A METHODOLOGY FOR ARCHITECTURAL MODELLING OF SPATIAL INFORMATION PRODUCTION PROCESSES IN THE CONTEXT OF BUSINESS PROCESS REINGENEERING

Javier MORALES*, Mostafa RADWAN, Rosilah SANI
*Instituto Geográfico Agustin Codazzi, Colombia
jmorales@itc.nl
International Institute for Aerospace Survey and Earth Sciences, the Netherlands
radwan@itc.nl, sani@itc.nl

Inter-Technical Comission IC8

KEY WORDS: Architectural Modelling, BPR, Modelling, Process, Process Modelling, System Architecture, System Design, Spatial Information Production, Geoinformation.

ABSTRACT

Many Spatial Information Production (SIP) Organizations around the world are under pressure to assess their capabilities from the business perspective. Several Business Process Reengineering (BPR) projects are initiated to facilitate their adaptation to changing requirements in the global information market, with a focus on the effective use of Information Technology. Several methodologies and commercial modelling tools are now available to help the process engineer analyze the behavior of real systems and its business processes. Describing the process by means of models is essential to predict the consequences of new design options. This paper presents steps for the design of a methodology for appropiate use of an architectural modelling technique which describes processes as sets of activities and interactions with conditions of occurrence at any moment in time. The modelling technique is used as a base for performance study and reengineering of spatial information production processes, as demonstrated in two research projects.

1 INTRODUCTION

Most of the Spatial Information Production (SIP) Organisations in the world are governmental bodies, usually called National Mapping Agencies (NMA), which 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. Nowadays, NMA's are facing many challenges concerning the fast developing GIS-market and the threat of new competitors who have a flexible approach to adapt to changing requirements and continuous development in information technology. In many countries NMA's are under the pressure of having to generate revenue and revise their mission to a business perspective and to be competitive, without violating its national mandate. NMA's should produce the foundation data for the GIS community and deliver diverse and customised products to the customer in time, at affordable costs, with the required quality to the customer's specifications. To accomplish this they also need to develop the necessary infrastructure to facilitate access to their databases.

The introduction of Information Technology (IT) and modern mapping systems can facilitate the introduction of new and more effective organisational design options. IT as enabler, however, means more than simply automating existing tasks. It means an innovative response to technology in ways that would not have been possible without that technology.

Several projects are initiated in a number of NMA's to assess their capabilities from a business perspective, identify performance problems and improvement goals, and develop plans for change with focus on the effective use of IT. 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, Workflow Management (WFM), Total Quality Management (TQM). BPR is defined as 'the radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance, such as quality, service diversity and speed'. Researchers have developed several methodologies, which provide techniques for organisations to examine existing procedures and reengineer its business processes, and to develop an organised approach for the implementation of change as suggested by the BPR plan.

In studying a process and seeking ways to improve it, one can come up with many alternatives, possibly involving changes in the standard procedures as well as incorporating a variety of features in order to support its accessibility to new environments. Any proposal for change, however, should be assessed for what strategic business advantages they offer and what support they can give to the execution of the business practices. Several commercially available modelling and simulation tools help the process engineer to systematically pursue design goals, representing, analysing and describing the process by means of models and quantifying the consequences of new design options.

The concept of BPR is yet to be adequately assessed for application in the spatial information production environment. The objective of current research activities at ITC is to investigate ways to strengthen the competitive power of Spatial information production organisations and improve its performance, through BPR, emphasising:

- Development of a methodology for undertaking BPR in NMA.
- Development of models to quantitatively evaluate the impact of BPR practices at both organisational and operational levels in NMA
- Application of modelling techniques to describe processes and their dynamic behaviours
- Definition of parameters or criteria for evaluating change scenarios and performance of processes using simulation techniques
- Use of commercially available tools for modelling, simulation and the management of workflow.

This paper focuses on the investigation and design of a methodology for architectural modelling of spatial information production processes, using cases from practice.

2 ARCHITECTURAL MODELLING APPROACH

2.1 The significance of modelling

Given the opportunity, people in spatial information production usually work out their own adaptable features to solve a problem in their particular application domain, thinking that, when all the pieces are put together later on, they will somehow fit and work. As a result many visions of organizational solutions are developed, resulting in incompatible pieces of work that are very difficult to integrate.

