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A Structural Approach to the Management and Optimization of Geoinformation Processes

Report by M. Mostafa Radwan,
Richard Onchaga and Javier Morales

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Table of contents

A Structural Approach to the Management and Optimization of Geoinformation Processes

with 73 figures, 63 tables and 5 appendices

Report by M. Mostafa Radwan, Richard Onchaga and Javier Morales

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Index of Figures

Index of Tables

Preface

Digital geoinformation technology had been introduced in many National Mapping Organisations (NMO) since the 60th, mainly to support data acquisition and to replace lengthy and rigid cartographic operations. Experience in these organisations, however, indicates that return on revenue on the heavy investment made is still below expectation. This due to the fact that most of these organisations National Survey Offices (NSO's) in the world are still characterised by their traditional way of doing business, built up in a time when government funds were secure and the mapping market was relatively stable. Further there is almost daily evidence that these organisations are facing many challenges concerning:

- The reduction of government funds to the national NSO's and the need to generate revenue to support its existence;
- The fast developing GIS-market and the merge of new generation of GI users;
- The long delays in responding to GIS users, as a result of the lengthy base-mapping programs, and consequently user's dissatisfaction;
- The need for diverse GI products and substitutes for the conventional base maps;
- The threat of new competitors who are encouraged by the present of cheap technology and easy access to row spatial data and have a flexible approach to adapt to changing requirements;
- The continuous development in information technology and its fast impact on the geoinformation industry.

In many countries, NMO's are under the pressure to revise their mission from business perspective and to be competitive, without violating its national mandate. In this pursuit they can benefit from modern concepts applied in other industries such as Business Process Redesign (BPR), formal methods for the dynamic modelling of processes, simulation modelling of processes and testing performance and the impact of change, Workflow Management (WFM), Total Quality Management (TQM), Structural Methodologies for the implementation of changes at both organizational, business and operational levels, etc.

The European organization for Experimental Photogrammetric Research OEEPE had approved a research proposal, presented by M.M. Radwan at ITC, to investigate these issues and prepare this publication. Within the framework of this proposal, several MSc. and PhD. students at the International Institute for Aerospace Survey and Earth Sciences ITC had conducted their research work, under the guidance of M.M. Radwan, in these fields. The objective is to develop methodologies for the re-design of NMO's, optimisation of spatial data production and dissemination processes and the operationalisation of modern concepts in operations management. The result of these research activities had been included in this publication.

The editors of this publication acknowledge the contribution of the Geoinformatics Management and Infrastructure Division at ITC, particularly Professor Richard Groot and Mr. Chris Paresi. Additional acknowledge to the work of the ITC MSc/PhD students:

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  - R. Sani; Dynamic modelling in the reengineering of geoinformation production processes.

- R. Onchaga; Performance Modelling of Geoinformation Production Processes.
- J. Dominguez; Guidelines for the implementation of a service-oriented strategy in a mapping organization, emphasis on designing products and processes involved in different levels of aggregation (product hierarchy and product diversity) and the role of modern mapping technology as enabling tool to implement a service-oriented strategy.
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1 INTRODUCTION

1.1 Motivation

Most of the Spatial Information Providers in the world today are the so-called National Mapping Agencies (NMA) although private participation is growing. The NMAs have for long been the workhorse for geoinformation production and servicing with national mandates to cover whole nations with base maps, develop maps to support land administration and generally meet the national demand for spatial information. Application of digital technology in these organisations can be traced back to the 1960s, but for long technology was primarily deployed to enhance the efficiency of existing operations through automation. Nonetheless the 90s' saw increased awareness amongst geoinformation production organisations of the enabling capability of information technology developments. As a consequence a growing number of these organisations have embarked on reengineering programmes to take advantage of technology developments and counter several challenges that confront them.

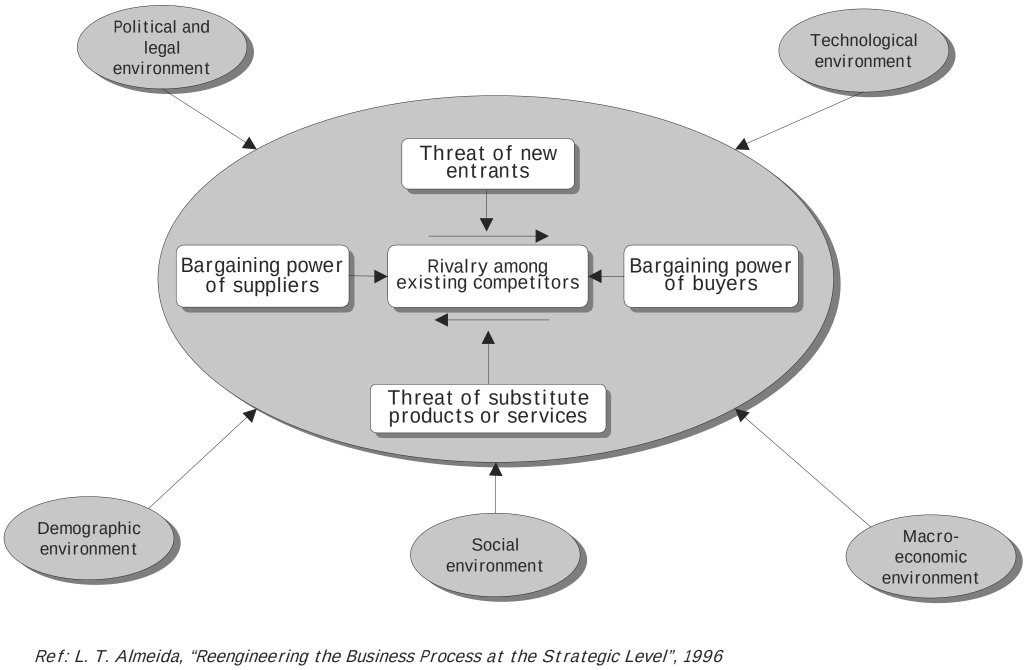

Figure 1-1 The five forces model

In the early days, geoinformation-processing organisations focussed on producing a limited range of specialised products, mainly paper maps at a hierarchy of standard scales. The content and quality of these products were defined by 'mapping experts' whose interaction with the end-users was very limited and little or no attention was given to what the users thought of the quality of these products. While this mass-production oriented culture may not be entirely unexpected considering the monopolistic position of the NMAs, the secure government funding they enjoyed and the relatively stable markets they commanded, it can no longer be sustainable in present times. As the wind of change sweeps, organisations will be forced to change their ways of operation either to defend their markets positions or because of the new capabilities and opportunities technological advancements unveil.

Careful analysis of the spatial data handling business environment using Michael Porters' Five Forces Model (Figure 1-1) reveals that among the key challenges geoinformation production organisations' face today are:

- Diminishing government funding which has created need for the organisations to generate revenue to sustain their activities;
- The proliferation of affordable and easy-to-use GIS tools has seen the emergence of a new generation of geoinformation users that is more sophisticated and better aware of product quality requirements, thus making unprecedented demands on NMAs;
- The expansion of the customer base as a result of growth in the number of application domains creates need for diverse geinformation products and substitutes for conventional base maps;
- The threat of new competitors who are encouraged by the presence of affordable technology for spatial data handling;
- Continuous developments in information technology impact on the acquisition, analysis and dissemination of spatial data, creating new processing options and opening up new markets e.g. the successful launch of Ikonos imaging platform with one metre spatial resolution is bound to open a host of new applications for satellite imagery. The same can be said of systems that enable real time kinematic positioning using Global Positioning Systems (GPS), digital photogrammetry, and laser altimetry, Geographical Information Systems (GIS) etc.

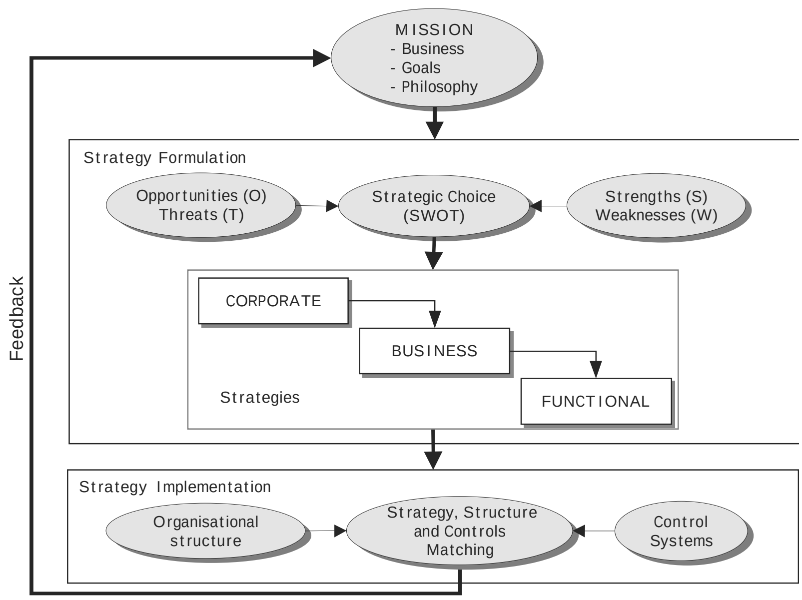

Figure 1-2 Strategic reengineering at all levels [Almeida, 1996]

It is without doubt that geoinformation organisations, and National Mapping Agencies in particular, need to redefine their strategic orientation and embrace modern business practices in their production processes to meet diverse customer demands without violating their national mandates. Over the last decade a number of NMAs have undertaken reengineering programmes in response to the market dynamics. Business process reengineering has been defined by [Hammer and Champy, 1997] as the radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance such quality, service diversity and speed.

While reengineering has been touted as the panacea to the problems afflicting NMAs it should be borne in mind that an enabling operating environment is necessary. The Ordnance Survey of Great Britain (OS) presents an excellent example of an NMA that has successfully reengineered its operations, nonetheless it was not before it was granted a special status; that of a Trading Fund – a status allowing it more commercial freedom than would otherwise be possible for a public sector organisation.

Innovative integration of information technology (IT) and modern mapping systems in geoinformation organisations should facilitate the introduction of new and more effective process design options. This contrasts sharply with the way organisations' previously applied technology to automate existing processes. The greatest benefits will accrue from being able to process geoinformation in entirely different ways, generate a whole new set of different products and disseminate this information in totally new ways that were not possible without the technology.

Reengineering an organisation is an expensive endeavour often faced with high resistance from workers and management alike. Evidently it cannot be sustainable if there is no support and commitment from top management. However, even with commitment from top management, a systematic approach to the whole reengineering exercise is necessary to ensure tractable designs and results.

Geoinformation organisations, or any organisation undertaking reengineering for that matter, will need as a first step to assess their capabilities from a business perspective. In other words, top management needs to make decisions and take actions that will give the corporation, its constituent business units and production processes a new a strategic orientation [Hunger and Wheelen, 1997]. In all cases management needs to identify existing and potential performance problems, define improvement goals and develop strategic plans for change focussed on the effective use of information technology. At each management level, a different set of strategic objectives will be developed, however each lower level objective should be constrained and linked to a higher level objective and in all the objectives should be such as to enable attainment of the corporate mission and vision (Figure 1-2).

Over the years several concepts, tools and methods have been developed and applied in industry that are potentially applicable to geoinformation organisations and their productions processes. The concept of Business Process Reengineering, incorporating strategic management principles, has been applied to organisations and processes in diverse environments leading to breakthrough improvements in performance. Business process modelling concepts, performance modelling and measurement methodologies, workflow management (WFM) and Total Quality Management (TQM) are all valuable tools that can be used to analyse, design, test, implement, control and monitor organisational structures and process designs to achieve radical improvements in performance. To effectively address the diverse user requirements and in applying the available tools to optimise performance and enhance their competitive advantage, NMAs need to, among other things:

- Realise the enabling role of IT as opposed to being an efficiency improving technology;
- Develop processes that support modular design of products based on basic components allowing for hierarchy in product complexity;
- Investigate alternative ways of generating products to meet varying quality requirements for different users;
- Design architectures and infrastructures that will facilitate outsourcing of resources while at the same time enhancing customer self-service capability to allow customers to access resources in the organisation and customise their products;

- Apply performance modelling tools and techniques in testing alternative strategies and design options and through careful implementation of WFM and TQM techniques institute a sound quality management culture;
- Participate in the development of various standards and guidelines for the production and dissemination of geoinformation

Several research studies have been carried out to explore the applicability of several concepts, methodologies and tools that have been successfully applied in industry to the geoinformation processing and management.

1.2 Organization of the report

The report is organised into six chapters. Chapter 1 is a general introduction to the subject of reengineering in geoinformation organisations outlining the main environmental factors underpinning the shift. The chapter also highlights keys areas where improvement efforts will need to be focussed.

Chapter 2 introduces the fundamental concepts of Business Process Reengineering and describes strategic management at both the corporate and the operational levels with reference to geoinformation organisations. Internal and external scanning are described, strategy development outlined and some BPR initiatives for geoinformation organisations presented. A BPR methodology is presented and discussed.

In Chapter 3 concepts for capturing and formal representation of business processes are discussed to enable formal description of processes.

After the conceptual design and formal description of processes, performance analyses are necessary to enable comparison of alternative process configurations. Chapter 4 introduces performance analysis and discusses queuing as a means of modelling the behaviour for quantitative analysis of the performance of geoinformation processes. Some potential performance goals are discussed. The chapter presents a performance modelling methodology based on the simulation technique.

Chapter 5 discusses simulation modelling as a performance evaluation technique.

Workflow management tools present a powerful means of streamlining and controlling processes. On the other hand total quality management provides systems that are continuously focussed on ensuring customer satisfaction in the production process through incremental quality improvements. Chapter 6 discusses both WFM and TQM as methods of implementing and supporting BPR respectively.

2 Business Process Reengineering (BPR)

2.1 Introduction

Business Process Reengineering (BPR) is a concept that originated in the private sector in the United States as a method of helping companies sustain and increase market share in a competitive and dynamic market place. Over the years, application of reengineering concepts has been extended to public agencies with a view of encouraging them to be more efficient and effective in their operations. National Mapping Agencies (NMA) provide typical examples of organisations that could benefit from reengineering programmes in view of the turbulence and complexity in the geoinformation business environment. As an introduction, alternative definitions of BPR are presented and its main characteristics discussed. Strategic visioning and planning are discussed, their roles explained. The chapter presents some BPR initiatives for spatial data handling and discusses a BPR methodology for geoinformation processing.

2.2 BPR defined

Depending on who one talks to, there can be many different definitions of Business Process Reengineering (BPR). [Dodaro et al, 1997] describe Business Process Reengineering (BPR) as a systematic, discipline improvement approach that critically examines, rethinks and redesigns mission-delivery processes in order to achieve improvements in performance in areas important to customers and stakeholders.

[Hammer and Champy, 1993] define BPR as “the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as quality, service and speed”.

Thomas Davenport, in his book Business Process Innovation [Davenport, 1993], says, “reengineering is only part of what is necessary in the radical change of processes. The term process innovation encompasses the envisioning of new work strategies, the actual process design activity and the implementation of the change in all its complex technological, human and organisational dimensions.”

The Department of Defence’s (DoD) Corporate Information Management (CIM) initiative defines business process reengineering in terms of functional process improvement. The DoD guidance defines functional process improvement as the application of a structured methodology to define a function's “as-is” and “to-be” environments, its current and future mission needs and end user requirements, its objectives and strategy for achieving those objectives, and a program of incremental and evolutionary improvements to processes, data, and supporting aids that are implemented through functional, technical, and economic analysis and decision making.

While all the above definitions are not absolutely similar, they have a great deal of commonality among them. They are all based on a vision for the future, they are not about improving the performance of existing processes; they are about creating new radically different process to provide breakthrough achievements in performance and customer satisfaction. BPR is essentially about recasting the management experiences of the industrial age into the information age framework (Electronic College of Business Innovation).

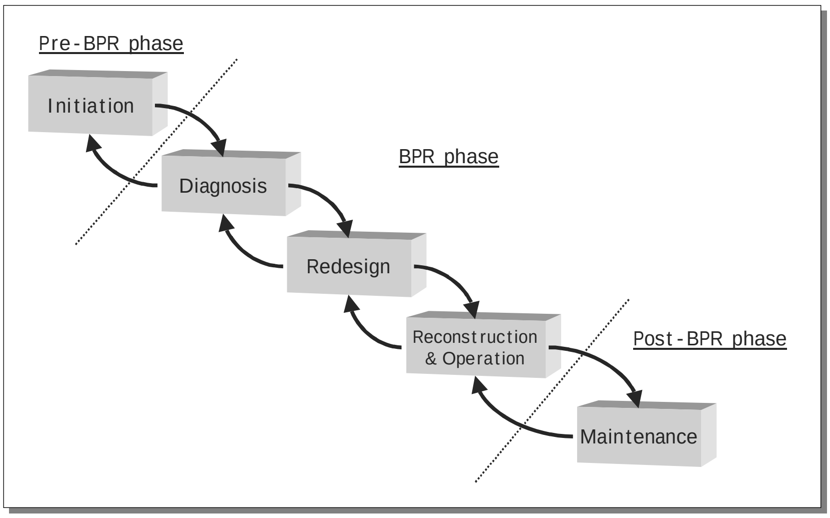

Figure 2-1 BPR Life Cycle [adopted from Bradley et al, 1996]

The need for reengineering in an organisation arises when there is either a business problem or a business opportunity. Business problems are characterised by organisations’ failure to realise its objectives, presence of unclear alternative courses of action, reduced funding or continuous drops in profits. Conversely, business opportunities are characterised by factors like changes in social patterns, presence of new methods of carrying out operations or new projects of national interest. The impact of enabling technology is double-edged and it is only organisations that recognise the need for change and successfully tap the synergy resulting from the merger of technology and business strategy to transform that will attain a lead in competitive advantage.

For long spatial data handling has been dominated by National Mapping Agencies. As monopolies, these organisations for long engaged in production and dissemination of products that have little or no focus on customers' needs. While this culture was the norm in the industrial age, it is unsustainable in the information age. In geoinformation processing for instance, increased customer disenchantment coupled with affordable enabling technology has spurred on unprecedented private participation in spatial data handling, an industry that was once the preserve of the NMA. This, among other things, has increased the complexity and turbulence in geoinformation environment, forcing most of these agencies to reengineer their way of operation. The Ordnance Survey of the United Kingdom provides an example of a NMA has successfully reengineered its operations on the face of reduced government funding and increased customer disenchantment.

For any Business Process Reengineering (BPR) project, three main phases can be identified in its life cycle. The *initiation phase* is the part of the pre-BPR and involves the development and definition of the organisation's mission and vision. The *BPR phase* begins with the identification of the organisation's core processes, which depict the current (AS-IS) situation. It includes the *diagnosis* of the deficiencies, bottlenecks and deadlocks of the existing processes. Business Process Modelling (BPM) techniques are applied to capture, represent and describe the business processes of the organisation. The new (TO-BE) system is determined through *redesign*. *Reconstruction* and *operation* effect the transition from the former system to the new one. The *Maintenance phase* is that part of the post-BPR phase concerned with continuous incremental improvement of the business processes. Figure 2-1 illustrates the phases of the BPR life cycle. The different phases employ different concepts, tools and methods, which form the subjects of discussion in the next sections.

2.3 Strategic visioning

Strategic visioning comes in the initial phase of the BPR project and aims at defining the direction in which an organisation is heading; irrespective of the strength of its technology or how passionately reengineering strategies are employed, an organisation headed in the wrong direction is bound to fail. Strategic visioning is about seeing the organisation through "new eyes", questioning what is possible and challenging the collective understanding within the organisation. It places a premium on insight and intuition, anticipating paradigm shifts, and creating new rules where the old ones do not apply. Strategic Visioning is about recognising windows of opportunity to create excellence or new opportunities, products or services. Ideally Strategic Visioning should be the trigger for all BPR projects.

As an illustration, the growth of the World Wide Web (WWW), development of geospatial data infrastructures and spatial data and metadata standards provide excellent opportunities for online acquisition and dissemination of spatial data and products. These developments also provide support for outsourcing or access to remote processing resources. Thus a mapping agency may not necessarily have to carry out all the activities involved in data acquisition, processing, analysis and dissemination. It may for instance use the numerous existing repositories of spatial data or establish links to use data acquired by private players. Likewise for disseminating the information, clearinghouses are a perfect option for online digital information. However, for analogue data and data on CD-ROM, floppy disks etc., an organisation can enter into an understanding with established outlets for distributing its products thus reaching as wide an audience as possible.

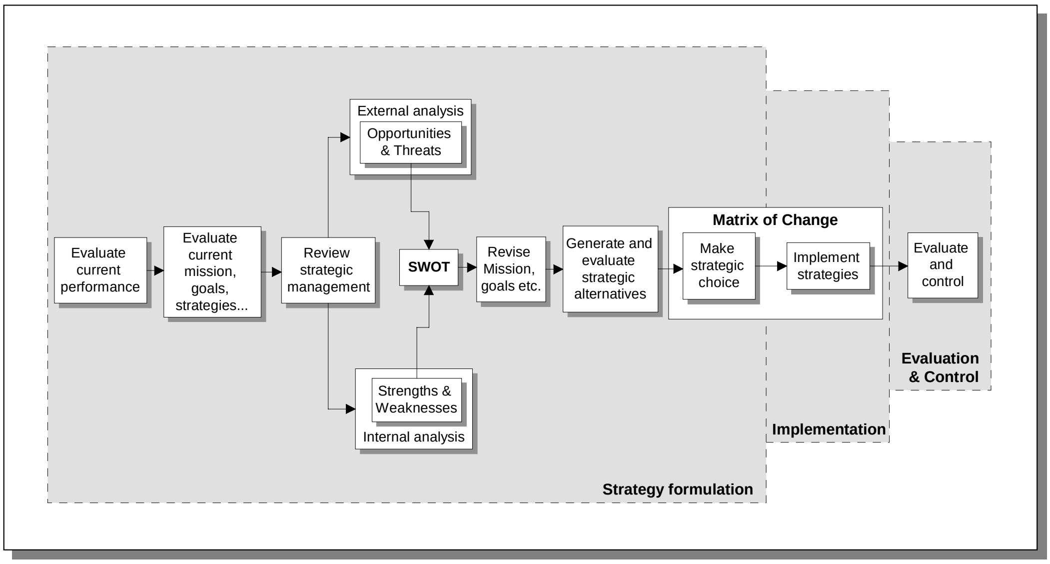

Figure 2-2 The Strategic Planning Process [Adopted from Hinger and Wheelen, 1996]

Strategic envisioning leads to the evolution of a corporate *Mission and Vision*. Strategic planning also called long-term planning yields actions justifying the nature and existence of every function in an organisation in line with the corporate mission and vision. It involves broad-scale information gathering, development and analysis of alternatives and generally constitutes that set of managerial decisions and actions that determine the long-run performance of the organisation. Strategic planning requires strategic *goals, performance measures* and *strategies* for each function based upon a strategic mission. Figure 2-2 shows an outline of the strategic planning process.

2.3.1 Mission

An organisation's mission is the purpose or reason for its existence i.e. it tells what the organisation is providing to society. It states what the organisation is now, and it states what it should be in future. A well-conceived mission statement the fundamental, unique purpose that sets a company apart from other firms of is type and identifies the scope of the firm in terms of the products offered and the market served. A typical mission statement for a National Mapping Agency (NMA) undertaking to reengineer its operations could be:

> *"To meet the Nation's general need for geoinformation supply, and to do so efficiently and cost effectively" [Karioki, 1999].*

2.3.2 Vision

The vision statement defines what the organisation hopes to be in future. It therefore is a source of inspiration for change and recapitulates how the organisation will realise its mission. It is the guidance for future action and the bedrock for elaborate and definite goals.

> *A typical NMA vision statement could be:*
> *"To be leaders in the field of geoinformation supply and to produce an accurate national database consisting of geodetic, topographic and cadastral elements, that is efficient and timely for use by government agencies, the private sector and general public. To provide leadership for the management of geoinformation and to improve the understanding and application of geoinformation and technology"*

2.3.3 What are Goals & Objectives?

Goals and objectives define the end results of a planned activity and they both should be selected to help realign a function with its vision. While objectives quantify achievements and provide a time frame within which they should be realised goals are open-ended statements, often qualitative in nature with no quantification of achievements and no time frame for completion. Nonetheless, both goals and objectives should be stated briefly and simply in such a way that everyone in the function understands them and sees their necessity. Lower level functional goals and/or objectives should be tied to those of the higher levels. A National Mapping Agency with the mission and vision statements presented above could for example have the following goals and objectives:

- Achieve 100% cost recovery in 5 years
- Generate products that are fit for purpose or use or
- Be responsive to customer requirements

The realisation of strategic objectives calls for a thorough understanding of the factors that drive or impede successful performance or those that are likely to do so in future; the critical success factors.

2.3.4 Critical Success Factors and Performance Evaluation

Critical success factors enable us to answer the question "*What does it take to accomplish our mission and achieve our vision?"* By evaluating internal strengths and weaknesses, discovering external threats and opportunities and reckoning stakeholder requirements with regard to products and services, factors critical to the fulfilment of corporate mission and vision can be identified. Objectives, goals and performance measures are defined to address the critical success factors.

Performance measures address the effectiveness, efficiency of an organisation and its responsiveness to market forces. Effectiveness is a measure of the organisations' ability to satisfy the customers i.e. *doing the right things* while efficiency is the ability to achieve the objectives at minimum cost that is, *doing things right.* Responsiveness indicates how effectively and efficiently the organisation adapts to changing market needs.

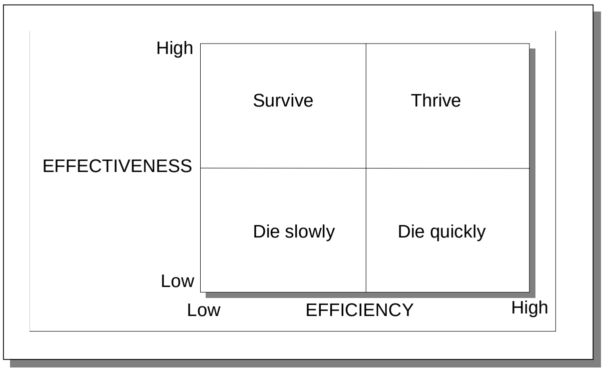

Figure 2-3 Effectiveness/ Efficiency Matrix [after Drucker, 1977]

The Effectiveness/Efficiency Matrix (Figure 2-3) demonstrates the results expected for an organisation's performance when measured in terms of efficiency and effectiveness [Drucker, 1977]. Organisations that are highly efficient yet poor in terms of effectiveness are the first to die in the market place. National Mapping Agencies were generally not effective in their production, thus they faced eminent death unless they changed their ways of operation to enhance effectiveness.

Measurement plays an important role in management. Through measurement an organisation monitors and evaluates its current performance, identifies the factors hindering or driving successful performance or those that could do so in future. This enables corrective measures to be put in place in good time. Measurement also enables identification and elimination of idle or non-value adding capacity thus achieving a lean organisation. A good measurement system should be comprehensive, including all levels of organisational hierarchy the important measures both financial and non-financial, indicators of past results and ‘predictors' of future performance covering all levels and the key areas of time, cost and quality. Issues of performance measurement are handled in greater detail in Chapter 4.

At the functional level performance modelling is used to test alternative re-design options and process configurations. The analysis provides a means of quantifying system behaviour and allows for comparing alternatives, locating bottlenecks and estimating throughputs. Measurement has a role in the control of processes and setting improvement targets. These targets are often called performance requirements with performance measures as the objective indicators of how well the objectives have been met.

2.4 SITUATION ANALYSIS

Before any BPR project can begin, a situation analysis is necessary. Situation analysis is the process of finding a strategic fit between external opportunities and internal strengths while working around external threats and internal weaknesses [Hunger and Wheelen, 1996]. It involves evaluating an organisation’s various external environmental factors in order to determine positive and negative trends that could impact on performance. Situation analysis is achieved through what is commonly known as SWOT analysis.

2.4.1 SWOT Analysis

SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. SWOT analysis is employed to analyse the situation of a business intending to enter a new area of the market or to assess the possibilities for a new business product to be launched in a given market. SWOT analysis enables an organisation to *identify* its *Strengths, Weaknesses, Opportunities* and *Threats* and gain a clear view of its current business situation. Through SWOT analysis consistency between different levels of the organisational hierarchy can be enforced with the lower level strategies being constrained by those of the higher levels (Figure 2-6).

SWOT analysis establishes basically two pairs of components. The threats and Opportunities are the results of conditions imposed by the environment that surrounds the organisation and are determined by external scanning. The Strengths and Weaknesses are internal elements that exist within the organisation and are determined through internal scanning. For the classical geoinformation organisations immediate threats include budget cuts from central governments, competition from new players and an elitist clientele. Opportunities arise from growth in application domains that create a larger market base and developments in enabling technologies that enable innovative options for spatial data handling and dissemination. The mass-oriented culture and functional structure of the NMA presents an obvious weakness while their expertise and technology, established markets and monopolistic positions provide relative strengths.

2.4.1.1 Internal Scanning

Internal scanning is a process that aims at establishing the strengths and weakness of an organisation. The weaknesses can be viewed as those things that need to be improved, those that are being done badly or those that should be avoided. As an example, national mapping agencies produce maps of very rigid standards and whose thematic content is pre-determined. The customer traditionally has no say on the process. This is undesirable and presents a weakness. Both internal and external views of the organisations' weaknesses should be sought. For instance within the structures of a NMA a map is considered of good quality if it contains as much thematic content as possible, however the customers find this far too complicated. Important also is to establish what others perceive as weaknesses which those within the organisation may not see. Strengths are market advantages of the organisation or those things that it does well from both the organisations view and that of the people it deals with. As stated before the monopolistic position of the NMA, their extensive technology and experienced human resource can be sighted as strengths.

In establishing the strengths and weaknesses of an organisation, one needs to look at a number of items among which there is the mandate of the organisation (if it is public), the stakeholders, the services or products the organisation provides and its interrelations with other organisations. Others include the internal structure and management of the organisation, existing quality management system and the general satisfaction or dissatisfaction of the organisations' customers. The organisations' level of technology, its emphasis on research and development and the motivation of the staff are other issues that often provide potential ground for weaknesses.

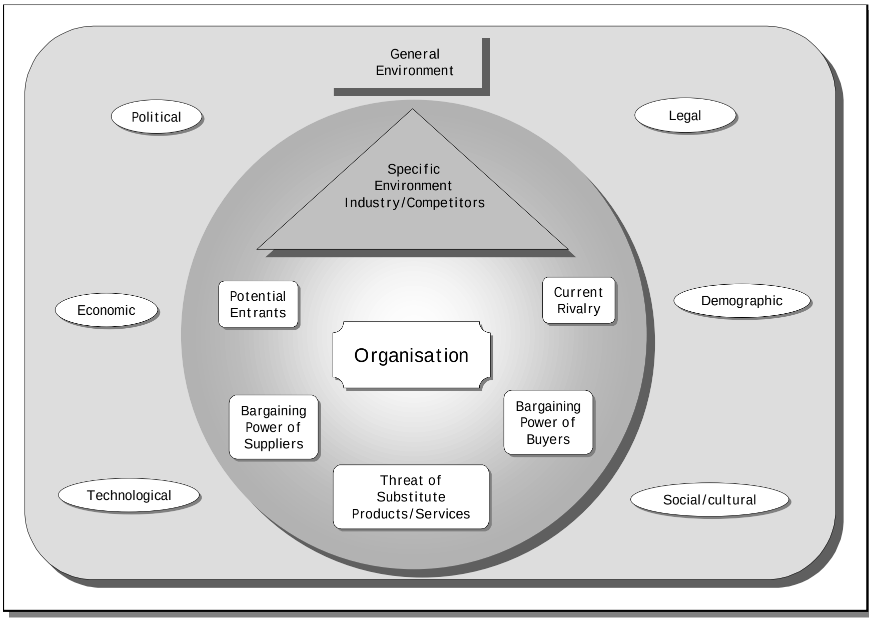

Figure 2-4 The five forces model.

2.4.1.2 External Scanning

The external environment of the organisation can be analysed using Michael Porter's Five Forces Model to establish the threats and opportunities that exist. The Five Forces model is a well-established and documented analytical methodology for understanding the dynamic interplay of forces that combine to determine the competitive situation and state of an organisation.

The Five Forces Model (Figure 2-4) asserts that the state of competition in an organisation is a function of the dynamic interplay of five forces within the specific industry environment [Boar 1993]:

- The Bargaining Power of Suppliers – This is the power of the suppliers to control quality, prices and overall conditions of purchase of goods and services. The suppliers are powerful when they are few, if it is expensive for the customers to change suppliers, or if there is no substitute product of similar or superior quality at better terms than the current supplier offers.

- The Bargaining Power of Buyers/Customers – This refers to the power of the customers of an industry to exploit their position to influence prices, quality and overall conditions of purchase of goods and services. A powerful buyer is a large volume buyer, has many alternative suppliers, or one for whom the product is expensive or forms a large part of the cost structure or is not important to the quality, or differentiation of his product.
- Threat of new Entrants – This is the degree to which or probability that new competitors will enter the marketplace to increase competition for market share. New entrants will have to overcome several obstacles e.g. the costs associated with achieving the necessary economies of scale for competitive pricing, the up-front investment required and restrictive laws or policies controlling entry into the market. Other obstacles are the total cost of switching products that will deter change of suppliers and non-economy-of-scale advantage that the incumbents enjoy e.g. patents, special skills, location, etc.
- Threat of Substitute Products/Services – The availability and attractiveness of substitute products and services to the buyers constrains the ability of an enterprise to control the pricing, quality and other factors of sale since the customer can switch to the substitutes. The substitute products are important if they offer a strong feature or functionality clone, enjoy better pricing performance or if the substitute-product industry is enjoying strong profitability and is looking for new markets in which to grow.
- Rivalry among Existing Competitors – This is the intensity of “manoeuvring for position” among the incumbent competitors and is a function of the number of competitors and the equality of their size, the anticipated growth in industry and the degree to which products by competitors are substitute each other.

An organisation operates in a general environment over which it has little control. The general environment consists of elements like economic, demographic, social/cultural, legal/political and technological environments that have an indirect effect on the organisation. In carrying out SWOT analysis it is important to consider all stakeholders i.e. customers, suppliers, employees, shareholders, government etc. to avoid conflict in their interests. Thus before any strategic decisions are made, the effect of each alternative to all the important stakeholders need to be considered.

Whereas situation analysis provides a reasonably good insight into the current situation, intuition and luck are needed to accurately predict the future. Faulty underlying assumptions have been identified as the most frequent cause of forecasting errors. A number of forecasting techniques such as extrapolation, brainstorming and statistical modelling are in use to forecast future scenarios. Forecasting in any BPR initiative helps in ensuring that an organisation does not direct a large proportion of its efforts in areas that will be rendered obsolete with the BPR life cycle.

2.4.1.3 The SWOT matrix

Situation analysis results in actions that reflect the strategy that will be chosen to make the move towards the desired future. The *‘AS_IS’* mission will be transformed into a ‘*TO_BE’* statement. This re-definition of elements within the organisation forms the basis for reengineering the organisation.

The SWOT matrix is built by matching the various Strengths and Weaknesses with the Opportunities and Threats, together providing a breakdown of possible sets of actions that enable an organisation to gain *competitive advantage* (see Figure 2-5). Only actions that reflect the organisation’s competitive advantage need to be considered. Table 2.1 shows a scheme of the different elements of SWOT and their desired values. The set of actions identified can be classified into any of the three organisational levels; however some might show up at several levels and must be put into the most pertinent level. The actions chosen should be the most relevant to strategic mission and need to comply with any constraints within the system i.e. political, technical, and economic etc. Although it is not clear where to place these constraints in the context of the SWOT matrix, they have to be kept in mind when planning and categorising the actions. The SWOT matrix tries to match external factors with internal factors. The sets of actions can be classified in terms of areas to *exploit, attack, explore* and *avoid.* Opportunities should be exploited by using the organisation's internal strengths. The same strengths should be used to attack and defend the organisation from external threats. The organisation should also explore opportunities that help it remove or minimise its weaknesses. Actions resulting from a match of weaknesses and threats should be avoided at all costs.

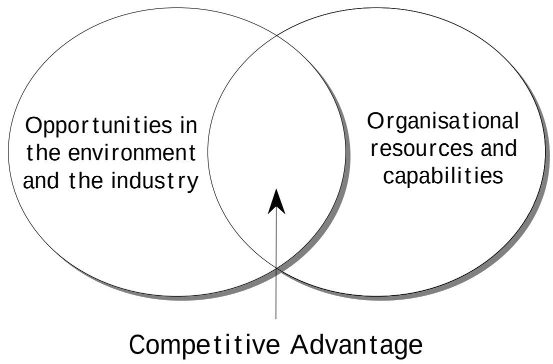

Figure 2-5 Competitive advantage

Table 2-1 SWOT Matrix with extension

Cons-traints:	OPPORTUNITIES (O)	THREATS (T)	O / T
STRENGHTS(S)	Set of actions to make use of the strengths to take advantage of the opportunities. Exploit	Set of actions to use the strengths to counter the threats. Attack	S/O/T (Exploit & Attack)
WEAKNESSES (W)	Set of actions to minimise weaknesses and make use of opportunities. Explore	Set of actions to remove weaknesses in front of the threats. Avoid	W/O/T (Explore what to Avoid)
S / W	S/W/O (Explore what to Exploit)	S/W/T (Avoid areas requiring Attacks)	S/W/O/T (Strong Competitive advantage)

Although the conventional version of SWOT analysis can be quite useful, it possesses one major limitation. It assumes that the only matches that merit consideration are S/O, S/T, W/O, and W/T and thus tends to ignore the fact that combined external factors when matched together with an internal factor or vice-versa can also play a significant role in the analysis. For example, an opportunity not taken advantage of may end up becoming a threat to the survival of the organisation. Therefore, such a combination of an opportunity/threat may be matched with an organisation's strength to counter it. [Arnold et al, 1999] designed the extended SWOT analysis to overcome this limitation.

Extended SWOT analysis (E-SWOT) provides planners with the means for considering all possible matches. As Table 2-1 shows, the E-SWOT matrix uses the SWOT matrix as its core, but adds seven new cells for matching purposes that allow for potentially critical matches to be made.

2.5 Strategy formulation

A strategy of an organisation forms a broad master plan stating how the organisation will achieve its mission and goals. It describes what needs to be done to the current AS-IS state to move towards one or more of the future or TO-BE, states. Strategies contain changes to prevent or correct problems or deficiencies, to emulate best practices or to implement innovation. Strategies can be categorised by the level in the organisation. A large multidivisional business firm typically has three levels of strategy namely corporate, business and functional strategies. NMAs are most likely to have two levels of strategy, the corporate and the functional levels.

Strategies at whatever level provide a direct linkage between strategic planning and business process reengineering. The main aim of formulating strategies is to maximise competitive advantage and minimise competitive disadvantage.

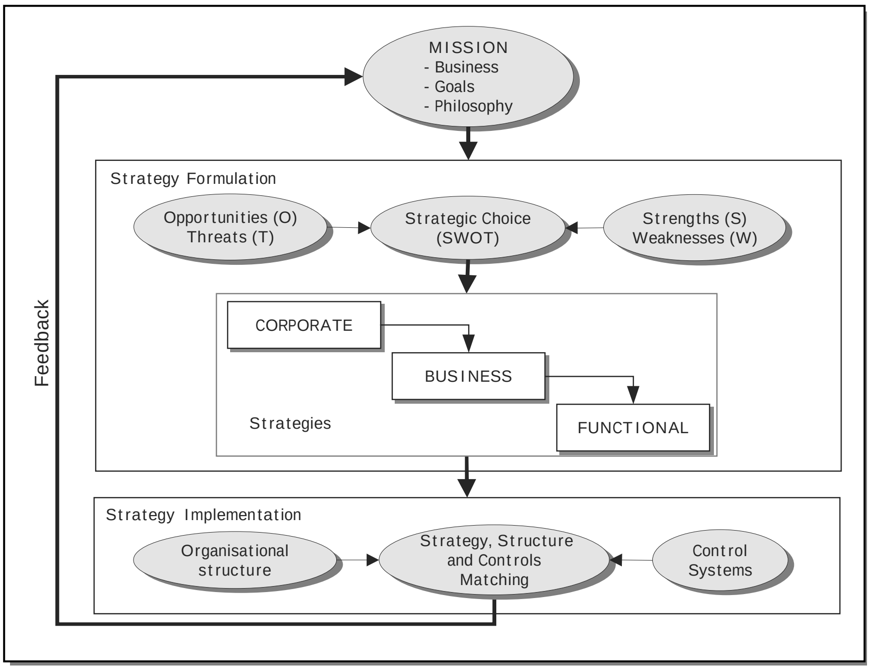

Figure 2-6 Strategic Reengineering at all Levels [Almeida, 1996]

A *Business strategy*, also called competitive strategy occurs at the divisional level and emphasises improvement of the competitive position of an organisation's products or services in the specific industry or market segment served by that division. An organisation's business strategy may be one of overall *cost leadership* (which seeks to produce products or services more efficiently than competitors) or *differentiation* (which attempts to distinguish the organisation's products or services from others in the same industry). Differentiation may be achieved by price, marketing image, product design, product quality or product support etc. An extension to these types of strategies is a *focus/niche strategy*, which concentrates on a specific regional market or buyer group. The organisation may use a differentiation or low-cost strategy but only focus on a narrow target market.

A *corporate strategy* describes an organisation's overall direction in terms of its general attitude towards growth and the management of its various businesses and product lines to achieve a balanced portfolio of products and services.

A *functional or operational level strategy* is concerned primarily with maximising resource utilisation. Within the constraints of the corporate and business strategies around them, functional strategies are developed in which the various activities and competencies are pulled together for the improvement of performance. The aim of functional level strategies is to enable the organisation to support business level strategies.

2.5.1 Policies and initiatives

A policy is a broad guideline for decision-making that serves to link the formulation of strategy with its implementation. Policies are meant to ensure that personnel throughout an organisation make decisions and take actions that support the organisation's mission, goals and strategies. An example of an organisational policy is one that disallows a cost reduction at the expense of overall product or service quality. Initiatives or programs on the other hand describe how improvement strategies can be accomplished and are the projects that realise functional improvements. They describe how strategies should be implemented in terms of specific actions, timelines, and resources. It is the task of the BPR work group to develop effective initiatives. In order to succeed at this task, the group must search for as many new and creative ways of doing business as possible.

2.5.2 Some possible initiatives in geoinformation processing

2.5.2.1 Maps on demand

Currently, conventional lithographic printing techniques are used to produce paper copies of the majority of mapping products. This practice is not economical for products with low demand. With the advent of newer technologies, high speed, large format printers have been coupled with innovative computer technologies to turn digital map data into a printed map. It is now possible to store and retrieve data from vast geospatial databases, and print a map on an as-needed basis, *i.e.* print on demand; thereby eliminating the need to warehouse a paper inventory of maps.

The concept of Maps on Demand (MOD) means that each map image can be created on demand from a geographic database. Using the print on demand technology, organisations can implement MOD printing, for selected infrequently requested map products. By providing MOD products, organisations can provide an alternative to traditional large volume printing and can improve the responsiveness to customers by providing access to scientific data in a format that other wise might not be available.

The OS has perfected the concept of MOD for specific customer requirements whereby; customers basically give their specific location of interest and the amount of detail they require. The products are prepared from databases almost in real time and pricing is dependent on factors such as amount of detail and size etc.

2.5.2.2 On-line updating

The proliferation of a myriad of pen-based computers in the recent years has revolutionised the way geoinformation is collected. The combination of these field computers with GPS and wireless communication makes it easy to collect field data and update distributed databases almost in real time. By keeping valuable professionals in the field instead of the office, pen computing boosts productivity. This ensures that information available to clients can be relatively current and other than the initial investment costs; the subsequent updating costs are much reduced. This would subsequently translate to cheaper up-to-date information and thus encourage more users to access spatial data and information.

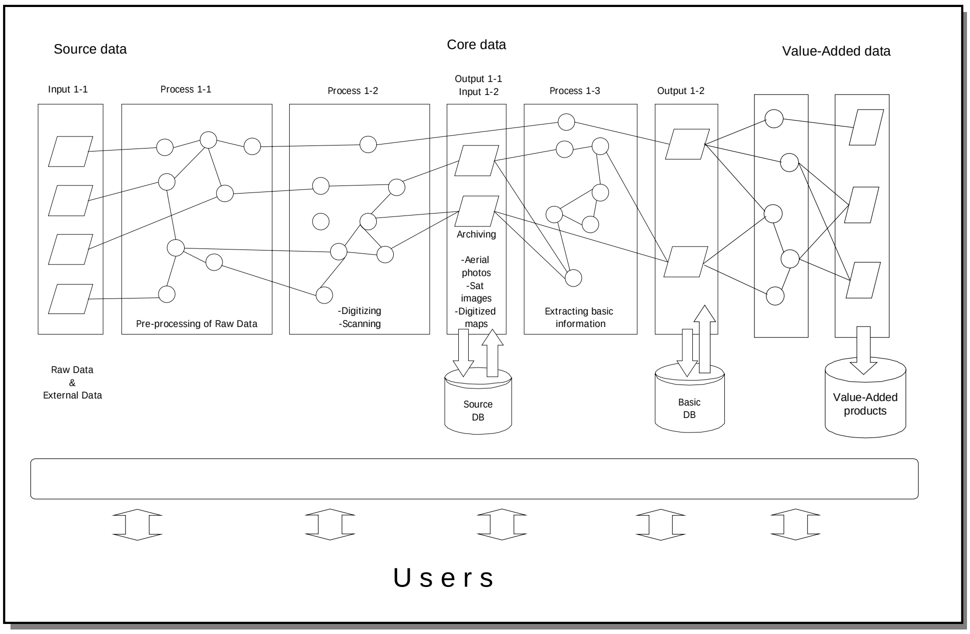

Figure 2-7 Hierarchical process levels [after Dominguez, 1998]

2.5.2.3 Hierarchical production

The generation (or provision) of any geoinformation product (or service) calls for certain basic operations or activities. These activities when identified and defined provide the basic building blocks in any geoinformation production process. [Dominguez, 1998] proposes the description of a geoinformation system at various levels of complexity. This concept presupposes that the basic building blocks have been defined and fully described. The system envisaged is an implementation of the value-chain concept, where every subsequent activity adds value to the product with the result that every step in the process yields a product that can be delivered to the customer. The capability to acquire data and information online, for use in value adding is an integral part of this system. Figure 2-8 illustrates the concept of product diversity and hierarchy.

