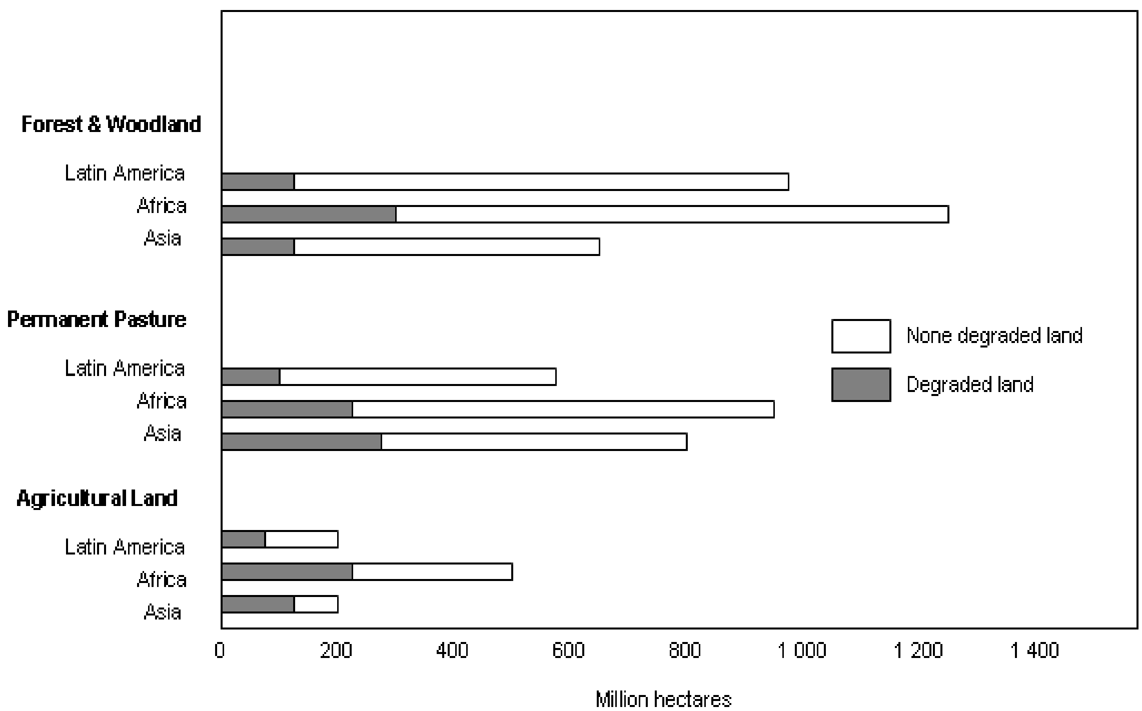

Figure A2.6: Land degradation by type of land use, 1945 – 1990
Source: Scherr and Yadav, 2001. www.ifpri.org/pubs/books/ufa_chpt21.pdf

Projected deforestation rates are shown in Table A2.3. Indications are that, though deforestation will reduce over time, due to replanting and conservation measures, a substantial amount of forest will still be lost, particularly in Latin America and Africa (Table A2.3). This will result in a decline in the productive capacity of land, reducing potential yields and leading to increased vulnerability to food insecurity. A study in 1995, by Ruttan Lal, on the impact of degradation in Africa estimated that yield reduction due to past erosion may range from two percent to 40 percent, with a mean of 8.2 percent for the continent and 6.2 percent for sub-Saharan Africa. If accelerated erosion continues unabated, yield reductions by 2020 may be 16.5 % for the African continent as a whole and about 14.5 % for sub-Saharan Africa (Scherr and Yadav, 2001: 135).

Table A2.3: Projected deforestation rates, 1995–2045 (in units of 1 000 km^2)

	1995	**2005**	**2015**	**2025**	**2035**	**2045**	**Cumulat Total**
Africa	46	39	33	29	25	25	1960
Asia	33	30	27	22	19	19	1480
Latin Ame	78	63	51	42	36	36	3050
Totals	157	132	111	93	80	79	

Source: Chapter **4 - Forest Degradation data: Edition 6, July 2007. http://home.alltel.net/bsundquist1/df.html#Ac**

Land degradation may lead to the conversion of land to lower-value uses and/or temporary or permanent abandonment of plots (Rosegrant, *et al.,* 2001b: 79-80, in du Toit, *et al*., 2003: 5-20). Degradation also diminishes agricultural income and economic growth. For example, in South and South-east Asia, estimates of total annual economic loss from degradation range from 1 to 7 percent of the agricultural gross domestic product.

2.2.2 *Water resources*

Water scarcity will be the most limiting threat to attaining projected yield growth (du Toit *et al*., 2003: 5-20). By 2020 global water needs will increase by 35 percent, with high demands on water resources, particularly in developing nations where droughts are currently very common and water withdrawals are projected to increase by 43%. With the uncertainties of global warming, policymakers will need to increase the awareness and responsiveness of farmers and societies to possible environmental changes and water needs. There will also be a need to increase research into crops that are heat-tolerant and that require little moisture. All of these factors will require flexibility in LIS functioning.