An architectural modelling approach to spatial information production is meant to provide a consistent unified vision that clearly describes the organization: where it is and where it is going to be in the future. That approach is used as the basis from which production lines and applications are developed. This is a very effective strategy for deploying critical projects and applications that must coexist with other systems within the organisation for a long period of time. Architectural models supply the framework for defining how applications, processes and subsystems interact to meet the organisation's business needs. This leads everyone within the organisation to understand the environment in which his or her particular business component will exist.

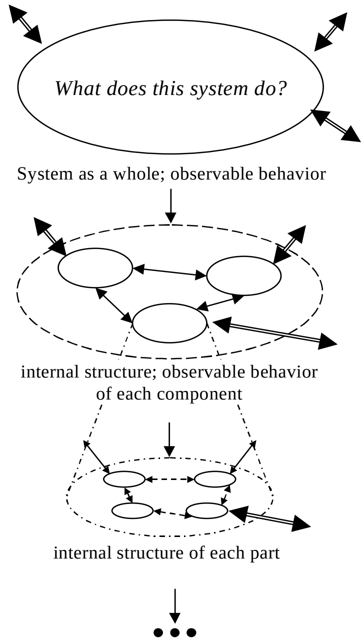

Figure 1. Steps in top-down design

Taking into account the aspects mentioned before, and using the background of many techniques for modelling and for system analysis and design, it is possible to depict a general structured organisational decomposition in a top-down fashion through various stages (Figure 1). In the first stage (at the highest level), models are used to describe the organisation and its external environment; they increase understanding of how the organisation fits into the world around it. This external perspective of a system describes its observable behaviour and shows its functionality, purpose and services to possible users. This level of modelling is very important for the monitoring of new requirements from customers, new legislations and even actions of the competition. In the second stage, models take the description of the organisation one step forward and identify the high-level deliverables: either products or reusable components, their interactions and interfaces. These are the components that support the high-level requirements of the organisation. This description should then provide the internal structure of the system and the observable behaviour of each of its components. Considering an organisation as a system, the recursive notion of system implies that this decomposition continues until we arrive at the lowest level at which components can be identified. This level is reached when the components are sufficiently identified for the purpose of the modelling in each particular case.

An extra dimension that is closely coupled with some of the levels of the model focuses on the technology that will support the organisation's activities. Since spatial information production is a technology-driven field, we need to take into consideration the technological needs of the organisation, and the technological constraints imposed by the particular working environment.

In the case of spatial information production organisations, a high degree of accuracy in process models is required. One reason is that process models could be used to optimise processes or production lines that have been undergoing improvements based on theoretical analysis and technical experience for several decades. It could also be argued that the need for modelling increases when organisations move to a higher degree of integration with a greatly increasing number of interacting components. This is a particular on-going situation in spatial information production and maintenance. An architectural modelling approach could therefore be an effective mechanism for humans to deal with the complexity of the systems they are trying to describe.

2.2 Processes and Process Modelling

In the context of this paper, a process is considered as a set of transformation steps or activities that convert raw data into meaningful (spatial information) products. Process modelling is then the representation of the activities, functions and processes that a system performs upon data that has been defined in an appropriate data model.

2.3 Why model a system?

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 analysed. 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.

This paper intends to incorporate both static and dynamic aspects of the system into the modelling technique. 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). Further developments on system modelling are expected from this research.

2.4 Why model a SIP system?

Spatial information production is a complex and expensive venture, and so are the processes involved. As global markets evolve, companies are using IT to deliver better service and improve their business. But business design is a big challenge for most SIP organisations, especially for National Mapping Agencies (NMAs), because of the complexity of their organisations. Moreover this change inertia is occurring because new infrastructures for geo-processing and business computing have become available. If business design is accompanied by the implementation of a new software system, the task becomes more complex since highly integrated applications would radically affect business processes. Without having a clear understanding of the organisation's processes, it is harder to implement change. The starting point must be the identification and definition of the goals of the SIP systems:

- What products and services are generated and delivered by the organisation?
- How can these products and services be described in terms of their structure, specifications and requirements?
- Which processes are needed to generate the different products and services?

The answers to these questions are fundamental to start the design of a business-driven approach for managing spatial information. For example, as a first global inspection of NMA's production systems, we observe that their SIP is based and supported by Geographic Information Systems (GISs). The main purposes of these supportive GISs are, firstly, to store geographic data that can be easily retrieved at will, and secondly, to facilitate the production of value-added information. A quality value-added product distinguishes the progressive organisation in today's market. Devising what this value-added product should be, and how to optimise its production, is where organisational and business models can be used. This paper stresses the need for a structured methodology for the management of SIP systems by analysing the production system and providing architectural concepts to aid in the design and analysis of the processes executed by SIP systems.