In this system geoinformation production is viewed as comprising of three basic levels (Figure 2-7). The first level encompasses acquisition of raw data, pre-processing activities and extraction of the basic data framework (as a standard product). The raw data, which includes aerial photographs, field data, satellite imagery etc., is stored in the *source database*. The extracted data is used to generate the *basic data framework* that is stored in what may be called a *basic database*. The framework data provides the geometric frame for the creation of other databases. It comprises the most common themes that geographic data users need, representing the best available data for an area certified, standardised and described according to a common standard. The framework data provides a foundation on which organisations can build by adding their own detail and compiling other data sets.

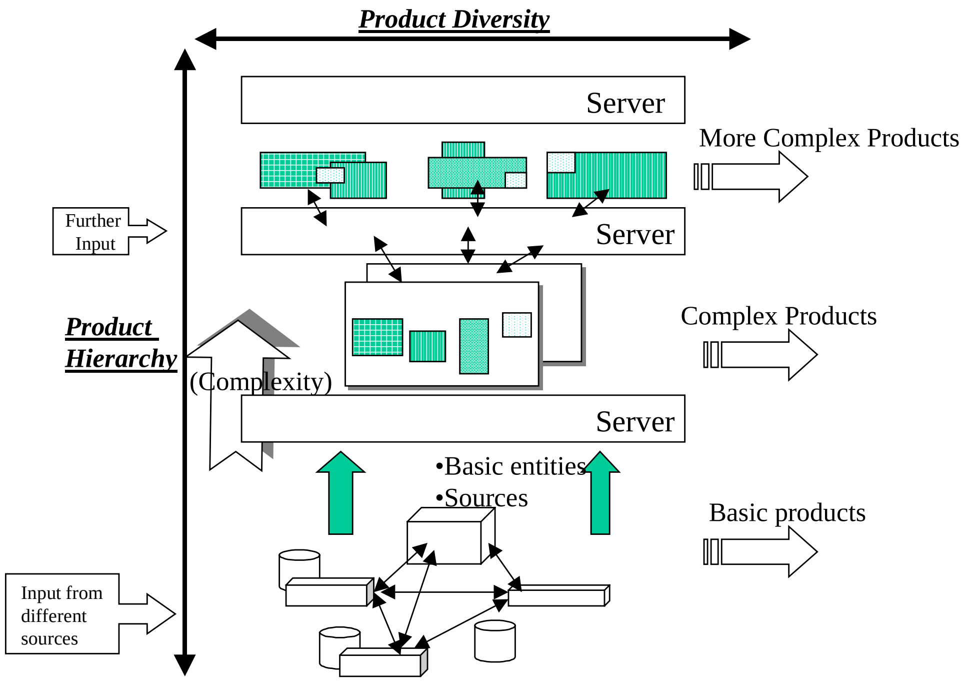

Figure 2-8 Product diversity and hierarchy within an integrated system [Dominguez, 1998]

The second level aims at creating the *Topographic database or Landscape database*. Topographic information is basically comprised of information derived from the source data through photogrammetric or digital image processing techniques. Through cartographic processing of the data in the topographic database, the *Cartographic database* results. This database contains all the necessary to publish standard topographic maps. Among the themes represented are hydrography, infrastructure, elevation data, geographic names, national grid and some standard symbology. At this level, topographic and cartographic information form the standard products.

The third level is considered the most important in the hierarchy for a service-oriented organisation. It is the level that supports generation of customised products. The third level uses information from both the first and second levels as well as information from other sources. A functionality that is rapidly growing is provision of tools to the user for accessing and processing information in the organisations' databases to design and generate their own products.

The number of levels and the complexity in the hierarchy is a strategic decision depending on the desirable level of services. Further, the organisation can decide which levels need to be fully supported financially and which levels could run on cost recovery or commercial basis.

2.5.2.4 Just in time concept

Many firms are now trying to adopt *"Just In Time" (JIT)* inventory control methods that originated in Japan for manufacturing purposes. In this approach, parts are delivered just before they are needed, and the organisation avoids having to store and pay for significant inventories of the parts. Most National Mapping Organisations today use what [Hammer and Champy, 1993] call the *Just-In-Case (JIC)*, concept. Such a concept demands that since it is uncertain when demand for products will come, or what quantities will be required, then the organisation must produce or store a little (sometimes a lot) extra just in case.

In implementing the *just-in-time* strategy, geoinformation suppliers will to be aware of the present customer requirements and their trends. Thus by designing appropriate system architectures, clients may be provided with the possibility to customise the products according to their requirements. This can be achieved by providing the customers access to the organisations database resources or through the adoption of a hierarchical production strategy.

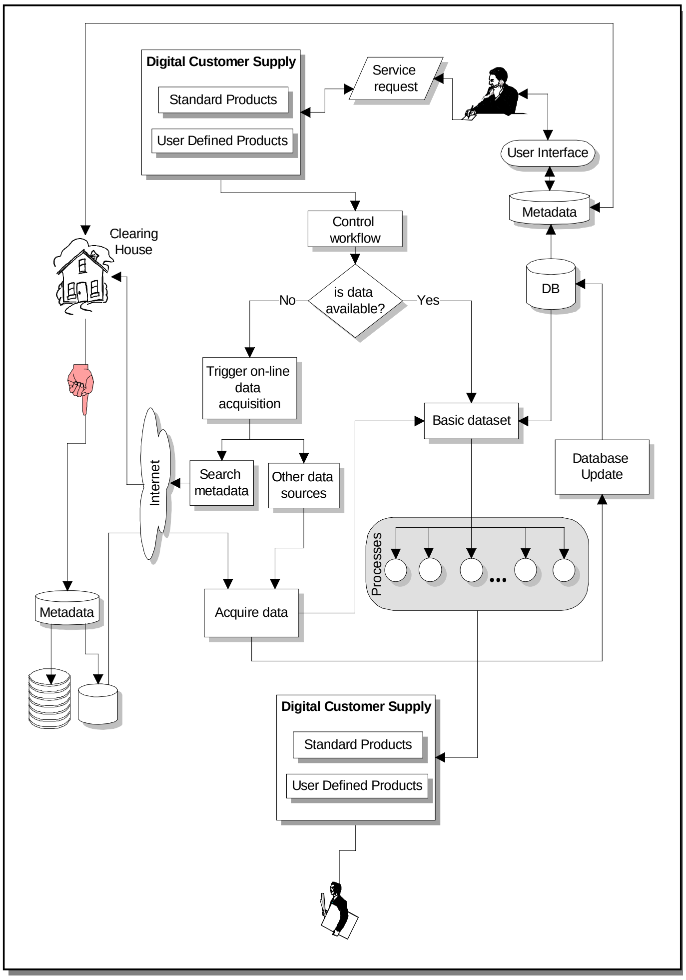

Figure 2-9   On-line Data Acquisition [Radwan, 1999]

2.5.2.5 On-line data acquisition strategy

Radwan, 1999 has proposed the formulation of a system implementing the JIT concept that triggers on-line data acquisition in circumstances when data is not available. And building on this idea, we develop a conceptual framework for this on-line data access model. This is as shown in Figure 2-9. The on-line data acquisition strategy works as follows:

A user submits a request either physically or via an electronic front door. A Digital Information Supply (DIS) unit checks to find out what data is available from the organisation’s databases. A control workflow is initiated to carry through the process. In the event that data is not available from the organisation’s databases, *on-line data acquisition* is triggered. Data maybe acquired from another organisation’s database through a metadata search via the Internet and spatial data clearing houses.

Alternatively, mobile mapping techniques, high-resolution satellite data[1], laser altimetry, GPS, Total stations, etc. The third alternative arises when data is already existing in the organisation's databases. In which case it forms the basic data if further processing is necessary or delivered straight to customers if no further processing is needed.

The basic datasets acquired will then undergo various value-adding processes and the result used to update the organisation's database in addition to being supplied to the customer(s) through the DIS unit. The organisation's database can be linked to a local meta-database, which can in turn be linked to outside users through spatial data clearing houses. A local user interface can be incorporated to enable users to search the metadata locally.

2.5.3 Alternatives

In the preceding discussions, several BPR initiatives for geoinformation processes were outlined. Since each initiative considers only one or a few areas for improvement, combinations of initiatives will have to be analysed in order to address each strategic goal. It is unwise to study all combinations of initiatives, as there will be too many unless the number of initiatives is small. A more practical method of analysis is to use alternatives.

Alternatives are logical packages of initiatives that work well together (Figure 2-10). Optimal alternatives address each goal and each alternative gives functional management a complete view of the financial and operational impacts of proposed changes. The creation of alternatives is an iterative process. First groups of initiatives that fit well together should be created. Then from each group, all but one of the initiatives that focus on the same problem are eliminated. This process of grouping and eliminating continues until each alternative becomes a complete and logical package.

To be a complete and logical package, an alternative must optimally be a set of *necessary* and *sufficient* initiatives. An initiative is necessary if an alternative could not address every functional goal without its inclusion. A set of initiatives is sufficient if the alternative it creates addresses every functional goal. Each initiative can be a part of one or more alternatives. Some initiatives may be in all alternatives.

2.5.3.1 Alternatives analysis

Alternative analysis helps management to realise an alternative that will bring the business closest to its vision. In the analysis, alternatives need not only be compared against each other but also against the baseline. The baseline provides the reference position for measuring progress in process improvement. The cost and performance of the baseline provide the threshold values for the cost and performance of the alternatives and an alternative that does not meet the threshold needs not to be considered. A complete alternative analysis should evaluate:

- the estimates of life cycle costs for each alternative;
- the sensitivity of the assumptions used to construct alternative investment costs and cost and performance impacts; and,
- the financial performance, risk, and other characteristics of the alternative.

2.5.3.2 Ranking alternatives

With all the obviously infeasible alternatives eliminated, value judgement based on cost and performance becomes necessary. It is usually easiest to make the first comparisons based on cost. Those alternatives with poor cost and other key performance measures are identified and set them aside. For alternatives with comparable costs and performance, those that incur risks without

[1] This should be interpreted as making an order for the images to a supplier

producing compensating benefits should be identified. A high-risk alternative may be less attractive than one slightly lower in performance improvement or slightly higher in cost but with considerably less risk. With few good alternatives left, the following considerations will facilitate ranking:

- Time required to recoup the investment (discounted payback);
- The savings of the alternative relative to its cost (return on investment and risk-adjusted return on investment);
- Flexibility or adaptability of alternative with respect to future options;
- Alternatives contribution to long-term goal and vision achievement;
- The time phasing of the alternative's resource requirements.

In addition to the above listed considerations, *benchmarking* can help an organisation realise an optimal alternative. Benchmarking means looking for organisations that are doing something best and learning how they do it in order to emulate them [Hammer and Champy, 1993]. Benchmarking ideally uncovers the best practices to be emulated.

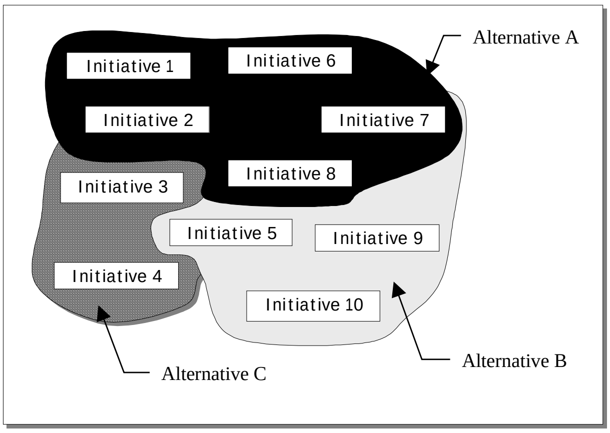

Figure 2-10   Packaging initiatives to alternatives

2.5.4 Business process modelling

The whole BPR process through strategic visioning and planning, situation analysis, strategy formulation and development of alternatives provides an organisation with tools and concepts for defining strategies, goals and alternatives to realise its mission and vision. In comparing alternative, the activities, inputs and outputs of each alternative need to be captured and formally represented to enable performance evaluation. Business process modelling concepts provide tools to capture and represent the behaviour and architecture of systems albeit in an abstract manner. These abstract representations, the system models, provide the basis for analysis and experimentation.

Reengineering focuses on the execution of process activities and utilisation of associated resources for the realisation of a product or provision of a service. In many organisations where dramatic breakthrough improvements have been achieved in the work processes, fundamental changes in work processes were often implemented and organisational structures modified to implement those changes.

The organisation is a system whose behaviour is manifested in its business processes. Generally, a *business process* is the set of internal activities performed to serve a customer. The purpose of each business process is to offer each customer the right product or service, with a high degree of performance measured against cost, longevity, service and quality [Jacobson, 1995]. It is worthwhile to note in this case that the term customer could have the literal meaning of customer, but it can also be another individual process in the environment that is external to the company, such as a partner or a sub-contractor. [Davenport, 1993] defines a process as *a structured, measured set of activities designed to produce a specified output for a particular customer or market;* a definition that is most interesting to outside observers such as shareholders and customers.

Function is a term that needs to be distinguished from process. [The Electronic College of Process Innovation, 1994] defines a function as a specified type of work applied to a product or service moving within a process. Functions are typically described in a hierarchical organisational chart detailing successive layers of management. As work crosses functional boundaries, internal suppliers and internal customers are created. Responsibility for the various resources and controls administered to the work progressively changes hands. Modern business management gurus are in favour of management by processes as opposed to management by function and many of the changes in organisations reflect this shift in management principles.

In studying a process and seeking ways to improve, upgrade or redesign it, one comes up with many alternatives often involving changes in standard procedures as well as incorporating a variety of new features in order to support its accessibility to new environments [Radwan et al, 1999]. Process modelling tools help the process engineer to systematically pursue design goals, representing, analysing and describing the process by means of models. Process modelling is essential for understanding process behaviour, how and where management tools can be incorporated to control it. By use of process models, one can show an organisation's processes and the information they create or use. A modelling tool therefore is a well-defined set of rules for the structuring of a model to meet the particular modelling objective.

A process model is an abstract representation of reality that excludes much of the world's infinite detail. The purpose of a model is to reduce the complexity of understanding a phenomenon by eliminating the detail that does not influence its relevant behaviour." [Curtis, Kellner, and Over, 94]. In other words, by creating a process model one can represent the aspects of interest of a process and eliminate those characteristics that are not relevant for the purposes of creating the model. Normally the process engineer bases the need of a model in achieving the following goals:

- Understanding the process
- Reasoning about the process
- Analysing the process
- Comparing the process
- Evaluating the process
- Measuring the process
- Communicating and documenting the process
- To aid design of process
- To work out the requirements for Information Technology (IT) support for process
- To incorporate management and simulation tools

A model to be used effectively for communicating the characteristics of a process needs to be precise, simple and well-structured and clearly related to the process that it models in such a way that it appeals to the intuitive understanding of those who have to use it. A model that is a conceptual image of a process that exists in the mind of the designer is called a *design*. When developing a design the designer combines abstractions of relevant aspects of the process, abstractions that are called *design concepts*. The set of design concepts together with their rules and constraints define a *design model*. Designs have to be developed, communicated and analysed. A *design language* is a notation for *representing* designs. Such a representation can have the form of a document. A design representation should be understood by all people who intent to use the design, for one reason or another.

A *specification language* is a design language which includes some very important elements like its syntax (constructs and operators) and semantics (meaning). Those elements must be derived from the relevant design concepts of the area of concern, making the specification language of general purpose in its application area. The specification language is used to represent designs (models with a prescriptive character). A design representation of a business process written using a specification language is called a *specification*. The relations between the terms described above are illustrated in Figure 2-11.

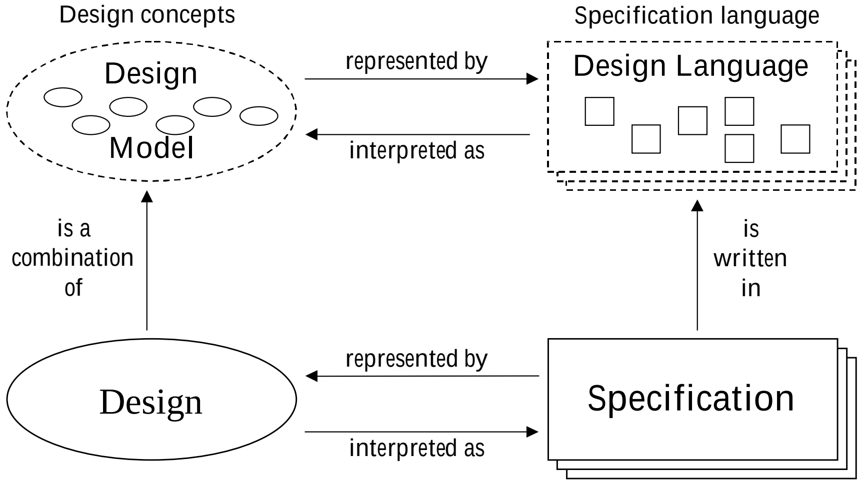

Figure 2-11 Relations between a design and its specification

Summarising, design concepts are used to create a design model of the required characteristics of a business process at a certain abstraction level. Because these conceptions have to be represented in an understandable way (to be transmitted for example), a specification language is necessary, as notation for representing the design model in a concise, complete and unambiguous way. The suitability of a specification language for creating specifications that represent a design depends on how faithful its capability is for representing the design concepts used to develop the design model.

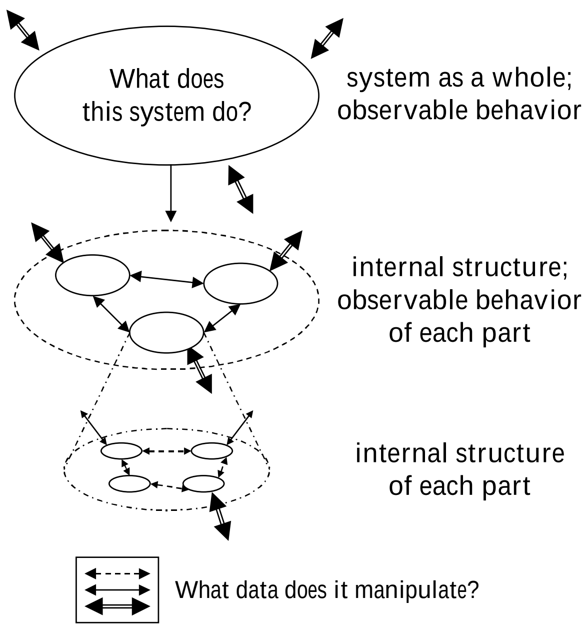

Figure 2-12 Steps of the design methodology

In creating a model, it is important that the process engineer concentrates on those aspects of the system that are relevant for the purpose of developing the model and follows a systematic way of working to reach the objective. It has to be mentioned that the techniques used for modelling processes focus mainly on the behaviour of the systems ("*what they do*"), and give less attention to the information or material they handle ("*what they manipulate*"). Chapter 3 discusses process-modelling concepts in greater depth.

2.6 Strategy implementation

Strategy implementation is the total sum of the activities and choices required for the execution of a strategic plan. It is the process by which strategies and policies are put into action through the development of programs, budgets, and procedures [Hunger and Wheelen, 1996]. Strategy implementation is an important component of strategic management and cases abound where improper implementation of good strategies has led to disastrous results. Therefore strategy formulation and strategy implementation should be considered as two sides of the same coin. Strategy implementation could involve changes within the overall culture, structure or management of the entire organisation. Strategy implementation, also called operational planning, involves day-to-day decisions in resource allocation. Issues that arise both in the strategy formulation and strategy implementation phases include decisions on who should carry out the strategic plan, what needs to be done and how is it going to be done. Unless these issues are not answered satisfactorily, achievement of the desired outcome is jeopardised.

2.7 Evaluation and control

Evaluation and control is the process by which corporate activities and performance results are monitored so that actual performance can be compared with desired performance. The resulting information is critical in taking correcting actions and resolving problems and can pinpoint weaknesses in previously implemented strategic plans thus triggering the entire process to begin again. Evaluation and Control is made-up of five steps viz. determination of what to measure, establishment of the performance standards, performance measurement, comparison of measured performance with the standard and taking corrective action if need be.

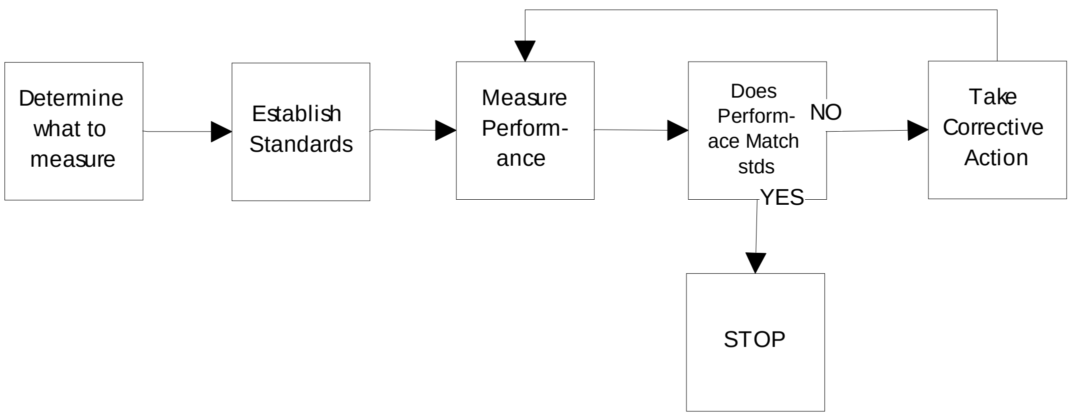

Figure 2-13 Five-Step Feedback Model

Top and operational managers must specify the processes to be implemented and the results to be monitored and evaluated. The results should be measured objectively and consistently and focus should be on all significant elements in the process regardless of difficulty [Hunger & Wheelen, 1996]. Performance standards indicating acceptable performance results with tolerance range need to be specified. Actual process performance is then obtained, through some defined procedures, and compared with the standards to identify any bottlenecks or weaknesses requiring corrective action. Although top management is often better at the first two steps it is important that it is involved in the implementation phases for good results. In the foregoing sections we have walked through the steps of a BPR project. In the next sections we look at how BPR can be employed in geoinformation processing.

2.8 Methodology for geoinformation processing

The concepts of BPR have been applied to many firms all over the world. Numerous cases have been cited as examples in nearly every text that deals with the subject. Unfortunately only a few of the cases encountered are geoinformation oriented.

Unlike most other industries, geoinformation production is both a trade and a profession. And even in the professional world, geoinformation production and dissemination seems to be in a class of its own. Geoinformation production is perhaps one of the professions, requiring relatively high initial capital investment to begin with. This contrast with a civil engineer, who can comfortably start a business, armed only with a low cost scientific calculator, a drawing board, pencil, scale rule and eraser. An architect could start with the same basic implements as the civil engineer, and probably with a less elaborate calculator. A medical doctor can start a small clinic with an initial investment of a stethoscope, clinical thermometer, a pen to jot down prescriptions and scant other equipment, all within reasonable financial grasp.

On the contrary, anyone wishing to collect and process geoinformation knows the difficulties of starting from scratch. To collect and process geoinformation, a surveyor will probably need a theodolite, some distance measuring equipment or, if using photogrammetric methods, access to aerial photography and some photogrammetric equipment, all of whose acquisition costs are usually gigantic. Despite the fact that personal computer based systems are bringing costs down, in general, geoinformation production is complex and expensive and so are the processes involved in its production. Over the years, we have seen the introduction of digital technology for mapping operations. However, these technologies have been merely used to substitute analogue technology with no change in what is done or how it is done.

It is no surprise then that many geoinformation production organisations have continued to do business in traditional ways. And even though many NMAs seem to recognise the need for change, they are sceptical to reengineer their operations mainly due to lack of a structured methodology and inherent fear of failure. Nonetheless, a number of geoinformation production organisations have taken the initiative to reengineer their organisations with some good measure of success.

The Ordnance Survey of Great Britain and the National Imagery and Mapping Agency (NIMA) of the U.S.A provide good examples. Other initiatives include The Swedish Land Data Bank System (LDBS), an on-line system run by the National Land Survey of Sweden (NLSS). Another good example is the Dutch Kadasters' IT 2000 program.

The market for geographical information continues to develop in both established and new markets. This is driven by the increasing diversity of applications and by the enabling effect of new and more powerful technologies. In response to the environmental changes, geographical information processing organisations need to embrace enabling technologies and introduce new ways of processing, necessitating Business Process Reengineering. In recognition of the need of standard and robust methods for successful engagement in projects, more particularly in the geoinformation arena, [Karioki, 1999] proposes a structured methodology and implementation strategy for Business Process

Reengineering in geoinformation production (Figure 2-14). In chapter 3 of his thesis entitled A Structured Methodology and Implementation Strategy for Business Process Reengineering in Geoinformation Production [1999], he also extensively discusses the impacts and opportunities offered by enabling technologies. The role of information technology and other enabling technologies is to facilitate the introduction of new and more effective design options and as the markets expand and technology advances the range of options possible is continually growing.

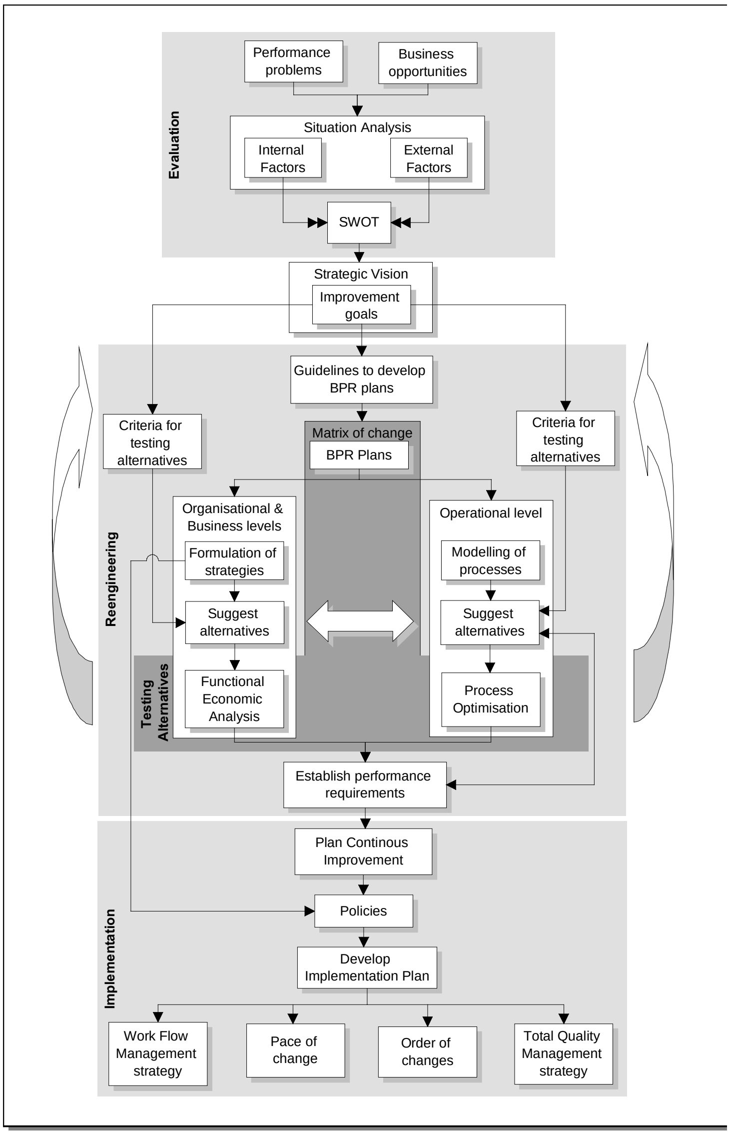

Figure 2-14 BPR Methodology

The BPR methodology proposed consists of three main components; Evaluation, Reengineering and Implementation (Figure 2-14). These components to some degree can be mapped onto the pre-BPR, BPR and post-BPR phases of the BPR life cycle.

The Evaluation component starts by considering existing performance problems or business opportunities in the organisations' environment. Through SWOT analysis, the strengths, and weaknesses of the organisations in view of the opportunities and threats existing are identified. In line with the strategic mission and on the basis of the results of this analysis, appropriate strategies are formulated to guide the BPR process.

The Reengineering component encompasses development and comparison of alternatives together with appropriate criteria for the comparison in line with strategies formulated. By use of the Matrix of Change the complex interrelationships surrounding change are discerned making the choice of alternatives a lot simpler. The Matrix of Change contributes to understanding issues of feasibility (stability of new changes), location, pace and stake holder interests. Each level in the organisational hierarchy will have its own alternatives, performance requirements and criteria for comparing the alternatives. For both the organisational and business levels, the TurboBPR[2] software that is freely available on the net is reasonably suitable for development and analysis of alternatives. In the functional level, simulation software like SIMPLE++ is needed. The outputs of the Reengineering component are sets of alternatives for implementation.

After BPR, continuous process improvement (CPI) is necessary and needs to be planned for. The Implementation component considers CPI in the development of the implementation plans. Other issues that should be considered include workflow management and total quality management.

2.9 Concluding remarks

In this chapter we defined Business Process Reengineering (BPR) and discussed the concepts and methods necessary to support its constituent phases. Strategy was introduced and discussed and its position in the framework of BPR explained. Situation analysis is essential for establishing the *strengths* and *weaknesses* of an organisation, and the *threats* and *opportunities* for the organisation. The SWOT analysis, a proven and elaborate situation analysis technique, was discussed. It was noted that, whereas BPR has found widespread application in industry over the years, its benefits are yet to be fully realised in the Geoinformatics industry. This was attributed to the general lack of sound methodologies to manage and guide effective BPR projects in geoinformation processing. A methodology for implementing BPR in geoinformation organisations was presented and some BPR options discussed.

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3 The Process Phenomenon

3.1 Introduction

The correct application of Information and Communication Technology (ICT) is a critical success factor for the optimal functioning and the competitive position of an organization. There should be a good adjustment between possibilities offered by ICT on the one hand, and the organization's needs and requirements on the other hand.

Since computer systems have been developed to cover almost every aspect of information processing, the systems which have emerged have grown too often complex, very costly and long to develop; further, they usually did not meet their expectations and have proved to be difficult to maintain.

The concern for more productive methods for the development of information systems has therefore tremendously increased during the last two decades. We try to look at some of the elements of research that have addressed the problem of developing efficient and effective Systems.

3.2 Systems

A system can be defined as a regularly interacting or independent group of items (components) forming a unified whole [Webster's dictionary]. Each system consists of an interdependent group of components, such that each component can be identified, analyzed and if necessary designed independently from the others. Every system is created with a specific purpose that is supported by the interactions between its components. Normally the parts of a system have to be identified from aggregation of smaller parts that together give a good idea of the identity of the system. The combination of components of a system is called *structure*. The roles of the components of a system are represented by the *functionality* (what it does). The combination of the system structure and its functionality is called *system architecture*. Once the proper architecture of a complex system is identified, it is easy to understand it and control it without being bothered about its details.

A system can be natural or artificial. We understand natural systems those that exist in nature (e.g. an animal, a storm), and artificial systems those that are conceived and built by humans (e.g. a computer, the World Wide Web). To properly recognize a system it has to be delimited (discrete). A discrete system is a system whose behaviour can be defined by a set of related events, where an event is an activity that produces a certain result, at a certain location and at a certain moment. Discrete systems can be distributed if they are composed of relatively autonomous subsystems that are physically distributed in terms of distance. An important feature of distributed systems is that the physical distance between its components implies communication, coordination, synchronization and concurrency.

3.3 System development

An artificial system is, by definition, created by man. It is developed to serve its environment; the environment should be able to function better with the system than without it. System development is the set of related activities with the purpose of creating such a system.

System development can take place in different ways. The most widely used is the one in which a developer directly reacts to misfits perceived in a current situation; Almost without thinking the developer makes changes to the situation, resulting in a system that allows its environment to function better than before. This is for example the way in which for thousands of years the shapes of shelters and houses evolved. Modern examples of this type of development process are the fixing of a bicycle tire or the assignment of an additional cashier in a supermarket when the queues in front of the pay-desks get too long. The applicability of this method is limited since the changes that can be made by this type of development process are small (this development method is commonly known as evolution). Another type of development processes is that in which a developer thinks about the desired system, creating conceptions or "mental diagrams" of it, which depicts the aspects of concern to the developer. By doing so, the developer can analyze which aspects of the current situation need improvement and how a new system can provide this improvement. This type of development process can be seen for example in the planning of a delivery route by a mailman, or the writing of a simple computer program.

Another type of development processes is the one in which developers do not only create mental diagrams of the system under development, but also "real diagrams", representations of their conceptions. Such representations mainly serve four purposes [Weger, 1997]:

- First, they help developers in overcoming the limits of their mental capacity. "Two minutes on the back of an envelope lets us solve problems which we could not do in our heads if we tried for a hundred years".
- Second, they help developers in making their ideas precise, consistent, and complete.
- Third, such representations allow the communication of ideas and decisions between developers. This is required in development processes that are too complex to be carried out by a single developer.
- Fourth, such representations allow the communication of requirements between developers and users. This is required in development processes in which the user of a system does not develop the system by himself.

Examples of this type of development processes are the development processes of skyscrapers, airplanes, telematic systems, and business processes. It is this type of development process the one we consider in this document, since it is the only one suitable for the development of complex systems. A system under development will soon become an element of the real world. To be able of distinguishing a system in the real world from a conception or a representation of this system, a system in the real world is called a *System Implementation* and its formal representation *System Specification*. The representation of the relevant aspects of a real system relevant to one's purpose, one constructs a conception of the system or a system specification.

System development is a complex venture upon which depends the quality of the developed system. In the field of spatial information production and dissemination, systems are created based upon requirements (from customers) and environmental constraints with the aim of process data to produce products and/or services. User's requirements help to define the system boundaries and possibly its high level structure. This implies that one has to consider what the system is doing and how it is achieved in order to successfully design a system. In this case data is processed and further converted into information that is delivered in the form of products and services. For such a reason system's specifications can be obtained from the exact identification and formulation of the activities involved in production of information. The aggregation of this activities form processes and a correct definition and implementation of them should deliver user satisfaction and organizational success.

Process modelling is a technique for system development that has as main objective to structure the system functions and thus to enable defining the functional specifications of the system to be developed. The functional specifications form the base for the technical design of the system, which in turn permit to define specifications on the base of which the information system can finally be implemented. The technique is mainly concerned with the definition of the data processing processes and their inter-relations.

3.4 Business processes

Business processes mainly represent a component of an organization's behaviour, which is executed based in an internal structure consisting of functionalities and their correspondent interconnections in a logical order and dependence.

The final result of a business process is formally considered to be an observable and quantifiable product/service. For the purpose of this document, we define a process of this kind as follows:

> *A process is a pattern of closely related events (activities, actions) that take place to lead to a particular result and can be manifested or implemented in many different ways.*

To properly decompose and represent a business process it is necessary to have a mechanism to identify and describe its internal structure, rules of dependency among its parts and intermediate states. These characteristics of a business process allow one to define the possible types of processes present in an organization.

- Structured: is the process for which the set of internal events and relationships is completely defined and the expected final result is known.
- Semi-structured: is the process for which the final result is known but the internal activities and relationships are only notorious at run-time.
- Unstructured: is the type of process for which nor the final product neither its internal behaviour is completely known.

3.5 Process representations and models

Description of processes can take form in many ways, and one of the most intuitive one is to use common narrative to express or describe what a process is all about. This is a commonly used strategy for the description of processes, but the fact is that such explanation might not be satisfactory since natural language often presents inherit ambiguity, can be semantically unclear and furthermore difficult to refer at in subsequent discussions.

Models either graphical or mathematical provide a more accurate manner of mapping and preserving relevant characteristics of a process that exist or is to be built. Models are representations expressed in a specific modelling technique. What is presented in a model and what is omitted is a decision of the modelling team and it depends on the purpose of making the model or in the specific features of the process that are the subject of the study.

> *"A process model is an abstract representation of reality that excludes much of the world's infinite detail. The purpose of a model is to reduce the complexity of understanding….. a phenomenon by eliminating the detail that does not influence its relevant behaviour." [Curtis, Kellner, and Over, 94]*

Models are created to serve a variety of purposes and are found to be very useful and in fact indispensable in many contexts. If exist, models are used by people with different interest and concerns mainly with the aim improving the shape of a real world subject. More specifically one can say that models can aid in:

- Simplifying complexity,
- Enhancing common understanding,
- Studying alternatives,
- Controlling the real world.

In the context of organizations, models of information processes and systems help in many ways, and what relevant for us is to use them to capture and represent process' behaviour. With such information available is then possible to perform rational analysis on a particular behaviour and tested it for consistency. It is also possible to use such information as a based for investigation of different possibilities of implementation in reality. Later on, these models can act as a repository of organizational knowledge useful for metadata production, quality certification and of course guidance for its existing and new users.

3.5.1 Passive models

Models have traditionally been created in a way that they only preserve their relationship with the real subject at the moment in time at which the modelling was undertaken. This means that once created it became independent of its subject. Many of today's models fall into this category. An entity-relationship diagram or a dataflow diagram represent the modeller's understanding of a particular subject at an specific point in time.

3.6 Process modelling

Why model a system? One reason is the design of a new system; another reason is the evaluation of an existing system and the comparison of proposed alternatives. The modelling process forces one to look at the system in a specific way, focusing on the objective of the study. This could quickly reveal system defects and possible improvements. A model is also often used to determine the efficiency, performance and capacity of a system.

A system can be modelled in different ways. The selected modelling technique depends on the system to be modelled, the types of questions to be answered, and how easily the model can be analyzed. Available modelling techniques can be separated into two categories: techniques for data modelling, and techniques for process modelling. A data model is used to describe the static space of a system whereas a process model describes the dynamic behaviour of a system.

It is imperative to incorporate both static and dynamic aspects of the system into a modelling methodology. Consider, for example, the performance indicators *quality* and *flexibility*. They have both static and dynamic aspects. The quality of a geo-information system is determined, amongst others, by the percentage of on-time deliveries (dynamic aspect) and the product quality (static aspect). The flexibility of a geo-information production system is particularly determined both by how quickly the system is able to respond to volume changes in customers' demand (dynamic aspect), and to what extent it can produce this response (static aspect).

In the context of spatial information, a process is considered as a the set of transformation steps (events or activities) that take place with the aim of converting raw data into meaningful (spatial information) products or services. Processes are to be organized in to information chains which defined core deliverables of a system. The concept of information chain is explained in detail in chapter 3.

Process modelling is then the representation of the activities and functions arranged in an information chain, that a system performs upon data that has been defined in an appropriate data model.

A process modelling methodology should enable one to define a business process for different types of organizations, in different operative contexts and of course at different levels of detail. Such a methodology must lead towards a complete and exhaustive definition of all the relevant components of a business process in the framework of the modelling objective.

3.6.1 Modelling principles

From a disclosure point of view, a model of a system can often be accessed by users at multiple levels of granularity. The minimum level is typically determined by the requirements set by the design goals. The content of the model at every level and their operability in a application area is also defined at the requirements definition stage. Since the quality of such models has to be accessed against these design goals, various aspects of the models can be evaluated:

- **Correctness**: This principle is based in syntax and semantics and it is measured by how closely a model complies with the structure and behaviour of the real system.
- **Relevance**: Characteristics of the real system should only be represented in a model if they correspond with the purpose of creating the model. Models should not contain

information which is irrelevant for their applicability keeping their usefulness high and their cost-benefit ratio down to an acceptable level.

- **Clarity**: This principle ensures that a model is fully understandable and usable by its users. Because models contain both technical and organizational information, it is imperative to break them down into the correct number of sub-views such that their users get exactly the information they are looking for.
- **Comparability**: Because the technology that supports model representation is not always consistent with the conceptual framework in which models are defined, it is important to define the mechanism to identify the objects or elements in the model between the different languages such that equivalent degrees of relevance and detail can be found.
- **Systematic structure**: The integration and consistency of the various levels of abstraction has to be kept such that it should be possible to actually integrate one level into the other.

Modelling is a creative practice and can not be completely directed by rules. However, if certain standards are observed, it is then possible to understand and validate them.

3.6.2 Modelling techniques

Modelling of complex business processes can only be effectively performed when supported by an integrated methodology. We consider a modelling methodology to consist of modelling concepts, their representation, computerized tools and methods, and pragmatic skills and guidelines for modelling, communicating, analyzing, (re)designing business processes. This methodology is accompanied by a design strategy such that a design trajectory as a whole is covered. An engineering methodology thus enables designers to systematically deal with all concerns, requirements and constraints involved in a complex business process redesign task.

3.6.2.1 IDEFØ - function modelling method

IDEFØ is a method designed to model the decisions, actions, and activities of an organization or system. Effective IDEFØ models help to organize the analysis of a system and to promote good communication between the analyst and the customer. As a communication tool, IDEFØ enhances domain expert involvement and consensus decision-making through simplified graphical devices that identify what the current system does right, and what the current system does wrong.

As an analysis tool, IDEFØ enables the modeller to identify what functions are performed, what is needed to perform those functions. Thus, IDEFØ models are often created as one of the first tasks of a system development effort.

IDEFØ features designed to enhance communication include the following:

- Diagrams based on simple box and arrow graphics: intuitive constructs and intuitive notions.
- The gradual exposition of detail is achieved through a hierarchical structure, consisting of broad functions at the top and successive levels of more finely grained detail functions.

The rules of IDEFØ require sufficient rigor and precision to satisfy needs without overly constraining the analyst. IDEFØ rules include the following:

- Control of the details communicated at each level
- Context is stated at beginning (no out-of-scope detail)
- Unique Labels and Titles (no duplicated names within a single model)

- Syntax Rules for Graphics (boxes and arrows)
- Data Arrow Branch Constraint (labels for constraining the data flow on branches)
- Input versus Control Separation (a rule for determining the role of data)
- Data Arrow Label Requirements (minimum labelling rules)
- Minimum Control of Function (all functions require at least one control)
- Purpose and Viewpoint (all models have a purpose and viewpoint statement)

3.6.2.2 IDEF3 – process description method

The IDEF3 Process Description Capture Method provides a mechanism for collecting and documenting processes (i.e. ordered tasks, each step dependent upon completion of the immediately preceding step; IDEFØ models express functions and activities; see Strengths and Weaknesses of IDEFØ).

IDEF3 captures precedence and causality relations between situations and events in a form of natural to domain experts by providing a structured method for expressing knowledge about how a system, process, or organization works. IDEF3 descriptions can:

- Record the raw data resulting from fact-finding interviews in systems analysis activities.
- Determine the impact of an organization's information resource on the major operation scenarios of an enterprise.
- Document the decision procedures affecting the states and life-cycle of critical shared data, particularly manufacturing, engineering, and maintenance product definition data.
- Manage data configuration and change control policy definition.

IDEF3 captures the behavioural aspects of an existing or proposed system. Captured process knowledge is structured within the context of a scenario, making IDEF3 an intuitive knowledge acquisition device for describing a system. IDEF3 captures all temporal information, including precedence and causality relationships associated with enterprise processes. The resulting IDEF3 descriptions provide a structured knowledge base for constructing analytical and design models. IDEF3 expresses structured descriptions. These descriptions capture information about what a system does or will do and also provide for the organization and expression of different user views of the same system.

There are two IDEF3 description modes, process flow and object state transition network. A process flow description captures knowledge of "how things work" in an organization, e.g., the description of what happens to a part as it flows through a sequence of manufacturing processes. The object state transition network description summarizes the allowable transitions an object may undergo throughout a particular process. Both the Process Flow Description and Object State Transition Description contain units of information that make up the system description. These model entities, as they are called, form the basic units of an IDEF3 description. The resulting diagrams and text comprise what is termed a "description" as opposed to the focus of what is produced by the other IDEF methods whose product is a "model".

3.6.2.3 UML - unified modelling language

The Unified Modelling Language (UML) is a modelling language for specifying, visualizing, constructing, and documenting the artefacts of a system-intensive process.

- Within a system-intensive process, a method is applied as a process to derive or evolve a system.

- As a language, it is used for communication. That is, a means to capture knowledge (semantics) about a subject and express knowledge (syntax) regarding the subject for the purpose of communication. The subject is the system under discussion.
- As a modelling language, it focuses on understanding a subject via the formulation of a model of the subject (and its related context). The model embodies knowledge regarding the subject, and the appropriate application of this knowledge constitutes intelligence.
- As it applies to specifying systems, it can be used to communicate "what" is required of a system, and "how" a system may be realized.
- As it applies to visualizing systems, it can be used to visually depict a system before it is realized.
- As it applies to constructing systems, it can be used to guide the realization of a system similar to a "blueprint".
- As it applies to documenting systems, it can be used for capturing knowledge about a system throughout its life-cycle.

There are five views that are particularly important to describing a system with the UML.

The **use-case view** of a system is of particular interest to end users, for this view captures the desired functionality of the system. This view is of importance to testers as well, for these use cases form the basis of regression testing for each executable release.

The **logical view** of a system is of greatest interest to analysts and designers, and serves to describe the vocabulary of the problem space, together with the architecturally significant mechanisms that realize the use cases from the first view. Within this view, you'll find application, data and business models that describe the problem space, together with classes, packages, subsystems, and collaborations that realize the system's use cases.

The **process view** of a system describes the system's decomposition into processes and tasks and the communication and synchronization among these concurrent elements. This view is of greatest importance to system integrators who must address the performance, scalability, and throughput of the system.

The **implementation view** of a system captures the artefacts as seen by a system's programmers, and serves to model the executable components and corresponding source files and content that form those executable parts. This view is at the centre of a project's configuration management practice, for it is these components that are assembled into executable releases at each iteration.

The **deployment view** of a system is of interest to a project's system and networking engineers who must craft the system's hardware topology and architect the system for delivery and installation. This view describes the physical network configuration.

All of these views may be expressed using the UML. For example, class diagrams may be used to show the static parts of the logical view, and component diagrams may be applied to the component view. The dynamic elements of each of these views may be captured using any of the UML's behavioural diagrams, such as interaction diagrams and statechart diagrams. Furthermore, with the UML's extensibility mechanisms, it's possible to tune the language to speak to the needs of a particular domain. By working with this common language of blueprints, different stakeholders can contribute to their specific area of expertise, while at the same time communicate with other stakeholders.