Developing nations are continuously faced with problems associated with poverty, climate change, resource degradation and a growing loss of biodiversity, all of which result in a high incidence of malnutrition. In order to address the problems of poverty and malnutrition, many of these countries will have to expand their agricultural production, either by horizontal (extensive area expansion) or vertical (intensive) means. Both ways exert pressure on the natural ecosystem, given that in many developing countries an additional one-third of their land cover is expected to be converted to agricultural and urban or built-up areas within the next 100 years (World Resources, 2000-2001, and 2000: 24).

In South Africa, for example, most of the high quality arable land (such as in the Western Cape) is already under use, and as such, there is limited room for horizontal expansion. Therefore, increased production will be either through intensive means or through expansion into areas not really suitable for agricultural production. With the advent of globalisation, characterised by competitiveness and efficiency, some farmers will be forced out of agriculture completely, while others will convert their agricultural farms into other uses such as agri-tourism. For both alternatives, the ill effects of pollution, degradation and destruction of the ecosystem are possible. Hence, information for planning intensive production, conservation and alternative land uses becomes vital.

2.3 Food production and cereals demand

FAO's 1985 study of the carrying capacity of land in developing countries, which compared Africa's projected future population with its food production potential, indicated that the number of countries unable to feed themselves will rise from 22 out of 49 in 1975, to 35 by the year 2025. The same study concludes that by 2025 Africa as a whole will be able to feed only 40 percent of its population (FAO, 2002, **www.fao.org/docrep/x5318E/x5318e02.htm**), which is indicative of a serious food insecurity scenario. Additionally, crop yields may be approaching their physical limitations in some high-yield systems, with environmental constraints and awareness adding uncertainty to future yield expectations from intensified agricultural production.

Table A2.4 gives trends in global cereal demand for 1994, 1997 and 2020. Growth in cereal demand in developing countries is projected to decline from 2.3 percent per year in 1994-97 to 1.3 percent in 1997-2020, mainly due to a slowdown in population growth rate and changes in dietary preferences, with worldwide demand for meat forecast to rise by more than 55 percent during 1997-2020. Even though demand is generally slowing, farmers in developing countries will not be able to keep pace (Rosegrant, *et al.,* 2001: 3).

Table A2.4: World demand for cereals (metric tons), 1994, 1997 and 2020

Year	**Developed Countries**	**Developing Countries**	**World**
1994	664	560	1208
1997	725	1118	1943
2010	822	1675	2496

Source: Rosegrant *et a*l., 2001, 2020 Global Food Outlook, www.ifpri.org/pubs/fpr/fpr30.pdf

However, in a global world, with open competition and prices determined by market forces, a nation's competitive advantage will be determined by either product uniqueness or differentiation, enabling higher prices or lower cost. AN LIS therefore becomes an important factor in creating national competitiveness by identifying unique spatial entities that can produce certain types of products for the international/national/regional markets.

2.4 Advances in information technology

Information is increasingly becoming a very valuable commodity in agricultural processes. Likewise, material science for information technology continues to produce a variety of new materials, with new properties and new applications. There is generally a doubling of productive capacity every nine to eighteen months (Soltynski, 2003: 4-22), with computer power doubling every 18 to 24 months (Moore, 2003: 4-25) (see Table A2.5), due to developments in computers, computer networking, data gathering, storage and manipulation, telecommunications, and sensing. These factors have implications for overall data and information quality and costs, as well as for the degree of sophistication of a given LIS.

Table A2.5: The key drivers of information technology

The key drivers of information technology	
Technology area	**Current Trend – Doubling period**
Integrated circuit (e.g., PCs)	x2 in speed & density every 18-24 months (Moore's Law)
Photonics (e.g., Optic Fiber	x2 in transmission capacity every 12 months (Gilder's Law)
Storage (Hard drives)	x2 storage density every 9 months
Wireless data transmission	x10 – x1000 in channel capacity in five years
Displays	x2 in pixels every 24 months
Software	x2 in operating system size every 24 months

Source: Murray, 2002, in Soltynski, 2003: 4 - 23

The manpower required also changes, as more and more systems become more user-friendly and thus do not require one to have an in-depth technical knowledge about the functioning of the artefact per se However, as more data from different sources becomes available, the skills and knowledge requirements for analysis and interpretation become more important

2.4.1 *Capacity and performance improvement in personal computers*

Forecasts of personal computer (PC) performance trends are shown in Figure A2.7. This increase in complexity and performance means that the cost of a unit of processing power has dropped dramatically over the past decade and will continue to do so (Soltynski, 2003: 4-25). The major impact of these developments for an LIS is that software and databases that previously needed a minicomputer in the $10 000 range can now be run on PCs in the $1 000 range.