There are two important issues that must be addressed to obtain a clear definition of the processes involved in SIP systems: the requirements necessary to specify processes, and the primitive concepts that are intrinsic to any process definition independent of why the process is being defined. These help in delimiting the study and defining the basis for the evaluation of the spatial information business processes. The evaluation will assess the value and capability of the processes according to properties such as Accuracy, Reliability and Scalability.

- *Accuracy* is the degree to which the output of a process matches the expected result.
- *Reliability* relates to the faithfulness with which a defined process is followed.
- *Scalability* concerns with the range of workload that the processes can accommodate.

3 A PROCESS DESIGN MODEL

"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, 94]. By creating a process model one can represent the aspects of interest of a process, and eliminate characteristics which are not relevant to the purpose of creating the model. Typically, process models serve the following purposes: -

- Understanding processes

- Reasoning about the processes
- Analysing 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

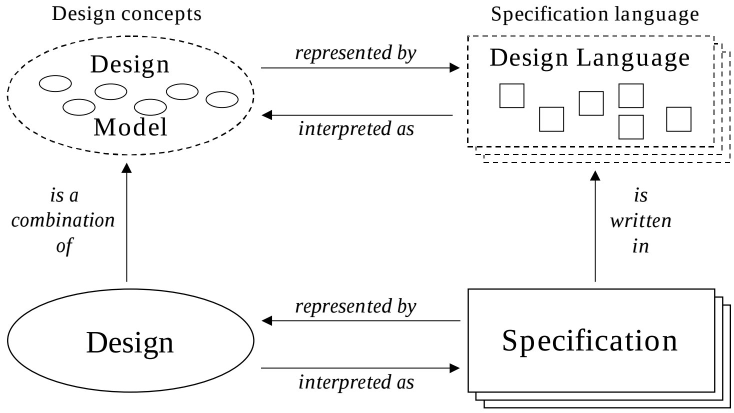

Figure 2. Relations between a design and its specification

This paper builds upon a design model conceived by the Architectural Group of the Center of Telematic and Information Technology (CTIT) at the University of Twente (UT), in their “Architectural design of distributed systems”. The core concepts introduced in that modelling approach are mentioned here.

For a model to be effectively used for communication, 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.

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 must be understood by all people who intend to use the design.

A *specification language* is a design language which includes important elements like its syntax (constructs and operators) and semantics (meaning). 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 relationships between the terms used when creating a model of a business process are shown in Figure 2.

Hence, 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 for representing the design model in a concise, complete and unambiguous way. The suitability of a specification language for creating specifications depends on its capability to faithfully represent the design concepts used to develop the design model.

It is important to mention that the technique described here focus mainly on the behavior of the systems (“*what they do*”), and less on the information or material handled by them (“*what they manipulate*”). In this paper, we introduce the fundamental elements of the architectural framework, which is fully described in Ferreira Pires (1994).

The concepts of *entity* and *behaviour* are introduced to model two distinct aspects of a system. An entity models the identity (existence) of a certain system or system part, while its behaviour models what the system or system part actually does (its functionality). An *action* is an abstract concept introduced to model an activity performed by a process. A system performs an activity in order to reach a *result* (a *product*). Some activities are executed by more than one entity in cooperation. For these 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.

Once design concepts for the modeling of the activities happening within a system 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). The *Causality condition* therefore defines how the occurrence of an action depends on the occurrence or not of other actions.

4 DESIGN OF THE METHODOLOGY

In order to develop a consistent and structured methodology for architectural modelling in Spatial Information Production (SIP) organisations, some steps are to be followed. These are the activities needed to identify all the requirements for modelling SIP processes, to find an optimum way for their representation, and finally a practical way of implementing them for various purposes like: system design, process optimisation, performance analysis, business process redesign or reengineering, etc. The procedure to be followed for the development of such a methodology is presented in Figure 3.