3.6.2.4 AMBER – Architectural modelling

AMBER is an architectural modelling building-box for business processes. It is used to look upon a business process from two principally different viewpoints: external and internal. The *external viewpoint* considers the business process as a whole with externally observable behaviour. The internal structure and behaviour are not observable from the external viewpoint. The external viewpoint thus considers the business process as a black box which only shows which services are provided to its environment. This viewpoint thus belongs to customers or clients of the considered business process. The customers are only interested in *what* the business process can do for them. They generally do not care and are not interested in the internal structure and behaviour as long as the service provided to them complies with their quality demands. The description of the external viewpoint consequently provides the most abstract view on a business process.

The *internal viewpoint* considers the internal composition of coherent sub-entities and their assigned behaviours which together realize the externally observable behaviour of the business process. The internal viewpoint thus considers *how* the business process provides its services to its environment. The latter viewpoint is that of a business process engineer. The business process engineer aims at specifying the internal structure and behaviour of the considered business process such that its services can be provided. The internal structure and behaviour are not unique, given a unique service description. There are numerous possible internal compositions thinkable that can provide a particular business service to its environment. This is also the basic BPR paradigm.

The external and internal viewpoints can be used iteratively, resulting in a gradual shift from what to how. Given an external viewpoint of a considered business process, one can identify for example a number of key organization units and their (interacting) behaviours which together are responsible for the business process. Each identified unit can again be considered from an external viewpoint with an internal structure and behaviour to be identified.

From a designer's point of view it is traditional to identify *aspects* to discerns domains of interest. This is also considered a means of abstraction. We refer to (Ferreira Pires, 1994) where such an approach is illustrated:

- The entity domain, in which structure of the business process is defined.
- The behaviour domain, in which the functioning of the business process is defined.

The entity and behaviour domain are related to each other by *assignment*. An *entity* is defined as a logical or physical part (or actor) of the business process. Relations between entities are represented by an *interaction point*. This interaction point can be interpreted as the service access point for customers to make use of the service provided by the system. It can also be seen as a logical or physical location at which an interaction between two or more entities occurs. By identifying entities and interaction points, one can work out the internal structure of a system.

Behaviour is depicted by means of *actions*, *interactions and attributes.* An *action* is an abstraction of some activity in the real world. Actions are used to model a unit of activity performed by a business entity. An action is the most abstract model of activity at the abstraction level at which the action is defined. *What* the whole activity does can be referred to as one abstract action. A more detailed model of *how* the activity is performed can be specified in refinement steps, in terms of sub-activities and their relationships. The relevant characteristics of these sub-activities can again be modelled by distinct actions. The action concept is independent of the abstraction level or granularity at which specific actions are modelled. Four essential characteristics of an activity are modelled as *attributes* of an action:

- data: the result (e.g. information and/or product) established in the action;
- location: defines the physical or logical location at which the action occurs;
- time: defines the time at which the data is established and becomes available;
- probability: defines the probability that an action occurs according to its definition, once enabled.

We think that the above attributes fully model the relevant characteristics an action at a certain abstraction level.

Another important concept is *interaction*, which is introduced to model that several sub-entities must co-operate to achieve a certain outcome. The interaction attribute values have the same type-classification as the above actions and result from a conjunction of all individual constraints. The resulting attribute values are available to all entities involved.

Causality relations and behaviour patterns. A business process is defined as a structured set of logically related tasks/activities performed to achieve a defined outcome. In other words the activities in the business are related. The relations between actions are modelled by means of causality relations. A causality relation states the conditions under which an action becomes *enabled,* its enabling conditions. When the causality conditions are satisfied, the occurrence of the action is enabled. Thus, only enabled actions may take place. These actions can, in their occurrence, refer to the occurrence and resulting attributes of actions with which they have an enabling relation. This property is called *reference*.

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4 Performance Analysis for Geoinformation Processes

4.1 Introduction

There is increasing need for geoinformation providers to proactively and effectively manage the performance of their operations. Performance measures should not only focus on the products but also on the processes generating these products. A growing number of geoinformation organizations have embarked on reengineering programs in response to changes in their respective business environments. Successful reengineering requires reliable and objective quantitative information as a basis for decision making at the design, implementation and operational phases of system development. There lack of appropriate methodologies in geoinformation production environments to provide reliable performance information to guide and manage reengineering initiatives. Performance analysis has for long been used in industry, providing concepts and tools to realize appropriate information for decision making. In this chapter performance analysis is introduced, and performance goals and objectives relevant to geoinformation organizations discussed to provide basis for the analyses. The chapter proposes and discusses the use of Queuing Theory to model the performance of geoinformation processes and presents a performance modelling methodology. Modelling is an analysis technique appropriate for systems under development, for operational systems however direct measurements apply. The chapter outlines performance measurement and its role in Continuous Process Improvement (CPI), a vital post-BPR phase for effective performance management.

4.2 Performance analysis

Performance analysis has been employed widely in industry to develop systems that meet expectations. The aviation industry, banking, telecommunications and automobile industries are typical examples of areas where performance analyses have been applied with success. As the turbulence in the geoinformation market heightens, sound and competitive business practices become a must for spatial information providers. As a result an increasing number of geoinformation organisations are undertaking reengineering programs. Successful ones will be those flexible enough to adjust quickly to changing market conditions, lean enough to beat any competitors' price, innovative enough to keep products and services technologically fresh and dedicated enough to deliver maximum quality and customer service. As geoinformation organisations embark on reengineering programs, the need for sound performance management systems becomes more apparent. Integral to performance management is performance analysis.

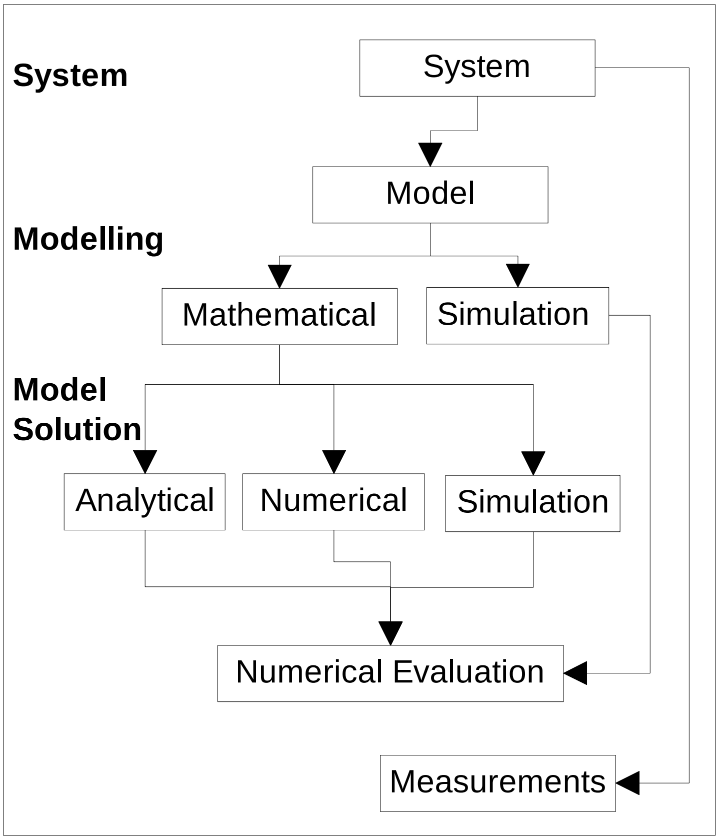

Figure 4-1 Performance Analysis [Nicola, 1999]

Performance analysis can be considered as being the first step in any problem solving or performance improvement effort. Careful analysis will uncover new perspectives on a problem or opportunity and determine all drivers towards or barriers to successful performance [Rosett, 1999]. The analysis identifies unused and non-productive capacity in systems, which often is the leading cause of unsatisfactory performance in organisations.

The analysis seeks and employs basically two broad categories of information. The first category is the perspectives that an organisation and its leaders are trying to put in place, the *directions* e.g. strategic objectives and goals. Second are the *drivers*, the factors blocking or aiding performance or those that may do so in future. Drivers are everything it takes to make performance. They define solutions, knowing what is causing bad performance or driving successful efforts, you know what you need to do to change or maintain the level of performance [Rosett, 1999]. Drivers are often called performance factors and examples may include the training and skill of workers, working culture in the organisation, level of technology etc.

For an operational system the analysis is called performance measurement. Thus if an organisation wanted to find out the number of thematic maps requested in a month, the information can be obtained by making a count of relevant entries in a register where all requests are entered on arrival. Alternatively the analysis can be on a model of a system being designed, in which case it is called performance modelling. Performance modelling and Performance measurement are complementary and at any moment the key consideration in deciding the evaluation technique is the life cycle stage in which the system is [Jain, 1991]. Measurements can only be made in an environment where it is known what needs to be measured, where and when it has to be measured and how many measurements will be sufficient. Thus the prerequisite for performance measurement is the availability of an actual system to measure upon [Haverkort, 1993].

4.3 Performance goals and measures for geoinformation processes

Any endeavour without clear goals is bound to fail and performance analysis projects are no exception. Trivial as the need for goals may sound, most performance analyses are done without clear goals. This is an undesirable scenario and it jeopardises the chances of obtaining reliable objective information from the analyses. Defining goals is no trivial exercise either since often the problems being addressed are vague from the outset. Geoinformation organisations considering reengineering need to develop a clear understanding of the performance goals desirable and appropriate performance measures.

In the complex geoinformation business environment, the number and type of spatial information providers continues to soar. While the business cultures of these players will be different, their strategic goals will without doubt include the critical elements of *innovative application of technology and optimal use of resources towards the realisation of responsive processes.* This global goal can be broken down in to components for which meaningful performance requirements can be set.

4.3.1 Performance goals

4.3.1.1 Maximise throughput

The application domains for spatial information are on the rise widening the customer base. Inevitably, spatial information providers will have to proportionately adjust their outputs to meet the increasing demand. Worse still, present day clients are not the naïve customers of past decades who readily accepted what was on offer. They need products tailored to their requirements in terms of time, quality and cost. The information providers therefore need to maximise the throughput of their processes both in numbers and diversity. Throughput is defined as the number of transactions or requests a process can complete in unit time and in this context it should be interpreted in terms of the number of user-requested services or products generated in unit time. Ability to generate many products that have not been requested is highly undesirable and it amounts to mass production. An organization with maximizing throughput as a performance goal will be keen on achieving maximum throughput with the existing resource capacity. Important is to establish whether current throughput is adequate to meet the market's demands and if not what extra resources are required.

Figure 4-2 illustrates the results of an experiment carried out to investigate the relationship between process average response time and throughput, read arrival rate. In a performance study, the Topographic Data Extraction (TDE) process, defined as the set of activities and resources that are involved in the generation of topographic information from aerial photographs, was used.. To realise a model for experimentation, it was required to model the architecture and behaviour of the process. Figure 4-4 shows the architectural and behavioural model of the TDE process developed. The TDE process model was implemented in SiMPLE++ simulation software for analysis. Although the model data used in the analysis was intuitively derived, valuable statistics like throughput and response time could be derived and easily scaled to reality. Through careful experimentation and analysis it is possible to realise an optimal process configuration.

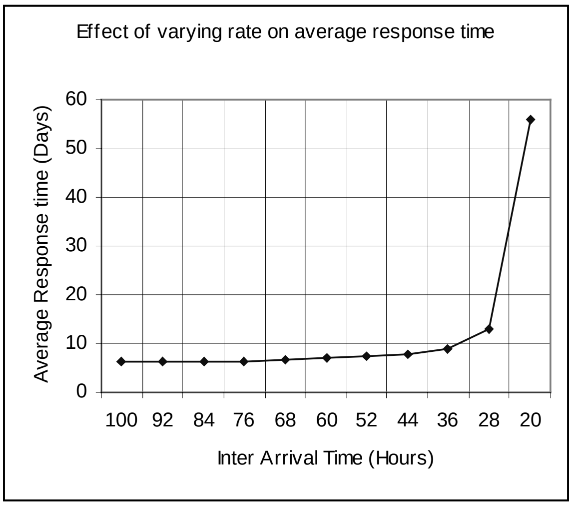

Figure 4-2 Effect of varying the arrival rate on response time

It is evident form Figure 4-2 that increasing the response time increases marginally with increasing inter-arrival time (the arrival is the inverse of the inter arrival time) till some critical value after which the system becomes unstable and additional resources become necessary. From Figure 4-2 it is evident that the system can handle jobs till an arrival rate of ***1/36 hr –1*** beyond which the average response time becomes unacceptable.

4.3.1.2 Increase process flexibility and responsiveness

Rapid advancements in information technology and digital technologies for spatial data handling have created a very dynamic geoinformation market. This dynamism is reflected in fluctuating demand for established products and increase in the number of new products in the market. It is desirable that processes are responsive i.e. be able to adapt to demand fluctuations and be flexible i.e. be able to reconfigure fast enough to offer new services or generate new products without significant changes in resources. Process owners need to continuously and critically study their markets while following trends in technology advancements if they are to gain or maintain a competitive edge.

The TDE process was used to study the effect of varying distribution of jobs for digital and analogue processing. This phenomenon is attributable to varying user preferences. This manifests as a change in the number of jobs processed in a production line. **Figure** 4-3 shows that good response times are obtained when at least 70 percent of the jobs are processed digitally. While this figure is bound to change significantly for individual processes and model parameters, the experiment identifies when the optimal use of resources is achievable.

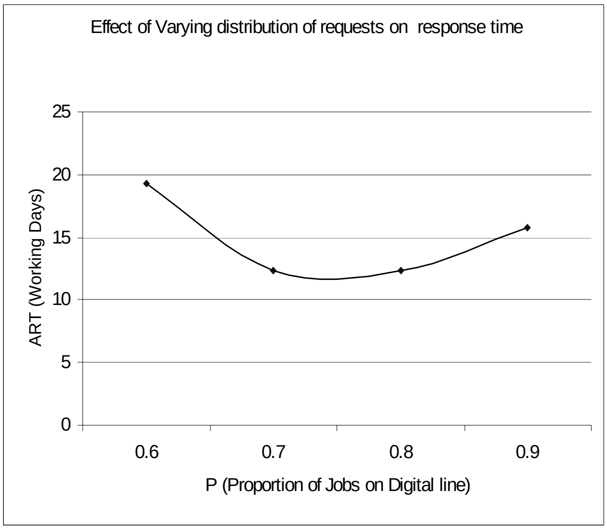

Figure 4-3 Optimal Distribution of requests

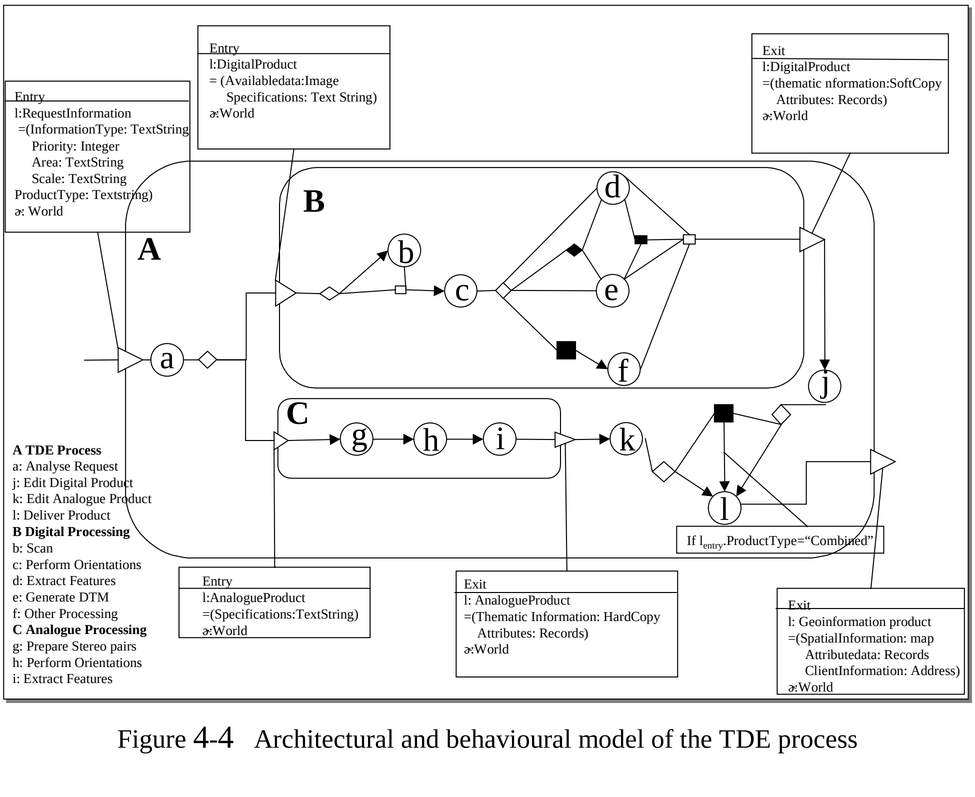

Figure 4-4 Architectural and behavioural model of the TDE process

4.3.1.3 Low production and product costs

With intensifying competition, only those organisations whose products and services are perceived as being good value for money with an equitable balance between the make-up of the product and services and the prices charged will survive. Successful organisations need to maintain lean processes offering high quality services and products whilst quickly developing new models and maintaining higher productivity. These requirements underscore the need for tightly linking production with customer needs therefore ensuring that products are *fit for the purpose* for which the customers require them. In a bid to lower production costs it becomes necessary to eliminate unused and unproductive capacity, institute hierarchical processing and outsource where necessary.

Low production costs translate within reasonable profit margins to low product costs. While the measures outlined above will help reduce production costs, a significant contribution to this will come from the working culture and motivation of the organisations' workers. Thus if any meaningful performance achievements are to be made, organisations need to institute structures that will motivate the workers, creating in them a sense of ownership of the process.

4.3.1.4 Increase product diversity

Geoinformation organisations need to adopt a service-oriented strategy if they need to handle various levels of complexity and product diversity. Dominguez (1998) proposed a hierarchical processing methodology for geoinformation processes. The methodology is based on the notion of value addition which supposes that every activity performed on a product is value adding and that the outcome of each activity is a product in its own right. An increasing number of spatial information users have access to affordable computing facilities. Consequently they are able to perform some of the activities which traditionally the spatial information providers did. To take advantage of this opportunity, organisations need to provide access to their databases and information resources so that users can access the basic products and customise them to their needs. Advancements in technology have meant that users need a wider spectrum of products as opposed to the limited range of standard products of yesteryears. Ideally, organisations should make technology exploitation one of their core competencies such that they anticipate the products or services to be expected of them in future before even the technology for providing them becomes available or the customers start asking for them. A competent research and development team is required for this to succeed.

4.3.1.5 Deliver products/services just in time

The Just in Time (JIT) concept originated in Japan as an inventory control method. In this approach parts are delivered just before they are needed to avoid expensive storage and inventorying. This concept has been extended so much so that the supplier of parts has direct access to the inventories of their consumers and need not wait for orders before supplying commodities [Hammer & Champy, 1997].

In the spatial perspective the "parts" to be delivered is the geo-data required to offer a service or to generate a geo-information product. It often is not possible to predict precisely the data requirements until a request has been received. However even after the request has been received, there is no guarantee that the required data can be acquired immediately. This is occasioned by the fact that external factors like the weather and climatic conditions have an influence on the data acquisition process and even with the best technology this could take considerable time ranging from a few hours to several weeks. To talk of the just in time concept as used by the Japanese would not be very meaningful in the spatial perspective. Rather this concept should be interpreted as the duration taken to provide a service or a product from when the request is submitted i.e. the time that it takes to respond to a request. The shorter this duration is, the more *just in time* the process will be.

To enhance the just in timeliness of processes, process managers need to institute consistent monitoring of market trends and advances in technology. Such an exercise will provide the necessary information to enable prediction of future products and demands. An organisation that prepares itself for future demands and trends will inevitably gain a significant lead on its competition [Hammer & Champy, 1997]. For an organisation to be able to process just in time it requires a strong customer focussed business culture as reflected in its workers and processes.

Organisations often need to acquire extra resources to enhance just in timeliness. While it is true that having more service providing entities leads to shorter queues hence improved response times, these come at a cost. Through modelling the gains to be made by deploying state of the art technology can be obtained by comparing with existing performance. This will justify expansion of the technology and other resources in the organization. As an illustration the effect of introducing more servicing entities was investigated on the topographic data extraction (TDE) process and the results are shown in Figure 4-5. It is evident from the figure that the response time is better when more servicing entities are used. However for values of P greater than 70%, the response times are not very different. Recalling that the process operates optimally in this range, it would indicate that the extra resources are not necessary.

The goals spelt out above are so inter-twined that talking of one exclusive of the others is difficult. Nonetheless they provide directions on which performance requirements can be pegged. Every performance analysis project addresses a performance problem. The performance problem should be very clear to the analyst before the objectives of the analysis and metrics are determined. The following discussions look at the possible performance measures for geoinformation processes.

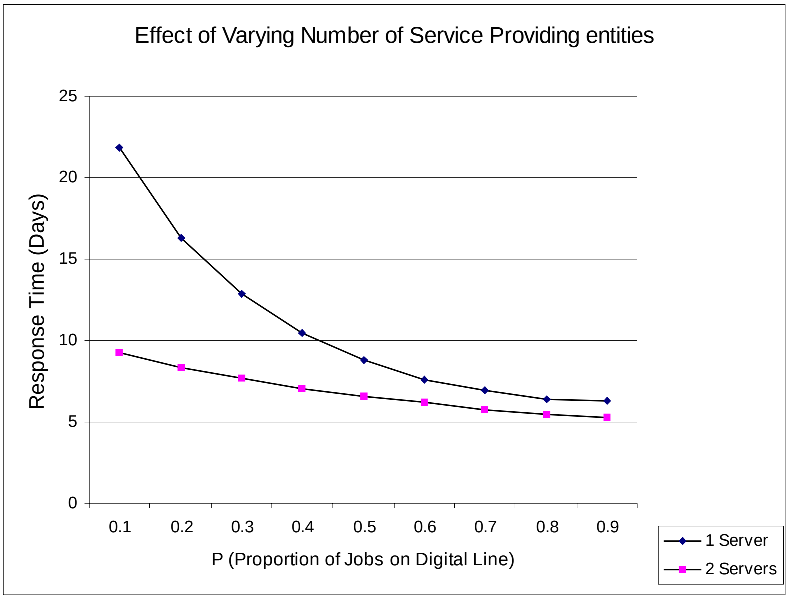

Figure 4-5 Deploying more resources

4.3.2 Performance measures

Every performance study requires criteria or metrics to indicate how well the performance objectives have been met. By developing metrics directly from the strategies and objectives, an organisation lays out a path by which its vision and mission, an intangible concept, becomes concrete and achievable. At the different levels of the hierarchy, different measures are adopted. At the corporate level for instance, management will be more concerned with customer retention and market share while at the functional level process managers are more likely to be concerned with system reliability, resource utilisation, process response time etc.

In recent times emphasis has shifted from the traditional accounting measures to non-financial measures at the corporate level. This is due to the fact that not all the strategic objectives of an organisation are purely financial in nature. And even if they were, its becoming increasingly apparent that an organisation that ignores key non-financial performance areas like customer satisfaction, employee morale and new product development can be fairly certain that it will not achieve its long-term financial objectives.

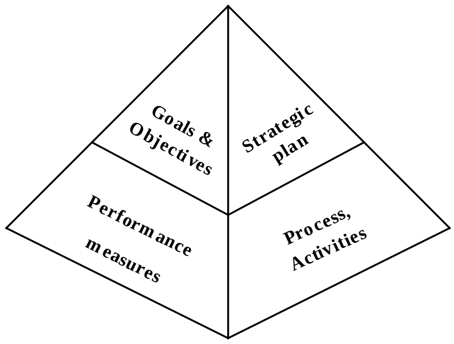

Figure 4-6 Performance Measures, Activities and Strategic Plans [Sani, 1998]

The careful choice and implementation of performance measures in an organisation is a necessary prerequisite to the achievement of its strategic objectives. While strategic plans are formulated to outline how an organisation will achieve its goals and objectives, performance measures are yardsticks for indicating how well the objectives have been realised

Appropriate measures enable effective monitoring, control and evaluation of system performance. Measures are often chosen to address a set of objectives in which case it becomes necessary to ensure that one dimension of objectives or set of dimensions is not stressed to the detriment of others [Alastair et al]. The measures adopted for performance modelling must be relevant, measurable or observable and easy to apply. On the other hand, the performance data needed should be affordable, available, and timely [Sani, 1998]. Performance measures can be classified under the following generic dimensions:

- Competitive advantage
- Financial performance
- Reliability and Quality of service
- Flexibility
- Resource utilisation
- Innovation

The first two dimensions reflect the success of a chosen strategy (end results) while the other four determine the competitive success (means or determinants). Examples of possible performance measures for the first two dimensions could be market share and annual profit respectively. Depending on the type of process one is dealing with and the objective considered strategy it is possible to identify a number of performance indicators.

At the functional level, to prepare the set of metrics, one needs to analyse all the probable outcomes of a process. The system may execute the job correctly, incorrectly or fail to perform the service. For a correctly performed service, performance can be measured by the time taken to perform the service, the rate at which the service is performed or the resources consumed while performing the service. These time-rate-resource metrics are called *responsiveness*, *productivity*, and *utilisation.* A resource with the highest utilisation is called a bottleneck and is the key limiting factor in achieving higher throughput.

For a service that is in-correctly performed an error is said to have occurred. Different types of errors are likely to occur and it is necessary to classify the errors and determine the probabilities for each class of error [Jain, 1991]. If the system does not perform the service, it is said to be unavailable or down or failed. The probability of failure, the mean time to failure or mean time between failures provides possible metrics for failed service. Similarly it is necessary to classify the failure modes and determine their respective probabilities.

Table 4-1 Performance measures for geoinformation processes at the functional level

Strategic Objective	Performance Metric
1. Maximum Throughput	Throughput
2. Enhanced Flexibility and Responsiveness	Response Time, Range of Products, Number of non –standard jobs rejected
3. Low Production / Product costs	Utilisation, Mean down-time, Mean Number of Reworks
4. Increased Product Diversity	Range of Products, Development time for new products
5. Just in Time Delivery of services and products	Response time, Waiting time, Queue length

In Table 4-1, the identified performance goals presented above are linked to potential performance measures (indicators). The list of measures indicated is not necessarily exhaustive and it applies to the functional level of the organisation where concern is on the effectiveness and efficiency of the actual production work.

4.4 Performance modelling

The art of modelling is arguably as old as mankind and the uses for models, as well as the forms they take vary significantly. Modelling the performance of a system aims at providing the highest performance at the lowest cost. By using models a design or configuration that offers the best cost-performance trade-off can be realised before any resources are committed to its implementation. Figure 4-7 below shows examples of issues for which modelling would support decision-making during the system evolution cycle.

Studying through modelling comes in handy when the system under study is too difficult (complex), too hazardous or too expensive to observe in operation. Often modelling is used to check hypotheses about the internal structure of a system when certain questions cannot be answered by observing the real system. In operational research, models are invaluable for abstracting the essence of the subject of inquiry, showing inter-relationships and facilitating analysis. Sani [1998] notes that models provide a platform for unambiguous communication, analysis and improvement, and better response to changes. A good modelling concept should therefore represent the structure and operations of a process simply and directly, have a holistic approach and be adaptable.

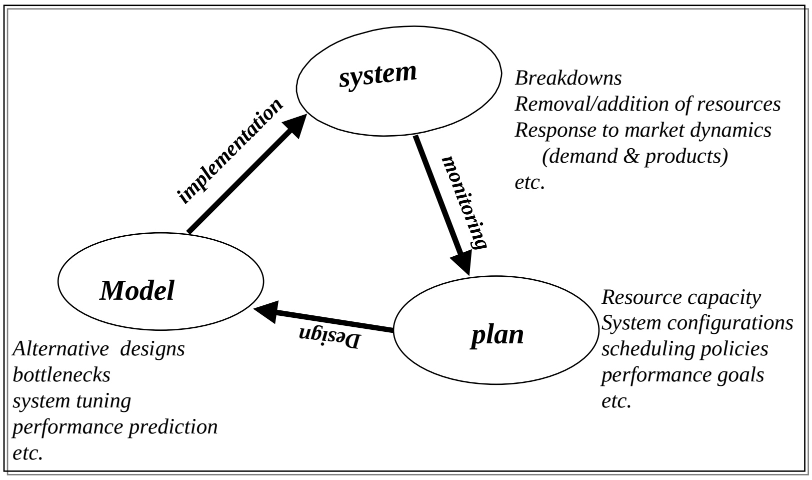

Figure 4-7 Models and Decision Making

4.4.1 Models and modelling

A model can be defined as a representation (physical, logical or functional) that mimics an object under study [Molloy, 1989]. In creating a model the system boundaries need to be defined and a host of assumptions made. A good model should closely approximate the target system and predict the relative effects for all the alternative courses of action with sufficient accuracy to permit a sound decision. This can only be achieved if the modelling objective is replicated in the model [Ernest, 1994]. Besides, replicating the modelling objectives makes it possible to attach meaning to the resultant outputs.

The modelling tools should be such that the performance estimates are obtained with sufficient confidence in accuracy with minimum effort [Mitrani, 1982]. Ideally, the modelling tools should also enable fast and easy creation of models even when describing very complex systems. They should also be flexible enough to model alternative system designs. Models can be classified along several dimensions and whilst it is not the intention to exhaustively define all possible modelling dimensions, it is necessary to describe those thought relevant to this study.

The first dimension characterises the model representation. An abstract model is one in which symbols representing some important aspects of the object or phenomena constitute the model. Mathematical and simulation models are examples of abstract models. Physical models, also called iconic models, are classified under this dimension [Page, 1994]. Descriptive and prescriptive models come under the dimension of the underlying study objective of the model. Descriptive models describe the behaviour of a system without any value judgement on the quality of the behaviour of the system while prescriptive models describe the behaviour in terms of quality.

Models may also be classified depending on the presence or absence of temporal aspects. A static model describes relationships that are invariant with time or where time doesn’t play a significant role e.g. snapshots of a system. Dynamic models on the other hand describe time-varying relationships. The fourth dimension identifies with the solution technique. Analytical, numerical and simulation models are classifications based on the methods of model solution (Figure 4-1). The presence of at least one state change that is a function of one or more random variables results in a probabilistic (stochastic) model otherwise the model is deterministic.

On more general terms, models may be qualitative or quantitative. Qualitative models are those that are concerned with the logical aspects of a system such as controllability, stability and the existence of deadlocks in system operation. Quantitative Models however, are those concerned with the quantitative system performance in terms of throughput, lead-time and other measures. This category involves discrete event simulation, Markov chains, queues and queuing networks. In performance modelling of geo-information production processes involves quantitative modelling.

4.4.2 Mathematical modelling

Mathematical models are idealised representations of systems expressed in terms of mathematical symbols and expressions describing the essence of the problem. Newton's laws of motion in Physics and the laws of supply and demand in economics present typical examples. Whilst the development of mathematical models is outside the scope of this study, it suffices to state that the models express the appropriate measure of performance as a function of decision variables (relating to the decisions to be made).

Mathematical models provide a very concise description of a problem, revealing important cause-and-effect relationships and generally tend to make the structure of the problem more comprehensible [Hillier et al]. The models also form bridges to the use of high-powered mathematical techniques and computers to analyse a problem. However mathematical models are necessarily abstract idealisations of a problem requiring approximations and simplifying assumptions if they are to be tractable. In effect unimportant details or factors that have approximately the same effect for all alternative courses of action are not to be considered. However, great care must be taken if the model is to remain a valid representation of the problem. Mathematical modelling can be split into the sub-types analytical and numerical modelling defined below.

- **Analytical models**: They express the performance measures as closed formulae in terms of model parameters. They are very accurate, fast and simple. However they are restricted to very simple problems and demand great scientific study and knowledge. Moreover, they are a very loose approximation of reality.
- **Numerical models**: Mathematical models of the numerical type contain exact algorithms where the performance measures can be instantiated with numerical values. Thus a series of equations can be generated and solved for the decision variables. These models offer solutions that are accurate but the precision is limited by the computing capability available. However advances in computing technology are poised to expand the scope of application of this model solution technique. Numerical models allow a quick and precise insight in a single instance of a system and they offer a fairly good approximation of reality.

4.4.3 Simulation modelling

The Oxford English Dictionary defines simulation as "*The technique of imitating the behaviour of some situation or system by means of an analogous model, situation or apparatus, either to gain information more conveniently or to train personnel.*". Simply put, simulation is the technique of building a model of a real or proposed system so that the behaviour of the system under specific conditions may be studied. Ernest (1994) defines Simulation as "the use of a mathematical/logical model as an experimental vehicle to answer questions about a referent system." Simulation is very general in nature and therefore applicable to systems of varying complexity. Despite this apparent versatility of simulation, it is by no means a panacea [Hillier et al, 1990]. Inherently, simulation is a rather imprecise tool and only provides statistical estimates, which do not provide additional insight into the cause-and-effect relationships within the system. By using simulation, one can only compare alternatives but cannot generate an optimal solution. Besides simulation is slow and fairly costly and often the results obtained turn out to be inadequate. Nonetheless, simulation models have a close correspondence to reality

Table 4-2 Criteria for selecting an analysis technique [Jain, 1991]

Criterion	Mathematical Modelling	Simulation	Measurement
1. Stage	Any	Any	Postprototype
2. Time required	Small	Medium	Varies
3. Tools	Analysts	Computer languages	Instrumentation
4. Accuracy*	Low	Moderate	Varies
5. Trade-off evaluation	Easy	Moderate	Difficult
	Small	Medium	High
6. Cost	Low	Medium	High
7. Saleability			

When modelling it is advisable to use at least another method validate the model that has been built. If for instance the analysis is via simulation, its results should be checked against those of real measurements, analytical or numerical solutions. Though sceptical, the statement *until validated, all evaluation results are suspect* holds true. There is possibility also to use the techniques sequentially. For example a simple analytical model may be used to establish an appropriate range for system parameters and simulation used to study the performance in that range thus considerably reducing the number of simulation runs required. Table 4-2 summarises the criteria to use in selecting an analysis technique.

While the need to reengineer the processes is clear, most spatial information providers are sceptical of change for lack of clear guidelines as to what changes need to be effected and how the impacts of these changes can be assessed and monitored. In chapter two a methodology for effecting BPR in geoinformation environments was presented. This chapter presents methodology for modelling the performance of geoinformation processes.

4.4.3.1 Queuing models

The passing of time plays an essential part in the world in which we live and most everyday-life decisions will require some inference on the future state of particular phenomena based on its past and present state. To be able to make reliable predictions requires that the phenomena be represented as some abstract scheme of a probabilistic nature. This abstract scheme is often called a random model. If the model is an adequate representation of the phenomena, it can be employed adequately to make calculated choices. The important feature of these random models is that they have time as the argument. Stochastic models have been widely used to describe phenomena that change randomly as time progresses [Hermanns, 1998].

Geoinformation processes are triggered by the arrival of a job or a request for spatial information, service or product. The request could be from an internal or external customer. Nonetheless, the instant of arrival and the time the request spends in the system exhibit random behaviour. This makes it possible to model geoinformation processes as probabilistic systems. The states that a geoinformation system can take are discrete as defined by the number of requests or jobs in the system. Geoinformation processes can be modelled as discrete event systems. A discrete event system can be thought of as a dynamic system, an entity equipped with a state space and a state transition structure. It is discrete in time and in state space and it is event driven i.e. it is driven by events other than or in addition to the tick of a clock and may be non-deterministic. Other examples of discrete event systems include manufacturing systems, traffic systems and communication protocols.

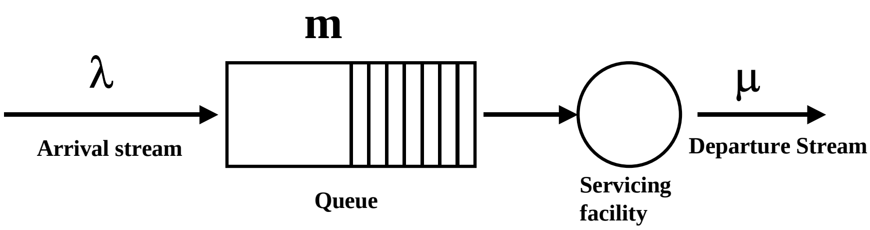

Figure 4-8 A Queuing Station

In any environment where jobs share a resource, and geoinformation processes are good examples, queues are inevitable. Consider a case where customers e.g. people, arrive at certain time instants at a service point (bank counter, air ticket counter etc.). These constitute events and the service facility requires a certain time to serve each customer and is capable of serving only a finite number of customers. If the customers arrive faster than the facility can serve them, they must wait in a queue. Typically, both the arrival and service times are specified to follow some probability distributions. Of interest then is the relation between the waiting times, queue lengths etc. and the given properties of the arrival and service. In practical applications, it would also be interesting to compare different modes of operation in terms of service, cost etc. Often the service facility offers more than one service and it may be necessary to establish if it is wise to have separate facilities for each service and how many such facilities will be sufficient. Depending on the arrival and service processes and the configuration of the service providing facility, different types of queuing stations can be defined. Important to note is that the resource under consideration is of limited capacity and is being used by a large population of customers.

In order to define a queuing system it is necessary to explain its main components:

- Arrival process: the customers will arrive at time instants ***t1,t2,……ti.*** The intervals between successive time instants are random variables called the inter-arrival times and are assumed independent and identically distributed.
- Service Time Requirements: the amount of service requested by any customer can generally be described by a stochastic variable that is assumed independent and identically distributed, often exponentially distributed.
- Number of Servers: this is the number of service providing entities and is variable.
- System Capacity: this is the maximum number of customers that can be allowed in the system and is influenced by the amount of waiting room available. The system capacity includes both the jobs waiting for service and those being served.
- Customer Population: this refers to the total number of customers who can ever come to the queuing station.
- Service Discipline: the manner in which customers are served is called the service discipline, the most common scheduling strategy being First Come First Served (FCFS).

4.4.3.2 Little's formula

Little's Law is one of the most commonly applied theorems in queuing theory. It derives its strength from its generality. It can be applied unconditionally and at many levels of abstraction. Besides, its form is very simple. Little's Law relates the average number of packets in a queuing station to the average number of arrivals per unit time and the average time spent in the queuing station as follows:

Mean Number in the system = arrival rate × *mean response time*

This relation applies to systems in equilibrium that is the law applies as long as the number of jobs that are entering the system is equal to the number of those completing service. Now if the rate of arrival is λ and packets are served on a FCFS basis for example, there are two possibilities for an arriving packet. If the queuing station is empty, the packet will be immediately served otherwise it waits until all those already in the station are served. Let the average response time be ***E[R]*** and the average number in the station be ***E[N]***.

Now, the response time is the time the packet will spend in the station before exiting after receiving service. If a packet waits for *E[R]* time units before leaving the queue and in the meantime new packets are arriving at rate λ, by the time it leaves then *λE[R]* packets will have arrived. Therefore the number of packets in the system on average will be given by:

$$E[N] = \lambda E[R]$$

which intuitively proves the statement made above. However more rigorous proves are available. This formula can be applied separately to the queue or the service station. The following will result:

$$E[N_q] = \lambda E[W]$$

$$E[N_s] = \lambda E[S]$$

where *E[W]* and *E[S]* represent the expected waiting and service times respectively. Since we are dealing with a single server, then *E[Ns]* can maximally be one and minimally be zero. Indeed *E[Ns]* also indicates the average time the server is busy and is often called the utilisation or traffic intensity.

4.4.4 Geoinformation processes, queuing models and simulation

In geoinformation processes, the arrival of a request from the customer, the start or completion of an activity all present events. The jobs arrive at some service station e.g. a photogrammetric digital workstation, scanner, GIS analysis platform, cartographic reproduction office, field office for data acquisition etc. It can be expected that the number of jobs arriving varies and that the servicing station has limited capacity as to the number of jobs that can be handled at any one moment. The arrival processes and the service demands of the jobs are essentially stochastic phenomena. Clearly then, geoinformation processes can be described as networks of queues whose performance can be evaluated through discrete event simulation. Geoinformation processes are often complex and simulation presents a robust method for performance evaluation.

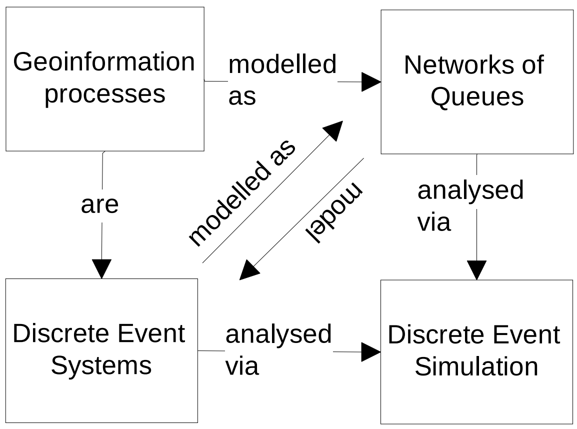

Figure 4-9 Geoinformation Processes and discrete event simulation

4.4.5 Results analysis

The very reason to do a simulation is the gathering of data from a model. After the performance measures have been collected, they need to be interpreted in the context of the original system or process. These measurements are basically experimental results and in order to get reliable results, we need to obtain averages, variances and confidence intervals for these results.

The derivation of mean values and confidence intervals is an application statistic and therefore cannot be treated here in all detail.

Given n observations $X_1,........,X_n$ we view them as a realisation of some stochastic variable X with mean value $E[X]=\alpha$, where α is the value we seek and is unknown. Let A be a new stochastic variable such that

$$A = f_A(X_1,......., X_n).$$

A is called an estimator of $E[X]$ and whenever $E[X]=\alpha$, the estimator A is called *unbiased.* Whenever $\Pr\{|A-\alpha|<\varepsilon\}\to 0$ when $n\to\infty$, the estimator A is called *consistent.* This implies that $Var[A]\to 0$ whenever the number of samples $n\to\infty$. Thus both *consistency* and *unbiasedness* are desirable properties of estimators.

For independent $X_1,........,X_n$

$$A = \overline{X} = f_A(X_1,........, X_n) = \frac{1}{n}\sum_{i=1}^{n} X_i$$

is an unbiased and consistent estimator of α. However, the requirement that X_i be independent is problematic since successive samples taken from a simulation are not independent. Several ways exist to go around this problem. One is to do n totally independent simulation runs accomplished by running the simulation program several time each time with a different seed for the random number generator. If in each simulation run, there are m samples, although the individual samples in each run are not independent, the run sample means will be independent.

The sample means are assumed independent and identically distributed and by the central theorem, $A = \overline{X} = f_A(X_1,........, X_n) = \frac{1}{n}\sum_{i=1}^{n} X_i$ will have a normal distribution with mean α and variance σ^2. Consequently, A will have a $N(\alpha,\sigma^2/n)$ and the random variable

$$Z' = \frac{A-\alpha}{\sigma/\sqrt{n}}$$

will have a $N(0,1)$ distribution. Recalling that both α and σ are unknown, we cannot use the above expression directly. However by substituting the sample variance

$$S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_i - A)^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_i{}^2 - 2AX_i + A^2)$$

for σ^2, the stochastic variable

$$Z = \frac{A-\alpha}{S/\sqrt{n}}$$

has a Student distribution with $n-1$ degrees of freedom. The student distribution with three or more degrees of freedom is a symmetric bell-shaped distribution, similar to the normal distribution. For $n \to \infty$, the Student distribution approaches a $N(0,1)$ distribution. By using a standard table for the *t*-distribution, the value of *z* can be found such that $\Pr\{|Z| \leq z = 1-\beta$ or $\Pr\{|A-\alpha| \leq zS/\sqrt{n}\} = 1-\beta$. The latter expression states that the probability that *A* deviates less than $zS/\sqrt{n}$ from it real (but unknown) mean value α is $1-\beta$. Stated differently, the probability that the real value α lies in the interval $[A - zS/\sqrt{n}, A + zS/\sqrt{n}]$ is $1-\beta$. The interval $[A - zS/\sqrt{n}, A + zS/\sqrt{n}]$ is called the confidence interval an the factor $1-\beta$ is called the confidence level.

The method discussed above is the method of *independent replicas.* This method has the disadvantage that the simulation has to be run from start several times, requiring that the transient behaviour at the beginning of every simulation has to be done each time the simulation is run. The method of *Batch Means* circumvents this problem.

The method of batch means consists of running along simulation run, discarding the initial transient behaviour and dividing the remaining observations into several batches or samples. For a run of *N+X* observations, where *X* is the number of observations that belong to the transient interval and discarded, the *N* observations are divided into $m = N/n$ batches of *n* observations each. The mean for each batch is computed as:

$$\bar{x}_i = \tfrac{1}{n}\sum_{j=1}^{n} x_{ij}\ ,\ \ i=1,2,\ldots,m$$

The overall mean is then computed via:

$$\bar{\bar{x}} = \tfrac{1}{m}\sum_{i=1}^{m} \bar{x}_i \ \text{ (i = Index)}$$

The variance of the batch means is computed as:

$$Var(\bar{x}) = \tfrac{1}{m-1}\sum_{i=1}^{m} (\bar{x} - \bar{\bar{x}})^2$$

The confidence interval for the mean response is

$$\left[\bar{\bar{x}} \pm z_{1-\alpha/2} Var(\bar{x})\right]$$

The confidence interval width is inversely proportional to $\sqrt{mn}$ thus it can be reduced by increasing the number of batches or the batch size. The batch size must be large so that the batch means have little correlation. Other methods that are used to circumvent the problem of dependency among observations in a simulation sample are the *regenerative method* and *spectral method.*

4.5 Performance modeling methodology

The previous sections have defined performance modelling and discussed its importance. This section presents a performance modelling methodology that can be used in the analyses (Figure 4-10). The process to be followed is highly iterative, an approach that is invaluable especially when a trade-off between several performance objectives has to be negotiated. In such a case it is likely that several iterations of the performance evaluation exercise is necessary, with the successive iterations employing adjusted performance requirements. Performance evaluation projects are unique depending on the performance problem being addressed and while it is not the intention to offer a rigid solution for executing simulation modelling projects, a structured and systematic approach to the exercise is a must. It will not only ease the modelling process but will also provide a better interpretation of the data collected.