The telecommunications industry is also undergoing dramatic changes, doubling every 12 months in terms of capacity (Gilder's law), and growing in cellular telephony networks and wireless Internet access. The cost of international phone calls also continues to drop, having fallen by a factor of four. This is expected to decline to the cost of a local call

(ITU, 2003: 4-28), due mostly to a fall in settlement rates because of competition, alternative routes and political pressure.

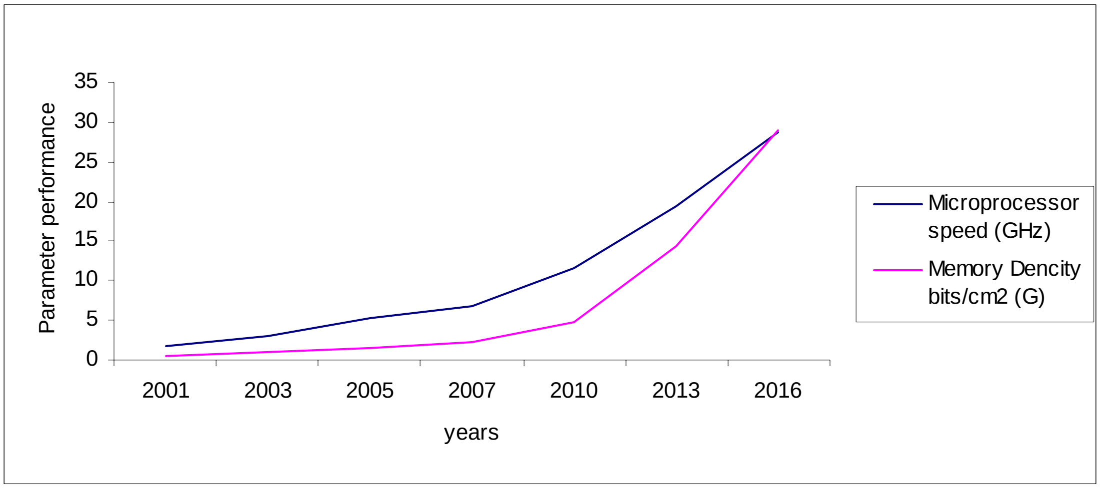

Figure A2.7: Forecasts for some microprocessor parameters (2001-2016)
Source: Soltynski, 2003:4-26

All these developments translate into cheaper LIS processes, with increased data and information quantity.

2.5 Major indications, data needs and implications for food security

Major indications of the workbook and implications for food security are the following:

i) Though generally there has been and will continue to be a decline in population growth rates in the future, there will be an increase in absolute numbers, especially in the developing world and particularly in sub-Saharan Africa. This increase in population presents both difficulties and opportunities. The existence of fewer young people allows for better training opportunities, which is favourable for activities requiring higher skills, such as those involved in LIS design and operation. This would increase the capacity for both growth and poverty. On the risk side, a large population will exert a lot of pressure on the land resource, leading to degradation, reduced land productivity, and thus an increased vulnerability to poverty and food insecurity. Another consequence of this is the financial need to keep the aged population economically active, given their wealth of experience. Therefore, data needs to be kept on population projections and age distribution, as well as on the distribution of the vulnerable groups in terms of space and time. Information on educational attainment is necessary to provide indications on the skills levels of the labour market. To support the increases in population that will be more concentrated in the urban areas of developing countries, food production will in future have to come from more and more marginalised areas, which will lead to increased soil degradation, deforestation and decreased land capacity for increased food production. Sub-Saharan Africa is, and will remain, the world's most vulnerable region in terms of water availability, global climate changes and general food security. This poses serious conservation challenges to forests as well as general biodiversity.

ii) Migration to cities normally implies modernisation of agriculture and a demand for information for planning intensive agriculture and nature conservation. Good data is therefore needed on land capabilities (quality, quantity and location), as well as on the rates and location of deforestation, biodiversity degradation and water resources. South Africans and people in general are now more conscious than before about the effects of their actions on the environment and the need for sustainability. To avoid a conflict of interest, there will be a need to identify those areas where conservation can be undertaken without necessarily interfering with agricultural production patterns. This requires identification of the best agricultural production and nature conservation areas, as well as a balancing of the tradeoff between the benefits of each activity. Information will thus be needed on intensive production, irrigation efficiency, and the impact of factors such as fertilisers and pesticides, as well as on infrastructure development needs and urban planning.

iii) Globally, there have been substantial achievements in economic growth, but in sub-Saharan Africa, per capita incomes, unemployment, and general poverty (especially urban poverty) will continue to be a challenge to the attainment of food security and a general improvement in standards of living. Though it is difficult to keep accurate data on these factors, for the close monitoring of living standards, there will need to be good records kept on employment/unemployment rates and income distribution, as well as on the numbers and geographic distribution of the poor and vulnerable groups, with health and nutritional levels being important indicators.

iv) There have been substantial achievements in IT development in terms of reduced costs, increased capacity, and processing speed. To take advantage of these opportunities will require increased investment in education and research and development. Close monitoring of research activities as well as education in engineering and among artisans will assist in refocusing the education system such that it is ready for the information age.

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