- Strategic evaluation of SIP systems: environmental scanning and evaluating existing goals, mission and strategies.
- Identification of the requirements necessary for modelling SIP processes by analysing applications, production plans and systems, and workflows. The results should provide information about sequences, data requirements, resources, duration and time, locations, measurable attributes, possible abstractions (semantic & ontology), etc. These findings are used to generate process representations for BPR, simulation, product and/or service planning and realisation, and workflow management.
- Description of the organisation as a system to support the conception, representation and implementation of its functionality. Description of the SIP system in terms of activities, triggers, resources and information used.
- Analysis of the suitability of existing process structuring techniques, to support the description of the SIP system at various abstraction levels of hierarchy. Analysis of the applicability of these techniques in a methodology supported by available technology in spatial information production.
- Definition of a structuring technique using object oriented concepts, based on the results of the previous steps. This technique should help in identifying and representing the fundamental aspects of the SIP processes by means of architectural concepts;
- Evaluation and categorisation of processes by their properties, such as: accuracy, fitness, maintainability, redundancy, performance, etc. This should assure their suitability for being incorporated in an specific place within the overall process;
- Modelling of a SIP system for optimised management. This optimisation will result in versatile use of processes to assure the highest provision of SIP services, and to ease the generation and evaluation of new design options.
- Evaluation of results and provision of recommendations.

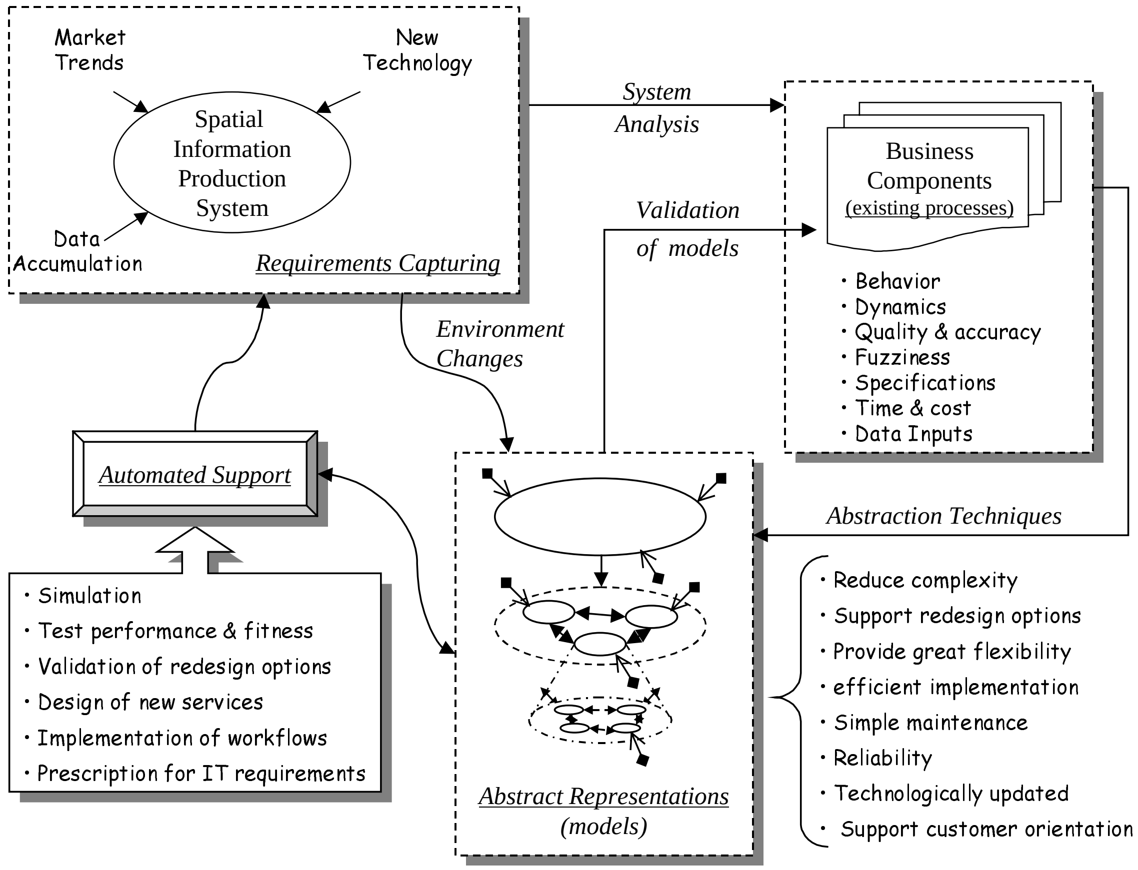

Figure 3. Steps for designing a modelling methodology for SIP

Applying such a methodology to SIP, we can expect to increase the responsiveness of the production system to changes in market, information and technology, which will increase the competitive power of SIP organisations. This topic is currently the subject of an undergoing Ph.D. research at ITC "Architectural Modelling of SIP Systems by J.M. Morales"

5 ARCHITECTURAL MODEL OF A SPATIAL INFORMATION BUSINESS PROCESS

To-date, research at ITC has addressed a number of the above design steps separately or the process modelling tools and techniques used. Karioki (1999) proposed a methodology for reengineering organisations that encompassed environmental scanning, strategic planning, and process definition. One of the architectural models he developed to demonstrate a typical core business in SIP is "soils, geology and land suitability data (thematic data) processing". (Figure 4).