The methodology has four primary operations. These are the problem formulation, process modelling, experimenting and reporting blocks. The activities in each of these blocks define what needs to be done and what the result should be.

It is extremely important that the goals of a performance evaluation exercise are clear for they not only dictate the data requirements but also guide in the choice appropriate metrics. Objective goals can only be realised if the factors affecting the performance of the process are clear. The assumptions made about the system being modelled should be documented for they are often revisited and changed. The objectives adopted at operational level should tie with the global organisational objectives as laid out by top management.

The process modelling operation includes the conceptual modelling, data collection and analysis, computer model development, verification and validation. Notably, the conceptual modelling, data collection and analysis should be carried out concurrently for they influence and enhance each other. Having a well-structured conceptual model can help define the appropriate data. Data analysis on the other hand can provide further insight into the system and help to improve the conceptual model. It should be borne in mind that it is not always possible to collect data since the system may not exist or even when it exists other extraneous factors inhibit successful data collection.

A properly designed experiment enables the analyst to obtain maximum information with the minimum number of experiments. This saves considerable labour, computer run time and generally reduces the cost of the exercise. Good experiments allow separation of the various factors and determination of their significance. The design of effective experiments, generation of simulation samples and analysis of the samples is all done in the experimenting operation.

Most analysts often overly concern themselves with the modelling and experimenting operations and tend to overlook the reporting of the findings. This is a pity because an analysis whose results cannot be understood by the decision-makers is as good as one that was never performed. The results should be presented as clearly and as simply as possible. The prudent use of words, graphs, and pictures to explain the results [Jain, 1991] is highly recommended. The four operations when followed well result in a focussed performance evaluation study that will be of great assistance to the decision-makers.

While the outlined procedures promise a successful performance evaluation exercise, it pays to note that the accuracy of the exercise improves with the analysts’ experience i.e. it is an art. Besides, the capability of the simulation software used plays a vital role especially in the implementation of logical relationships. The whole process is iterative and may take considerable time.

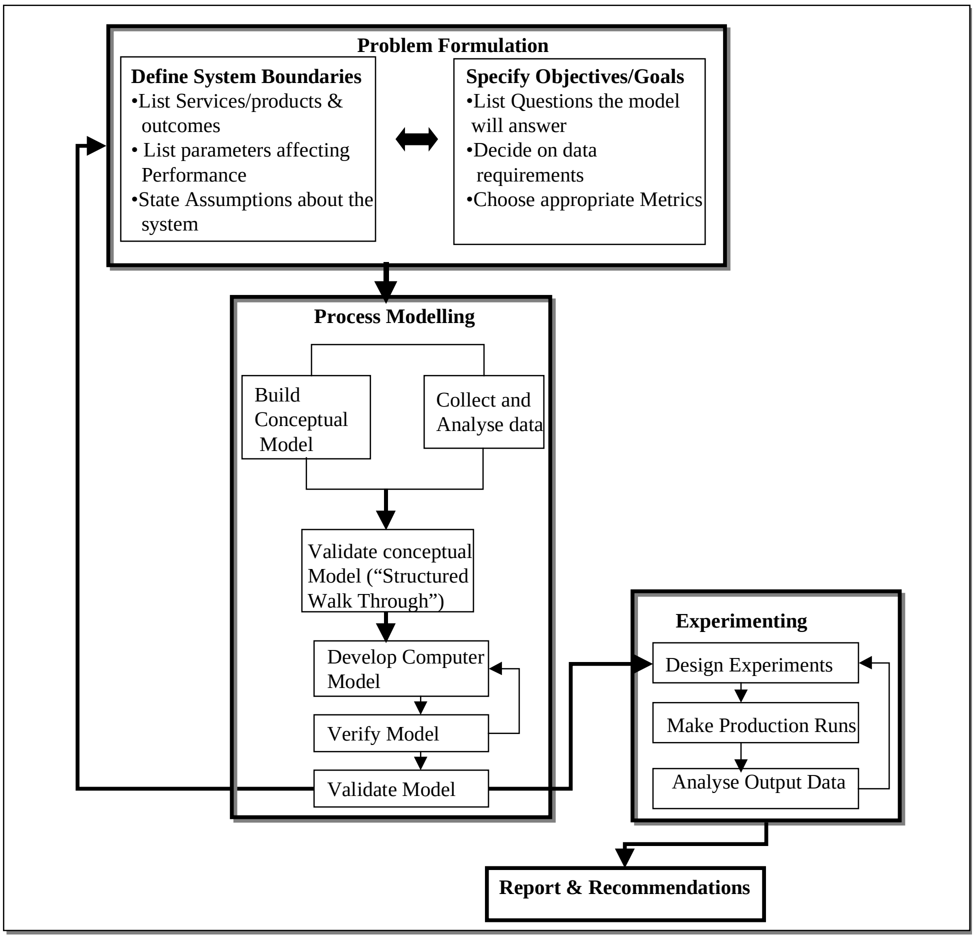

Figure 4-10 Simulation Modelling Methodology

4.6 Performance measurement

At the functional level, performance measurement monitors a process to realise data that will provide insight into how effectively and efficiently the process is achieving its set objectives. The data obtained will bring to the fore any existing or future bottlenecks to successful performance enabling management to take corrective action in good time.

Although measurements are the real thing, they may not necessarily give accurate results since the environmental parameters, such as system configuration, type of workload, and time of measurement may be unique to the experiment. Again the parameters may not be representative of the range of variables found in the real world. Therefore the accuracy can vary from very high to nil when using the measurement technique. However a distinction has to be made between the accuracy of the results and the correctness of the conclusion drawn; a result that could be very correct may be misinterpreted and wrong conclusions made.

At the corporate level, Performance Measurement Systems serve to promote focus and alignment, facilitate communication and provide a 'forward looking' vision so that people are encouraged to change their behaviour in a way which is consistent with corporate goals. The measurement system needs to be comprehensive, including measures from all operational areas and of all types. It should include financial and non-financial measures, indicators of past results and predictors of future performance, and measures covering the key areas of time, cost and quality. Nonetheless, all these measures must be put in the context of the organisations' strategic objectives.

4.7 Concluding remarks

This chapter discussed performance analysis for the strategic management of geoinformation processes. Performance analysis was introduced and its role within the framework of strategic management explained. The chapter defined and illustrated potential performance goals and presented performance measures for geoinformation processes. Various approaches to performance analysis were presented. Geoinformation processes, due to the nature and stochastic behaviour, were defined as discrete event systems that can be modelled as networks of queues and analysed through discrete event simulation. The chapter closed by presenting a simulation modelling methodology for analysing the performance of geoinformation processes. Simulation presents a powerful technique for modelling the performance of complex systems. The next Chapter outlines the main concepts of simulation modelling.

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5 Simulation Modelling

5.1 Introduction

The main role of simulation is to support decision-making. Since the 1950s computer simulation has been applied to support decision making in solving a wide range of problems leading to improvements in efficiency, reduced costs and profitability (Robinson, 1994). Generally speaking, simulation amounts to mimicking the behaviour of a real system in a controlled environment in order to predict what its behaviour would be if experiments on the actual system were possible. The growing popularity of business process reengineering (BPR) has seen many organisations redesign their operations in a bid to realise dramatic improvements in performance. Simulation comes in handy for testing alternative strategies and process configurations before any resources are committed to the actual implementation. It provides robust tools for analysing the performance of systems of varying complexity. This chapter discusses the fundamental principles of simulation modelling and outlines the basic phases of simulation projects.

5.2 Definition and background to simulation modelling

The Oxford English Dictionary defines simulation as "*The technique of imitating the behaviour of some situation or system by means of an analogous model, situation or apparatus, either to gain information more conveniently or to train personnel*." Alternatively computer simulation may be defined as the discipline of designing a model of an actual or theoretical physical system, executing the model on a digital computer, and analysing the execution output. Simply put, simulation is the technique of building a model of a real or proposed system so that the behaviour of the system may be studied under specific conditions. Ernest [1994] defines Simulation as "the use of a mathematical/logical model as an experimental vehicle to answer questions about a referent system."

Simulation is very general in nature and therefore applicable to systems of varying complexity and at different levels of abstraction. In addition to its use as a tool to aid better understanding and optimising of performance or reliability of systems, simulation is also extensively used to verify the correctness of designs of products or processes. It is highly interdisciplinary finding wide application in all aspects of industry, government and academia. However for problems that have analytical solutions, the analytical solution provides far more insight in the behaviour of the system than the numerical answers simulation offers. Simulation results only provide information about a problem solution not on the range of possible solutions or the sensitivity of the answers to changes in system parameters. Besides, simulation is slow and fairly costly and often the results obtained turn out to be inadequate. However, cases abound where simulation is the only viable alternative [Haverkort, 1994] and in general simulation models have a close correspondence to reality.

That simulation models have close correspondence to reality is important since it's often too expensive, risky or impossible to experiment on real systems due to legal, time, cost or safety constraints. Systems that change with time and involve randomness are good candidates for simulation. Modelling complex dynamic systems theoretically needs too many simplifications and the emerging models may therefore not be valid. Simulation does not require many simplifying assumptions, making it the most suitable tool even in absence of randomness. While the main application of simulation over the years has been to analyse the behaviour of systems, in present days simulation is being applied to support a widening variety of purposes including training, interaction, visualisation, hardware testing, and decision support in real-time, just to name a few.

5.3 Simulation terminology

Digital computer simulation has been defined as the process of designing a model of a real system and conducting experiments with it on a digital computer. There are three basic types of simulation: Monte Carlo, Continuous and Discrete Event Simulation. Monte Carlo simulation is a method by which an inherently non-probabilistic problem is solved by a stochastic process and the explicit representation of time is not required. In continuous event simulation, systems are studied in which the state continually changes with time. Examples are physical processes describable by continuous functions, e.g. a system of differential equations with boundary conditions. On the hand discrete event simulation concerns systems of discrete state. In either case time could be taken as being discrete or continuous as may be appropriate.

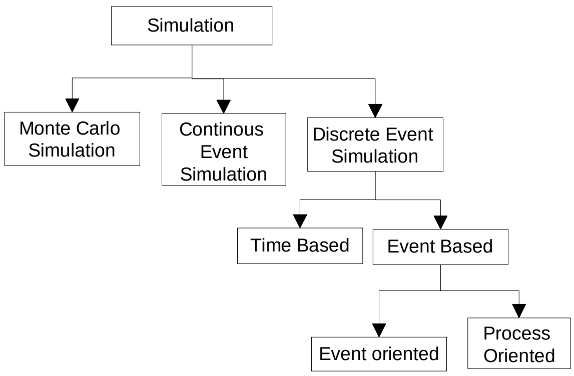

Figure 5-1 Classifying Simulations

A system is a part of the world that we choose to regard as a whole, separated from the rest of the world for some period of consideration. It is a whole entity which we choose to consider as containing a collection of components, each characterised by a selected set of data items and patterns, and by actions which may involve the component itself and other components. The system may be real or imagined and may receive input from, and/or produce output for, its environment. A model is then an abstraction of the system intended to replicate some properties of the system. In discrete event simulation the concepts of state and time are of utmost importance. The following primitives have been identified to permit precise delineation of the relationship between these fundamental concepts:

- An *instant* is a value of system time at which the value of at least one attribute of an object can be altered
- An *interval* is the duration between two successive instants
- A *span* is the contiguous succession of one or more intervals
- The *state* of an object is the enumeration of all attribute values of that object at a particular instant

The above definitions form the basis of the widely used simulation terminology:

- An *activity* is the state of an object over an interval
- An *event* is a change in an object state, occurring at an instant, and initiates an activity precluded prior to that instant. An event is said to be determined if the only condition on event occurrence can be expressed strictly as a function of time. Otherwise, the event is contingent
- An *object* activity is the state of an object between two events describing successive state changes for that object
- A *process* is the succession of states of an object over a span (or the contiguous succession of one or more activities)

The concepts of event, activity and process form the basis of three primary conceptual frameworks (worldviews) within discrete event simulation namely event scheduling, activity scanning and process interaction. In an event scheduling worldview, the modeller identifies when actions are to occur in a model. In an activity scanning worldview, the modeller identifies why actions are to occur in a model. In a process interaction worldview, the modeller identifies the components of a model and describes the sequence of actions of each one. These views have their strengths and weaknesses and are often appropriate for different circumstances.

5.4 Simulation projects

Simulation has been presented as a flexible tool for system analysis, the complexity of the system under investigation or its domain of application notwithstanding. Nonetheless, simulation projects like any other follow some logical order. Most, if not all simulation projects are predictive in nature, trying to establish some facts about a system based on an abstraction. This calls for adoption of a systematic approach to simulation projects if results are to be reliable. Lack of clear focus and an inconsistent approach can in extreme cases lead to huge losses of investment or cause undesirable damage.

Recent advancements in simulation software capabilities support on-screen animations to portray running simulations enabling the status of the model to be viewed as it progresses. Interaction with the simulation can also be supported. This capability is not only appealing but also eases the modelling process since the simulation can be built in small steps especially when modelling complex systems.

5.4.1 Phases of a simulation project

A simulation project consists of four main phases, which tend to follow the logical order of any problem-solving project, starting with the problem definition and moving towards completion and implementation. Each phase is in turn made up of a sequence of steps. Although often presented as a tandem flow of phases, a practical simulation project rarely flows as such. Mostly as the study progresses previously unknown information becomes available making it necessary to revisit previous steps or phases. Following is a description of the different phases.

5.4.1.1 Problem definition

The problem definition phase aims at establishing the problem being addressed and devising an approach for solving it. It is in this phase that the objectives for the simulation are set. For simple simulation projects the objectives may be obvious to everyone involved but the scenario changes rapidly as the size and complexity of the model increases. In most cases the problem is not clear and it may require extensive discussions with the client before they become apparent. Clear objectives help to direct the simulation. Sometimes it is advisable to include issues that may not be pertinent in the current problem but may become important in future. In so doing, the resultant model will be easily adaptable to that future situation when the need arises. Often simulation projects are set up just to develop models. This is undesirable because even when experimental objectives are found, the model may not be suitable since the relevant details will have probably not been included [Robinson, 1994].

A simulation performance objective comprises three integral components viz. *achievements, measurements* and *constraints*. The achievements are basically the aims of the project e.g. increasing throughput. Measurements indicate the desired level of achievement e.g. 10 percent. It is against the measurements that the success of the process will be judged. The achievements will be made under certain conditions, which may be in terms of money, resources or time. Whichever the case, the conditions define the constraints. The objectives are often called performance requirements.

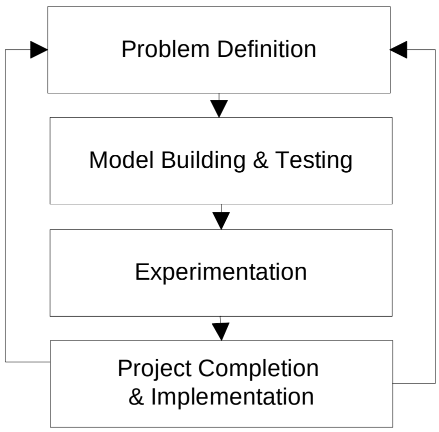

Figure 5-2 Phases of a Simulation Project (Robinson, 1994)

Jain (1991) identifies the qualities desirable of a good a performance statement as specificity, measurability, acceptability, realisability and thoroughness summarised as SMART. Specificity refers to the achievements and measurability to measurements. Sometimes numerical values are set on the basis of what appears to be good or what can be achieved. It is good practice however to have configurations such that the requirements are high enough to be acceptable and yet low enough to be realisable in view of present constraints. Thoroughness dictates that the requirements are set on all possible outcomes.

5.4.1.2 Model building and testing

A model is an abstraction that replicates certain desirable properties of a system. The set of properties replicated should be such that the resulting model will provide answers to some specific questions about the system. Having decided on the objectives, a model needs to be developed. The construction of a model is as much an art as it is a science, and while there may lack rigid rules governing the modelling exercise, most analysts agree on the credibility of starting with a modestly detailed model.

5.4.1.3 System definition

The very first step of a modelling exercise is to define the system boundaries and the aims of study. This step is synonymous to conceptual modelling. While it is not possible to talk of an isolated system in reality, the boundaries should be set such that external influences will be inconsequential to the study in light of the set objectives. It pays to realise that if the problems being addressed were fully understood, then probably simulation would be unnecessary since the solution would already be known. The very purpose of a simulation is to understand the problem and identify solutions [Robinson, 1994]. In simulations therefore some assumptions will always be made, which will be subject to refinement as the study progresses.

These assumptions have to be documented. There is a tendency of wanting to model everything without stopping to figure out what is necessary. In setting the system boundaries, the analyst defines what needs to be included in the model and to what level of detail. A rule of thumb is to model the minimum amount of detail necessary to achieve the project's objectives. Once too much detail is added there may not be sufficient data to support the model and moreover too much time will be taken in running the model.

The principle is that if the model is too broad and too detailed, precious time is wasted. Again if the model is too narrow and there is not enough detail, then the accuracy is open to question. Although it is advisable to use simple models, care should be taken that no important elements of the system are ignored. With the conceptual modelling completed, a listing of the elements to be included and the detail required for each element is established. This list together with the assumptions made will be used in the data collection phase.

5.4.1.4 Data collection and analysis

A simulation project requires a lot of data. Depending on the project objectives, the data required may be quantitative, logical, descriptive or a combination. Quantitative data could either be deterministic or stochastic. Nonetheless, the data required can be shown to play three basic roles. These roles are building the simulation model, setting the initial levels for experimental factors and checking the validity of the model. By establishing the data requirements for these roles, one will have sufficiently defined the data needed for the project.

Often for new systems, data may not exist. In such circumstances expert intuition and experience are often employed in making assumptions on the data requirements. The assumptions made should be documented and sensitivity analysis on such data is often necessary. Other options around the problem of lack of data include using the model to create the data, simplifying the model to omit data not readily available and changing the objectives of the project. Another issue that needs consideration is data accuracy. A model can only be as good as the data input. Regardless of the method used to collect the data, the decision of how much data to collect is often a trade off between cost and accuracy. Data collection often takes a lot of time and it maybe desirable to perform the data collection and conceptual model formulation concurrently.

5.4.1.5 Model building

Before the actual coding of the model into the computer, it is good practice to structure the model on paper. The time spent in planning the model structure is time well spent and the model is made clearer and is documented. Besides structure planning, model building comprises of coding and documentation in some chosen software environment.

- **Model Verification**: It is important that the model built does what it is expected to. Model verification is analogous to debugging a computer program. Likely errors include logic representation and syntax. Errors related to the representation of logic often present the greatest difficulty. However, the more complex the model, the longer the time verification will take.

- **Model Validation**: Validation is concerned with determining whether the simulation model is an accurate representation of the real system. Intuitively then, if a model is valid, then the decisions made on the basis of observed model behaviour should tie closely with those that could be made by physical experimentation with the real system if it were possible. A valid model is both accurate and able to meet the objectives of the simulation project for which it is being used [Robinson, 1994].

5.4.1.6 Experimentation

The purpose of simulation is to be able to study the behaviour of a system by varying certain model parameters and studying their effects on some response variable. To derive maximum information from the study, properly designed experiments are needed. Experimental design and data analyses have great impact on the success of a simulation project. Experiments wrongly designed will yield erroneous results that will lead to wrong conclusions. Similarly accurate data that is wrongly evaluated will lead to erroneous decisions.

The goal of proper experimental design is to obtain maximum information with minimum number of experiments. A proper analysis of experiments separates out the effects of the various factors thus enabling determination of the significance of each factor. There are several terms that are used in experimental design and analysis, and these are briefly described below:

- Response Variable: This refers to the outcome of the experiment and is generally the measured response (performance) of the system
- Factors: These are the variables that affect the response variable
- Levels: The values that a factor can assume are called levels. Each level constitutes an alternative for that factor
- Primary Factors: These are the factors whose effects need to be quantified
- Secondary Factors: There are factors whose effects are not to be quantified although they impact on the performance
- Replication: The repetitions of the experiments are called replications
- Design: An experimental design consists of specifying the number of experiments, the factor level combinations of each experiment and the number of replications for each experiment
- Experimental Unit: The entities used for the experiment are called experimental units. Examples could be machine operators while measurements are being performed. Good experimental design should minimise as much as possible the impact of variation among the experimental units
- Interaction: This is the dependency between the levels of different factors

5.4.2 Steps in planning of experiments

Experiments are executed so that inferences can be made from their results. The inferences that can be made depend on the way the experiment was carried out and sometimes it becomes evident that no inferences can be made from the results of an experiment or that the results do not provide answers to the questions the experiment was intended to investigate. These statements underscore the need for careful planning of the experiments. Often too little time and effort is put into the planning of experiments.

It is good practice to make a written draft of the proposals for any experiment [Cochran & Cox, 1992]. This not only guides the experiment but also ensures that all relevant considerations are made for realising the objectives of the experiment. The draft will basically consist of three parts: statement of the objectives, description of the experiment and, outline of the method of analysis

This statement could take the form of the questions to be answered, the hypothesis to the tested or the effects to be estimated. The aim is to make the statement lucid and specific. The statements should include an account of the area, over which generalisations are to be made i.e. a description of the assumptions made and the population to which the samples refer. The draft should also contain a description of the proposed method for drawing conclusions from the results. Though a valuable section, the description of the method of analysis is often omitted in many drafts. It may contain graphs, tables or accounts of the tests of significance to be made.

5.4.3 Project Completion and Implementation

A simulation project will not be considered a success until it has been carried out, and carried out well. In this phase the results arrived at are communicated and implemented. It is important that the documentation is completed and the project reviewed, for further analysis if need be.

5.5 Pitfalls in simulation modelling

In computer simulations, one should always be aware of the fact that "if you feed in trash you get out trash". That is to say before any reliable results can be reached, it is important that valid models are built, correct input data applied and suitable results analysis techniques applied. It is not uncommon to have correct results that are erroneously interpreted leading to wrong conclusions and decisions. Key areas that need particular attention are the model development process, the choice and use of simulation software and modelling the stochastic behaviour of the system.

The need for having clear and well-defined goals for the simulation project cannot be overemphasised. These goals should address the clients' concerns. While it is true to some degree that the results of performance analyses can be subjective and depend on experience of the analyst, the training and qualification of the analyst will without doubt be influential. Not all software is suited for all applications and use of an inappropriate package can either demand unnecessary effort or the model has to be changed to accommodate the way that particular package works, this would not be without loss of accuracy.

The use of incorrect probability distributions to model system randomness is probably one of the main pitfalls in modelling. This may be the result of lack of sufficient data or understanding of the role of random behaviour in the model. The main purpose of using simulation is to model system randomness and it's absolutely necessary that appropriate distributions be applied if any reliable deductions are to be made from the simulation results.

5.6 Concluding remarks

Simulation modelling is a methodology that has been extensively used in industry and research to solve a wide range of problems. In manufacturing, simulation studies have led to increased efficiency, reduced costs and profitability. Geoinformation production organisations are undertaking reengineering programs in order to maintain lean, efficient and effective processes. How innovatively these organisations use enabling technology, integrate experiences and popular practice in industry in their operations will be crucial in the realisation of the strategic objectives. Computer simulation due its versatility offers great opportunities to these organisations to design and test alternative strategies and process configurations, study the effect of new technology and quality management systems before resources are committed to their implementation.

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6 TQM and WFM in Geoinformation Processing

6.1 Introduction

Total Quality Management (TQM) and Workflow Management (WFM) are concepts that have been extensively applied in industry to streamline business processes. WFM and TQM allow organisations to automate the control and co-ordination of process activities, and institute sound quality control measures. The concepts of WFM and TQM focus on continuously improving the effectiveness and efficiency of business processes. Recent years have seen concerted efforts towards the development of quality control standards and specifications while the number of workflow management systems in the market continues to rise by the day. Regrettably, the application of these concepts in the geoinformation domain to date has been incidental and very limited in scope. This scenario is set to change fast as market dynamics force geoinformation providers to institute radical changes in the way they process and provide services and products. Reengineering efforts in geoinformation handling organisations_stand to benefit from effective introduction and integration of WFM and TQM tools. This chapter addresses the concepts of WFM and TQM with particular reference to geoinformation processing and explores the potential they hold for GIS processing.

6.2 Workflow management (WFM): an introduction

Present day organisations need to have the ability to swiftly respond to market changes. However this is only possible if the organisation has a structure that is as dynamic as the global climate it inhabits [Koulopolous, 1995]. As organisations re-invent themselves to accommodate the demands of their particular markets, the processes by which business is performed become the centres of focus. Consequently, all performance improvement efforts must of necessity address the business processes. Workflow technology provides functionality to capture, analyse and control business processes [Workflow handbook, 1997]. Although it is a technology yet to mature, workflow management has already been successfully applied to co-ordinate and streamline processes in a diversity of industries leading to improved efficiency and effectiveness.

The importance of a workflow accrues from the fact that a process or organisation is a collection of interdependent activities connected by linkages. The linkages occur when the performance and execution of one activity affects other activities. Workflow enforces the logic that governs the linkages and transition of the activities in a process ensuring that all activities are performed by the right resource at the right time. It supports the business process by bringing together the human and information resources needed to complete each activity in the process. This leads to improved efficiency and process control resulting from standardisation of procedures. It enhances the ability to manage processes by making performance problems more explicit.

6.2.1 WFM defined

Workflow technology enables organisations to capture both the information and tasks needed to support a business process and the rules governing its execution. The rules include schedules, priorities, routing paths, authorisations, security and the roles of each individual involved in the process. As a result, the business process is automated, in whole or in part, such that work is passed from one participant to another for action according to a set of procedural rules in an effort to minimise the cost of adding value [Morales, 1998]. In addition, information on the status of the process is always available. This information enhances the organisations' ability to respond to customer enquiries and supports re-routing and re-distribution of workload in the process.

Workflow technology provides functionality to match-make between resources and tasks in a process. When a task requires a person for its completion, the workflow system supports the necessary matching by either delivering the task to the individual named during the process definition or to a group of people, each of whom is capable of performing the task. Similarly, the workflow system ensures that tasks are matched with the appropriate information resources that are required for their completion.

Workflow systems support process management by making the process logic an explicit, discrete layer of design representation, which can be reasoned about and altered. They also allow designers to create, collect and evaluate performance metrics to support process improvements. While most workflow products provide some level of process management, they vary greatly in their capabilities. However, at its most sophisticated, a workflow system might perform load balancing between different workloads and groups of people besides dynamically adjusting the process to be followed depending on the availability of resources and the performance of the process environment.

Evidently, a workflow system not only captures the business logic, but also matches resources and tasks in a process providing valuable information to support process management. In this regard a workflow can be viewed as *a tool set for the proactive analysis, compression and automation of information-based tasks and activities* [Koulopolous, 1995]. A workflow management system can be described as being a pro-active system for managing a series of tasks defined in one or more procedures [Workflow Handbook, 1997], with the workflow system ensuring that the tasks are passed among the appropriate participants in the correct sequence, and completed within set times. The participants could be either people or other systems.

The foregoing definition creates the impression that workflow cannot exist without the element of automation. In any organisation the flow of material, information or knowledge must be co-ordinated in order to deliver a product or a service. In this sense, workflow has always existed in all organisations, automated or not. What is new about workflow management is the explicit representation of business process logic that allows for computerised support [Van der Aalst, 1999].

Business process managers need to measure process performance to be able to adequately integrate different computer systems and applications if they are to achieve good returns on investments in information technology. While reengineering offers a comprehensive approach to redefining an organisation, workflow offers the means to analyse, compress, and automate the information-based process models that make up the business. Clearly then workflow is not only complementary to but also provides the metrics for reengineering.

Technology developments of the past decade led to a proliferation of isolated islands of computing environments. Within organisations, separate functional departments maintained proprietary information and data repositories, and application tools, which often were incompatible between departments. It can be said that workflow evolved out of a growing desire to unify and co-ordinate these rapidly growing islands of automation into enterprise information systems. As can be expected, workflow shares goals, exhibits functionality similar to and makes use of several established technologies like E-mail, project management, databases, objected-oriented programming, and CASE tools. The growth of technologies like Electronic Data Interchange (EDI), the Internet, and the World Wide Web (WWW) that support sharing of business processes among multiple organisations will without doubt create need for inter-organisational workflows. The rise in electronic commerce, virtual organisations and extended enterprises manifest that more and more organisations are crossing organisational boundaries [van der Aalst, 1999].

There are two main categories of workflow products; those that use forms and messages and those using centralised workflow engines. The first category of products uses a messaging service to route a process instance through its predefined tasks and the execution of the logic is handled at the workers' desktop through the interaction between the form package and the mail system of the worker. The user interface is the form and the matchmaking between tasks and people is usually done at the definition stage of a process instance. The latter group of products consists of a centralised workflow engine that implements and governs the transitions between tasks based on the process models. It also updates the process-instance database on the state of each process instance. Communication between the server engine and the worker is facilitated through client software at the workers desktop. With the growth of the World Wide Web a new web-based workflow architecture, very close to the centralised engine paradigm, is emerging and could provide the standard for future workflow systems.

6.2.2 Business process modelling for WFM

To develop and maintain a system-wide workflow model is complex, time consuming and very susceptible to error. The alternative is to use process models to combine sets of related activities and define them as smaller business oriented workflows. Each local workflow model could describe in detail the flow of work of one or more of the components of a business process. By means of process models the process engineer can easily differentiate between atomic interrelated workflows. Another factor supporting the modelling of processes is the fact that once a process has been modelled, the model provides a stable platform for its further extension an adaptation. It also improves the reusability since the people involved with it understand its purpose, and its applicability in other environments is easily seen.

The workflow-modelling framework can be seen as consisting of two different development layers: the workflow meta-layer and workflow specification layer. The workflow specification layer focuses on the development of workflow oriented application systems for specific business tasks i.e. development of workflow models and workflow oriented application systems for specific applications. The workflow meta layer defines the underlying modelling characteristics and provides the necessary computerised support. The Workflow Process Definition Language (WPDL) and workflow management system (WMS) are components of the meta-layer.

Numerous Workflow Management Systems (WFMS) and corresponding WFDL exist. Significant differences exist between the several WFMS available affecting the manner and capabilities of workflow oriented application systems. Nonetheless, in all systems modelling concentrates on the processes to be performed, with the process being defined as a co-ordinated set of activities that are connected in a specific order to achieve a common goal. Following are definitions of some basic concepts of workflow modelling.

6.2.2.1 Activities

An activity is the description of a piece of work that forms one logical step within a process. Process' activities that are logically related in terms of their contribution to the overall realisation of the business process form the core of a process definition. An activity is typically the smallest unit of work that is scheduled by a workflow engine during execution. A workflow activity requires human and/or machine resources(s) to support its execution, but not necessarily bound to any particular actor. These resources are named within a workflow system as workflow actors or participants. The term Workflow Participant is normally applied to a human resource but it conceptually includes machine-based resources. When an activity requires no human resources and is handled automatically by a computer application, the normal terminology for the machine-based resource is Invoked Application.

6.2.2.2 Flow of work

The flow of work determines the control and data flow between activities. The basic idea is that changes in the flow of work are mostly independent of changes concerning individual activities.

6.2.2.3 Actors or participants

Actors perform the activities and they could be either human or computers. The human actors perform manual activities while the computers perform workflow activities. Actors may be assigned activities during run-time or during process definition. Roles are becoming increasingly powerful design constructs enabling workflows to exhibit a degree of automatic load balancing. Rather than explicitly defining the relationship between specific individuals and tasks, at design time, the designer merely specifies the role of the person who should perform the task. At run-time the workflow looks at the individuals who are able to take up that role and identifies an appropriate actor, taking into account the performance and availability of the actor among other things.

Figure 6-1 depicts the relationships between process modelling and workflow terminology, and gives a clear picture of where they play a role in the design of a system using a combination of the two technologies. In the case of a business process its formal representation or process definition is obtained using a formal modelling technique. The model of the business process is used by a workflow management engine to control the execution of the instances of the activities of the process (Figure 6-2, right column). The model comprises of sets of activities that may be manual or automated that also create activity instances when a flow is running under the control of the workflow management system.

People refers to a workflow as the automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules. This automation is defined within a Process Definition, which identifies the various process activities, constraints and associated control data used to manage the workflow during its execution. Many individual process instances may be operational while running a workflow of a process, each associated with a specific set of data relevant to that individual process instance (or workflow "Case").

The workflow management system consists of software components that store and interpret process definitions, create and manage workflow instances as they are executed, and control their interaction with workflow participants and applications. It also includes tools for administrative and supervisory functions, like work reassignment or escalation, and audit the management of information on the overall system or on individual process instances. An individual business process may have a life cycle ranging from minutes to days or even months, depending upon its complexity and the duration of the various constituent activities. Such systems may be implemented in a variety of ways, using a wide variety of information technologies and communications infrastructure and operate in an environment ranging from small local workgroup to inter-enterprise groups.

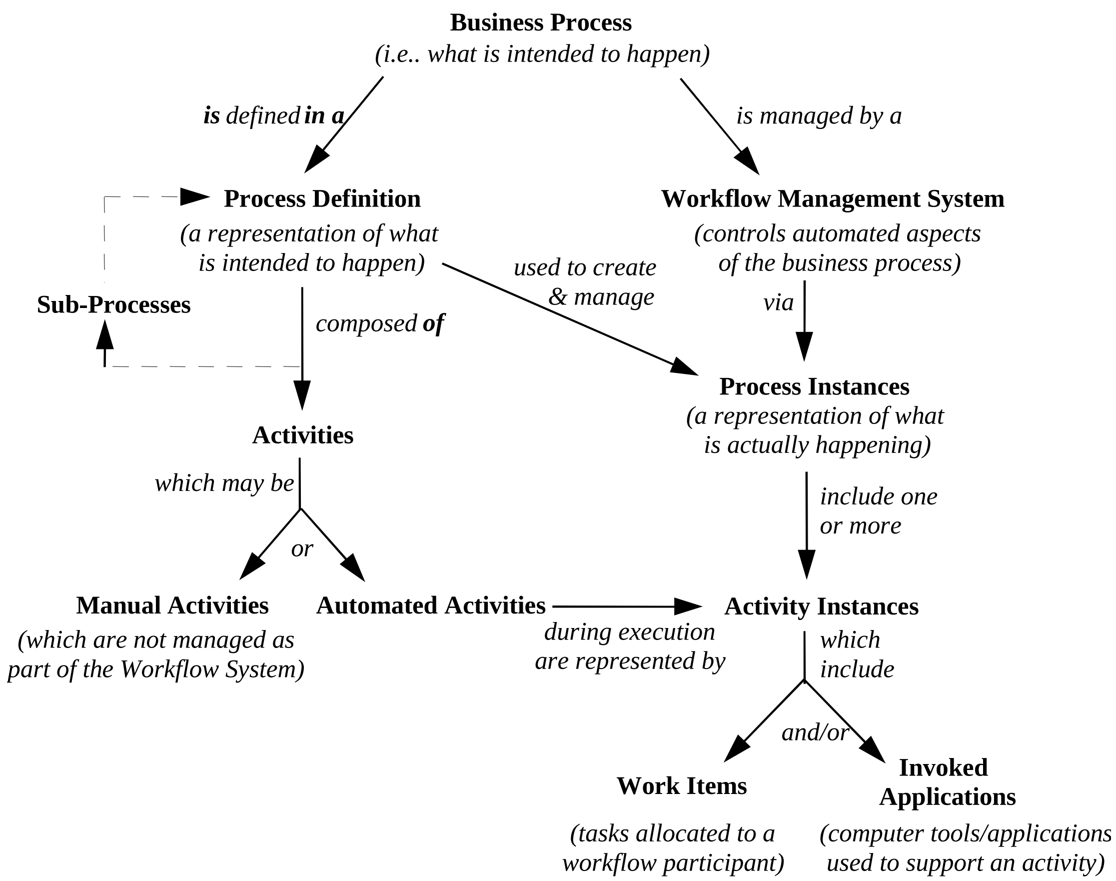

Figure 6-1 Relationship between terminology [Workflow Handbook, 1997]

6.2.3 Process definitions and process instances

6.2.3.1 Process definition

In order to create a process definition, modelling tools that vary from the informal ("pencil and paper") to sophisticated and highly formalised ones are used. When modelling tools are used to analyse, model, describe and document a business process the output from this process modelling and design activity is a process definition which can be interpreted at runtime by a workflow engine. The process analysis, modelling and definition tool may include the ability to model processes in the context of an organisation structure (although this is not a mandatory aspect of a workflow model).

The process definition is understood as the representation of a business process in a form that supports automated manipulation by a workflow management system. It consists of a network of activities and their relationships, the criteria to indicate the start and termination of the process, and information about the individual activities, such as participants, associated applications, necessary data, etc. (Figure 6-2 left column "process *I* or *J*"). The process definition may contain references to sub-processes, separately defined, which make up part of the overall process definition.

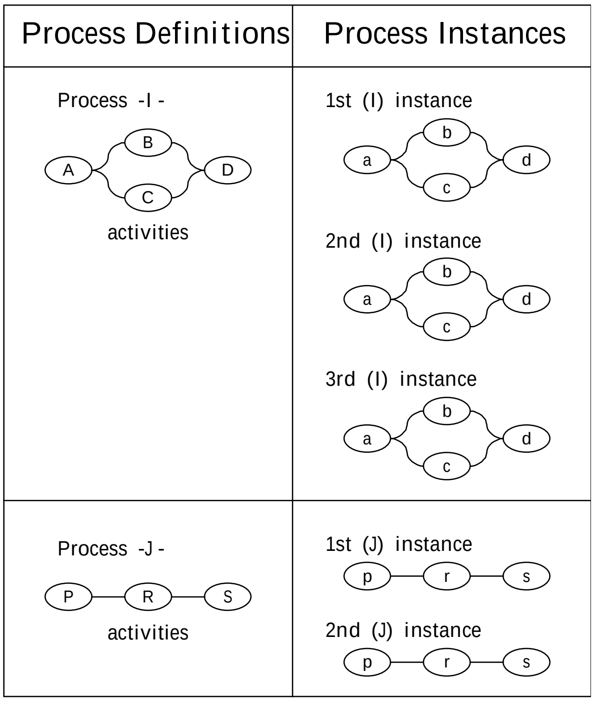

Figure 6-2 Process terminology

Figure 6-2 shows in the left column the definition of the processes *I* and *J* with all the activities involved, and in the right column, how their replicas run under the control of a workflow management engine every time a new instance is on execution in a workflow system.

6.2.3.2 Process instances

A process instance (Figure 6-2 right column) is the representation of a single occurrence of a process definition in the workflow system. Each process instance owns its data and criteria, and is capable of independent control and audit as it progresses towards completion or termination. Also activity instances occur when the system is at work, and they only use the data associated with the process instance they belong to.

In order to make a better use of the processes definitions, and to be able to satisfy one of the basic characteristics of the system concept under consideration in this document a different view of process instances is used. Figure 6-3 is an example of the creation of combined process instances based on the set of process definitions *J* and *I*. Simple request instances that are exact replicas of the original definition can be run in the workflow management engine as explained before (1^{st} and 2^{nd} instances in the right column). However for a complex request, a different process instance that is not predefined in the processes' definitions is needed to carry out the job. In such cases, instances that are combinations of the process definitions (3^{rd} and 4^{th} instances in the right column) are created interactively using criteria stored in the process models, and scripts to read a virtual database that the WFM engine uses to recognize whether there are more workflows connected to the workflow under execution or not.

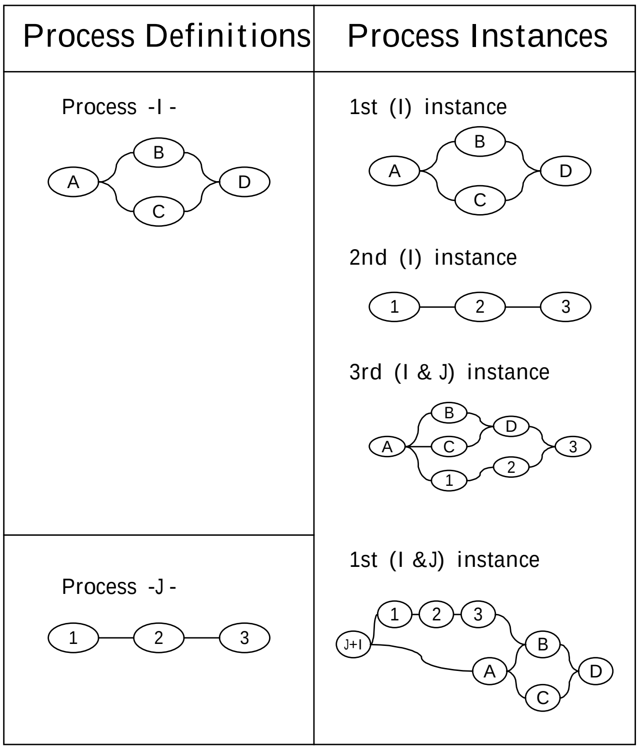

Figure 6-3 Combined process instances

Whilst it is true that business process reengineering and workflow modelling overlap in the object of investigation, the goals pursued, the techniques used and the methodical concepts, there still are a number of characteristics that justify differentiation between the two [Workflow Handbook, 1997]. Business Process Reengineering (BPR) primarily aims at analysing and designing systems and their parts. As a consequence the business systems are analysed and variants and alternatives revealed, investigated and evaluated. Ideally therefore BPR should be based on business process models. However, BPR concerns itself with run-time issues only as far as it is sufficient to provide feedback about the effects of reengineering. In contrast workflow modelling focuses on the execution of the business processes hence their analysis and design are directly targeted at the run-time. The successful application of both technologies to a business process calls for a two-stage modelling procedure, *the business process model-based approach to workflow modelling.*

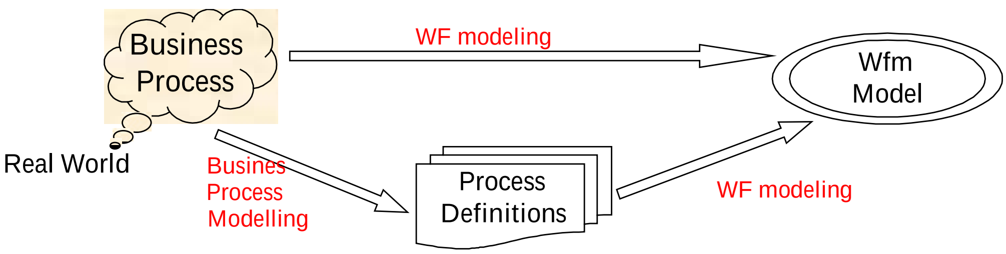

Figure 6-4 A business Process Model-Based approach to Workflow Modelling

During the first stage the overall business process model is specified therefore identifying the relevant business tasks to be supported. In the second stage the workflow models are used to specify the domain-related requirements for workflow oriented application systems. The modelling results through this approach are better in quality, more reproducible and re-usable.

6.2.4 Geoinformation business processes and WFM

The past four decades have witnessed a lot of developments in spatial data handling. The maturity of the global positioning systems (GPS), satellite imaging, radar remote sensing, laser altimetry etc. all provide capability for acquiring spatial data of unsurpassed integrity. Since the 1960s' when the first geographical information system was built, big strides have been made towards enhancing the capabilities of these systems. Information technology advancements on the other hand provide a multitude of opportunities for alternative processing and dissemination of geo-spatial data. National geographical information infrastructures (NGII) have sprung up and with the World Wide Web extending to every corner of the globe, it will not be long before spatial data will be shared rapidly and conveniently between any matrix of destinations.

The effect of IT has not only been to influence spatial information producers, it has also influenced spatial information users as well. Information communities want to have rapid and reliable access to geographic information, which they can manipulate as needed in order to work as efficiently as possible. Today's easy access to IT has converted the users to a more knowledgeable, less patient and more critical clientele that demands a diversity of customised products. Adapting the organisations to respond to the needs of these clients requires solutions different from just using IT to speed up the traditional map production process. Coupled to this has been steadily declining budgetary allocations from central governments to the National Mapping Agencies (NMA), organisations that have for long been the sole spatial information providers (SIP). This scenario has created a rather turbulent and complex operating environment, forcing many SIP to contemplate reengineering programs in a bid to enhance their efficiency and effectiveness.

The success of geoinformation organisations in reengineering rests on how innovatively they employ enabling technology to enhance their competitive advantage. There is need to redefine and redesign their processes and at the same time the cultures of the workers need to change to be compatible to the corporate mission and vision. Over the years, most of these organisations have employed technology to enhance the efficiency of activities aligned with functional departments. This has led to isolated islands of information within the organisation with a workforce very protective of their specialised tasks. As organisation strive to be lean, eliminating all idle and non-productive capacity, its imperative that the flow of work be better controlled and co-ordinated. Workflow provides this critical link between people and technology. The effective deployment of workflow technology in geoinformation production processes will help geoinformation organisations adapt to their changing structures and by maintaining the consistency between the implemented and designed processes, provide an effective means of controlling and monitoring the processes and organisation at large. Workflow Management facilitates total quality management (TQM) and provides the tools to improve communication and responsiveness, bridging the gaps between layers of management.

6.3 Total quality management (TQM)

Geoinformation organisations need to provide high quality services and products to their customers just in time. These organisations therefore need to have a clear concept of what the customer needs during the design and implementation of geoinformation production processes to ensure that the needs will finally be met. Traditionally spatial information providers defined quality exclusively in terms of positional accuracy and geometric integrity. The quality control systems present as practised by most geoinformation production organisations are lacking in two basic respects: they refer to products without consideration of the process that generates them and secondly the quality they check is as defined by the producer instead of consumer. Evidently therefore the notion of quality needs to be extended to reflect the customer-focus of present day systems, technological advancements and established quality management practises. Further, the production processes should be designed in a structured way, eliminating all non-value adding or idle capacity and providing high performance in the key areas of time, quality and cost. In this section, the concepts of quality policy, quality assurance and quality system are outlined within the global framework of total quality management (TQM) in an organisation and its processes.

6.3.1 Quality management

6.3.1.1 What is quality?

Quality is generally defined as *the sum of all the factors that enable ownership satisfaction and bring customers back to buy a product or a service again and again*. The quality of an organisation's products and services define its competitive edge in the market, the quality being such as to provide customer satisfaction. Other definitions of quality include "fitness for purpose of use" [*Peterson*, 1993] and "the total composite product and service characteristics of marketing, engineering, manufacturing and maintenance through which the product and service in use will meet the expectation by the customer" [Feigenbaum, 1961]. Customer satisfaction is such an essential measure that it should have a status in corporate culture. A quality product is one that is fit for use (purpose) or one that conforms to requirements or one that is dependable, customer satisfying and affordable [*Weng*, 1997].