The architectural model defines the causality relations between all activities within this process. For example, activity "F" **Feature Extraction** is enabled only if the data required for the job is available in digital form. Otherwise, activity "C" **Scanning** is first enabled then followed automatically by **vectorising** and **noise removal**.

The model also demonstrates the notion of *abstract representation* in a top-down design approach. **Scanning** is a process in its own right and can be further decomposed at a more detailed abstraction level to determine, say, the utilisation of various scanning resources for conversion of non-digital thematic maps.

The strategic direction of a SIP organisation defines its enterprise-wide goals, which impact the operational targets of its business processes. These targets are often measured in terms of performance parameters such as response time, resource utilisation, and product quality. In a collaborative research project between ITC and the University of Twente to investigate the effects of parameter changes on the behaviour of a system's performance model, the process metadata of the above model was further enhanced by Ganzevles (1999). Table 1 represents a number of metadata types required to optimise production of spatial information according to the measure of "processing time". In this research, an object-oriented simulator was used to analyse the effects of changes on production performance.

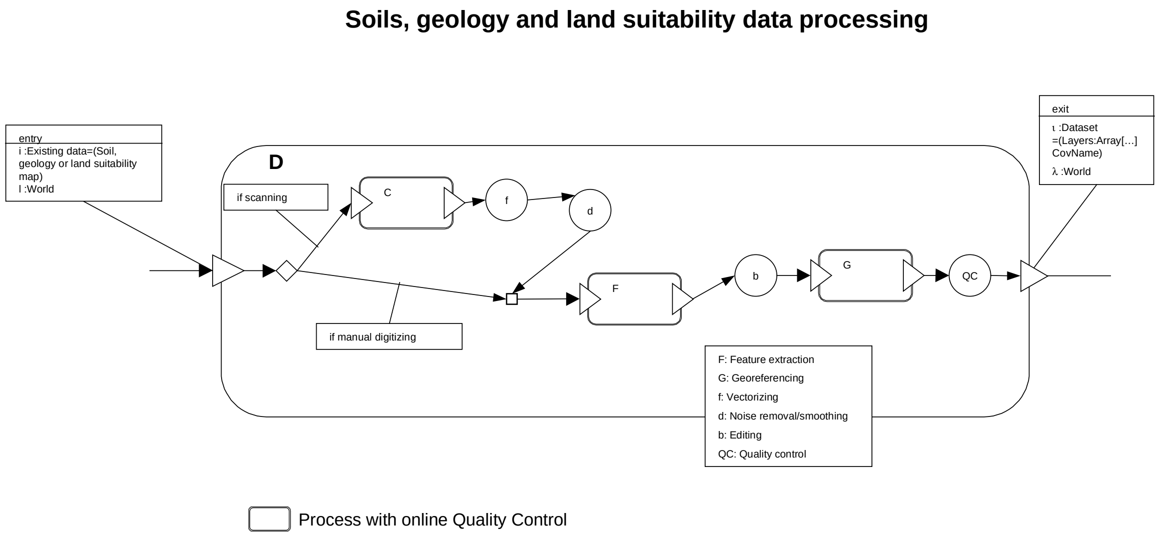

Figure 4. Process defnition using architectural modelling technique

6 CONCLUDING REMARKS

Architectural modelling can be used as an adaptive and comprehensive method to overcome a number of limitations in designing SIP systems, to reinforce a direct move of SIP organisations towards a more effective and profitable business. Business process modelling, when properly applied, has proven its contribution in streamlining system development, systems integration and interoperability, component reusability and reduction in maintenance and upgrading cost, which would be an encouraging environment for spatial information producers to work in. A key point in architectural modelling is that its effective execution depends, to a large extent, upon the correct focus given to the purpose of the models. This approach is more appropriate for an enterprise-wide business improvement project; a total system perspective is essential for a successful effort.

REFERENCES

Ambler S. W., 1998. Building Object Applications that Work, Cambridge University Press, England.

Armistead, C. and Rowland, P. 1996. Managing Business Process: BPR and Beyond, John Wiley & Sons, Inc., Chichester, England. ISBN 0-471-95490-X.

Ferreira Pires L., 1994. Architectural Notes: a Framework for Distributed Systems Development, Ph.D. Thesis, Centre for Telematics and Information Technology (CTIT), University of Twente, the Netherlands.

Ganzevles J.H., 1999. Simple++ simulation of a business process for performance analysis, Project Report for the International Institute for Aerospace Survey and Earth Sciences (ITC) and University of Twente, The Netherlands.

Grimshaw D.J., 1994. Bringing Geographic Information Systems into Business, Geoinformation International, Cambridge, United Kingdom. ISBN 0-470-23426-1.

Hawryszkiewycz I., 1997. Systems Analysis and Design: 4th edition, Pretince Hall, Australia. ISBN 013-896887-X.

Hunger J.D., Wheelem T.L. 1997. Essentials of Strategic Management, Addison-Wesley, ISBN 0-201-42186-0.

Karioki J. 1999. A Structured Methodology and Implementation Strategy for Business Process Reengineering in Geo-information Production, MSc. Thesis, the International Institute for Aerospace Survey and Earth Sciences (ITC), The Netherlands.

Keisler C. 1973. Model Theory, North-Holland Publishing Company, the Netherlands. ISBN 0-7204-2273-6.

Laudon K.C., Laudon J.P., 1995. Essentials of Management Information Systems: Organization and Technology, Prentice-Hall International, Inc., United States of America. ISBN 013-320136-8.

Quartel D.,1997. Actions relations: Basic design concepts for behaviour modelling and refinement, Ph.D. Thesis, Centre for Telematics and Information Technology (CTIT), University of Twente, the Netherlands.

Riggs J.L., 1987. Production Systems: planning, analysis and control, John Wiley & Sons, Inc., New York, United States of America. ISBN 0-471-85888-9.

Sinderen M.J. van, 1995. On the Design of Application Protocols, Ph.D. Thesis, Centre for Telematics and Information Technology (CTIT), University of Twente, the Netherlands.

Taylor D.A., 1995. Business Engineering with Object Technology, John Wiley & Sons, Inc., New York, United States of America. ISBN 0-471-04521-7.

Vissers C.A., Ferreira Pires L., Quartel D.A.C., and Sinderen M.J. van, 1998. The architectural design of distributed systems: Reader for the Design of Telematic Systems, University of Twente, the Netherlands.

Weger M. de, 1998. Structuring of Business Processes: An architectural approach to distributed systems development and its application to business processes, Ph.D. Thesis, Centre for Telematics and Information Technology (CTIT), University of Twente, Enschede, the Netherlands.

Table 1. Example of process metadata for analysis of SIP processing time based on a request for a map of 60×80 cm.

Code	Activity name	Description of activity	Spread in processing time	Lower bound - Upper bound	Average processing time
"D" Soils, Geology and Land Suitability data processing					
b	Editing	The layers that result after the feature extraction process require some editing before undergoing further processing. The editing step includes various checking techniques (batch or interactive) that ensure a smooth data set. A thorough search through the different layers should be done, eliminating over/undershoots, gaps and any other missing or redundant information that prevents the consistency of the information.	much *spread quite high since several sub-processes are involved which can cause a certain spread*	8 – 40h	24h
D	Noise removal	After the scanning process the resulting image normally has some kind of noise. Noise has to be removed to improve the quality of the image and the products obtained later from it.	much *the more noise there is, the higher the processing time will be*	1 – 8h	4h
F	Vectorising	This action converts a raster file into vector representation of the data. The vector data **may** then undergo editing processes to ensure topological consistency.	medium *because of the 'may'*	2 – 12h	8h
QC	Quality control	The quality of the data that is used in any GIS is very important since it determines the success of the potential products. During the processing of the input data for the Information System there are **several factors** that will be constantly monitored and controlled (Lineage, Positional accuracy, Attribute accuracy, Completeness, Logical consistency, Currentness etc). Besides this, there are many specific activities that implicitly have a quality assessment. That helps to ensure a high quality product and avoid having to repeat previous activities.	little *the number of factors to be monitored is constant, but the monitoring of each factor has a certain spread*	3 – 5h	4h