ISO 8402 (1994) defines the quality of a product as the totality of its features and characteristics that bear on its ability to satisfy stated or implied needs. Quality is not an intrinsic property; rather it is a function of the global perception of the users' satisfaction and thus is observed during the use of a product. Quality management has two concerns:

- Product Quality assessment that concerns the final product or service; in geoinformatics the quality of the product, spatial data or information, is described as the fitness for use (purpose) of the particular dataset and is documented by the data quality elements. The data quality elements include completeness, logical consistency, and positional, temporal and thematic accuracy. Product quality assessment forms the subject of quality control
- Process Quality that handles the quality of the processes needed to produce the products or service, and in the wider sense the quality of the organisation; process quality can be achieved by following a structured approach in the design stage, removing all idle or non-value adding capacity while providing functionality for a hierarchy of products. Performance modelling based on the objectives established in the strategic planning phase will provide metrics to guide the choice of the optimal alternatives. Performance measurement on the other hand will help establish bottlenecks and potential obstacles to successful performance.

The quality management system (QMS) is composed of all parts of the organisation and deals with both the quality of the processes and products. The institution of a quality management system in an organisation requires the commitment of top management and should be enshrined in the corporate quality policy.

6.3.1.2 Quality policy

The quality policy reflects the overall intentions and direction of the organisation regarding quality as expressed by top management. The quality policy forms an integral component of corporate policy. The Ordinance Survey, the National Mapping Agency of Great Britain has its mission as being *the customers' first choice for mapping today and tomorrow*. It has the following stated corporate goals:

- be leaders in the field of geospatial and topographic data, linking mapping, information and technology;
- anticipate and meet the needs of our customers with services and products that are fit for purpose;
- build long-term, mutually beneficial relationships with our customers, suppliers and business partners;
- maintain, constantly improve and safeguard the National Topographic Database;
- constantly improve our quality and efficiency;
- excel through confident and committed staff and;
- operate within and contribute to Government policies.

It is evident that the quality policy is an integral component of the corporate mission as underscored in the corporate goals. Quality management determines and implements the quality policy. The implementation of the quality policy is effected through quality management principles.

6.3.1.3 Quality control (QC) and quality assurance (QA)

The ISO defines Quality Control (QC) as the operational techniques and activities that are used to fulfil requirements for quality. It aims at monitoring the process and eliminating causes of unsatisfactory performance at relevant stages of the quality loop as to result in economic effectiveness. In contrast Quality Assurance (QA) is defined as all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given quality requirements.

Quality control is therefore reactive and corrective in nature and it provides the procedures to find out errors and correct them often necessitating reworking. This involves checking a case against some established quality criteria to establish if desirable quality requirements have been met and is analogous to performance measurement. Familiar examples are accuracy checks in triangulation schemes and image classification. Quality assurance on the other hand evaluates the factors that affect the adequacy of a design or specification for intended applications. Analogous to performance modelling, it provides predetermined procedures to assure satisfaction of the needs of the customer, the owner and the organisation [Weng, 1997]. While quality control centres on the products or services, quality assurance focuses on the integrity and validity of the process that leads to the product and is proactive and preventive. Strategic planning, process modelling and performance modelling procedures provide processes that will potentially result in products that meet expectations. Integration of workflow management applications and performance measurement procedures ensure that the integrity of the processes is maintained and continually improved with changes in the business environment.

According to the working groups on geographical data quality, quality can be seen as consisting of two different components, an external component and an internal component. The external quality being the appropriateness of the specifications to the user community's needs i.e. if the specifications actually correspond to an actual need in the user community while the internal component refers to the respect of the specifications and basically establishes if the product is actually what was intended in the specifications. Thus quality is good only if both internal and external components are good.

6.3.1.4 Total quality

The concept of total quality came into being in the 1980s' and has been defined as "a management approach of an organisation, centred on quality, based on the participation of all its members and aiming at long term-term success through customer satisfaction [ISO 8402,1994]. This concept, that is often called total quality management (also called total quality control in Japan), aims at continuously increasing value to customers by designing and continuously improving organisational processes and systems. [*Weng*, 1997] defines total quality as an effective system for integrating the quality-development, maintenance and improvement efforts of various groups in an organisation to enable production and service at the most economical levels, which allow for full customer satisfaction. Emphasis is put on customer and total organisation participation. Other key concerns are continuous process improvement, performance measurement and a capable and committed leadership and teamwork participation.

Total quality management (TQM) is ideally a philosophy of management that strives to make the best use of all the available resources and opportunities for constant improvement. It provides key business improvement strategies and is an essential management issue for enhanced efficiency and competitiveness. The effective design and implementation of total quality management in an organisation is based on three fundamental principles [Tenner et al, 1992].

6.3.1.5 Customer focus

Quality is based on the concept that everyone has a customer and that the requirements, needs and expectations of that customer must be met every time if the organisation as a whole is going to meet the needs of the external customers. This concept requires a thorough collection and analysis of customer requirements.

6.3.1.6 Process improvement

The concept of continuous improvement is based on the premise that work is the result of a series of interrelated steps and activities that result in an output. Continuous attention to each of these steps in the work process is necessary to reduce variability of the output and improve the reliability of the process.

6.3.1.7 Total improvement

This approach begins with the active leadership of senior management and includes efforts that utilise the talents of all employees in the organisation to gain competitive advantage in the market place. Employees at all levels are empowered to improve their outputs by coming together in new and flexible work structures to solve problems, improve processes and satisfy customers.

Whilst not within the scope of this discussion, it suffices to mention that over the years several approaches to TQM have been developed and in application. These include Deming's Fourteen Points for Management, Juran's Quality Trilogy, Hoshin's Plan-Do-Check-Act Approach, Quality Improvement Paradigm (QIP), Quality Function Deployment (QFD) etc. Extensive discussions on these approaches can be found in the many textbooks available.

6.3.2 Quality management system (QMS)

A quality system can be defined as a documented organisation structure consisting of purposes, procedures, resources and techniques with the objective to assure quality in the organisations. Thus a quality management system is composed of all parts of an organisation, dealing with both the products and the processes in the organisation. It may be defined through the definition of responsibilities, interfaces, main processes and procedures required to achieve the quality objectives of the organisation in respect with the quality policy.

The ISO 9000 has published extensive standards providing a normative framework for defining a QMS in a consistent way while paying special attention to continuing improvement and users' satisfaction. The results of a QMS consists of a lot of quality proves produced along the production steps, giving trust to the customers before they use the product. However these standards were primarily meant for manufacturing goods and their application to geographical information is still an open issue. Mapping agencies will therefore need to interpret and connecting the ISO standards to geographical information.

6.3.2.1 Why the need for QMS in geoinformation processing?

Recent surveys indicate that at least 50% of the European National Mapping Agencies have implemented a quality management system with an increasing number showing strong indication of doing so in future. Since the early seventies, the number of NMAs implementing QMS has grown exponentially and has doubled since 1995 with the growing need in manufacturing industry for ISO certification. This is a strong indication of growing concern among geoinformation producing organisations towards quality management. The ISO 9001 standard appears to have been the most popular, most likely because of its elaborate chapters on design and specification. There exists a strong desire among the National Mapping Agencies to seek certification. This is cited as a means of improving reliability, an official acknowledgement, as a way of having better subcontracting policy and as a means of maintaining the level of quality inside the organisation.

The benefits of implementing a QMS in geoinformation production organisations may be summarised as offering four advantages: provision of better management, satisfying user demands, product and process quality improvement and meeting external requirements. Better management is about increasing benefits and productivity by establishing the amount of product inspection and related cost investments towards the realisation of users' satisfaction. It involves the definition of responsibilities and interfaces defining application rules to every employee thus introducing quality improvement in the daily operations of the organisation. It promotes the culture of measurement, calibration and accountability whenever necessary, providing a tool for reducing overlapping work, protecting know-how and for reducing costs when staff changes.

A QMS provides a consistent approach towards meeting customer needs. Thirdly a QMS helps design and implement processes and products that serve to meet user requirements. This calls for a high level of process control, facilitating the detection, management and prevention of errors. Besides, it provides control and inspection proves to customers and gives more information on the products. Lastly, for NMAs, a QMS will provide a better platform for the realisation of their national mandates.

The adoption and implementation of a QMS is not without a downside. There exist fears in the long term of increases in production costs, bureaucracy and reduced workers' satisfaction especially in event of complex quality management systems. The CERCO (EUROGEOGRAPHICS) working group on quality is intensively involved in quality issues with regard to geographical information with the main issues of concern being Quality Management and ISO 9000, Data Quality and Data Standards. The working group on quality has extensively researched and reported on quality issues and geographical information, findings that provided substantial input for these discussions. While ISO quality management systems provide the basis of QMS implementations in geoinformation production, their explicit discussion was not necessary since these are elaborately treated elsewhere.

6.4 Concluding remarks

In this climate of tremendous change, geoinformation organisations are running lean. As the problem shifts from eliminating idle capacity and cutting direct costs coping with flattened models imposed by existing business and economic conditions, there is acute need for responsive processes. Need exists therefore for technologies that will enable organisations to restructure on a continuous basis while at the same time empowering the workers. Workflow management and total quality management provide a set of tools with proven capability for streamlining and controlling businesses while at the same time instilling a quality management culture in organisations for continuous improvement.

Workflow management now provides a solution to an age-old problem: controlling, monitoring, optimising and supporting business processes. The technology is maturing, although thus far its application has mainly been limited to *within* organisations. With the increasing number of business processes where multiple organisations are involved, it is desirable that workflow management provides functionality to handle interorganisational workflows. Current research effort is directed in this direction. With an increasing number of geoinformation organisations instituting reengineering programs, quality issues are taking centre-stage. There is a growing need not only to ensure high quality products and services for the users, but also the processes need to be redesigned, optimised and continually monitored providing measures for continuous improvement. Quality management systems have been extensively deployed in industry and the past years have seen an increasing number of geoinformation organisations implementing them in an effort of institutionalising the concept of quality management in geoinformation processing.

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Appendix A: Situation Analysis of a Geoinformation Production Organisation

A.1 Introduction

A hypothetical National Mapping Agency (NMA) is described and used as a case for testing the BPR concepts presented in chapter 2. The AS_IS situation is analysed and a decision for change reached. A SWOT analysis is carried out to identify the strengths, weaknesses, opportunities and threats in the organization's environment. These form the basis for formulation of BPR plans and analysis of their economic viability. TurboBPR and Matrix of Change tools are used in the analyses. In view of the limitations of a hypothetical data, the analysis stops at the corporate level.

A.2 As-Is situation

The Mapping Division of the NMA is responsible for the collection, storage, processing, visualisation and dissemination of topographic map series, human settlement planning maps and cadastral plans both in urban and rural areas. Since its foundation, the organisation has by mandate of the government been involved, in the collection, storage, processing, visualisation and dissemination of topographic maps, as well as the production of maps for settlement planning and cadastral purposes.

Topographic map series for the whole country are produced at scales 1:50.000, 1:250.000 and 1:1.000.000. The human settlement planning maps cover just the major cities and rural settlement areas, those are produced at scales of 1:2.500 and 1:5.000, while cadastral maps are in a range of scales from 1:500 to 1:10.000 according to user requirements. These requirements are governed mostly by the lot and parcel sizes for cadastral maps while requirements for topographic and human settlement maps are governed by the purpose for which the maps are prepared. All the organisation's products are in paper form and are prepared following very rigid cartographic standards imposed by the NMA. The NMA lacks a policy of communicating with the users to determine their current and future requirements. The main users of the products of Mapping Division are to date:

- The Urban Planning and Human Settlement Department
- The Land Administration Department (land allocation and registration)
- Different Government Departments (e.g. Ministry of Defence, Ministry of Public Works)
- The private sector for all kinds of engineering and utility activities
- The general public, using mainly cadastral plans.

To produce the maps and plans, the NMA receives aerial photography from the private sector and geodetic control network data from its own Geodetic Surveys Division. The data are processed in the NMA's Mapping Division consisting of the following sections:

- Photogrammetric Section (geo-referencing and feature extraction based on geodetic data and aerial photographs and producing stereo plots)
- Land Surveying Section (field completion based on stereo plots and producing field overlays)
- Cartographic Section (cartographic processing, based on stereo plots and field overlays and producing map colour separates or black and white plans)
- Reproduction Section (using cartographic products and producing maps and plans)
- Distribution and Sales Section (filing and selling maps and plans at marginal distribution costs).

The NMA has proceeded for years with this production system in order to achieve its national mandate to provide map coverage of the entire country as far as the budget provided by the national government allows. Recently, the NMA however came into a difficult situation due to the dissatisfaction of the user community on its products and the response time to request for up-to-date information. The users, especially those coming from the private sector and general public dealing with engineering activities are changing their requirements and necessities in terms of the format and the quality of the data produced. However, the current structure does not allow the organisation to respond properly to those changes. Although the quality offered by the organisation is high, and without doubt there is a consolidated distribution network, there is still increasing dissatisfaction within the user community. It is thus providing an ideal environment for the creation and growth of new and small enterprises devoted to providing spatial information and trying to fill the gaps that the organisation is leaving.

The developments in information technology and decrease in costs associated with it acquisition is another factor that runs in favour of the competition. This is because the competition consisting mainly of smaller firms is now able to acquire cheap technology and perform some of the operations that the organisation is used to do. Besides that, the central government's policy is cutting the normally assigned budget, causing a new worry for the administration and thus pushing it to become economically self-sufficient. The NMA is now under pressure to revise its strategy and working procedures. There is need for it to look at the different pressures (Figure A-2) facing it so as to establish its performance problems.

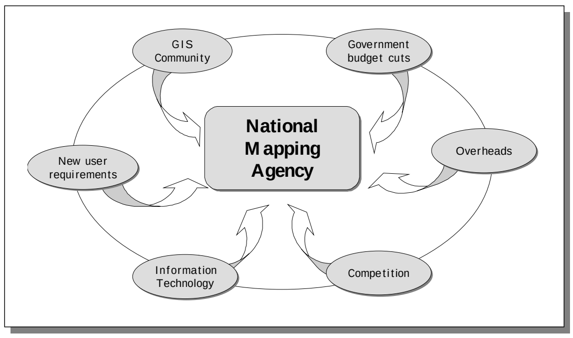

Figure A-1   Pressures facing national mapping agency

Figure A-2 is a reproduction of Figure 2-14, which was encountered in Chapter 2. However, the steps are now referenced in the methodology with numbers to enable one visualise how the case is linked to the methodology. Those numbers are used in the following sections as cross-references to the methodology, making it easier to follow through the case study as the methodology is applied. However the order of the numbers is not necessarily the logical sequence of the procedures.

A.3 NMA's performance problems (Step 1)

The NMA seems to have a number of performance problems. Among the ones requiring urgent attention are:

- Continuing dissatisfaction of the user community. The user community requires data that is accurate, complete and current. NMA's data needs to be more up-to-date than is the case currently. Besides, the long lead-time it takes to process orders is a source of complaints from customers since requests from customers are rarely handled on time.
- Government cut in budget for most of government services, including the NMA. The NMA is having problems meeting its recurrent budget and this is likely to worsen with

complete budget cuts from the government. The NMA has therefore to look for new ways of meeting its budget and reduce its overheads.

- Competition from the private sector involved in the production and selling of geo-information. The competition is able to offer a diversity of value added products to customers and in shorter time. Besides, the good price advantage being offered by the competition is likely to drift the NMA's customers away from it.
- Developments in information technology, encouraging users to address many GIS applications and to request on-line access to existing information hosted in many organisations, a service, which the NMA is currently unable to offer.

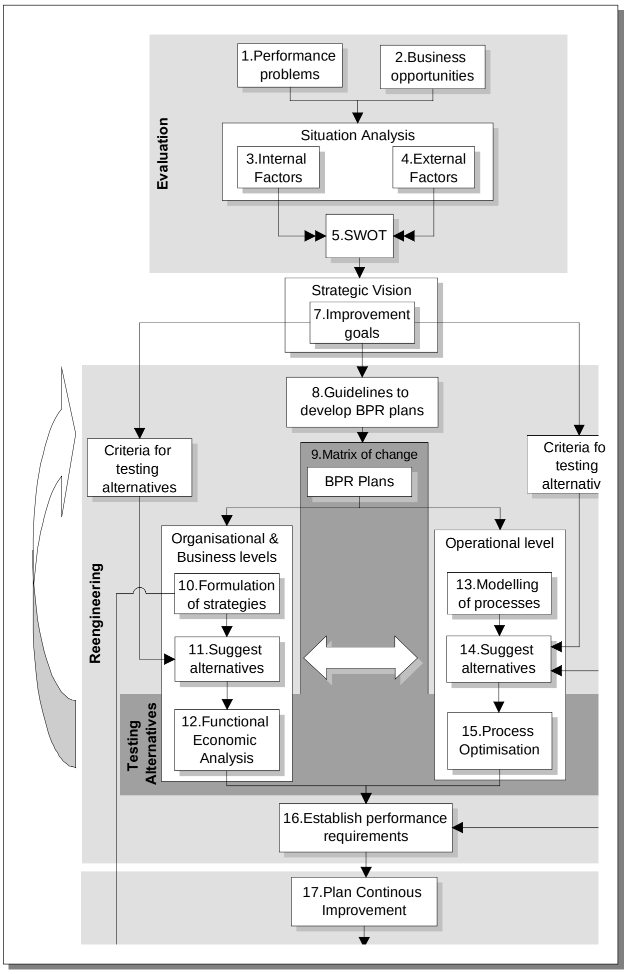

Figure A-2 Stepping through the methodology (text-window on the right is cut off)

The problems indicate that the organisation needs changes at every level. A new way of management, introduction of new technology, current process redesign, diversification of products and a marketing strategy are probably needed.

A.4 Business opportunities (Step 2): Decision to change

Following the identification of performance problems, the NMA went through a process of system analysis (information requirement determination and situation analysis of the current system). It has been found that the present production system of the Mapping Division of the NMA (fully analogue, linear and based on rigid cartographic standards) has severe limitations in responding to customer requirements.

The Director of the NMA considers that going digital (introducing digital equipment/systems in the current production system) will solve most of the problems of responding to the new requirements of the users of the information produced by the Mapping Department of the NMA. A number of equipment (hardware) and software was purchased in the various production sections of the NMA and the staff was trained on how to use the equipment to do the jobs they used to do manually. Top management now considers that implementing radical changes in the organisation will move it in a direction that will enable it to anticipate its customers' needs and integrate enabling technologies into its business plans.

A.5 Situation analysis internal and external scanning (Steps 3 & 4)

Despite the performance problems identified above, several business opportunities exist for the NMA. Analysing the external factors that affect the organisation helps in identifying good opportunities and sources of threats. Michael Porter's Five Forces Model is used to analyse the forces facing the organisation to establish the weak and strong competitive health of the organisation and subsequently expose the opportunities available and threats facing it. The results of this analysis are shown in From that analysis, several opportunities can be seen. The NMA needs to look at ways with which these opportunities can be exploited. Similarly, a number of threats can identified for which the NMA needs to identify ways through which those threats can be attacked, This implies that the NMA should seek to gain competitive advantage, which brings in the need to perform a SWOT analysis.

A.6 SWOT analysis (Step 5)

Matching the internal and external factors provides the SWOT elements. The results of the SWOT analysis of the National Mapping Agency are provided in Table A-2.

A number of actions that could lead to a reengineered organisation have been listed and an extract of them is provided. At this stage, no efforts are made to rank or prioritise the actions as this procedure is done using the Matrix of Change method (Step 9) as in Figure A-3.

The resulting actions give guidelines as to what strategies and initiatives are necessary for consideration in formulating a strategic vision and setting improvement goals. Improvement goals will provide the criteria for testing various alternatives and also give guidelines for developing BPR plans as can be inferred from the referenced BPR methodology illustrated in Figure A-2 and described in Chapter 2.

Table A-1   Five forces model analysis for NMA

Five Force	Five Force Factor	Strong competitive health	Weak competitive health	Notes	
Supplier	Concentration of suppliers	Many ✔	Few	The NMO can source Aerial photography/Geodata from many suppliers	O
	Product differentiation	Commodity ✔	Proprietary	Several suppliers are able to supply the same type and quality of products (Aerial photographs/geodata)	O
	Switching costs	Low ✔	High	The NMO would not experience enormous expense in changing suppliers	O
	Substitute products	Many	Few ✔	There exists few suitable substitutes for aerial photos/Geodata e.g. Satellite images	T
	Customer bypass	Not possible ✔	Easily done	NMO customers will not find good use of raw geodetic data and photography from suppliers	O
	Customer importance	Very	Unimportant ✔	Suppliers have diversified sets of customers to whom they can offer the same products	T
Buyer	Concentration of buyers	Diversified ✔	One customer	The buyers of the NMA's products are diverse	O
	Product is commodity	Differentiated ✔	Commodity	The products are not easily acquired elsewhere	O
	Product as part of buyer's cost structure	Low percent	High percent	?*	T
	Buyer's profitability	High ✔	Low/marginal	The profitability of the buyers gained from the use of the NMA's products is relatively high	O
	Importance of product	Critical ✔	Required	The use of the NMA's products is critical to the buyers success in their ventures	O
	Product viewed as an expense	Saves customer money ✔	Expense	The NMA products save money for customers	O
	Supplier bypass	Cannot	Can ✔	Buyers can bypass the NMA's and purchase photos and geodetic data directly from the NMA's suppliers	T
Threat of entry	Economies of scale	Large volume ✔	Small volumes	Profits can only be made by selling either in large quantities or supplying to many customers	O
	Product differentiation	Differentiated	Commodity	?	
	Switching costs	High	Low ✔	The costs of customers changing to a different supplier for the same products are low.	T
	Capital requirements	High ✔	Low	Competitors entering the market require a high degree of up-front investment.	O
	Non-economy-of-scale advantages	Many ✔	Few	The NMA enjoys government support, can enforce copyright laws and has experience in mapping etc	O
	Distribution channel access	Blocked	Open ✔	NMO distributors can also supply products offered by competitors	T
	Government policy	Block new entrants	Underwrite new ✔	The government policy does not block new entrants into the field.	T
	Retaliation of incumbents	Strong record	No retaliation history ✔	The NMA has not demonstrated that it will strongly defend its markets from new entrants	T
Substitute products	Strong substitute	No	Yes ✔	For some products customers may switch to GIS data or use satellite images	T
	Substitute price/performance	Lower than product	Higher that product ✔	Substitute products are experiencing better price performance improvement than NMA products	T
	Profitability of substitute product industry	Low	High ✔	Substitute product industry (GIS, imagery etc) is enjoying strong profitability and looking for new markets	T
	Competitor rivalry	Low	High	?	
Competitor rivalry	Number and equality of competitors	Few and smaller ✔	Many and bigger	The number of competitors are few and their sizes are smaller compared with the NMA	O
	Market growth	High	Low ✔	The anticipated growth in the industry for use of conventional products is low	T
	Product differentiation	Differentiated	Commodity ✔	The NMA's products can be produced with the same quality by several competitors	T
	Switching costs	High	Low ✔	The expenses the NMA customers would incur in changing to another supplier are low.	T
	Fixed costs	Low	High	?	
	Unit of capacity increment	Low ✔	High	Since the NMA already has the data, the amount of additional products produced per investment is low	O
	Exit barriers	Few	Many	?	
	Diversity of corporate personalities	Same	Different	?	

** ? indicates unclear choice*

Table A-2 SWOT analysis for the NMA

		OPPORTUNITIES	THREATS
	Constraints • Regulations imposed by government • Production standards (standards for data exchange, formats) • Budgetary controls • *Etc…*	• The NMO can source Aerial photography/ Geodata from many suppliers hence the opportunity to bargain for lower prices • Several suppliers are able to supply the same type and quality of products (Aerial photographs/geodata) hence opportunity to source the data from the best offer. • The NMO has opportunity to change suppliers at low cost • NMO customers will not find good use of raw geodetic data and photography from suppliers hence opportunity to supply value-added products • Opportunity to supply the buyers of the NMA's products who are diverse • The products are not easily acquired else-where hence opportunity to create a monopoly • The profitability of the buyers gained from the use of the NMA's products is relatively high hence opportunity to create long term relationships with the buyers • The use of the NMO's products is critical to the buyers success in their ventures thus creating the opportunity to have a continued supply of customers • The NMO's products save money for customers making the opportunity for them to buy more products and often • Profits can only be made by selling either in large quantities or supplying to many customers • Competitors entering the market require a high degree of up-front investment hence opportunity to create a viable marketing policy • The NMO enjoys government support hence opportunity to enforce copyright laws • Number of competitors are few and smaller hence opportunity to fight off rivalry • Low unit of capacity increment since the NMO already has the data hence the opportunity to create additional products from existing data.	• There exists few suitable substitutes for aerial photos/Geodata e.g. Satellite images • Suppliers have diversified sets of customers to whom they can offer the same products such as aerial photography • Buyers can bypass NMO for raw products posing that they can create the type of products offered by the NMO • Buyers have low switching costs hence the NMO could loose them as customers • Distribution channel access is open therefore competitors can use them • Government policy does not block new entrants • No retaliation history therefore new competitors can thrive in the industry • Strong substitutes exist that can make buyers switch to their use • Substitute price performance better thus encouraging customers to switch • Profitability of substitute product is high • Low market growth for conventional products • Current NMO's products (maps) are a commodity that could be obtained elsewhere • Low customer switching costs hence the threat of losing customers • Competitors are able to provide products faster
STRENGTHS	• ability to produce high quality cartographic products • experience in conventional mapping operations • abundance of existing up-to-date data (topographic maps, human settlement planning maps, cadastral plans) • support for change by the government • good distribution network • well trained personnel • availability of modern hardware and software in the organisation • Presence of a Director with a vision and will to effect necessary changes within the organisation	• Using the support for change by the government, the ability to produce high quality cartographic products and well trained personnel, launch advertising campaigns to introduce the organisation to the customers • Using good distribution network take advantage of opportunity to supply the buyers of NMO's products and increase market share • Using the well trained personnel, take advantage of opportunity to supply value added products • Using the abundance of existing up-to-date data, and the opportunity offered by the non-availability of the data elsewhere, create a monopoly • Using the availability of modern hardware & software and the opportunity offered by inability of competitors to acquire the same readily, create a viable marketing policy to attract more customers and sell more products/services • Using the strength of the presence of a Director with a vision and the opportunity offered by government support, enforce copyright laws to safeguard the NMO data and its use • Based on the experience in conventional mapping and the existence of only a small number of competitors, create products that can be differentiated to fight off rivalry • Based on the ability to produce high quality cartographic products and the opportunity offered by low capacity increment, create additional products from existing data and thus generate more revenue	• advertise based on the experience in mapping operations and good distribution network to overcome competition from the private sector • Use the competing private sector organisations to carry out sub-contact works thus reducing the organisations overheads • based on the ability to produce high quality products, improve competition by creating a diversity of products, distinct quality of products according to different requirements • Using the support for change by government, encourage the formulation of policies that will remove the threat of new entrants • Using the availability of modern hardware and software, create new products/services to counter the threat of low market growth for conventional products • Based on the abundance of existing up-to-date data, create a pricing policy that will remove the threat of substitute products • Based on the ability to produce high quality cartographic products, create high quality products that will make customer switching costs high

		OPPORTUNITIES	THREATS
WEAKNESSES	• Organisation is functionally based • rigidity to cartographic standards • <u>Technology</u> • lack of databases • lack of on-line access to information • lack of experience in use of digital technology though training has been provided • slow response time to request for up-to-date information • no structured way to implement quality • lack of diverse products • no marketing strategy/business culture • lack of operations management, process definition, project planning, workflow management (management skills) • overheads as a government organisation that makes data acquisition expensive	• update the technology to take advantage of the opportunity offered by the power of technology • create databases to enable the provision of data to all users (speed update operations, make component of GII, improve response time) • develop a marketing mechanism to respond to the new requirements of the users • re-educate staff to take advantage of the opportunity offered by enabling technology • Create a diversity of products/services to take advantage of profits that can only be made by selling more or to more customers • Introduce a marketing strategy to make more users be aware of the organisation's products • Implement quality control measures to ensure the NMO's products /services enable the customers to be successful in their ventures • Introduce concepts of operations management to create long term relationships with customers • Reduce overheads by taking advantage of the opportunity to source data from many suppliers and at low costs	• decrease response time to request for up-to-date information to counter the threat of dissatisfaction of user community • develop a marketing strategy based on the customers' needs to create a diversity of products to eliminate dissatisfaction of user community • Initiate remuneration strategies to stimulate creativity of employees encouraging creation of new products and avoiding loss of employees. • Update technology to enable creation of new products and remove the threat of low growth for conventional products • Manage by processes rather than by functions to speed up response to customer requests

A.7 List of possible actions

From the SWOT matrix, the following list of possible actions can be extracted. An inspection of the list will reveal that some related actions appear several times, hence they need only be utilised once in the procedure following this one.

1. Using the support for change by the government, the ability to produce high quality cartographic products and well-trained personnel, **launch advertising campaigns** to introduce the organisation to the customers.
2. Using good distribution network, take advantage of opportunity to supply the buyers of NMA's products and **increase market share.**
3. Using the well-trained personnel, take advantage of opportunity to **supply value added products.**
4. Using the abundance of existing up-to-date data, and the opportunity offered by the non-availability of the data elsewhere, **create a monopoly.**
5. Using the availability of modern hardware & software and the opportunity offered by inability of competitors to acquire the same readily, create a viable marketing policy to **attract more customers and sell more products/services.**
6. Using the strength of the presence of a Director with a vision and the opportunity offered by government support, **enforce copyright** laws to safeguard the NMA data and its use.
7. Based on the experience in conventional mapping and the existence of only a small number of competitors, **create products** that can be differentiated to fight off rivalry.
8. Based on the ability to produce high quality cartographic products and the opportunity offered by low capacity increment, create additional products from existing data and thus **generate more revenue.**
9. **Advertise** based on the experience in mapping operations and good distribution network to overcome competition from the private sector.
10. Use the competing private sector organisations to carry out **sub-contract** works thus **reducing the organisation's overheads.**
11. Based on the ability to produce high quality products, increase competition by creating a **diversity of products**, distinct quality of products according to different requirements.
12. Using the support for change by government, encourage the **formulation of policies** that will remove the threat of new entrants.

13. Using the availability of modern hardware and software, **create new products/services** to counter the threat of low market growth for conventional products.
14. Based on the abundance of existing up-to-date data, create a **pricing policy** that will remove the threat of substitute products.
15. Based on the ability to produce high quality cartographic products, create high **quality products** that will make customer-switching costs high.
16. **Update the technology** to take advantage of the opportunity offered by the power of technology.
17. **Create databases** to enable the provision of data to all users, speed update operations, improve response, and enable linking to a Geoinformation Infrastructure.
18. Develop a **marketing mechanism** to respond to the new requirements of the users.
19. **Re-educate staff** to utilise enabling technology more effectively and **reduce cycle times**.
20. **Create a diversity of products**/services to take advantage of profits that can only be made by selling more or to more customers**.**
21. Introduce a **marketing strategy** to make more users be aware of the organisation's products.
22. Implement **quality control** measures to ensure the NMA's products /services enable the customers to be successful in their ventures.
23. Introduce concepts of **operations management** to create long term relationships with customers.
24. **Reduce overheads** by taking advantage of the opportunity to source data from many suppliers and at low costs.
25. **Decrease response time** to request for up-to-date information to counter the threat of dissatisfaction of user community.
26. Develop a marketing strategy based on the customers' needs to create a **diversity of products** to eliminate dissatisfaction of user community.
27. Initiate **remuneration strategies** to stimulate creativity of employees encouraging creation of new products and avoiding loss of employees.
28. **Update technology** to enable creation of new products and remove the threat of low growth for conventional products.
29. Manage by **processes** rather than by functions to speed up response to customer requests.

A.8 Strategic Planning

The SWOT analysis elements help in setting the direction for the strategic plan[1]. Using TurboBPR software as a tool, a detailed reengineering plan is formulated by setting the organisation's vision and mission statements, setting a number of goals and performance measures, developing strategies and initiatives. The pertinent details of the strategic plan whose project life is five years are:

> ***Mission Statement*** *"To meet the Nation's general need for geoinformation supply, and to do so efficiently and cost effectively"*
>
> ***Vision Statement*** *"To be leaders in the field of geoinformation supply and to produce an accurate national database consisting of geodetic, topographic and cadastral elements, that is efficient and timely for use by government agencies, the private sector and general public. To provide leadership for the management of geoinformation and to improve the understanding and application of geoinformation and technology"*

A.9 Formulation of goals, strategies and initiatives (Steps 7 – 10)

To address the performance problems of the organisation a total of four goals were set as required in section 2.3.3. A total of five performance measures are tied to these goals. Eight strategies were

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[1] *Refer to Appendix A2 for the detailed Strategic Plan.*

formed to achieve the performance measures for which a total of fourteen initiatives were proposed to implement them as shown in Table A-3.

The development of initiatives was achieved by analysing the actions derived from the SWOT analysis (see list of possible actions) using the Matrix of Change (**Step 9**). Actions appearing severally in the list are utilised only once. The analysis (Figure A-3) enabled their interactions with current set of practices to be analysed resulting in prioritising of the actions according to importance and how they compliment the organisation's activities towards meeting the goals. Based on the analysis, some initiatives, which obviously ranked poorly, were discarded in favour of those that are likely to offer more gains to the organisation. Major consideration was on the attainment of the performance measures. Table A-3 illustrates how the goals, performance measures, strategies and initiatives are linked together.

A.10 Mapping of goals, performance measures, strategies and initiatives

Table A-3 Planning linkages

G1				Achieve 100% cost recovery in 5 years
	P1			Government/public funds dependence
		S8		Reduce overheads
			I7	Multiple raw products sources at lower costs
			I8	Sub-contract tasks to private sector firms
			I9	Reduce the workforce
	P5			Annual Revenue
		S5		Increase products/services diversity
			I10	Create and sell additional products
		S6		Attractive pricing policy
			I7	Multiple raw products sources at lower costs
G2				Produce appreciated quality products
	P3			Percent of orders accepted by customers
		S1		Total Quality Management
			I2	Training of staff to utilise modern technology effectively
			I14	Quality Control
G3				Respond promptly to user requirements
	P2			Percent of orders delivered within specified time
		S2		Improve response time
			I3	Eliminate Non-Value-Adding operations
			I4	Create databases
			I5	Reduce cycle times
			I11	Maps on Demand
			I12	On-line data acquisition
		S4		Update the technology
			I6	Update technology
G4				Provide data that is accurate, current and complete
	P4			Percentage of data that is not more than three years old
		S3		Periodic data update
			I13	On-line updating
		S4		Update the technology
			I6	Update technology
		S7		Integrate disparate sources of geodata
			I12	On-line data acquisition

Legend

G: Goals P: Performance measures S: Strategies I: Initiatives

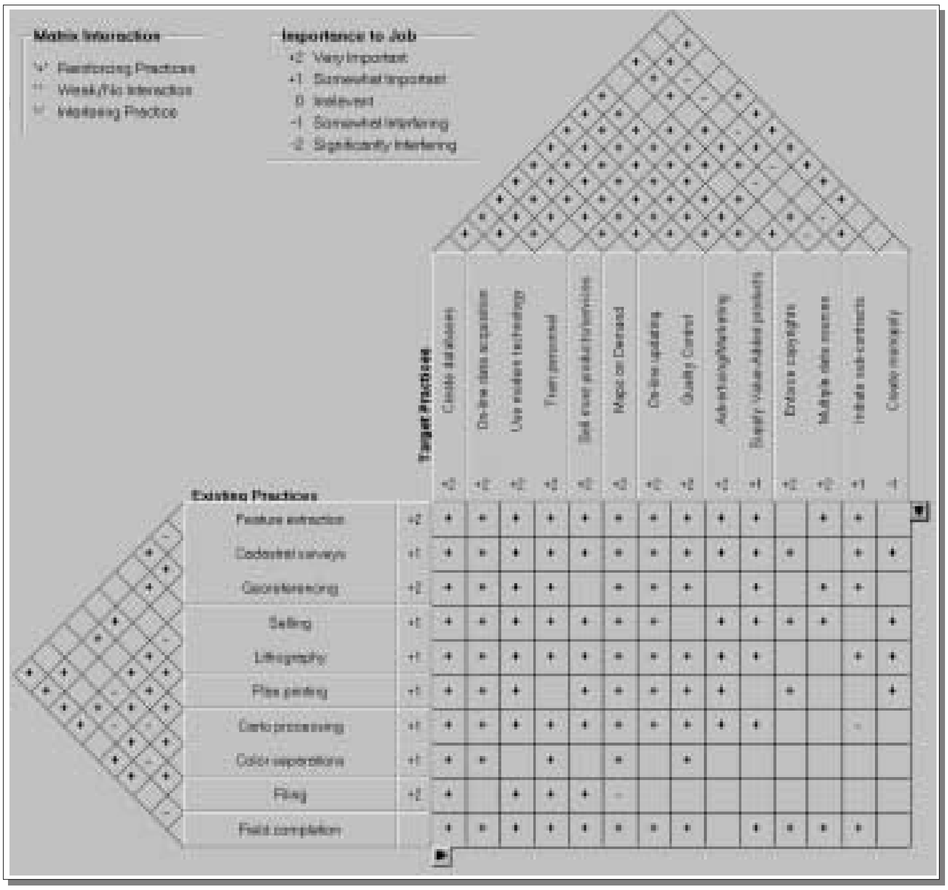

Figure A-3 NMA's Matrix of Change

A.11 Cost and performance comparisons (Steps 11 & 12)

Detailed operational As_Is and projected costs were input into TurboBPR application as part of the Functional Economic Analysis. In addition, related cost and performance impacts were calculated using the same application. A selected number of initiatives were packaged into three different alternatives (A, B and C) (Step 11: Suggest alternatives). These alternatives were then analysed for economic viability and impact on the performance of the organisation. Comprehensive details of the strategic plan including the initiatives packaging, costs and performance impacts are shown in Appendix A2. A strategic choice was made of Alternative B based on its ability to meet performance targets each year and on the other economic indicators as can be seen in Table A-4 and Table A-5 respectively.

Table A-4 Performance comparison

Performance measure	Baseline	Alt. A	Alt. B	Alt. C
Government/public funds dependence	Red	Yellow	Green	Yellow
Percent of orders delivered within specified time	Red	Green	Green	Green
Percent of orders accepted by customers	Red	Green	Green	Green
Percentage of data that is not more than three years old	Red	Green	Green	Green
Annual Revenue	Red	Green	Green	Green

Legend:

Red:	Never meets target
Yellow:	Meets target some of the years
Green:	Meets target all the years

Table A-5 Economic analysis

	ALT A	ALT B	ALT C
RADCF Savings Hi	2,233.57	1,392.19	2,889.66
RADCF Savings	1,135.02	252.57	1,926.67
RADCF Savings Lo	42.05	-881.30	968.43
ROI 1999 (%)	-45.91	-51.95	-52.43
ROI 2000 (%)	-42.56	-47.89	-41.69
ROI 2001 (%)	-35.69	-40.60	-32.64
ROI 2002 (%)	-13.65	-20.06	-7.75
ROI 2003 (%)	10.15	2.10	18.95
RA ROI Hi (%)	20.90	12.09	29.79
RA ROI (%)	10.15	2.10	18.95
RA ROI Lo (%)	0.36	-7.01	9.11
IRR (%)	12.51	4.70	18.98
Discounted Payback (years)	4.57	4.90	4.29

The shift to a new way of working is closely linked to the detailed strategic plan (Appendix A2) and in particular the results of the Functional Economic Analysis. Based on the analyses, the following initiatives have been selected based on the performance measures and economic analysis. These are the initiatives used in Alternative B.

I2 Training of staff to utilise modern technology effectively

I3 Eliminate Non-Value-Adding operations

I4 Create databases

I6 Update technology

I7 Multiple raw products sources at lower costs

I8 Sub-contract tasks to private sector firms

I9 Reduce the workforce

I10 Create and sell additional products

I12 On-line data acquisition

I13 On-line updating

I14 Quality Control

These initiatives should now be implemented at the operational level to assist the organisation move achieve its mission.

A.12 *Operational level processes (Steps 13 to 15)*

The core process of the organisation is to provide geoinformation. This core process is made up of several other sub-processes within the core process in the organisation. Along with this, there exist several other support processes such as human resources management, supplies etc. While these are not addressed in this case study, it is very important to analyse the interactions of these processes with the core process. These will help gather understanding as to how the support processes could affect the core process(es).

A.13 *As-Is Process models (Step 13)*

To provide awareness as to how the organisation is currently working, modelling of the current situation is necessary. We do this by first illustrating in an abstract way, the current functional structure of the organisation using a flow chart. Further on, we model the operational processes by use of the UT Architectural concepts. Figure A-4 depicts the functional nature of the current organisation.

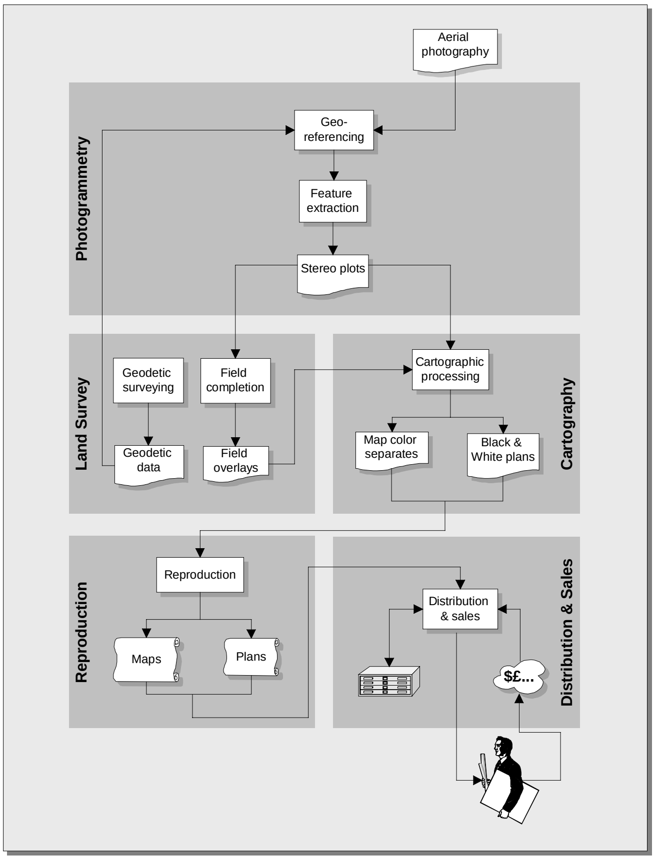

Figure A-4 As-Is functional structure

The process models consisting of the five activities involved in the NMA's geoinformation production processes are shown in Figure A-5.

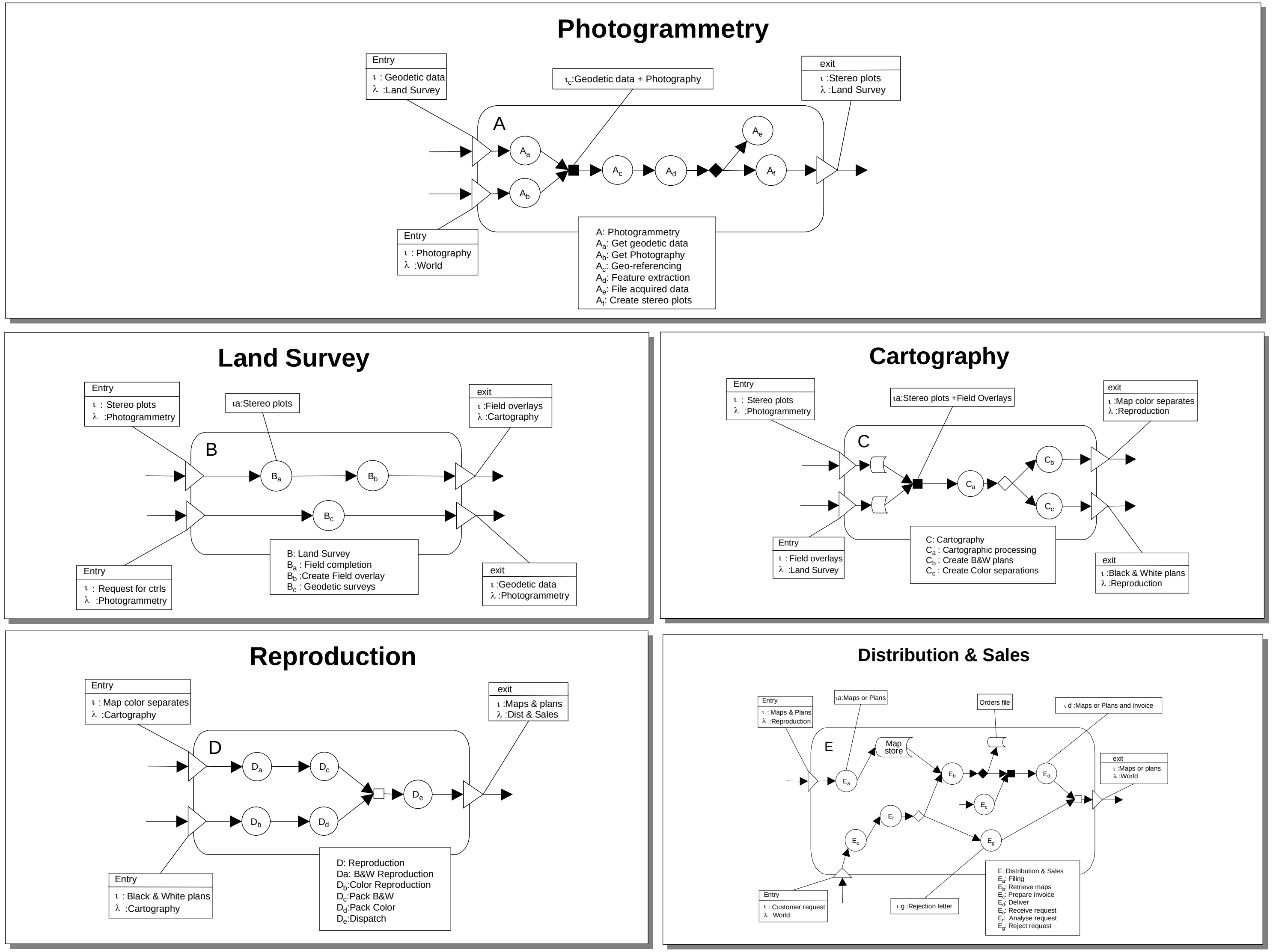

Figure A-5 As-Is process models

A.14 Where-to-be situation

This section refers to steps 16 to 19 of the methodology (Figure A-3) but were not covered in this case study. However, based on the selected initiatives (see costs and performance comparisons steps 11 & 12), an implementation decision should be made within the context of the BPR project.

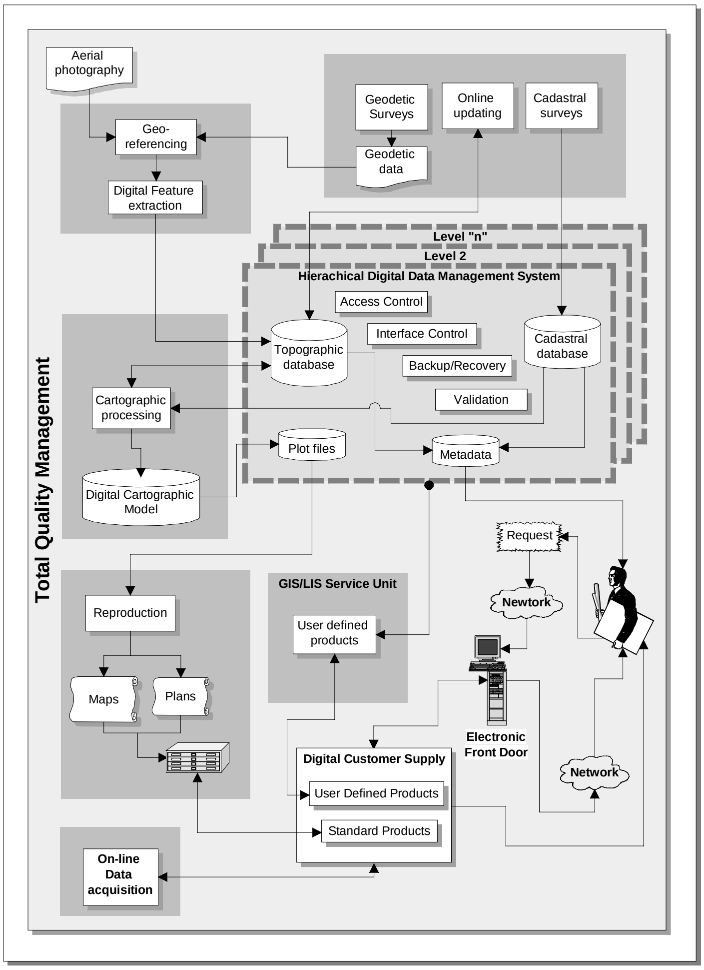

Figure A-6 Proposed operational structure

Strategically, the organisation should be taking more care about the user community and its interests; after all, the economic subsistence will be based mainly on those. The NMA should make continuous research of user’s requirements with the aim of providing satisfaction to the users. This signifies that there is a need for structural client interaction.

The principal premeditation is to have an organisation economically independent, with strong presence on the geoinformation market, able to offer appreciated quality products and flexibility to respond promptly to the user requirements. With these, the organisation should aim at **diversification by products and by markets**, that is, introduce new products into existing markets and develop new markets for existing products.

Operationally, the organisation should reengineer its processes so as to adequately address all the user requirements and in an efficient way. These requirements are such as timely delivery of products and services, products or services that are current, of high quality and fit for use and products with added value according to customers' specifications.

The current set-up, which is functionally based, is inadequate in answering all the user requirements. The non-availability of databases makes timely delivery of data, services or products virtually impossible. Similarly, since the various functional divisions have to wait for the predecessors to complete and hand over their work to the successors, a lot of time is spent waiting. Consequently, update operations take a long time to accomplish.

A.15 Proposed set-up

With the above background information, we propose a new infrastructure set-up for the core process as illustrated in Figure A-6. This structure still performs the organisation's core business, that of providing geoinformation. However, the availability of databases will reduce the response times needed to supply customers with products and services. In addition, the introduction of on-line data updating and access will ensure up-to-date information is always available. Further, the Digital Data Management System (DDMS) can have several layers of access, enabling different user requirements to be met. These would for instance mean that course data can be made available at some higher layer while more specialised products can be derived from the foundation data and made available at lower level layers. In other words, the organisation should aim at outlining the various production processes in a hierarchy, enabling it to handle various levels of complexity in product diversity a system such as that proposed in the thesis of Dominguez, [1998].

The new operational set-up addresses several of the factors addressed in this thesis. Radical changes are seen as necessary to ensure a new-look organisation is born. These changes however need not be done all in one go. The strategic plan outlines the time span for effecting the changes so that the organisation can be reengineered in five years time more or less.

A.16 Concluding remarks

This chapter involved a case study of a mapping organisation in need of change. Although that organisation is a hypothetical one, its way of working has been modelled in a manner very close to a real organisation.

The case study demonstrates how improvement alternatives integrate some BPR options highlighted in section 2.5.2. These include on-line data acquisition and concurrent engineering, online updating, JIT, hierarchical processing etc. The reengineered processes also take advantage of opportunities offered by enabling technologies such as networking including Internet, DBMS, pen computing. GPS, total stations for online updating and digital mapping techniques etc.

The methodology proposed Chapter 2 has been applied to come up with a representation of a reengineered organisation by carrying out the hierarchy of activities proposed. This has resulted in clarifying issues that would be difficult to demonstrate in the absence of a case and has served to test the methodology and the supporting tools. Process optimisation and testing of alternatives at the operational level was not achieved. However, the economic evaluation of alternatives was adequately illustrated.

Appendix B: Plan for Reengineering a Geoinformation Production Organisation

B.1 Strategic Plan

Mission Statement:

To meet the Nation's general need for geoinformation supply, and to do so efficiently and cost effectively.

Vision Statement:

To be leaders in the field of geoinformation supply and to produce an accurate national database consisting of geodetic, topographic and cadastral elements, that is efficient and timely for use by government agencies, the private sector and general public. To provide leadership for the management of geoinformation and to improve the understanding and application of geoinformation and technology.

Goals:

<u>G1</u>: Achieve 100% cost recovery in 5 years:
This goal addresses the need for the organisation to perform its day to day operations without relying on government funds.

Related Goals from other Plans: None

<u>G2</u>: Produce appreciated quality products:
This goal addresses the need for having products that are of high quality and are fit for use by customers.

Related Goals from other Plans: None

<u>G3</u>: Respond promptly to user requirements:
Customers demand prompt response to their requirements. The organisation must be able to improve response time to user requirements in terms of provision of required products and provision of information that is up-to-date. In addition, customers are demanding a diversity of value-added products as opposed to traditional products. The organisation should be able to promptly respond to these new user requirements by providing products and services that improve customer satisfaction by meeting changing customer requirements and expectations.

Related Goals from other Plans: None

<u>G4</u>: Provide data that is accurate, current and complete:
This goal addresses the need for the organisation's data to be accurate, current in terms of being up-to-date and complete in terms of national coverage.

Related Goals from other Plans: None

Performance Measures

<u>P1</u>: Government/public funds dependence:
Definition: amount of funding received annually from government or public funds

Validation: Yearly audits of accounts

Units	1998	1999	2000	2001	2002	2003
Thousands of $	11,000	8,000	6,000	4,000	2,000	0

P2: Percent of orders delivered within specified time
Definition: annual percent of orders in which the correct product or service is delivered within date and time specified by customers.

Validation: quarterly audit of a random sample of orders

Units	1998	1999	2000	2001	2002	2003
%	30	40	50	60	80	100

P3: Percent of orders accepted by customers
Definition: Annual percent of orders that are not rejected by clients.

Validation: Monthly audits of a random sample of orders

Units	1998	1999	2000	2001	2002	2003
%	50	60	70	80	90	90

P4: Percentage of data that is not more than three years old
Definition: Level of current-ness of maps and digital data that meets the needs of customers.

Validation: Half-yearly checks.

Units	1998	1999	2000	2001	2002	2003
%	0	10	30	50	80	100

P5: Annual Revenue
Definition: Amount of revenue collected yearly from sale of products and services.

Validation: Yearly audits

Units	1998	1999	2000	2001	2002	2003
Thousands of $	5,000	6,000	7,000	8,000	9,000	10,000

Strategies

S1: Total Quality Management:
Re-educate staff to take advantage of the opportunities offered by IT as an enabling technology. This will help to ensure that new technologies in the organisation are utilised to their maximum capabilities. It will also ensure that the operators do not merely use modern technology to automate what they used to do manually.

S2: Improve response time:
Create databases to enable the provision of data to all users, speed update operations, make a Geoinformation Infrastructure component and improve response time to customer requests. This will counter the threat of dissatisfaction of the user community.

S3: Periodic data update:
Data that is out of date should be periodically updated.

S4: Update the technology:
Update the technology to take advantage of the opportunities offered by the power of technology. Up-to-date technology will help to speed up operations thus reducing response time.

Table B-1 Mapping of goals, performance measures, and strategies

Achieve 100% cost recovery in 5 ye
Government/public funds dependen
Reduce overheads
Annual Revenue
Increase products/services diversity
Attractive pricing policy
Produce appreciated quality produc
Percent of orders accepted by custo

S5: Increase products/services diversity:
Based on the ability to produce high quality products and the opportunity offered by low capacity increment, create additional products from existing data and thus generate more revenue

S6: Attractive pricing policy:
Based on the abundance of existing data, create a pricing policy that will enable the creation of a monopoly.

S7: Integrate disparate sources of geodata:
None

S8: Reduce overheads:
Use the services of competing private sector organisations to carry out sub-contract work thus reducing the organisation's overheads.

B.2 Operations Analysis

Products and services

PS1: Topographic maps 1:50,000
Customers/Stakeholders: Government Departments, Private sector

PS2: Topographic maps 1:250,000
Customers/Stakeholders: Government Departments, Private sector

PS3: Topographic maps 1:1,000,000
Customers/Stakeholders: Government Departments, Private sector

PS4: Human settlement maps 1:2,500
Customers/Stakeholders: Urban planning & Human Settlement Department

PS5: Human settlement maps 1:5,000
Customers/Stakeholders: Urban planning & Human Settlement Department, Government Departments

PS6: Cadastral plans
Customers/Stakeholders: General public, Land Administration Department.

Activities and activity costs

Table B-2 Activity costs

A0	Provide Geoinformation products	6,796
A1	Distribute & sell	200
A2	Reproduction	700
A21	Reproduce maps	500
A22	Reproduce plans	200
A3	Perform cartographic processing	200
A31	Prepare map colour separates	150
A32	Prepare B&W plans	50
A4	Perform land survey activities	3,000
A41	Provide field overlays	1,000
A42	Cadastral surveys	2,000
A5	Perform photogrammetric operations	1,500
A51	Perform georeferencing	300
A52	Extract features	1,200
A6	Support activities	1,196

Table B-3 As-Is operations costs

1998	1999	2000	2001	2002	2003
6,796	7,475.6	8,223.16	9,045.48	9,950.02	10,945.03

Products and service costs

Table B-4 Products and services

Title	**Annual Volume**	**Total Cost (T$)**	**Unit Cost (Actual $)**
PS1 Topographic maps 1:50,000	100,000	1,690	16.9
PS2 Topographic maps 1:250,000	30,000	679	22.63
PS3 Topographic maps 1:1,000,000	10,000	387	38.7
PS4 Human settlement maps 1:2,500	10,000	350.81	35.08
PS5 Human settlement maps 1:5,000	5,000	244.54	48.91
PS6 Cadastral plans	500,000	2,235	4.47

Unallocated:

Sources and Costs A0 Provide Geoinformation products 1,209.64 Support services

A1	Distribute & sell	10	None
A2	Reproduction	3.64	None
A21	Reproduce maps	3.64	None
A22	Reproduce plans	0	None
A3	Perform cartographic processing	0	None
A31	Prepare map color separates	0	None
A32	Prepare B&W plans	0	None
A4	Perform land survey activities	0	None
A41	Provide field overlays	0	None
A42	Cadastral surveys	0	None
A5	Perform photogrammetric operations	0	None
A51	Perform georeferencing	0	None
A52	Extract features	0	None

B.3 Initiatives

I1: Press & Web-based advertising

By way of placing advertisements in journals, magazines and periodicals and maintaining a corporate Homepage on the World Wide Web (WWW), advertise so as to reach more customers. To be continuously implemented in 5 years.

Supports the following Strategies: *None*

Table B-5 Cost and performance for I1 - Press & Web-based advertising

Title	Units	1999	2000	2001	2002	2003	2004
Initiative Cost	Thousands	0					
Cost Impact	Thousands	0	0	0	0		
P1- Government/public funds dependence	Thousands of $	0	0	0	0	0	0

I2: Training of staff to utilise modern technology effectively

Re-training will help to ensure that employees do not merely automate manual tasks, thus under utilising the modern technology that has been acquired by the organisation. Proper training will guarantee that equipment is fully and effectively utilised. To be implemented over 5 years.

Supports the following Strategies: *S1 Total Quality Management*

Table B-6 Cost and Performance for I2 - Training of staff to utilise modern technology effectively

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	10	6	4	4	5
Cost Impact	Thousands	10	6	4	4	5
P3 - % of orders accepted by customers	%	5	10	15	20	20

I3: Eliminate Non-Value-Adding operations

Current operations that do not add value to the product should be eliminated, provided the removal of these operations will not be detrimental to the quality of the desired products. This initiative has zero costs.

Supports the following Strategies: *S2 Improve response time*

Table B-7 Cost and performance for I3 - Eliminate non-value-adding operations

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	0	0	0	0	0
Cost Impact	Thousands	-747.56	-822.32	-904.55	-995	-1,094.5
P2 - % of orders delivered within specified time	%	5	10	15	15	15

I4: Create databases

The existence of databases will ensure that available information is accessible at short notice, enabling required processing to proceed without unnecessary delays.

Supports the following Strategies: *S2 Improve response time*

Table B-8 Cost and performance for I4 - Create databases

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	1,000	1,000	500	200	100
Cost Impact	Thousands	224.27	246.69	271.36	298.5	328.35
P2 - % of orders delivered within specified time	%	1.25	5	7.5	12.5	17.5

I5: Reduce cycle times

The amount of time required by each process should be reduced. This could be by way of increasing resources for critical processes.

Supports the following Strategies: *S2 Improve response time*

Table B-9 Cost and performance for I5 - Reduce cycle times

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	30	16	5	4	4
Cost Impact	Thousands	-1,495.12	-1,644.63	-1,809.1	-1,990	-2,189.01
P2 - % of orders delivered within specified time	%	0	5	10	15	17.5

I6: Update technology
New equipment should be used to keep pace with modern practices.

Supports the following Strategies: *S4 Update the technology*

Table B-10 Cost and performance for I6 - Update technology

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	2,820	2,750	2,610	75	45
Cost Impact	Thousands	0	0	0	0	0
P2 - % of orders delivered within specified time	%	5	10	20	40	60
P4 - % of data that is not more than three years old	%	4.9	14	25.2	44.8	70

I7: Multiple raw product sources at lower costs
By taking advantage of the opportunity to source data from many suppliers, price advantage can be obtained. To be implemented throughout the project life cycle, i.e. 5 years. No associated investment costs.

Supports the following Strategies: S6 Attractive pricing policy, S8 Reduce overheads

Table B-11 Cost and performance for I7 - Multiple raw product sources at lower costs

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	0	0	0	0	0
Cost Impact	Thousands	-747.56	-822.32	-904.55	-995	-1,094.5
P1 Government/public funds dependence	Thousands of $	-3,000	-3,900	-5,070	-6,591	-8,568.3
P5 Annual Revenue	Thousands of $	1,000	1,300	1,690	2,197	2,856.1

I8: Sub-contract tasks to private sector firms
Use small private sector firms to carry out sub-contract work.

Supports the following Strategies: *S8 Reduce overheads*

Table B-12 Cost and performance for I8 - Sub-contract tasks to private sector firms

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	0	0	0	0	0
Cost Impact	Thousands	-1,120	-1,232	-1,355.2	-1,490.72	-1,639.79
P1 Government/public funds dependence	Thousands of $	-50	-500	-1,000	-2,000	-4,000

<u>I9</u>: Reduce the workforce
Introduce early retirement scheme to encourage more employees to retire and reduce the organisation's payroll.

Supports the following Strategies: *S8 Reduce overheads*

Table B-13 Cost and performance for I9 - Reduce the workforce

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	500	300	100		
Cost Impact	Thousands	3.6	3.96	4.36	4.79	5.27
P1 Government/public funds dependence	Thousands of $	-760	-800	-1,000	-1,500	-2,000

<u>I10</u>: Create and sell additional products
Based on the ability to produce high quality cartographic products and the opportunity offered by low capacity increment, create additional products from existing data and thus generate more revenue. To be implemented in 5 years.

Supports the following Strategies: S5 Increase products/services diversity

Table B-14 Cost and performance for I10 - Create and sell additional products

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	10	10	5	0	0
Cost Impact	Thousands	135	141.75	148.84	156.28	164.09
P1 Government/public funds dependence	Thousands of $	0	0	0	0	
P5 Annual Revenue	Thousands of $	9,600	12,480	16,224	21,091.2	27,418.56

<u>I11</u>: Maps on Demand
Print maps on demand instead of creating an inventory of paper maps. This should be for specialised maps that are not in very high demand. A one-time investment is required for this purpose.

Supports the following Strategies: *S2 Improve response time*

Table B-15 Cost and performance for I11 - Maps on demand

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	1,000				
Cost Impact	Thousands	-74.76	-82.23	-90.45	-99.5	-109.45
P2 Percent of orders delivered within specified time	%	5	10	12	15	15

I12: On-line data acquisition

Should data not be available from the organisation's databases, on-line data acquisition should be triggered. The data can be obtained from other organisations online via the Internet or acquired through other means such as GPS, ground surveys etc.

Supports the following Strategies: S2 Improve response time & S7 Integrate disparate sources of geodata

Table B-16 Cost and performance for I12 - On-line data acquisition

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	60	64	57.6	51.84	46.66
Cost Impact	Thousands	37.38	41.12	45.23	49.75	54.73
P2 - % of orders delivered within specified time	%	1.25	5	7.5	12.5	17.5
P4 Percentage of data that is not more than three years old	%	1.75	5	9	16	25

I13: On-line updating

Use pen computers, total stations and GPS to update data.

Supports the following Strategies: *S3 Periodic data update*

Table B-17 Cost and performance for I13 - On-line updating

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	127	127	77	32	17
Cost Impact	Thousands	22.43	24.67	27.14	29.85	32.84
P4 Percentage of data that is not more than three years old	%	10	20	30	80	100

I14: Quality Control

Every process should have quality checks or have a system of guaranteeing quality.

Supports the following Strategies: *S1 Total Quality Management*

Table B-18 Cost and performance for I14 - Quality control

Title	Units	1999	2000	2001	2002	2003
Initiative Cost	Thousands	5	3	2	2	2
Cost Impact	Thousands	5	3	2	2	2
P3 Percent of orders accepted by customers	%	10	10	20	25	25

B.4 Alternatives

Table B-19 Package initiatives

Initiative Name	Baseline	Alternative		
		A	B	C
I1 Press & Web-based advertising	No	No	No	No
I2 Training of staff to utilise modern technology effectively	No	Yes	Yes	Yes
I3 Eliminate Non-Value-Adding operations	No	Yes	Yes	No
I4 Create databases	No	Yes	Yes	No
I5 Reduce cycle times	No	No	No	Yes
I6 Update technology	No	Yes	Yes	Yes
I7 Multiple raw product sources at lower costs	No	Yes	Yes	Yes
I8 Sub-contract tasks to private sector firms	No	Yes	Yes	No
I9 Reduce the workforce	No	No	Yes	Yes
I10 Create and sell additional products	No	Yes	Yes	Yes
I11 Maps on Demand	No	No	No	Yes
I12 On-line data acquisition	No	Yes	Yes	No
I13 On-line updating	No	Yes	Yes	Yes
I14 Quality Control	No	Yes	Yes	Yes

Table B-20 Cost and performance comparisons (economic analysis)

	ALT A	**ALT B**	**ALT C**
RADCF Savings Hi	2,233.57	1,392.19	2,889.66
RADCF Savings	1,135.02	252.57	1,926.67
RADCF Savings Lo	42.05	-881.30	968.43
ROI 1999 (%)	-45.91	-51.95	-52.43
ROI 2000 (%)	-42.56	-47.89	-41.69
ROI 2001 (%)	-35.69	-40.60	-32.64
ROI 2002 (%)	-13.65	-20.06	-7.75
ROI 2003 (%)	10.15	2.10	18.95
RA ROI Hi (%)	20.90	12.09	29.79
RA ROI (%)	10.15	2.10	18.95
RA ROI Lo (%)	0.36	-7.01	9.11
IRR (%)	12.51	4.70	18.98
Discounted Payback (years)	4.57	4.90	4.29

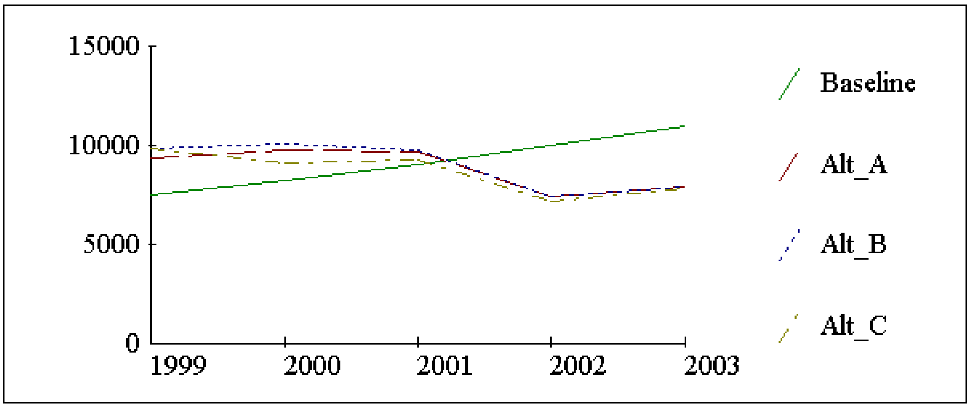

Figure B-1 Alternative costs

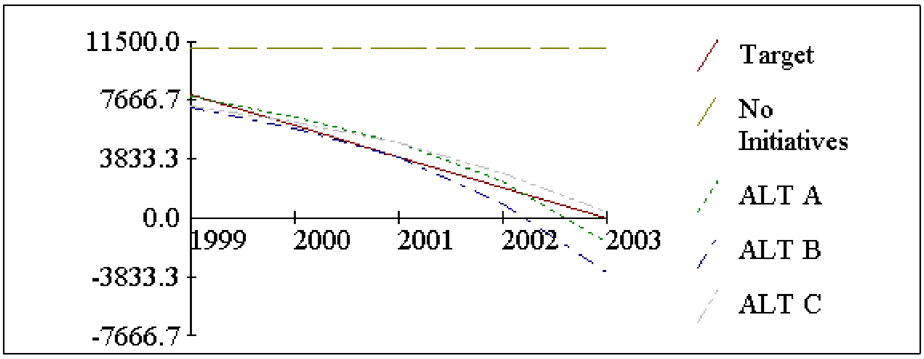

Figure B-2 Government/public funds dependence

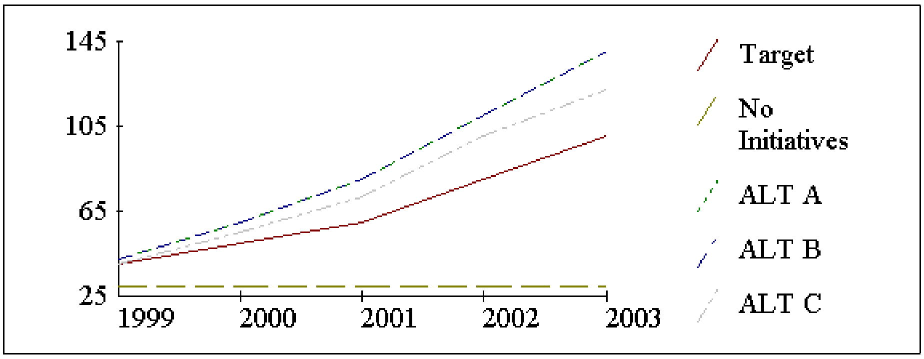

Figure B-3 Percent of orders delivered within specified time

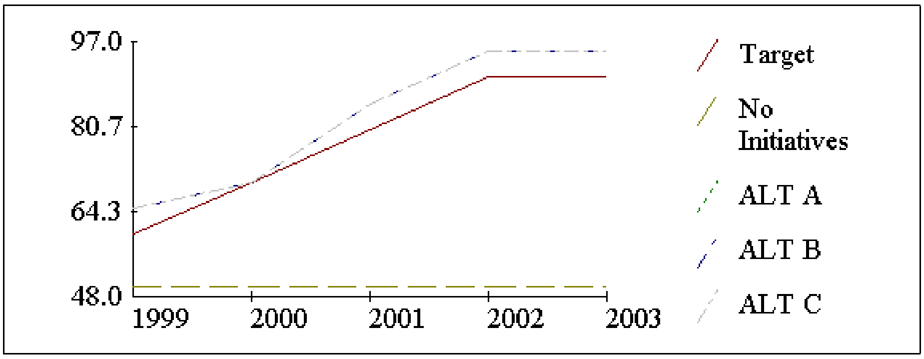

Figure B-4 Percent of orders accepted by customers

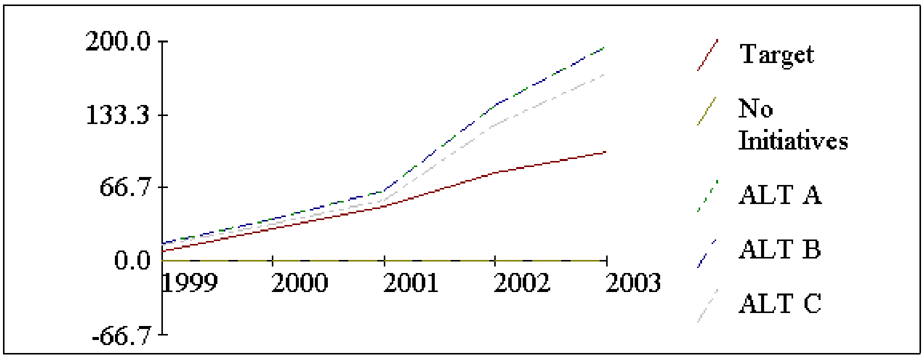

Figure B-5 Percentage of data that is not more than three years old

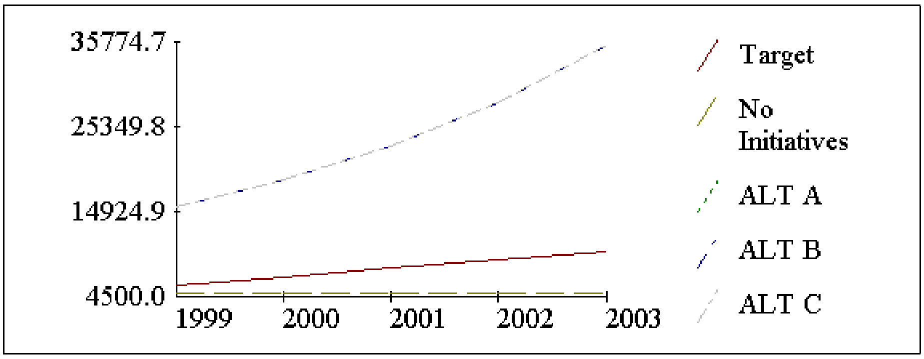

Figure B-6 Annual revenue

Table B-21 Performance comparison

Performance measure	Baseline	Alt. A	Alt. B	Alt. C
Government/public funds dependence	Blue	Yellow	Green	Yellow
Percent of orders delivered within specified time	Blue	Green	Green	Green
Percent of orders accepted by customers	Blue	Green	Green	Green
Percentage of data that is not more than three years old	Blue	Green	Green	Green
Annual Revenue	Blue	Green	Green	Green

Legend:

Blue:	Never meets target
Yellow:	Meets target some of the years
Green:	Meets target all the years

Table B-22 Initiatives cost, actual versus predicted

Sources	Cost (act/pre/diff)		
I2 Training of staff to utilise modern technology effectively	0	10	-10
I3 Eliminate Non-Value-Adding operations	0	0	0
I4 Create databases	0	1,000	-1,000
I6 Update technology	0	2,820	-2,820
I7 Multiple raw product sources at lower costs	0	0	0
I8 Sub-contract tasks to private sector firms	0	0	0
I10 Create and sell additional products	0	10	-10
I12 On-line data acquisition	None	60	None
I13 On-line updating	None	127	None
I14 Quality Control	None	5	None

Table B-23 Performance costs, actual versus predicted

Sources	Cost (act/pre/diff)		
P1 Government/public funds dependence	0	7,950	-7,950
P2 Percent of orders delivered within specified time	0	42.5	-42.5
P3 Percent of orders accepted by customers	0	65	-65
P4 Percentage of data that is not more than three years old	0	16.65	-16.65
P5 Annual Revenue	0	15,600	-15,600

Table B-24 Planning linkages

G1				Achieve 100% cost recovery in 5 years
	P1			Government/public funds dependence
		S8		Reduce overheads
			I7	Multiple raw products sources at lower costs
			I8	Sub-contract tasks to private sector firms
			I9	Reduce the workforce
	P5			Annual Revenue
		S5		Increase products/services diversity
			I10	Create and sell additional products
		S6		Attractive pricing policy
			I7	Multiple raw products sources at lower costs
G2				Produce appreciated quality products
	P3			Percent of orders accepted by customers
		S1		Total Quality Management
			I2	Training of staff to utilise modern technology effectively
			I14	Quality Control
G3				Respond promptly to user requirements
	P2			Percent of orders delivered within specified time
		S2		Improve response time
			I3	Eliminate Non-Value-Adding operations
			I4	Create databases
			I5	Reduce cycle times
			I11	Maps on Demand
			I12	On-line data acquisition
		S4		Update the technology
			I6	Update technology
G4				Provide data that is accurate, current and complete
	P4			Percentage of data that is not more than three years old
		S3		Periodic data update
			I13	On-line updating
		S4		Update the technology
			I6	Update technology
		S7		Integrate disparate sources of geodata
			I12	On-line data acquisition

<u>Legend</u>
G: Goals P: Performance measures S: Strategies I: Initiatives

B.6 Detailed Worksheets: Operation Costs:

Table B-25 Initiative costs: I1 - Press & Web-based advertising

Item	1998	1999	2000	2001	2002	2003
Salaries	6000	6600	7260.00	7986.00	8784.60	9663.06
Office Space	100	110	121.00	133.10	146.4	161.05
Telephone	10	11	12.10	13.31	14.64	16.11
Electricity	5	5.5	6.05	6.65	7.32	8.05
Water	2	2.2	2.42	2.66	2.92	3.22
Maintenance	10	11	12.10	13.31	14.64	16.11
Consumables	12	13.2	14.52	15.97	17.56	19.32
Equipment	4	4.4	4.84	5.32	5.85	6.44
Field work	300	330	363.00	399.30	439.23	483.15
Sub-Contract work	50	55	60.50	66.55	73.20	80.53
Marketing/advertising	3	3.3	3.63	3.99	4.3923	4.83
Overtime pay	300	330	363.00	399.30	439.23	483.15
Total	6796	7475.6	8223.16	9045.47	9950.02	10945.03

* Initiative costs: I2 - Training of staff to utilise modern technology effectively

Item	1999	2000	2001	2002	2003
Training	10	6	4	4	5
Total	10	6	4	4	5

* Initiative operations costs impacts: I2 - Training of staff to utilise modern technology effectively

Item	1999	2000	2001	2002	2003
Annual training & seminar fees	10	6	4	4	5
Total	10	6	4	4	5

* Initiative operations costs impacts: I3 - Eliminate non-value-adding operations

Item	1999	2000	2001	2002	2003
Operations cost	7475.6	8223.16	9045.476	9950.0236	10945.026
Cost impact	-747.56	-822.316	-904.5476	-995.00236	-1094.5026

* Initiative costs: I4 - Create databases

Item	1999	2000	2001	2002	2003
Data conversion	1000	1000	500	200	100
Total	1000	1000	500	200	100

* Initiative operations costs impacts: I4 - Create databases

Item	1999	2000	2001	2002	2003
Operations cost	7475.6	8223.16	9045.476	9950.0236	10945.026
Cost impact	224.268	246.6948	271.36428	298.500708	328.35078

* Initiative performance impacts: P2 - Percent of orders delivered within specified time

Item	1999	2000	2001	2002	2003
AS-IS% delivered within specified time	30	30	30	30	30
TO-BE% delivered within specified time	35	50	60	80	100
TO-BE minus AS-IS	5	20	30	50	70
Impact from database creation	1.25	5	7.5	12.5	17.5

* Initiative costs: I5 - Reduce cycle times

Item	1999	2000	2001	2002	2003
Increase resources	10	6	5	4	4
Process optimisation	20	10			
Total	30	16	5	4	4

* Initiative operations costs impacts: I5 - Reduce cycle times

Item	1999	2000	2001	2002	2003
Operations cost	7475.6	8223.16	9045.476	9950.0236	10945.026
Cost impact	-1495.12	-1644.632	-1809.0952	-1990.00472	-2189.0052

* Initiative performance impacts: P2 - Percent of orders delivered within specified time

Item	1999	2000	2001	2002	2003
AS-IS% delivered within specified time	30	30	30	30	30
TO-BE% delivered within specified time	30	50	70	90	100
TO-BE minus AS-IS	0	20	40	60	70
Impact of reducing cycle times	0	5	10	15	17.5

* Initiative costs: I6 - Update technology

Item	1999	2000	2001	2002	2003
Computers	50	30	20	20	20
Digitizers	10	10			
Servers	10		10		
Digital photogrammetric equipment	2500	2500	2500		
Networking	50	10	10	5	5
Plotters	50	50			
Scanners	50	50			
Software	100	100	70	50	20
Total	2820	2750	2610	75	45

* Initiative operations costs impacts: I6 - Update technology

Item	1999	2000	2001	2002	2003
Operations cost	7475.6	8223.16	9045.476	9950.0236	10945.026
Cost impact	0	0	0	0	0

* Initiative performance impacts: P4 - Percentage of data that is not more than three years old

Item	1999	2000	2001	2002	2003
AS-IS% delivered within specified time	0	0	0	0	0
TO-BE% delivered within specified time	35	50	60	80	100
TO-BE minus AS-IS	35	50	60	80	100
Impact from updating technology	4.9	14	25.2	44.8	70

* Initiative operations costs impacts: I7 - Multiple raw product sources at lower costs

Item	1999	2000	2001	2002	2003
Operational cost	7475.6	8223.16	9045.476	9950.0236	10945.026
Cost impact	-747.56	-822.316	-904.5476	-995.00236	-1094.5026

* Initiative performance impacts: P1 - Government/public funds dependence

Item	1999	2000	2001	2002	2003
Impact on dependence	-3000	-3900	-5070	-6591	-8568.3

* Initiative performance impacts: P5 - Annual revenue

Item	1999	2000	2001	2002	2003
Impact on revenue	1000	1300	1690	2197	2856.1

* Initiative operations costs impacts: I8 - Sub-contract tasks to private sector firms

Item	1999	2000	2001	2002	2003
Data collection	-100	-110	-121	-133.1	-146.41
Distribution & Sales	-10	-11	-12.1	-13.31	-14.641
Marketing	-10	-11	-12.1	-13.31	-14.641
Aerial photography	-1000	-1100	-1210	-1331	-1464.1
Cost impact (savings)	-1120	-1232	-1355.2	-1490.72	-1639.792

* Initiative performance impacts: P1 - Government/public funds dependence

Item	1999	2000	2001	2002	2003
Impact	-50	-500	-1000	-2000	-4000

* Initiative costs: I9 - Reduce the workforce

Item	1999	2000	2001
Retirement benefits	500	400	300
Total	500	300	100

* Initiative operations costs impacts: I9 - Reduce the workforce

Item	1999	2000	2001	2002	2003
Operation costs	7475.6	8223.16	9045.476	9950.0236	10945.026
Retirement benefits	500	400	300	100	
Salaries(Annual)	1000	1100	1210	1331	1464.1
Savings from unpaid salaries	-60	-66	-72.6	-79.86	-87.846
Sub total	3.6	3.96	4.356	4.7916	5.27076

* Initiative performance impacts: P1 - Government/public funds dependence

Item	1999	2000	2001	2002	2003
Salaries	6000	6600	7260	7986	8784.6
Impact	-760	-800	-1000	-1500	-2000

* Initiative costs: I10 - Create and sell additional products

Item	1999	2000	2001	2002	2003
Value added products creation	10	10	5	0	0
Total	10	10	5	0	0

* Initiative operations costs impacts: I10 - Create and sell additional products

Item	1999	2000	2001	2002	2003
GIS products/services	30	31.5	33.075	34.72875	36.4651875
On-line LIS services	50	52.5	55.125	57.88125	60.7753125
GPS services	10	10.5	11.025	11.57625	12.1550625
Training services	5	5.25	5.5125	5.788125	6.07753125
Route maps	10	10.5	11.025	11.57625	12.1550625
Tourist maps	10	10.5	11.025	11.57625	12.1550625
Other products/services	20	21	22.05	23.1525	24.310125
Impact on operations cost	135	141.75	148.8375	156.279375	164.09334375

* Initiative performance impacts: P5 - Annual revenue

Item	1999	2000	2001	2002	2003
GIS products/services	3000	3900	5070	6591	8568.3
On-line LIS services	5000	6500	8450	10985	14280.5
GPS services	300	390	507	659.1	856.83
Training services	100	130	169	219.7	285.61
Route maps	100	130	169	219.7	285.61
Tourist maps	100	130	169	219.7	285.61
Other products/services	1000	1300	1690	2197	2856.1
Total	9600	12480	16224	21091.2	27418.56

* Initiative costs: I11 - Maps on demand

Item	1999
High speed plotting equipment	1000
Total	1000

* Initiative operations costs impacts: I11 - Maps on demand

Item	1999	2000	2001	2002	2003
Operations Cost	7475.6	8223.16	9045.476	9950.0236	10945.026
Cost impact	-74.756	-82.2316	-90.45476	-99.500236	-109.45026

* Initiative costs: I12 - On-line data acquisition

Item	1999	2000	2001	2002	2003
Internet access	10	9	8.1	7.29	6.561
Data acquisition	50	55	49.5	44.55	40.095
Total	60	64	57.6	51.84	46.656

* Initiative operations costs impacts: I12 - On-line data acquisition

Item	1999	2000	2001	2002	2003
Operations cost	7475.6	8223.16	9045.476	9950.0236	10945.026
Cost impact	37.378	41.1158	45.22738	49.750118	54.72513

* Initiative performance impacts: P2 - Percent of orders delivered within specified time

Item	1999	2000	2001	2002	2003
AS-IS% delivered within specified time	30	30	30	30	30
TO-BE% delivered within specified time	35	50	60	80	100
TO-BE minus AS-IS	5	20	30	50	70
Impact from On-line data acquisition	1.25	5	7.5	12.5	17.5

* Initiative performance impacts: P4 - Percentage of data that is not more than three years old

Item	1999	2000	2001	2002	2003
AS-IS%	0	0	0	0	0
TO-BE%	35	50	60	80	100
TO-BE minus AS-IS	35	50	60	80	100
Impact from On-line data acquisition	1.75	5	9	16	25

* Initiative operations costs impacts: I13 - On-line updating

Item	1999	2000	2001	2002	2003
Operations cost	7475.6	8223.16	9045.476	9950.0236	10945.026
Cost impact	22.4268	24.66948	27.136428	29.8500708	32.835078

* Initiative costs: I13 - On-line updating

Item	1999	2000	2001	2002	2003
Global Positioning Systems(GPS)	50	50	25	10	5
Communications equipment	2	2	2	2	2
Pen Computers	25	25	25	10	5
Total Stations	50	50	25	10	5
Total	127	127	77	32	17

* Initiative operations costs impacts: I14 - Quality control

Item	1999	2000	2001	2002	2003
Operations cost	7475.6	8223.16	9045.476	9950.0236	10945.026
Cost Impact	5	3	2	2	2

B.7 Alternatives Details

Table B-26 Alternative (A) total costs

Item	1998	1999	2000	2001	2002	2003
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs Hi	0	4435.2	4356	3581.16	401.324	237.2216
Initiative Impact Hi	0	-1876.128	-2079.416	-2299.443	-2538.234	-2800.213
Total Costs Hi	6796	10034.67	10499.75	10327.19	7813.115	8382.033
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs	0	4032	3960	3255.6	364.84	215.656
Initiative Impact	0	-2181.047	-2413.402	-2665.73	-2940.344	-3241.793
Total Costs	6796	9326.553	9769.759	9635.347	7374.52	7918.889
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs Lo	0	3628.8	3564	2930.04	328.356	194.0904
Initiative Impact Lo	0	-2485.967	-2747.388	-3032.016	-3342.455	-3683.373
Total Costs Lo	6796	8618.434	9039.771	8943.5	6935.922	7455.743

Table B-27 Alternative (A) Percent of orders accepted by customers

Item	1998	1999	2000	2001	2002	2003
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact Hi	0	16.5	22	38.5	49.5	49.5
Total Performance Hi	50	66.5	72	88.5	99.5	99.5
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact	0	15	20	35	45	45
Total Performance	50	65	70	85	95	95
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact Lo	0	13.5	18	31.5	40.5	40.5
Total Performance Lo	50	63.5	68	81.5	90.5	90.5

Table B-28 Alternative (A) Percent of orders delivered within specified time

Item	1998	1999	2000	2001	2002	2003
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact Hi	0	13.75	33	55	88	121
Total Performance Hi	30	43.75	63	85	118	151
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact	0	12.5	30	50	80	110
Total Performance	30	42.5	60	80	110	140
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact Lo	0	11.25	27	45	72	99
Total Performance Lo	30	41.25	57	75	102	129

Table B-29 Alternative (A) Percentage of data that is not more than three years old

Item	1998	1999	2000	2001	2002	2003
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact Hi	0	18.315	42.9	70.62	154.88	214.5
Total Performance Hi	0	18.315	42.9	70.62	154.88	214.5
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact	0	16.65	39	64.2	140.8	195
Total Performance	0	16.65	39	64.2	140.8	195
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact Lo	0	14.985	35.1	57.78	126.72	175.5
Total Performance Lo	0	14.985	35.1	57.78	126.72	175.5

Table B-30 Alternative (A) Government/public funds dependence

Item	1998	1999	2000	2001	2002	2003
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact Hi	0	-2745	-3960	-5463	-7731.9	-11311.47
Total Performance Hi	11000	8255	7040	5537	3268.1	-311.4696
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact	0	-3050	-4400	-6070	-8591	-12568.3
Total Performance	11000	7950	6600	4930	2409	-1568.3
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact Lo	0	-3355	-4840	-6677	-9450.101	-13825.13
Total Performance Lo	11000	7645	6160	4323	1549.9	-2825.13

Table B-31 Alternative (A) Annual revenue

Item	1998	1999	2000	2001	2002	2003
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact Hi	0	11660	15158	19705.4	25617.02	33302.13
Total Performance Hi	5000	16660	20158	24705.4	30617.02	38302.13
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact	0	10600	13780	17914	23288.2	30274.66
Total Performance	5000	15600	18780	22914	28288.2	35274.66
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact Lo	0	9540	12402	16122.6	20959.38	27247.19
Total Performance Lo	5000	14540	17402	21122.6	25959.38	32247.19

Table B-32 Alternative (B) total costs

Item	1998	1999	2000	2001	2002	2003
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs Hi	0	4985.2	4686	3691.16	401.324	237.2216
Initiative Impact Hi	0	-1872.168	-2075.06	-2294.652	-2532.963	-2794.415
Total Costs Hi	6796	10588.63	10834.1	10441.99	7818.386	8387.831
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs	0	4532	4260	3355.6	364.84	215.656
Initiative Impact	0	-2177.448	-2409.442	-2661.374	-2935.553	-3236.522
Total Costs	6796	9830.152	10073.72	9739.703	7379.311	7924.16
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs Lo	0	4078.8	3834	3020.04	328.356	194.0904
Initiative Impact Lo	0	-2482.727	-2743.824	-3028.095	-3338.143	-3678.629
Total Costs Lo	6796	9071.674	9313.336	9037.42	6940.234	7460.486

Table B-33 Alternative (B) Percent of orders accepted by customers

Item	1998	1999	2000	2001	2002	2003
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact Hi	0	16.5	22	38.5	49.5	49.5
Total Performance Hi	50	66.5	72	88.5	99.5	99.5
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact	0	15	20	35	45	45
Total Performance	50	65	70	85	95	95
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact Lo	0	13.5	18	31.5	40.5	40.5
Total Performance Lo	50	63.5	68	81.5	90.5	90.5

Table B-34 Alternative (B) Percent of orders delivered within specified time

Item	1998	1999	2000	2001	2002	2003
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact Hi	0	13.75	33	55	88	121
Total Performance Hi	30	43.75	63	85	118	151
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact	0	12.5	30	50	80	110
Total Performance	30	42.5	60	80	110	140
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact Lo	0	11.25	27	45	72	99
Total Performance Lo	30	41.25	57	75	102	129

Table B-35 Alternative (B) Percentage of data that is not more than three years old

Item	1998	1999	2000	2001	2002	2003
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact Hi	0	18.315	42.9	70.62	154.88	214.5
Total Performance Hi	0	18.315	42.9	70.62	154.88	214.5
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact	0	16.65	39	64.2	140.8	195
Total Performance	0	16.65	39	64.2	140.8	195
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact Lo	0	14.985	35.1	57.78	126.72	175.5
Total Performance Lo	0	14.985	35.1	57.78	126.72	175.5

Table B-36 Alternative (B) Government/public funds dependence

Item	1998	1999	2000	2001	2002	2003
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact Hi	0	-3429	-4680	-6363	-9081.899	-13111.47
Total Performance Hi	11000	7571	6320	4637	1918.1	-2111.469
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact	0	-3810	-5200	-7070	-10091	-14568.3
Total Performance	11000	7190	5800	3930	909	-3568.3
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact Lo	0	-4191	-5720	-7777	-11100.1	-16025.13
Total Performance Lo	11000	6809	5280	3223	-100.1001	-5025.13

Table B-37 Alternative (B) Annual revenue

Item	1998	1999	2000	2001	2002	2003
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact Hi	0	11660	15158	19705.4	25617.02	33302.13
Total Performance Hi	5000	16660	20158	24705.4	30617.02	38302.13
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact	0	10600	13780	17914	23288.2	30274.66
Total Performance	5000	15600	18780	22914	28288.2	35274.66
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact Lo	0	9540	12402	16122.6	20959.38	27247.19
Total Performance Lo	5000	14540	17402	21122.6	25959.38	32247.19

Table B-38 Alternative (C) Total costs

Item	1998	1999	2000	2001	2002	2003
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs Hi	0	4952.2	3533.2	3083.3	128.7	80.3
Initiative Impact Hi	0	-1892.063	-2096.944	-2318.725	-2559.443	-2823.543
Total Costs Hi	6796	10535.74	9659.416	9810.053	7519.281	8201.784
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs	0	4502	3212	2803	117	73
Initiative Impact	0	-2141.409	-2369.8	-2617.768	-2887.586	-3183.759
Total Costs	6796	9836.191	9065.36	9230.709	7179.437	7834.268
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs Lo	0	4051.8	2890.8	2522.7	105.3	65.7
Initiative Impact Lo	0	-2390.756	-2642.656	-2916.81	-3215.729	-3543.975
Total Costs Lo	6796	9136.645	8471.304	8651.364	6839.593	7466.75

Table B-39 Alternative (C) Percent of orders accepted by customers

Item	1998	1999	2000	2001	2002	2003
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact Hi	0	16.5	22	38.5	49.5	49.5
Total Performance Hi	50	66.5	72	88.5	99.5	99.5
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact	0	15	20	35	45	45
Total Performance	50	65	70	85	95	95
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact Lo	0	13.5	18	31.5	40.5	40.5
Total Performance Lo	50	63.5	68	81.5	90.5	90.5

Table B-40 Alternative (C) Percent of orders delivered within specified time

Item	1998	1999	2000	2001	2002	2003
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact Hi	0	11	27.5	46.2	77	101.75
Total Performance Hi	30	41	57.5	76.2	107	131.75
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact	0	10	25	42	70	92.5
Total Performance	30	40	55	72	100	122.5
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact Lo	0	9	22.5	37.8	63	83.25
Total Performance Lo	30	39	52.5	67.8	93	113.25

Table B-41 Alternative (C) Percentage of data that is not more than three years old

Item	1998	1999	2000	2001	2002	2003
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact Hi	0	16.39	37.4	60.72	137.28	187
Total Performance Hi	0	16.39	37.4	60.72	137.28	187
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact	0	14.9	34	55.2	124.8	170
Total Performance	0	14.9	34	55.2	124.8	170
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact Lo	0	13.41	30.6	49.68	112.32	153
Total Performance Lo	0	13.41	30.6	49.68	112.32	153

Table B-42 Alternative (C) Government/public funds dependence

Item	1998	1999	2000	2001	2002	2003
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact Hi	0	-3384	-4230	-5463	-7281.9	-9511.47
Total Performance Hi	11000	7616	6770	5537	3718.1	1488.53
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact	0	-3760	-4700	-6070	-8091	-10568.3
Total Performance	11000	7240	6300	4930	2909	431.7
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact Lo	0	-4136	-5170	-6677	-8900.101	-11625.13
Total Performance Lo	11000	6864	5830	4323	2099.9	-625.1303

Table B-43 Alternative (C) Annual revenue

Item	1998	1999	2000	2001	2002	2003
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact Hi	0	11660	15158	19705.4	25617.02	33302.13
Total Performance Hi	5000	16660	20158	24705.4	30617.02	38302.13
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact	0	10600	13780	17914	23288.2	30274.66
Total Performance	5000	15600	18780	22914	28288.2	35274.66
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact Lo	0	9540	12402	16122.6	20959.38	27247.19
Total Performance Lo	5000	14540	17402	21122.6	25959.38	32247.19

Table B-44 No initiatives

Item	1998	1999	2000	2001	2002	2003
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03

Table B-45 All initiatives

Item	1998	1999	2000	2001	2002	2003
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs Hi	0	6118.2	4703.6	3696.66	405.724	241.6216
Initiative Impact Hi	0	-3285.057	-3629.237	-4004.247	-4413.518	-4863.024
Total Costs Hi	6796	10308.75	9297.524	8737.892	5942.231	6323.624
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs	0	5562	4276	3360.6	368.84	219.656
Initiative Impact	0	-3747.323	-4136.306	-4560.924	-5025.058	-5534.978
Total Costs	6796	9290.277	8362.855	7845.153	5293.806	5629.705
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Operations Costs	6796	7475.6	8223.16	9045.476	9950.023	10945.03
Initiative Costs Lo	0	5005.8	3848.4	3024.54	331.956	197.6904
Initiative Impact Lo	0	-4209.59	-4643.374	-5117.601	-5636.598	-6206.931
Total Costs Lo	6796	8271.811	7428.187	6952.413	4645.379	4935.785

Table B-46 All initiatives, percent of orders accepted by customers

Item	1998	1999	2000	2001	2002	2003
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact Hi	0	16.5	22	38.5	49.5	49.5
Total Performance Hi	50	66.5	72	88.5	99.5	99.5
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact	0	15	20	35	45	45
Total Performance	50	65	70	85	95	95
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	50	60	70	80	90	90
Current Performance	50	50	50	50	50	50
Initiative Impact Lo	0	13.5	18	31.5	40.5	40.5
Total Performance Lo	50	63.5	68	81.5	90.5	90.5

Table B-47 All initiatives, percent of orders delivered within specified time

Item	1998	1999	2000	2001	2002	2003
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact Hi	0	19.25	49.5	79.2	121	156.75
Total Performance Hi	30	49.25	79.5	109.2	151	186.75
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact	0	17.5	45	72	110	142.5
Total Performance	30	47.5	75	102	140	172.5
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	30	40	50	60	80	100
Current Performance	30	30	30	30	30	30
Initiative Impact Lo	0	15.75	40.5	64.8	99	128.25
Total Performance Lo	30	45.75	70.5	94.8	129	158.25

Table B-48 All initiatives, percentage of data that is not more than three years old

Item	1998	1999	2000	2001	2002	2003
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact Hi	0	18.315	42.9	70.62	154.88	214.5
Total Performance Hi	0	18.315	42.9	70.62	154.88	214.5
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact	0	16.65	39	64.2	140.8	195
Total Performance	0	16.65	39	64.2	140.8	195
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	0	10	30	50	80	100
Current Performance	0	0	0	0	0	0
Initiative Impact Lo	0	14.985	35.1	57.78	126.72	175.5
Total Performance Lo	0	14.985	35.1	57.78	126.72	175.5

Table B-49 All initiatives, government/public funds dependence

Item	1998	1999	2000	2001	2002	2003
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact Hi	0	-3429	-4680	-6363	-9081.899	-13111.47
Total Performance Hi	11000	7571	6320	4637	1918.1	-2111.469
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact	0	-3810	-5200	-7070	-10091	-14568.3
Total Performance	11000	7190	5800	3930	909	-3568.3
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	11000	8000	6000	4000	2000	0
Current Performance	11000	11000	11000	11000	11000	11000
Initiative Impact Lo	0	-4191	-5720	-7777	-11100.1	-16025.13
Total Performance Lo	11000	6809	5280	3223	-100.1001	-5025.13

Table B-50   All initiatives, annual revenue

Item	1998	1999	2000	2001	2002	2003
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact Hi	0	11660	15158	19705.4	25617.02	33302.13
Total Performance Hi	5000	16660	20158	24705.4	30617.02	38302.13
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact	0	10600	13780	17914	23288.2	30274.66
Total Performance	5000	15600	18780	22914	28288.2	35274.66
Item	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Target	5000	6000	7000	8000	9000	10000
Current Performance	5000	5000	5000	5000	5000	5000
Initiative Impact Lo	0	9540	12402	16122.6	20959.38	27247.19
Total Performance Lo	5000	14540	17402	21122.6	25959.38	32247.19

Appendix C: Performance Modelling of the Topographic Data Extraction Process

Performance studies are primarily aim at supporting decision-making, helping study the behaviour of systems and factors that affect their performance. In the case the methodology developed in Chapter 4 applied to the topographic data extraction process (TDE), a core process in geo-information production environments. The process model is implemented in the SIMPLE++ simulation environment for performance analysis. The case is based on the performance goals and measures discussed in Chapter 4 of the report.

SIMPLE++ is process simulation software developed by Technomatrix Technologies Ltd (http://www.tecnomatix.com/defaultnf.asp) that enables the design, simulation, visualization and optimization of production systems and processes. Its' an objected oriented modelling tool with a fairly large library of objects to choose from and has been extensively applied in industry to analyze bottlenecks, and optimize throughput and buffer sizes.

C.1 Problem formulation

The growing need to reengineer geoinformation processes makes it necessary to investigate the factors impacting on these processes and quantify their effects. Consequently, the global objective of this case study is:

- To investigate the primary factors that influence performance in geo-information production processes.

Geo-information production encompasses many processes but this study looks at the Topographic Data Extraction (TDE) process. Performance evaluation projects use different metrics for different goals and at different levels of abstraction. The goals of this study are responsiveness and just in timeliness and the process response time provides the most appropriate metric. The specific objectives of this study are:

- To study the primary factors affecting the average response time (ART) of the Topographic Data Extraction geo-information process
- To quantify the relative effects of the primary factors on the average response time

For the purposes of this study, a request will is considered as being the equivalent of geo-information requirements or needs for a single map-unit. In the event of one for more than one map unit, it will be interpreted as being more than a single request. Every request has four basic attributes: Type, Scale, Priority and Area. Type refers to the kind of geo-information sought, which may be Altimetric or Planimetric. The Scale attribute assumes the qualitative values of large and small while Priority may assume the integer values of 1 or 2 corresponding to high and low priorities respectively. The priority of a request indicates the urgency with which the request should be handled and is expressed as a function of the response time. Urban and rural define the domain for the values of the Area attribute. The values assigned to the attributes are assumed uniformly distributed and independent. Table A-1 shows the mean values used.

C.1.1 Topographic data extraction (TDE) process

The TDE process may be visualised as consisting of three sub-processes, the Reception and Analysis, Analogue and Digital sub-processes (Figure C-2). The digital and analogue sub-processes are the modes of processing an arriving job can take while the reception and analysis sub-process is in charge or receiving the request and assigning the appropriate processing mode depending on its primary attributes. The case looks at only those jobs that can be processed.

C.1.2 Performance factors

The following performance factors were identified:

1. The Rate of Arrival (Workload): The requests arrive at random intervals to the TDE process and their rate defines the workload on the process. The negative exponential distribution was used to model the random arrival behaviour.
2. Load Distribution: An arrival request may be processed in the digital or analogue way depending on its values for the primary attributes. The number of requests in either production line defines its workload. However, this number varies over time and this can have adverse influences on the performance of the process.
3. Product Diversity: The TDE process has potential to generate diverse products. This will include new and standard products. The range and number of products generated with sufficient quality by the process is a measure of its performance.
4. System Capacity: In any production environment the number of resources is finite limiting the number of jobs that can be allowed in the system at any moment. This limiting number defines the capacity of the system.
5. Number of Service Providing Entities: Geo-information processing makes extensive use of stereo-plotters and digital workstations among other instruments. Besides personnel, the number of these machines available can only be finite and often indicates the production capacity of the system. Acquisition of additional resources should therefore be geared towards improving the performance of the process.
6. Quality Constraints: Focus in present manufacturing environments is on providing quality services and products to users' satisfaction. A definition of quality for geo-information products or data that is getting widespread acceptance is its fitness-for use. Thus a geo-information product or service is of quality if it is fit for use in a particular context. An integral component to quality control is quality checking. The products will be checked for thematic, positional and temporal accuracy, completeness and logical consistency. Jobs that fail the checks are fed back into the system for refinement. This increases the utilisation and degrades the process response time.

C.1.3 Data requirements

It is required to define distributions and mean values for the following model parameters:

- Inter-arrival time
- Mean chance of occurrence of the attribute values
- Service time requirements
- Mean chance of occurrence of the different types of product

In the absence of real data, some intuition was necessary to assign the distributions and estimate the mean values for the model parameters. The arrival behaviour to all activities in the system was assumed to be Poisson. The average mean times shown in Table C-1 were used. These values can be very different from observed values in reality.

C.2 Process modeling

Table C-1 Mean values for model parameters

Attributes		Mean Chance of Occurrence
Type	Planimetric	0.7
	Altimetric	0.3
Scale	Large	0.8
	Small	0.2
Priority	1 (High)	0.5
	2 (Low)	0.5
Area	Urban	0.6
	Rural	0.4
Product		
Extracted Features		0.5
DTM		0.35
Other-process		0.15
Available Data		
Digital		0.4
Analogue		0.6

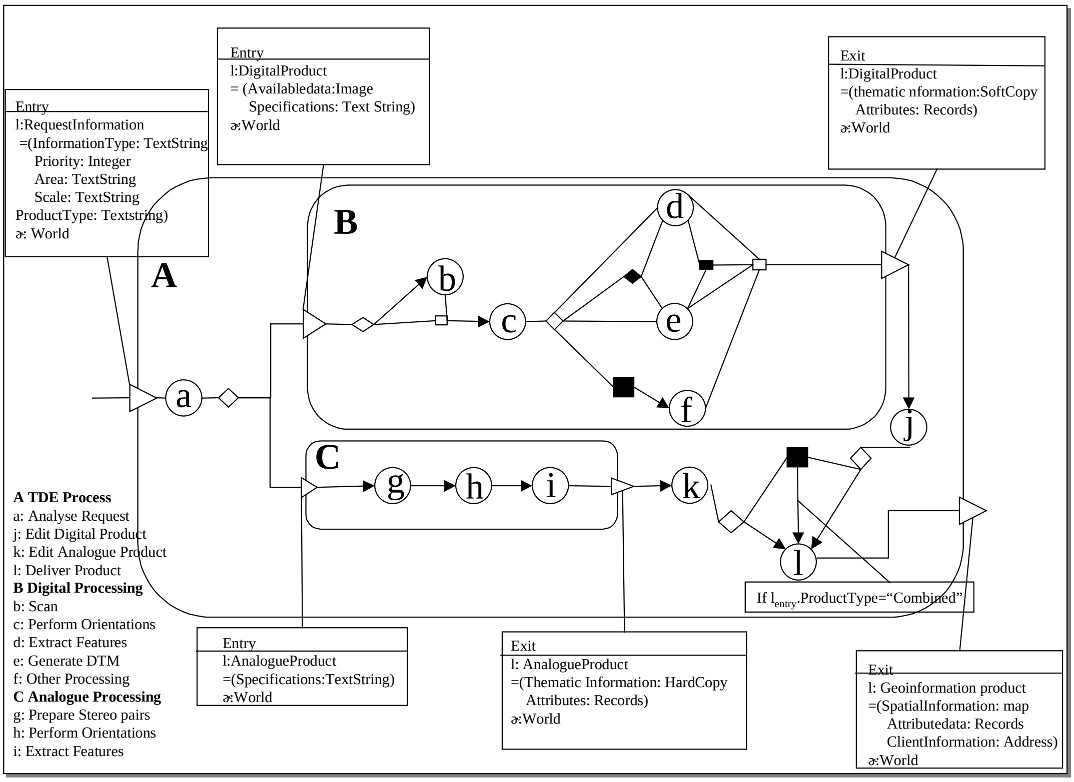

Figure C-1 Behavioural model of the TDE process

The conceptual model of the TDE process is described as a flow of activities and decisions resulting in the desired product. The TDE process has been visualised as comprising three main service-blocks namely Reception and Request Analysis, Digital, and Analogue sub-processes. The architectural modelling concepts developed at the University of Twente (UT) were employed to build the process behaviour model (Figure C-1).

- The Reception Block
  On arrival the request is received and analysed in the Reception and Analysis block. The analysis has two aims. First, to establish if the request can be processed or not and second to choose a mode of processing for those requests to be processed. The former decision is dependent on the availability of resources while the latter depends on the attribute values of the request. For convenience, Editing has been included in the Reception and Analysis.
- The Analogue Block
  A job to be processed in the Analogue mode has three service requirements that are sequentially provided. The stereo-pairs need to be prepared and orientations done before features can be extracted.
- The Digital Block
  Digital data is required for digital processing. If data is analogue, scanning has to be done before orientations. If extracted features are sought, then Feature Extraction is invoked, or if a Digital Terrain Model (DTM) is desired, DTM generation has to be initiated. However, the possibility of some other products, like reformatting data or attribute updates etc., exists creating need for the extra activity Other-process.

The product needs to be checked to ensure that all the information requested has been considered and that it is in the right format and medium. This checking should in no way be confused with quality checking as previously explained.

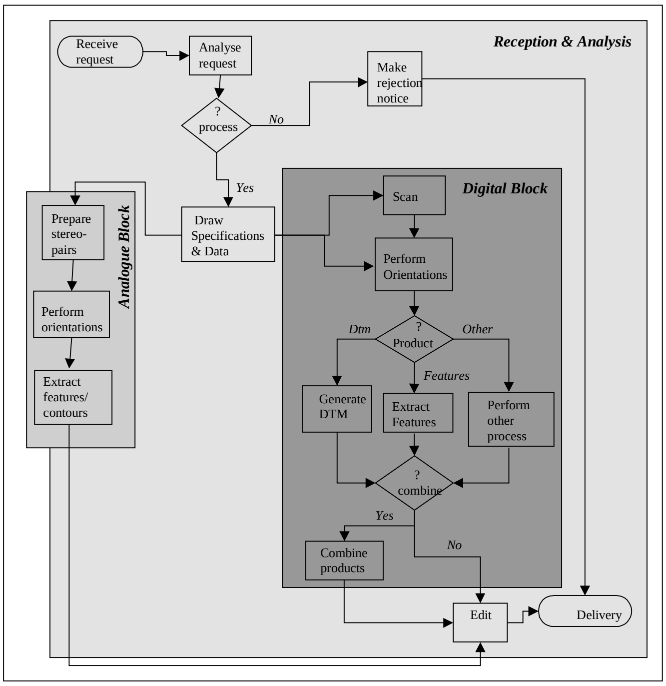

Figure C-2 The topographic data extraction (TDE) process alternative costs

C.2.1 Model verification and validation

The analogue and digital production lines are modelled, verified and validated separately before being combined to create the TDE model. Simulation is through Simple++ software.

Table C-2 Process activities and model equivalents

Activity (Conceptual Model)	Simulation Model	Associated Method
Request Analysis	Analy_req	Mtd_Analysis
Data checking	DataCheck	Mtd_Check
Scanning	Scan	-
Orientations (Digital)	Orientations	-
Choice of production process	Job_Assign	JobAssign
Feature Extraction (Digital)	Feature_Extrac	-
DTM Generation	DTM_Gen	-
Other-process	OtherProc	-
Product Checking	prodCheck	-
Preparation of Stereo Pairs	prepStrprs	-
Orientations	Orientns	-
Feature extraction (Analogue)	featExtrac	-
Edit	Edit	-

C.2.1.1 Model verification

The conceptual model shows need for several decisions as the request moves through the system. The decisions include choice of processing mode, opting for scanning and for correct activity for specified product. Verification ensures these decisions are made correctly e.g. it should be verified during simulation that 60% of the jobs requiring digital analysis require scanning.

C.2.1.2 Model validation

For validation, the computed expected response time E[R] is compared to the observed average response time $\overline{R}$ at 95% level of confidence. A desirable interval would be *1% of the average around the average* for the parameter of interest, which would yield an interval of $[0.99\overline{A}, 1.01\overline{A}]$ where $\overline{A}$ is the average of the parameter of interest. All the activities are implemented as M|M|1 queues.

The methods Method_Begin and Method_End are common to and perform the same tasks in all the models. The Method_Begin keeps count of the movable units (MU), representing requests, generated by sourceNew. The method has a counter, *index*, which is incremented by one each time an MU is generated until the desired number, *totalN* is reached. When *index* equals *totalN*, the sourceNew is stopped. The Method_End computes the response time for each request and stores it in a TableFile. The response time is computed as follows:

$$@.entryTime - @.creationTime$$

The creationTime is the time the request is generated while the entryTime is the time the MU enters the drainNew for destruction. The parameter *zet* is set according to the desired level of confidence, in our case $zet = 1.65$ corresponding to 95% level of confidence (for a *student t distribution*). The parameter *index1* is a counter for the requests entering the drainNew for destruction and "*n*" is the batch size.

C.2.1.3 Interpretation of time in the models

Topographic Data Extraction systems are such that they are shut down over some periods. Indeed in the National Mapping Organisations, these systems are only up between 8.00AM and 5.00PM over the working weekdays. This scenario affords only 8 (eight) hours in a working day. In the model the working hours are concatenated such that the periods the system is down are neglected*. In which case then 3 (three) working days of 8 hours each of the system will constitute 1(one)-model day of 24 hours. Recalling that the inter-arrival time of requests to the system is 10 (ten) working days, then the correspond inter-arrival time to be used in the model is obtained as $(10\times 8)/24 = 80/24$ Days

This translates into 3days 8 hours. This is the 'beta' value assigned to the sourceNew of the Total Basic Model. To obtain the 'beta' values for the digital and analogue lines, we make use of the splitting property of Poisson streams. Based on the decision tree of Figure 5.3, the arrival stream is split into digital and analogue streams with relative probabilities $\alpha_1 and \alpha_2$ (Format) respectively. Thus

$\lambda_1 = \alpha_1\lambda = 0.778\lambda$ and $\lambda_2 = \alpha_2\lambda = 0.222\lambda$

Now 'beta', the inter-arrival time is given by

$$beta = \tfrac{1}{\lambda}$$

Let beta1 and beta2 represent the beta value or inter-arrival times for the digital and analogue lines respectively,
then

$$beta1 = 1/\lambda_1 = 1/(0.778\times\lambda) = \tfrac{1}{0.778}\times 3days:8hours = 4days:6hours:49\min s:39.9486\sec s$$

$$beta2 = 1/\lambda_2 = 1/(0.222\times\lambda) = \tfrac{1}{0.222}\times 3days:8hours = 15days:00hours:21\min s:37.2973\sec s$$

These are the values implemented in the digital and analogue models for validation.

C.2.1.4 Validation of the analogue production line

The analogue production line consists of three main activities that are executed sequentially. These are preparation of stereo-pairs (prepStrPrs), orientations (Orientns) and feature extraction (featExtrac). They all have exponential service times and are implemented as M|M|1 queues, with response times given by

$$E[R] = E[S]/(1-\lambda E[S])$$

In validation the computed value of the response time E[R] using queuing theory and the observed average response time are compared. The expected response time is computed by summing up the expected response times for each of the three queuing stations as:

$$E[R]_{total} = E[R]_{prpStr\,\mathrm{Pr}\,s} + E[R]_{Orientations} + E[R]_{featExtrac}$$

Given that these activities are sequentially executed, they have the same arrival stream of packets, λ. consequently,

$$E[R]_{total} = E[S]_1/(1-\lambda E[S]_1) + E[S]_2/(1-\lambda E[S]_2 + E[S]_3/(1-\lambda E[S]_3)$$

Where the subscripts 1,2 and 3 refer to prpStrPrs, Orientns and featExtrac activities respectively.

* This manipulation of time is subject to discussion and is used just for convenience

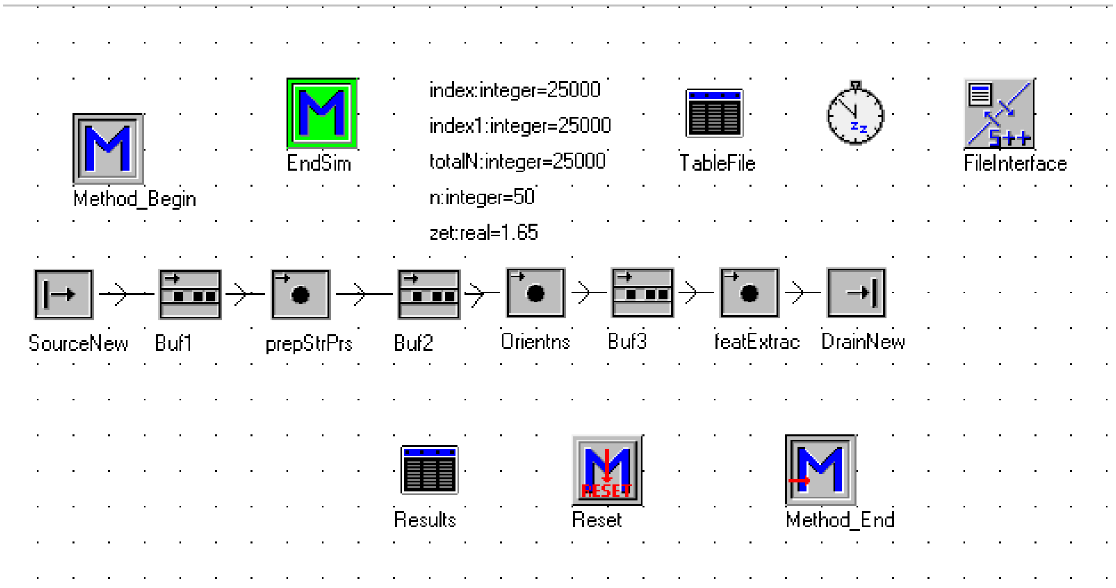

Figure C-3 Validation of the analogue production line

Table C-3 presents the results obtained. The column (CI/ART)*100 computes the relative length of the CI while the columns ART-CI and ART+CI show the lower and upper bounds for E[R]. From the table, for fairly low simulation runs E[R] and ART compare well, an indication that the model is a close approximation to the system.

Table C-3 Validation of the analogue production line

Sim	**total N**	**n**	**E[R]**	**ART**	**CI**	**CI/ART*100**	**ART-CI**	**ART+CI**
1	25000	50	244105.3911	244250.9626	3625.46399	1.48431922	240625.4986	247876.4266
	Analogue production line			Average response time: ART - Confidence interval: CI				

C.2.1.5 Validation of the digital production line

From Figure C-4 it is evident that the arrival stream splits at two instants, at the exits of the dataCheck and Job_Assign activities. Assuming Poisson arrivals and an α_i probability for the *i*th path, then $\lambda_i = \alpha_i \lambda$ where λ is the arrival stream before any splitting occurred.

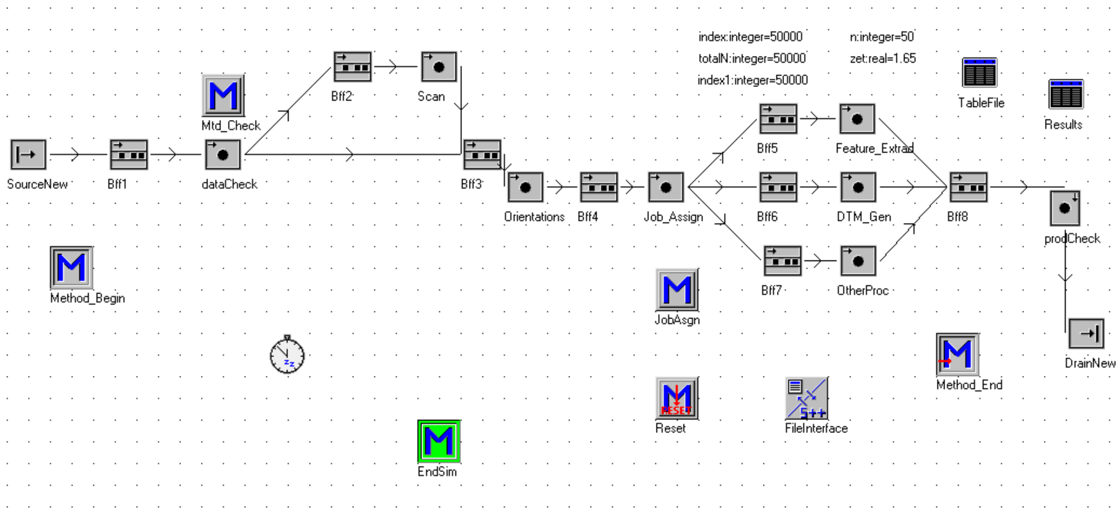

Figure C-4 Validation of the Digital Production Line

The corresponding expected response times is obtained as

$$E[R]_i = \alpha_i E[S]_i / (1 - \alpha_i \lambda E[S]_i)$$

$$E[R]_{total} = \sum_{i=1}^{k} E[R]_i$$

k being the number of processes in the system. It should be noted that the dataCheck and the Job_Assign single processes have zero service times.

Table C-4 Validation of the digital production line

Run	totalN	n	E[R]	ART	CI	(CI/ART)*10(	ART-CI	ART+CI
1	25000	50	150950.655	148462.891	3089.1491	2.08075505	145373.7418	151552.04
2	50000	50	150950.655	149817.116	2225.5494	1.48551076	147591.5668	152042.6655

It is evident from the results of

Table C-4 that the model behaves as expected for fairly low values of *totalN* and small batch size of 500.

Table C-5 Validation of the total basic model

Run	totalN	n	E[R]	ART	CI	(CI/ART)*100	(ART-CI)	(ART+CI)
1	50000	500	185268.6	184305.61	2300.63	1.248270042	182004.978	186606.2415

C.2.1.6 Validation of total basic model

The total basic model consists of the analogue and digital lines combined. In addition there are two other activities, request analysis and editing. The request analysis activity chooses the processing mode based on the attribute values of the request. On the other hand, the Editing activity comprises those corrective tasks that may be necessary in the event of a product having some defects or inconsistencies. They both have exponential service time requirements.

Table C-5 presents the validation results for the total basic model which indicate that for relatively short simulation runs the model achieves the required confidence levels. On the basis of these results it can be concluded that the model behaves as expected. The verified and validated model may then be used in experimentation.

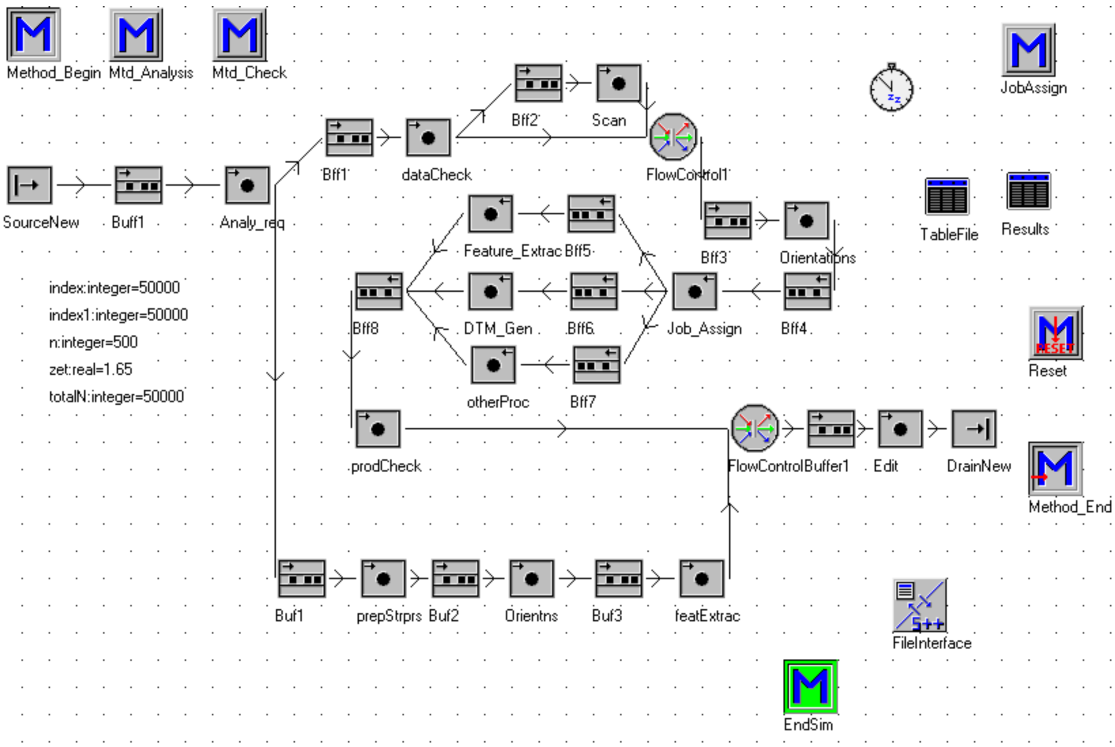

Figure C-5 Validation of the total basic model

C.3 Experiments

The experiments investigated the effects of four primary factors viz. rate of arrival, load distribution, quality constraints and number of service offering entities. The response variable in all cases was the average response time (ART). Several levels of the factors were used and the effect on the response variable observed.

C.3.1 Experiment 1: Effect of varying workload on average response time (ART)

In the experiment the inter-arrival time was decreased from a high of 100 hours to a low of 20 hours and the average response time observed. Figure C-6 shows the results.

It is evident from the results obtained that the response time generally increases with the rate of arrival as expected. For low loads (inter-arrival times greater than 44 hours) the increase in response time is almost lineal, however beyond 44 hours the response time increases sharply. Beyond 28 hours the system becomes unstable. This observation is consistent with the service demands of the system in the model. Feature extraction is the bottleneck in both production lines. However, the feature extraction station on the digital line is the bottleneck for the whole system i.e. it has the highest service demands in the whole system.

Let the service demand be ϑ, then the service demand on feature extraction station (digital line) is given as

$$\vartheta_D = \lambda \times p \times 0.5 \times E[S]_{feature\_Extraction}$$

but $p \cong 0.778$ (from Fig 5.1b) and $E[S] = 50 Hours$ where λ is the arrival rate to the system. Thus

$$\vartheta_D = \lambda \times 0.778 \times 0.5 \times 50 = 19.45 \times \lambda$$

The service demands on the feature extraction station of the analogue line is similarly computed as:

$$\vartheta_A = \lambda \times 0.222 \times E[S]_{feature\_extraction} = \lambda \times 0.222 \times 56 = 12.432 \times \lambda$$

It is evident that $\vartheta_A < \vartheta_D$, proving that the feature extraction station of the digital line is the bottleneck in the system. Knowing the service demands of the bottleneck, the maximum rate is obtained via

$$\lambda_{\max} = 1/\vartheta_{bottleneck}$$

Thus for our system $\lambda_{\max} = 1/\vartheta_D = 1/19.45$ (Hour)$^{-1}$. Recalling that the inter-arrival time is the inverse of the rate, then the minimum inter-arrival time is obtained as

$$1/\lambda_{\max} = 19.45 \text{ Hours}$$

Since the utilisation should always be less than unity, it implies that the inter-arrival time should always be greater than 19.45 hours for stability. For inter-arrival times close to 19.45 hours the system is very unstable. Acceptable response times are obtained for inter-arrival times of up to 36 hours, beyond this extra servicing entities may be necessary.

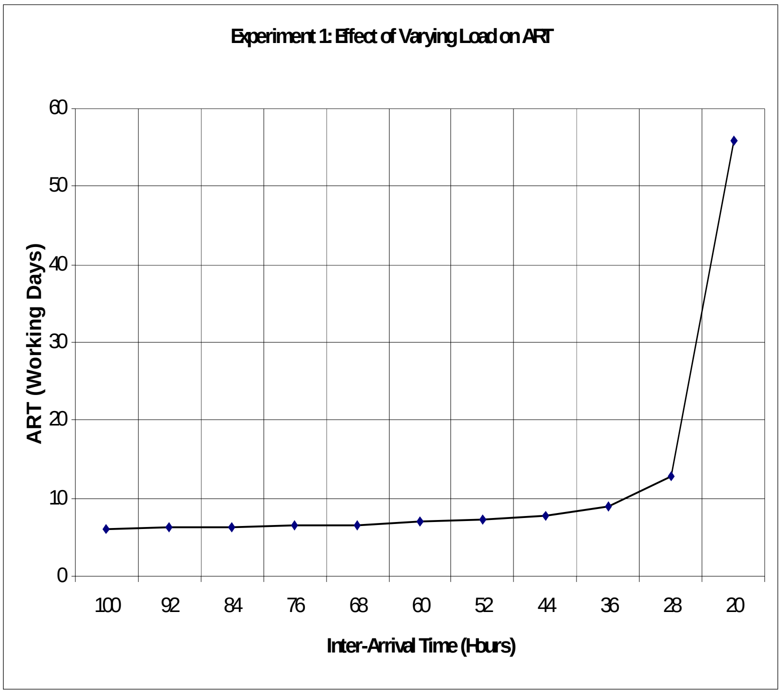

Figure C-6 Effect of varying workload on ART

C.3.2 Experiment 2: Effect of varying load distribution on ART

The request analysis activity distributes jobs according to their values of the primary attributes. On average the digital line receives the greater portion of jobs (about 78%), however this figure is bound to change. In this experiment the proportion of the jobs on the digital line was varied for three different inter-arrival times. Experiment 2a employed an inter-arrival time of 144 hours, Experiment 2b, 52 hours and Experiment 2c 28 hours. The results are presented in Figure C-7.

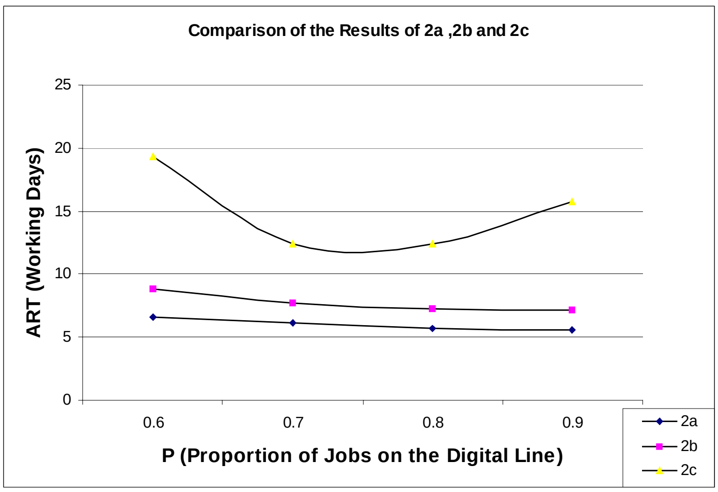

Figure C-7 Results of experiment 2

The results indicate that with high inter-arrival times, the response time is better; a result that is consistent with Experiment 1. For both Experiments 2a and 2b the average response times are good, except for very low values of *p* (*p*<0.5) and the load distribution is not critical long as the digital line has at least half the jobs. Experiment 2c however indicates that the optimum distribution is realised when the digital line receives about 75% of the jobs. This figure seems to validate the model parameters assumed in Table C-1.

C.3.3 Experiment 3: Effect of varying quality constraints on ART

Experiment 3 investigated the effects of introducing quality checks in the TDE process. The quality checks consume resources and time, therefore they should only be conducted when necessary. In this experiment, the checks were implemented as probabilities of jobs being fed back into the process or activity. Three scenarios were considered and the results compared. In case one, either production line had a single check at the end. Case two had a check for each activity in the production lines. The third case had only one check for the quality of the orientation activity which in both cases reduced by half the chances of failure in the succeeding activities. Again, several levels for the chances of failure were used. The results are presented in Figure C-9.

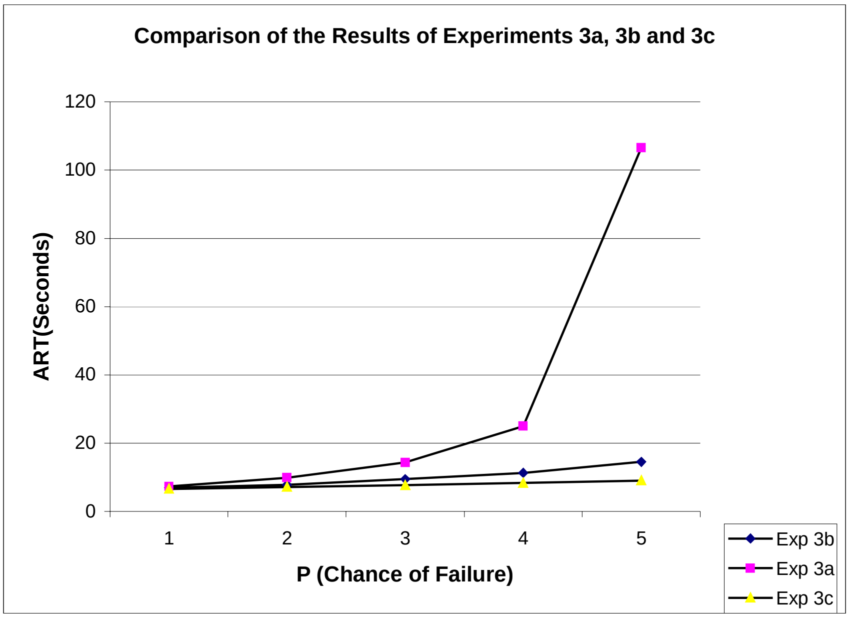

Figure C-8 Comparison of results 3a, 3b and 3c

It is evident that performing a single check gives the worst response time, which is intuitively appealing. Experiment 3c offers the best response time.

C.3.4 Experiment 4: Effect of introducing more servers on ART

In analysing the effect of the number of servicing providing entities, two experiments were conducted. In the first case only one server was assumed for each activity as in the previous experiments. The second case considered two service-providing entities for each activity. In both cases the inter-arrival time of 72 hours was used and the proportion of jobs on the digital line varied between 0.1 and 0.9. The results are shown in Figure C-9.

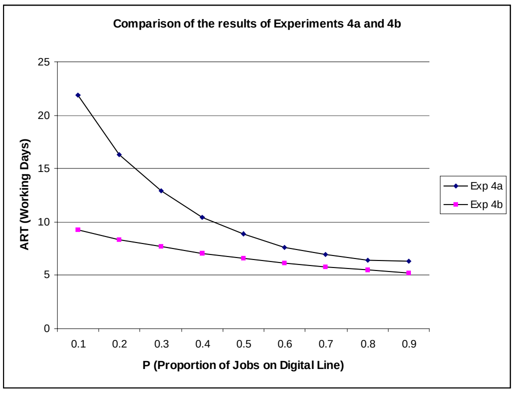

Figure C-9 Comparison of the results of experiments 4a and 4b

The graphs of Figure C-9 illustrate the effect of employing more service providing entities. By deploying an extra server on each line the response time improves by between 60% and 15% with the greater improvement being for lower values of "p" (proportion of jobs on the digital line). However, for the load used, there is only marginal improvement for higher values of "p" especially for $p \geq 0.7$. The implication is that at this workload the extra server is not justified.

Appendix D: Workflow Application

D.1 WFMS Software used:

The workflow case studies has been developed in the ActionWorks Metro software which uses a communication based approach modelling technique based on *F. Flores* and *T. Winograd* theory.

The ActionWorks suite is a product of Action Technology designed for workflow management. It integrates the World Wide Web, messaging, line-of-business and production applications into one collaborative work process

D.1.1 Software components:

The Action Works software has three basic components, which are part of the *Metro Environment:*

- ActionWorks Process Builder: The process builder is a tool to design and analyse business processes.
- ActionWorks Process Manager: It offers quality control, administration and maintenance for the business processes created with the Process Builder.
- ActionWorks Metro: is the process application platform. It uses Web-based environment for delivering interactive, responsive workflow application for the Internet and Intranets.

The Metro environment is the combination of hardware and software necessary to provide Metro application to client web browsers via an Intranet and/or the Internet. To be able to run the Metro Applications it is necessary to have some supporting software: a database server, a web server and a mail server. In addition, a web browser must be installed on each Metro user's machine.

D.1.2 Modelling principles:

As other process methodologies, the ActionWorkflow method provides a set of understandable structures and repeatable standard practices to produce repeatable and measurable results. It enables the practitioner to produce tools for process navigation and design, and maps that show what normally cannot be shown or seen. It allows observation, understanding, and identification of seemingly complex phenomena like business processes. It includes an explicit or implicit understanding of the nature of co-operation, co-ordination, and work.

The ActionWorkflow Process Map contains five basic elements:

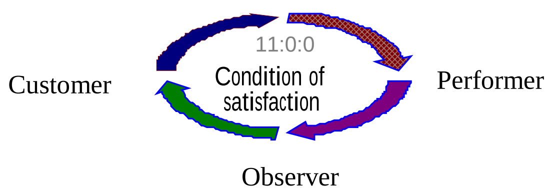

Figure D-1 ActionWorkflow process map elements

D.1.2.1 Five basic elements

The five basic elements of an Action Workflow are:

- Customer: The customer is the person for whom the work is performed. Customers evaluate performed work and determine if it meets their expectations.
- Performer: The performer is the person who is accountable for the work being done and for notifying the customer when the work is done.
- Condition of satisfaction (COS): The condition of satisfaction specifies the work to be performed by the performer.
- Observer: The observer is a person who may comment on the process but is not required to act in the process to move it to completion. The observer has no active role, only a management or monitoring role.
- Cycle Time: The cycle time is the time between the moment a request or offer is formulated to the time a customer declares satisfaction. It is used to set or calculate time values for any phase of each workflow in the business process. The cycle time allows quick analysis of time spent on each activity in the process.

D.1.2.2 Four phases

The four phases of the workflow are familiar parts of a normal business transaction but more definitively specified for the process model:

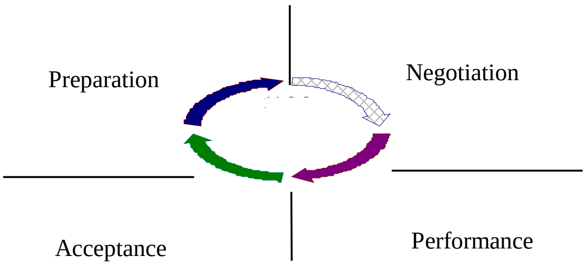

Figure D-2 ActionWorkflow phases

- In the preparation phase, the customer proposes work to be performed by the performer.
- Negotiation: the customer and performer may or may not need some negotiation to come to agreement about the work to be performed.
- Performance: the performer performs the work and reports completion. During this phase, several possible outcomes may result in reversion to the preparation and negotiation phases.
- Acceptance: the customer evaluates the work and declares satisfaction, in which case the workflow is completed. Rejection of the work can also be modelled, in which case the customer declines to accept the completed work and returns it to the performer.

D.2 Topographic Data Extraction Case

D.2.1 Description of the Process:

The process can be seen as composed by the following activities:

- Analysis of the request, coming from an internal client within the organisation. The analysis has two aims. First, to establish if the request can be processed or not, and second to choose a mode of processing (stereoplotter or Digital Photogrammetric Workstation (DPW)) for those request to be processed. The former decision is dependent on the availability of resources while the latter depends on the attribute values of the request.
- If the request goes through the analogue processing, the stereopairs are prepared, oriented and the features are extracted. The required controls are done over the activities.
- If the request goes through the digital processing, the stereo aerial photographs may or may not need to be scanned to generate a digital file. Once in digital format, orientation is performed and its result is checked.
- According to attributes, the request can go through different procedures. If feature extraction is sought, then Feature Extraction is invoked or if a Digital Terrain Model (DTM) is desired, DTM generation has to be initiated. However the possibility of some other products, like reformatting data or attribute updates, etc, exists creating need for the extra activity Other-process.
- After generation the product is checked for quality control and then edited to add attributes, make corrections on topology, etc.
- Finally the product is delivered to the client.

Note:

In a previous study a performance analysis has been carried out for the TDE process, having one of the conclusions that a quality checking should be done after orientation because the chance of failure in the succeeding process is halved.

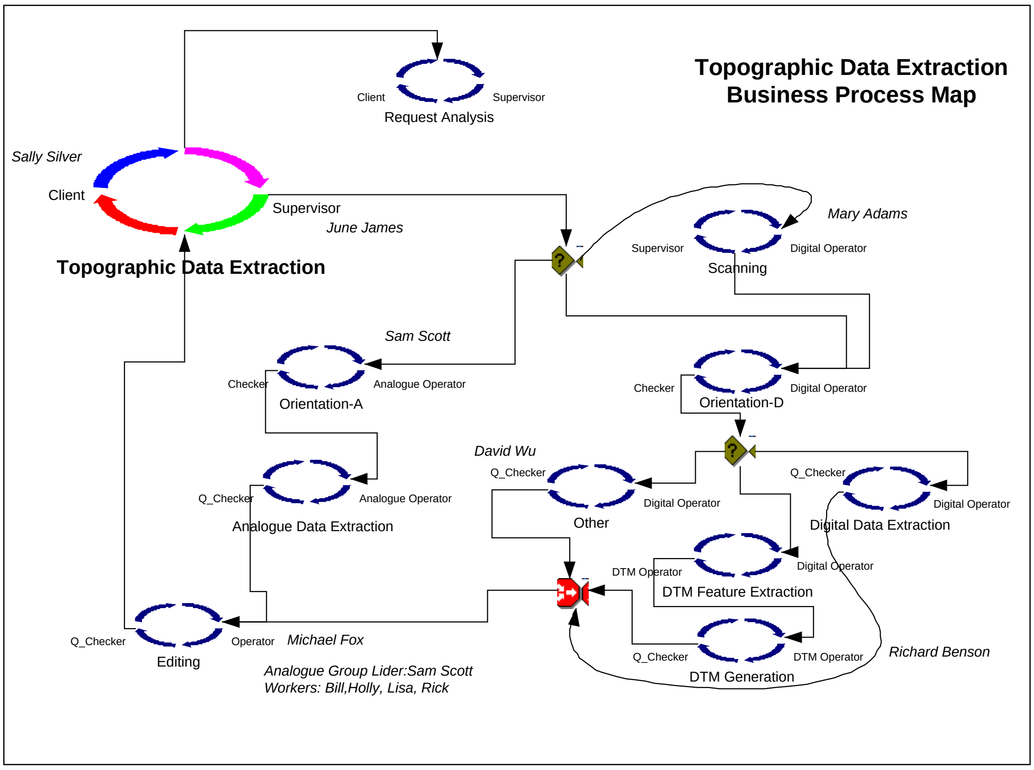

Figure D-3 Topographic data extraction business process map

D.2.2 Results:

D.2.2.1 Process definition:

The process was analysed and modelled using the Process Builder. Figure D-2 shows the resulting Business Process Map (BPM). The quality controls are done during the acceptance phase of the processes. Besides the Process Definition, application forms using HTML and Metro Mark-up language have been developed to implement the process on Metro. Once finished, the software checks the logic and consistency of the BPM to generate the application to be installed in Metro.

D.2.2.2 Web application:

Once the process definition was generated, it was installed on the Metro server by using the Process Manager. Roles and identities were defined to recreate a working place. The process definition was run, just to see the network of commitments and possibilities to get the work done but the real processes weren't executed. Figures D-3, D-4, and D-5 show some of the screen shots the users receive in a Metro environment.

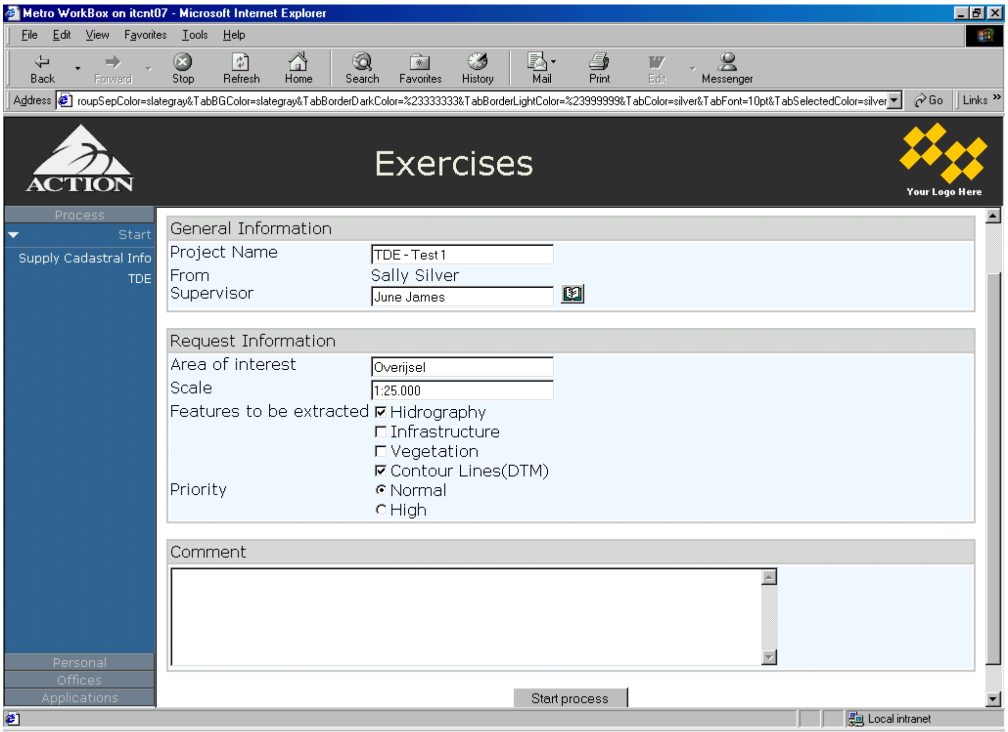

Figure D-4 Metro environment: Initial form to trigger the process

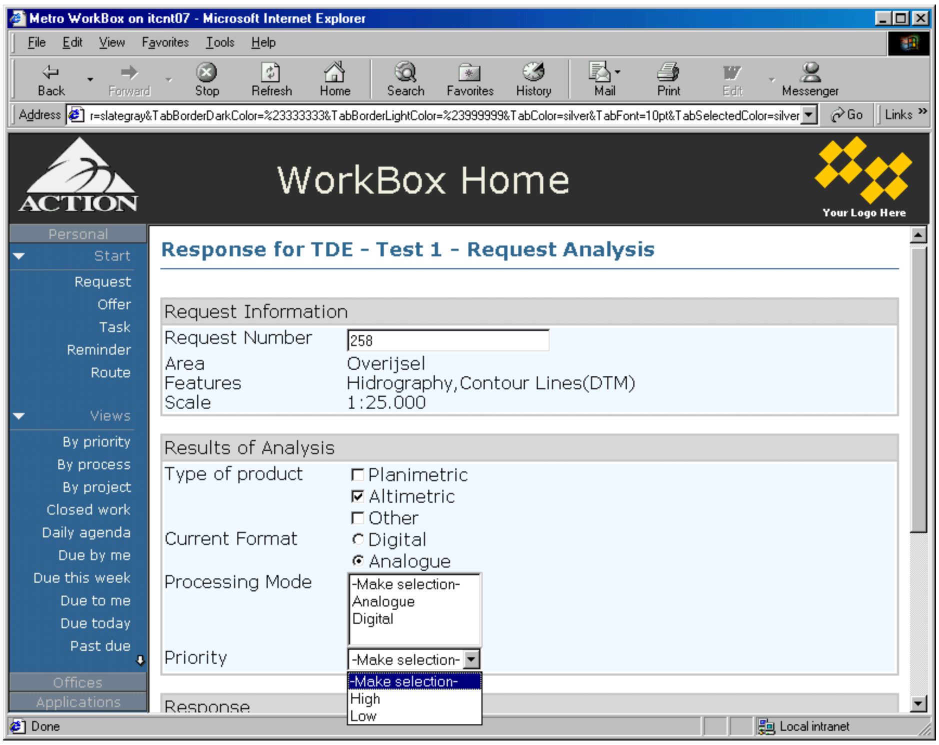

Figure D-5 Metro reply form for request analysis process

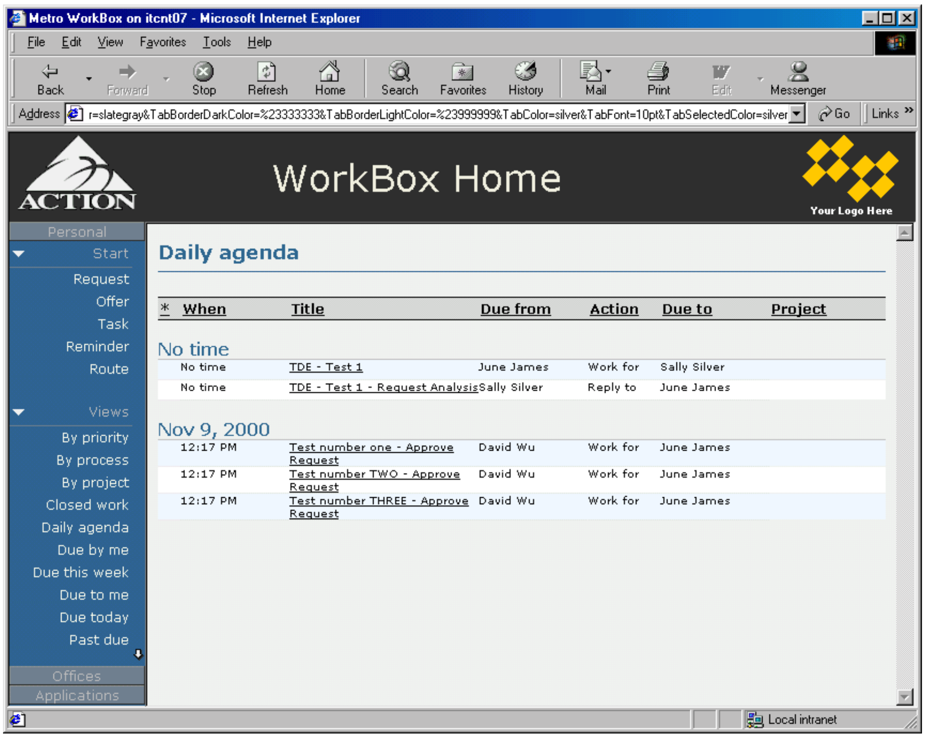

Figure D-6 The Work List

As mention before, the processes were not performed. The intention was to see the tools, and capabilities of a WFMS. The analysis of the process was done before in a performance study and the resulting model was translated to the communication approach and implemented.

D.3 Supply Cadastral Information Case

D.3.1 General Information

A cadastral organisation produces two types of information: Cadastral and Topographic. The production of cadastral information is the cadastre's core competency but also production of large-scale Topographic Map is done as a complementary activity.

Information is mainly requested by the regular customers (about 80% of cases) but is also available to the general public. Most regular customers have on-line access to the organisation's information; these are professional clients such as municipalities, provincial and national governments, notaries, utility companies, financial institutions and real estate agents. The ad-hoc customer (non-regular client) is normally a member of the general public who occasionally needs information regarding a current or potential property. This second category of customer obtains products via the counter service at cadastral municipalities' offices or through telephone, telefax or ordinary mail request.

D.3.2 Description of the Process

- The organisation receives customer request on standard form through the digital network, fax, phone, letter or through the counter.

- Analyse request to check customer's right of access to information. Then, if these checks are passed, generate product specification. The type of information is determined, i.e. whether cadastral or topographic. If the product is directly available and customer's financial account is reliable, initiate work order for product to customer.
- If the information requested is not available and cannot be acquired, the request is returned.
- If the information is available, it is necessary to determine whether it is in the cadastral registers or in other registers. The cadastral registers are those in the digital and updated database. The other registers are in analogue archives and/or on microfiches.
- Extract basic information from archives and/or databases.
- Prepare product according to specifications. Post-processing may be necessary to obtain the desired hardcopy or digital formats. Check product against order specification. Package product and prepare invoice. Update administrative/customer databases.
- Deliver product and invoice, if payment has not yet been made.
- Regular customers are invoiced via accounts that are paid periodically.
- If a non-regular customer made the request, the bill is made and paid at the counter, following product specification through normal mail. Upon receipt of payment, production continues. Payment must be received within a specified number of days, otherwise the work order is cancelled.

D.3.3 Results

D.3.3.1 Process Definition

A preliminary analysis of this process had been made to identify the processes. From these processes (technical and administrative) *Primary Workflow* and *secondary workflows* have been establish. The resulting Business Process Map can be seen in Figure D-6. In addition, the Business Process (BP) Roles are identified (a person, or a group). For this case, the following BP roles have been defined:

Table D-1 Descriptions of roles in the business process "Supply of Cadastral Information"

BP ROLE	DESCRIPTION
Client	Makes the request
Service Officer	Receives the request and delivers the final product after checking quality
Service Assistant	Approves request. (Checks availability of data and checks whether customer is allowed to get the data)
Secretary	Send letter to customer in case of reject request
Financial clerk	Prepares invoice and certifies that payment has been done
Assistant Cadastral Info Supply	Prepares cadastral product according to specifications. Extract info from digital database.
Assistant Topographic Info Supply	Prepares topographic product according to specifications. This could include tasks as extract the data, make layouts or rasterize.
Assistant Info Supply	Prepares cadastral product according to specifications. The retrieval is from analogue archives. Field sketch or digital reconstruction may be needed.

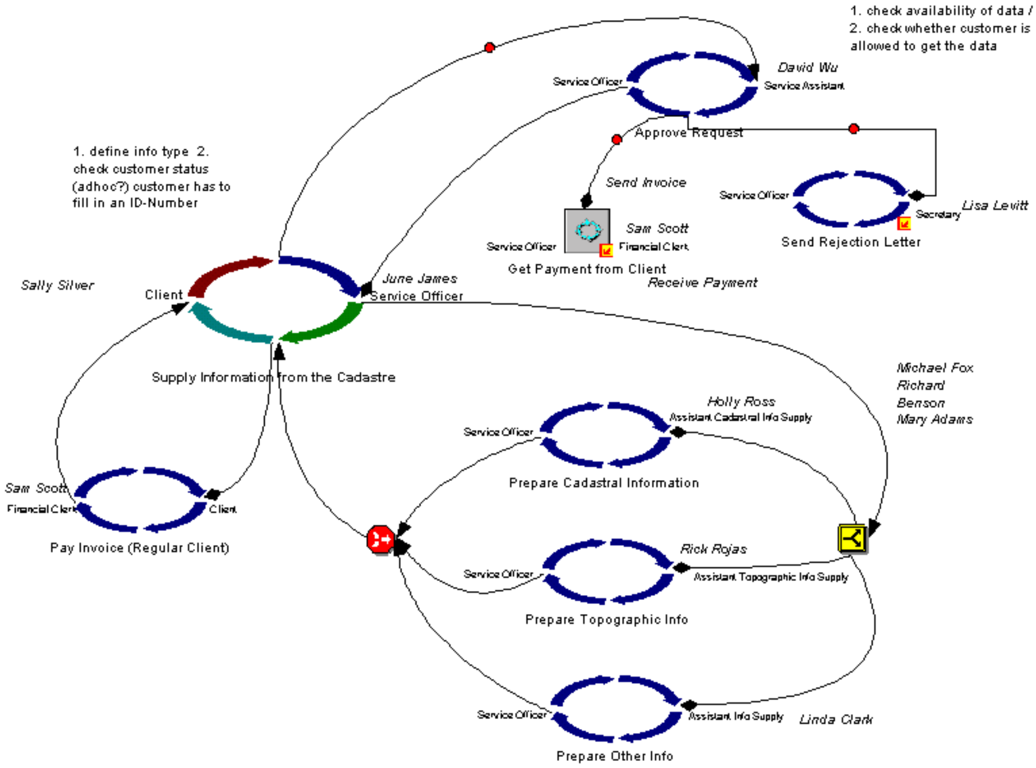

Figure D-7 Cadastral info supply business process map

D.3.3.2 Web application

As the previous case, the Business Process Map is checked by the software in terms of logic and consistency with the rules. Once this test is passed, the application is generated and can be installed in the Metro Server. The different business Process roles are translated into identities with names of persons or offices in charge of the work to be performed and/or reviewed.

Some of the screen shots presented to the process administrator and users can be seen in the figures below.

Figure D-7 shows the New Office window to create an office, define manager and role assignment as some of the options.

In Figure D-8, Business Process Roles, Organisational Roles, Offices and identities can be defined or modified for an installed Business Process.

The authorized users must submit name and password as shown in Figure D-9.

The reply form for the production processes (Cadastral, Topographic and Other) is shown if Figure D-10.

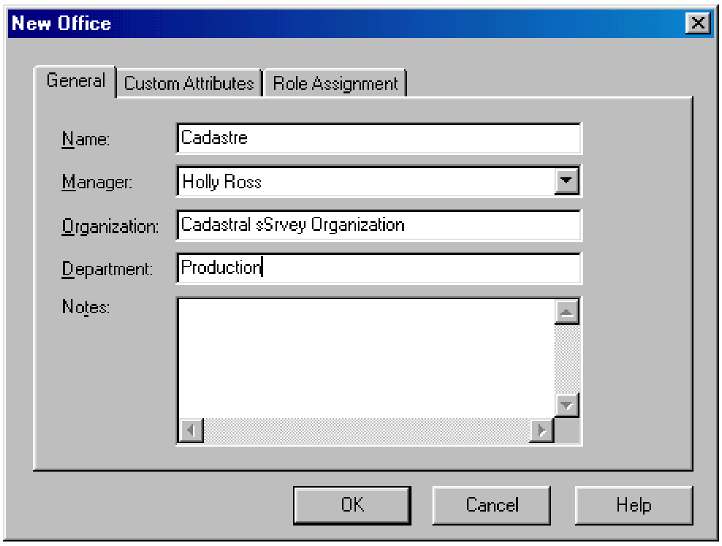

Figure D-8 Process administrator: New office creation

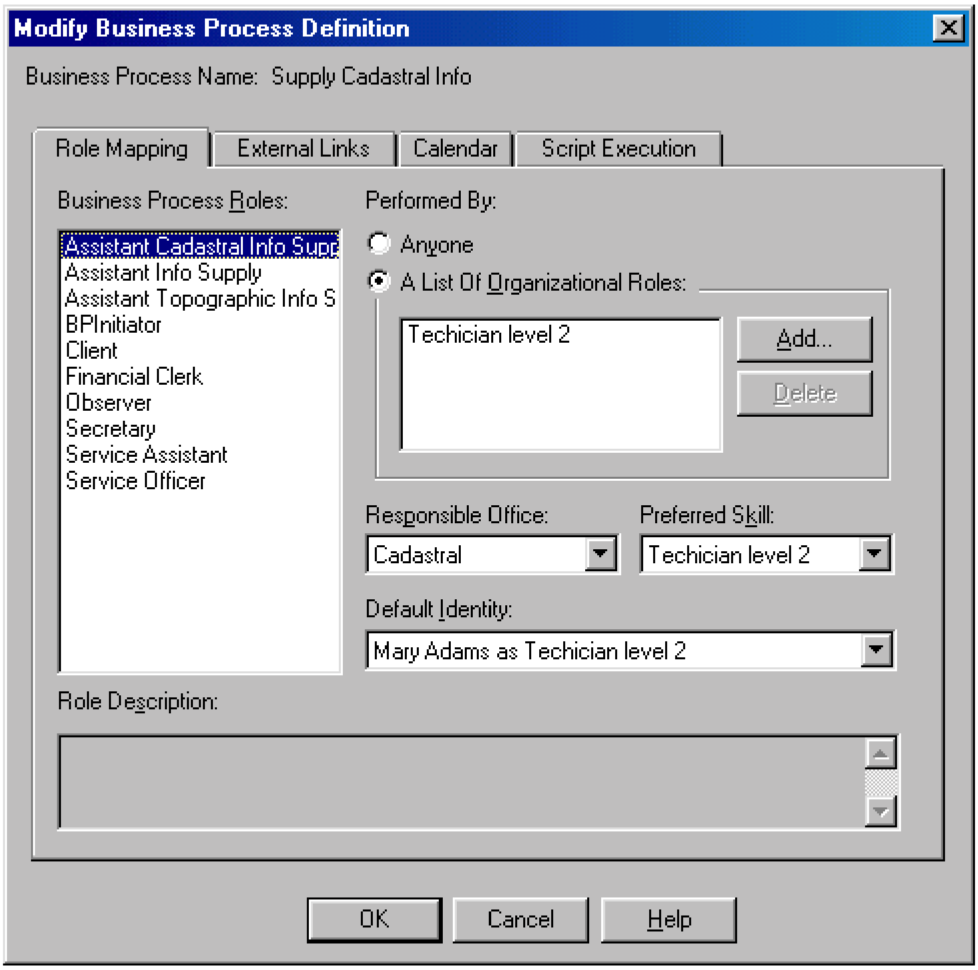

Figure D-9 Business process window

Figure D-10   Password (login) dialog box

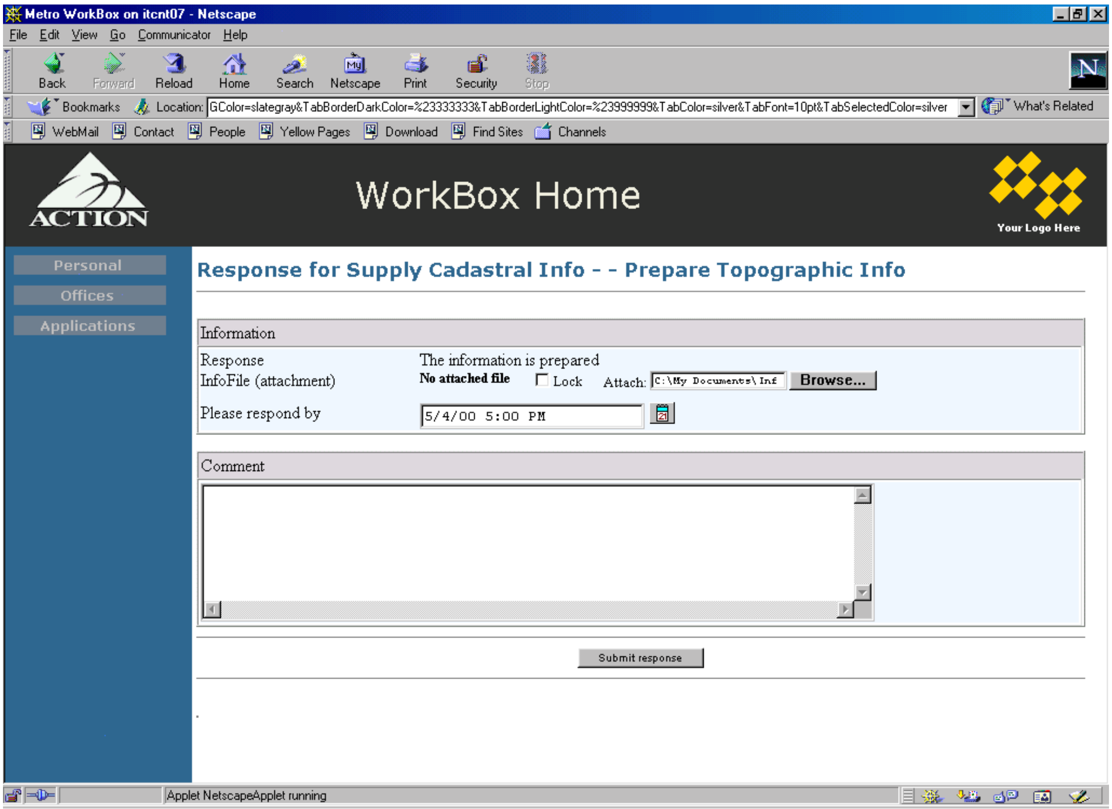

Figure D-11   Reply form for “Cadastral”, “Topographic” and “Other” processes

Appendix E: Process modelling with AMBER[2]

"A process model is an abstract representation of reality that excludes much of the world's infinite detail. The purpose of a model is to reduce the complexity of understanding….. a phenomenon by eliminating the detail that does not influence its relevant behavior." [*Curtis, Kellner, and Over, 1994*]. In other words, by creating a process model one can represent the aspects of interest of a process, and can eliminate the characteristics of it which are not relevant for the purpose of creating the model. Normally the process engineer based the need of a model in achieving the following goals:

- Understanding processes
- Reasoning about the processes
- Analyzing processes
- Comparing processes
- Evaluating processes
- Measuring processes
- Communicating and documenting the processes
- To aid design of processes
- To work out the requirements for Information Technology (IT) support for processes
- To incorporate management and simulation tools

For a model to be effectively used for communicating the characteristics of a process to the people interested or involved on it, it has to posses these properties:

- Precise enough to avoid confusion on what it means (preciseness);
- Simple enough or well-structured enough to be understood;
- Clearly related to the process that it models, such that it appeals to the intuitive understanding of those who have to use it.
-

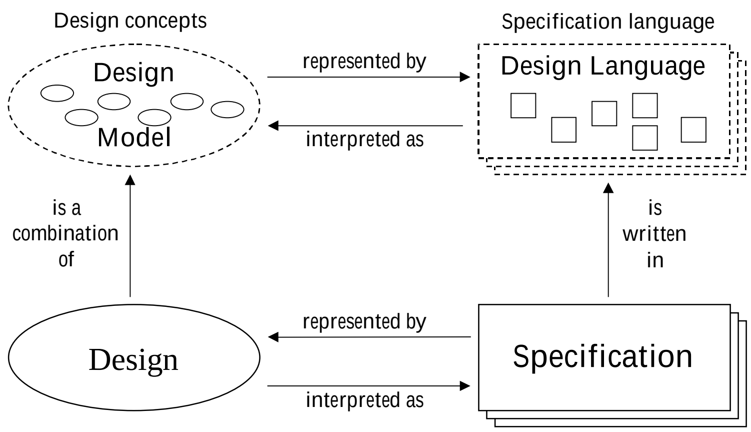

Figure E-1 Relations between a design and its specification

[2] Amber is business process modeling method developed at the Center of Telematics and Information Technology at the University of Twente (the netherlands) see references.

The model of a business process under development is a conceptual image of a process that exists in the mind of the designer. Such a model is called a *design*. When developing a design the designer combines abstractions of relevant aspects of the process; those abstractions are called *design concepts*. The set of design concepts together with their rules and constraints define a *design model*. Designs have to be developed, communicated and analyzed. A *design language* is a notation for *representing* designs. Such a representation can have the form of a document. A design representation should be understood by all people who intent to use the design, for one reason or another.

A *specification language* is a design language which includes some very important elements like its syntax (constructs and operators) and semantics (meaning). Those elements must be derived from the relevant design concepts of the area of concern, making the specification language of general purpose in its application area. The specification language is used to represent designs (models with a prescriptive character). A design representation of a business process written using a specification language is called a *specification*. All the relations between the terms used to when creating a model of a business process are shown in Figure E-1.

Summarizing, design concepts are used to create a design model of the required characteristics of a business process at a certain abstraction level. Because these conceptions have to be represented in an understandable way (to be transmitted for example), a specification language is necessary, as notation for representing the design model in a concise, complete and unambiguous way. The suitability of a specification language for creating specifications that represent a design depends on how faithfully its capability is for representing the design concepts used to develop the design model.

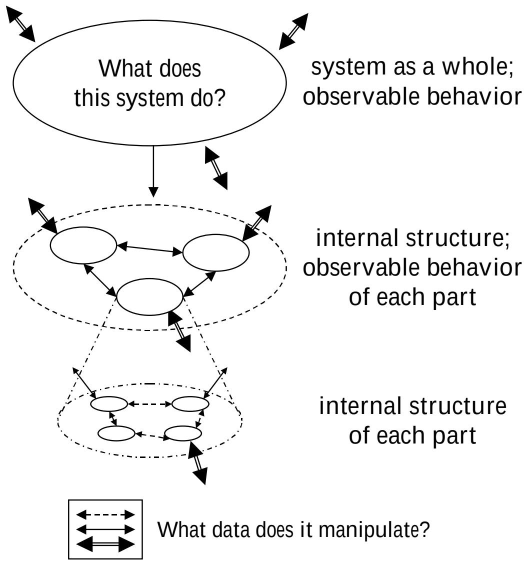

Figure E-2 Steps of the design methodology

Important in creating a model by abstraction of a process, is that the process engineer has to: 1) concentrate on the aspects that are relevant for the purpose of developing the model; and 2) to apply a method or to follow a systematic way of working to reach the objective (Figure E-2). It is important to mention that the techniques used for modeling processes, focus mainly on the behavior of the systems ("*what they do*"), and give less attention to the information or material handled by them ("*what they manipulate*").

The information presented above and in general in this section has been based in the concepts conceived by the Center of Telematic and Information Technology (CTIT) of the University of Twente (UT), in their "design model or architectural design for open distributed systems".

E.1 Entities

Entity is an abstract concept used to describe the identity of a process either existing or being built in the real world. Every process has certain characteristics that can be represented as characteristics of its corresponding entity, it means that an entity models the mechanism that carries the characteristics/properties of a process. An important feature about the entity concept is that it allows to reason about the process without worrying about its characteristics, however it is meaningless to talk about a process that has not characteristics or properties. This feature facilitates the task of the process engineer in identifying what has to be modeled as the entity and to abstract from it the characteristics valid for the purpose of the model under development. It means that the same entity can have different properties if it is located in models which focuses differ one from the other. Considering other terminology, synonyms of an entity are “object”, “unit” and “thing”

When designing a new business process, structuring it in terms of entities helps because the model can be used straightforward as a prescription for the implementation. For example, if activities have to be carried out by computers or people, those activities in the model should be structured such that the entities are defined by such properties, which makes easier to implement the model later in a workflow management engine.

E.1.1 Interaction points

For a process to have a reasonable meaning, it should interact with its environment. Then it is interesting for the purpose of modeling only if one has access to it and can do something with it. Interaction points are the locations (logical or physical) at which entities can interact with their environment. Two or more entities can only interact if they have one or more interaction points in common. Therefore, an interaction point models the mechanism used by entities in order to interact. The graphic representation of entities and their interaction points is shown in Figure E-3 (a) shows the normal representation, and (b) an alternative representation.

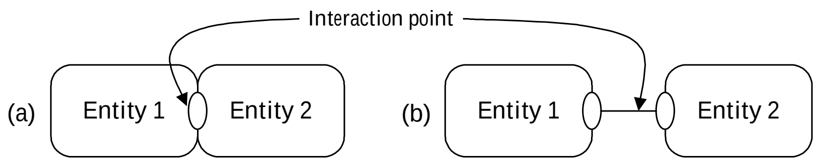

Figure D-3 Two entities with their interaction points

E.1.2 (De)Composition

It is important to be able to represent processes with the suitable degree of granularity. Process owners and managers need to see the overall pattern of the process without getting much involved in the details, however details are important when the objective of designing a process is to control it and to make it work efficiently. For this purpose design concepts allow to decompose an entity into its constituents. The resulting entities should be interconnected by means of interaction points that allow them to cooperate, besides the interaction points of the original entity should be kept to maintain the consistency of the overall diagram. When an entity is decomposed the resulting entities represent the internal structure of the original one, since the decomposition results in more details of the entity under consideration, it is normal to refer to this process as the refinement of the original entity.

E.2 Behaviour concepts

The behavior tries to model a particular process as an entity of its functionality (*what it does*). Behavior is represented for a collection of related activities, such that each activity is either performed by an entity alone, or by multiple entities in cooperation. The concepts that model these forms of activities and their relationships are the basic building blocks for defining behaviors.

E.2.1 Activities and actions

To perform activities is the essential purpose of processes: by performing activities, the processes do what they are conceived for. An example of an activity can be filling up an application form. Activities have a huge variety of examples in real-life considering the required expertise or machinery, complexity, time duration, etc. An *action* is an abstract concept introduced to model an activity performed by a process. Consequently, for the purpose of modeling, an action has to be assigned to the entity that represents the process under consideration. However, this understanding of an activity is not enough to define an action. In real-life a process performs an activity in order to reach a *result* (a *product*). In the case of the previous example, once the form has been filled up, the needs and the personal data of the client are known by the system. It means the aim of performing the activity has been obtained. This is the key for defining an action, it models the purpose and the most essential characteristics of any activity, its resulting product. The possible graphical representations of actions and their attributes that are described in the next paragraph are shown in Figure E-4.

Since actions do not always produce the same output as it changes according to the given conditions, there is a need of fully define an action. It is done using attributes to model its essential characteristics, like: the type of output, the time moment at which the product becomes available and the location where the product can be found. Therefore, an action has three attributes:

- The *information attribute* [ι], which models the product of an activity;
- The *time attribute* [λ], which models the time moment when an activity reaches its result;
- The *location attribute* [τ], which models the location at which the result of an activity is available.
-

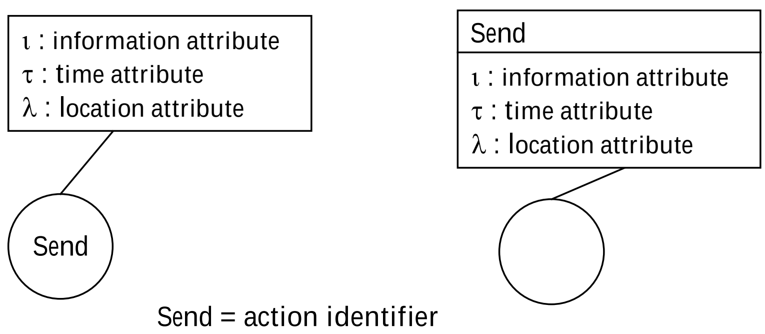

Figure E-3 Graphic representation of actions

For the output of an activity three possible alternative forms are taken into consideration: a concrete product (e.g. a map), information (e.g. data), or a delivered service (e.g. a georeferenced dataset). These different forms of products are modeled as values of the information attribute, and they are understood as "information on the product", conveyed in the information attribute of an action. An activity has fix or variable time duration but the output of it becomes available at a certain time moment. The time moment at which the activity finishes and its result is available is represented by the time attribute of the action that models the activity. As well as being available at a certain time moment, the output of an activity has to be available at a certain location and that location is represented by the location attribute of the action that models the activity. The three mentioned attributes represent the characteristics of an activity that are of interest to other activities once this activity has been successfully completed. In conclusion actions model *what* result is established in an activity, *when* and *where*, but not *how*.

E.2.2 Interactions

Some activities are executed by more than one entity in cooperation. For example when asking for a loan in the bank, the activity has to be performed by the bank agent and the client in cooperation, most probably a negotiation goes on until the two parties agree on the conditions (amount, payment form, etc.). For this type of situations the concept of interaction is introduced. It models an activity performed by two or more entities in cooperation. The concept of interaction is considered as the refinement of an action. It defines a specific distribution of the responsibility for performing the interaction over multiple entities. This implies that any rules for the use of the action concept also applies to the interaction concept. In Figure E-5 the diagrammatic way of representing interactions is shown.

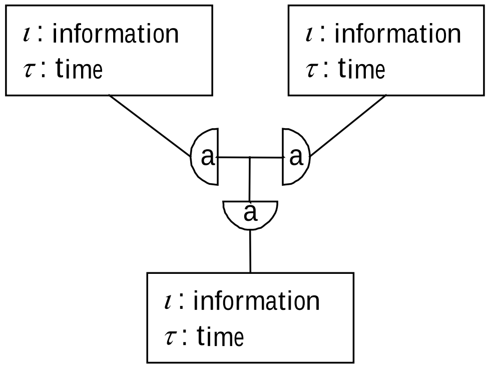

Figure E-4 Interaction representation

E.2.3 Relations

Once design concepts for the modeling of the activities happening within a process are defined, it is necessary to find design concepts to represent the relationships between the different activities. The occurrence of an action either depends on the satisfaction of a condition defined by a relation, or it can happen at any time from the beginning of a behavior execution (initial action). This is modeled using the concept of causality relation, it defines the condition of the occurrence of an action (result action) and it has some characteristics to consider:

- The *Causality condition* defines how the occurrence of an action depends on the occurrence or not of other actions.
- The *Action attribute constraints* define how the attribute's (time, location & information) values established by actions in the causality condition influence the occurrence of the result action and its attributes.
- The *Probability attribute* defines the likelihood of the occurrence of the result action in case that the causality condition and the action attribute constraints are satisfied in a behavior execution.

An action is only allowed to occur if the causality condition and the action attribute constraints defined in the relation of this action are satisfied. Since a behavior consists of one or more actions, causality conditions are used to model the relations between actions and a behavior can then be defined in terms of a set of causality relations of the actions belonging to that behavior.

The use of causality conditions allows modeling the temporal ordering of action occurrences. In reality, there are three possibilities of temporal ordering between two actions *a* and *b*, which happen at times τ_a and τ_b respectively: $\tau_a < \tau_b$, $\tau_a = \tau_b$ or $\tau_a > \tau_b$. They do not overlap each other, which means that if one of them holds for certain behavior execution, the other two do not hold, therefore the causality conditions of action *b* can be defined using basic causality conditions.

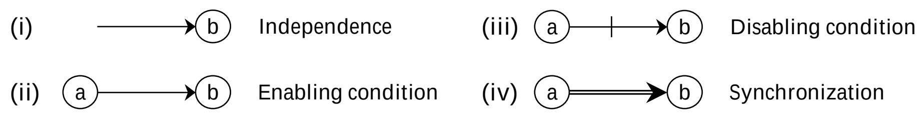

Figure E-5 Basic causality conditions of action *b*

In Figure E-6 the basic causality conditions are presented. They show that considering two actions *a* and *b*, the result of the behavior of action *a* is a condition for the occurrence of action *b* as follows: (i) Action *b* can occur at any time, no matter what is happening with other actions; (ii) Action *a* must occur before action *b* can occur; (iii) Action *a* must not occur before neither simultaneously with action *b* in order that action *b* can occur; (iv) Action *a* and action *b* must occur at the same time.

Although the satisfaction of a causality condition of an action allows the occurrence of this action, it does not guarantee that the action actually occurs. To handle this characteristic, the *Uncertainty attribute* is added to the action. It defines the probability of that an action occurs when its causality condition is fulfilled. Two occurrences are distinguished (Figure E-7):

- *must*, defines that the result action *will certainly* occur when the associated condition is satisfied (conditional probability = 100%), representation [!].
- *may,* defines that the result action *may or may not* occur when the associated condition is satisfied (conditional probability < 100%), representation [?].

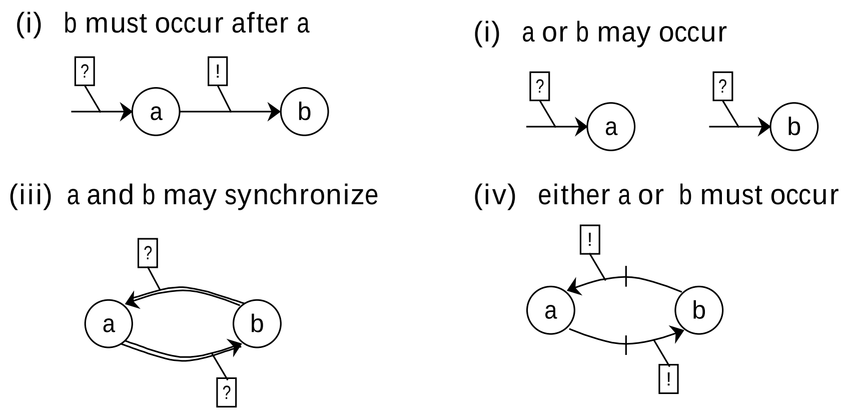

Figure E-6 Actions relations

Additionally to the design concepts mentioned above, and to finish the picture of the different representations of the possible behavioral events in a process, **Figure E-8** illustrates the composition rules of actions. (i) Shows the *conjunction condition* that represents that action *b* is the reassemble of the three previous actions, so, for action b to happen *a1*, *a2* and *a3* must have happened before. (ii) Shows the *alternative occurrence* so, for action a to occur, either action *b* or action *c* should happen before.

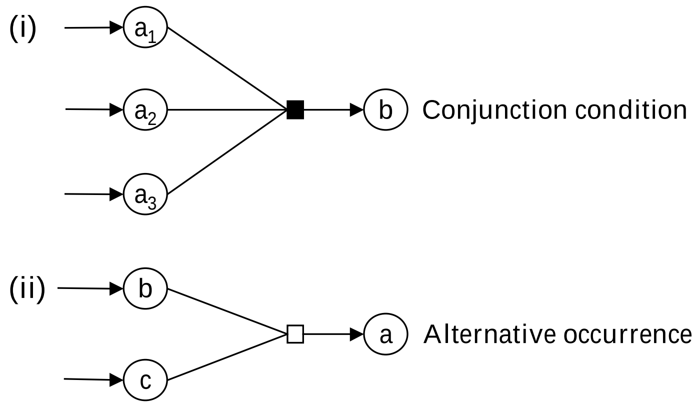

Figure E-7 Notation for conjunction and alternative occurrence of actions

E.2.4 Information, time and location attributes

A primary view of the use of the action's attributes was presented in Section D.2.1 where it was explained that these attributes allow to model the establishment of information, time and location values in action's occurrences. It means that the result of an action, the place where that result can be obtained and the time when it is available in the system can be stored in form of values. An extension of the application of the attributes presented now in order to model the establishment of information, time and location values to the dependencies between action occurrences better known as causality conditions.

The information attribute can be used to constrain the occurrence of an action in three different ways:

- defining the *information value domain* that models which values are allowed as result of the occurrence of action itself. It means that the universe of information values can be reduced to a certain range that represents the domain of the information values that an action can manage. Figure E-9 shows that actions *a* and *b* can only work with certain types of data structure [raster, vector] and [raster] respectively. It means that the relation between the two actions only allows one possible result which is a raster type of output, because action *b* only supports raster format although action *a* can produce either raster or vector formats.

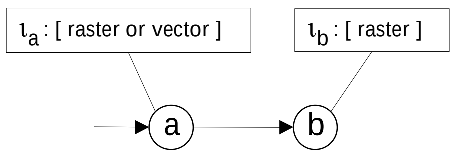

Figure E-8 Information value domains

- defining *information reference relations* that can be used to model how the information value of an action depends on the information value of its enabling action. It means that the possible values for the information attribute of action *b* are not independent, they are defined by conditions given to the result value of the information attribute of action *a*, as shown in Figure E-10. Or in other words action occurrence *b* refers to the information value of other actions. Figure E-10 illustrates that the information value of action *b* depends on the information value of action *a* such that the value of ι_b must be the value of ι_a in Tiff format.

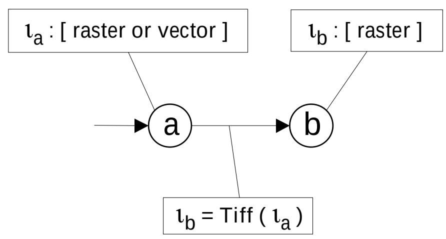

Figure E-9 Information reference relation

- or defining *information causality conditions* that models how a causality condition can be extended to define conditions on the information values of its enabling actions. The conditions establish on the causality conditions must be satisfied in order to allow the occurrence of the result action. Figure E-10 shows an example with two alternative causality conditions that enable action *a*, $(c \wedge d) \vee b$. So the information causality condition defines that "if $c \wedge d \rightarrow a$ then the condition of $\iota_a = \iota_d + \iota_c$ has to be satisfied" and "if $b \rightarrow a$ then the condition to be fulfilled is $\iota_a = \iota_b$ x 2". It also shows that not all the information values that are output of the enabling conditions of *a* are supported by *a*, so in case of $b \rightarrow a$ if $\iota_b > 3$ then action *a* can not occur because the output of the causality condition $\iota_a = \iota_b$ x 2 gives a value that lies out of the information domain of action *a* [3..7].

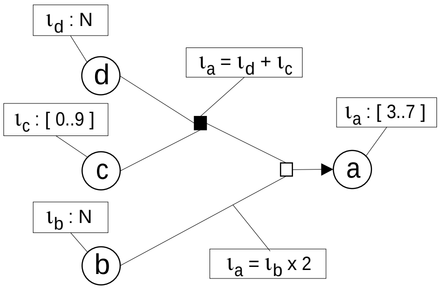

Figure E-10 Information causality conditions

The same kind of extension shown to the information attribute can be applied to the time and location attributes. Examples on the use of the attributes are presented in section 5.3 where some models are presented.

The above mentioned capabilities of the information, time and location attribute together with the uncertainty attribute represent a powerful tool to model and possibly control the instability, variability and fuzziness of the behavior of the geoinformation processes. The cases where even having a proper well defined workflow of activities to create a product, a satisfactory output can not be guarantee (like when working with remotely sensed data), may be controlled identifying the possible causes of variability and modeling them applying conditions on the values of the information, time and location attributes that model the output of an activity.

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