
**The Application of the Unified Modelling
Language and Soft Systems Methodology for
Modelling the Production Process in an
Aluminium Plant**

by

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Abstract

This research explores the combined use of soft systems methodology (SSM) and UML based business process modelling (BPM) techniques. These two techniques are integrated to provide a framework for the analysis and definition of suitable business process models. Such integration better supports developers following object-oriented (OO) approaches than traditional business process modelling.

The thesis describes the importance and difficulties in getting development projects aimed at the correct needs. We provide an overview of current business process modelling practices. From this it is argued that current practices show two major weaknesses. Firstly, the modelling language that is used is not a current standard amongst developers who now expect OO and UML based approaches. Secondly, the techniques used do not emphasise analysis, often resulting in a lack of appreciation of the problem. In order to deal with these inadequacies, the thesis critically examines suitable techniques that can be used to analyse and model business processes to support the developer's requirements. The examination of SSM reveals that the technique does deal with the analysis limitations of current business process modelling techniques. SSM has been linked to information systems provision by previous researchers. Unfortunately the examination of these research attempts shows that the linking is conducted in an ad-hoc manner with no underlying theoretical basis or emphasis on business process modelling. We show how soft systems methodology techniques can be married with Eriksson and Penker (2000) UML business process modelling techniques following Mingers (2001) multi-methodology framework in a way that can overcome these difficulties. This combined business analysis and modelling technique is applied to the production process in an aluminium rolling plant. Based on the experiences at one site, the integrated approach is able to deal with the complexities caused by multiple stakeholders, and is able to provide a UML representation of the required business process to guide developers.

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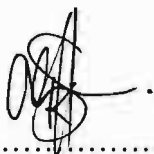
The management of Hulett Aluminium for allowing me the research opportunity.

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DECLARATION

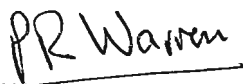
I hereby certify that this research is the result of my own investigation, which has not already been accepted in substance for any degree and is not being submitted in candidature for any other degree.



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LIST OF ABBREVIATIONS

BPM	Business Process Modelling
BM	Business Modelling
BPR	Business Process Re-engineering
CBD	Component Based Development
CIV	Critical Input Variable
COV	Critical Output Variable
DFD	Data Flow Diagram
ERP	Enterprise Resource Planning
IS	Information Systems
OO	Object Oriented
OOAD	Object Oriented Analysis and Design
OOSE	Object Oriented Software Engineering
OMG	Object Management Group
OR	Operations Research
PCV	Process Control Variable
SOP	Standard Operating Procedure
SSM	Soft Systems Methodology
TQM	Total Quality Management
UML	Unified Modelling Language

CHAPTER 1 Introduction

1.1 Introduction to Business Process Modelling

Probably the most significant factor affecting the successful delivery of a software project is the correct definition and communication of the needs that have to be satisfied. Business process analysis and modelling is the primary mechanism responsible for defining and communicating the needs to which software projects owe their existence.

The 1990's have witnessed the rise of business process approaches to information systems development. Over the entire decade there has been a series of initiatives, innovations and technologies at the heart of which is the concept of a business process. We have seen the advent of business process re-engineering (BPR) (Hammer and Champy, 1993:1-20), popularisation of workflow and enterprise resource planning (ERP) (Kumar and Hillegersberg, 2000:23-25). All these initiatives somehow indicate that it is now widely accepted that the business process is central to organisational change and IT development initiatives. In other words the business process serves as the unit of design and the unit of evaluation in change programs. A fundamental activity of all these process-improvement initiatives is business analysis and modelling.

Business engineering is the analysis, specification, and modelling of business processes with associated resources (Eriksson and Penker, 2000:6). The basic structure of a business process is a combination of business logic, organisational structures and information technology resources. The objective of business modelling is to derive a set of documents that describe the current operation of the company and the intended operation of the company (Eriksson and Penker, 2000:4). Information technology has become a crucial enabler of business process designs. Changing the way a business works these days literally means changing the underlying information systems (Boar, 2001:11). An emerging approach is to use the business process model, not only as a method, but also as an instrument that is able to support various methods in the analysis, design, implementation and evolution of information systems. Used in this way, process modelling appears to be central to the business-engineering life cycle as a whole,

embracing analysis, design, implementation, maintenance and evolution (Weston, 1999:843).

Business analysts perform process modelling activities. The business modelling approaches used by business analysts originated during the structured analysis and design era (Bond, 1999:165-166). Unfortunately the artefacts generated during the process modelling activities cannot be readily used to support an object oriented (OO) or component based development (CBD) process (Jacobson *et al.*, 1999:15-31).

The unified rational process developed by the object management group (OMG) has emerged as the de-facto standard for developing, commissioning and maintaining software. This process approach to developing and maintaining software developed in the OO paradigm is a model driven process where the analysis model becomes the design model through a process of refinement. To arrive at an integrated approach to developing and maintaining object-oriented systems there have been many initiatives on how to model processes, using the unified modelling language (UML) and object oriented techniques (Jacobson *et al.*, (1999:1-13); Eriksson and Penker (2000:14-15); Popkin (2001:1-2))

Apart from this realisation that business modelling techniques need new ways off communicating requirements to OO developers, a significant part of the research community also indicate that tools being used to define requirements are not equipped to handle the complexities that arise during the definition of requirements. Authors who have analysed modelling approaches being used for requirements specification claim that there is insufficient attention to social, political and cultural issues. These issues normally play a significant role in the success of many information systems projects. Very often a lack of attention to these softer issues results in the project not meeting the legitimate needs of stakeholders (Galliers (1994:165); Ormerod (1995:292); Mingers (1995:21); Nuseibeh and Easterbrook (2000:43)).

In view of the above, business process modelling needs further investigation in order to improve these shortcomings. The following section will review a problem at Hulett Aluminium, a plant located in Pietermaritzburg that requires more effective techniques to define and communicate information system requirements.

1.2 Discussion of the Problem with the Production Process

Hulett Aluminium is the largest semi-fabricator of aluminium products in Africa. The business of Hulett Aluminium is organised into two major sections viz., a rolling operation and an extrusion operation. The rolling division, which is the major operating company of Hulett Aluminium, is the focus of this report. Hulett Aluminium will refer to the rolled products business operation in the remainder of this report. Hulett Aluminium has recently expanded its manufacturing facility of the rolling operations and now supplies many export and local customers. The company has a combination of manual and automated machinery. Hulett Aluminium makes many products, which are ordered by customers in a range of dimensions and metallurgical options. The plant is unique in that it does not standardise on a few products, but has a diverse product portfolio, which can be ordered in many specific sizes and metallurgical properties.

The production of rolled aluminium products requires process operations on several machines to meet the requirements of customers. When customers place orders with Hulett Aluminium, these orders are verified, captured and planned as works orders then issued as lots into production when metal is available. A lot ticket, which describes the operations that need to be performed on a piece of metal, accompanies a lot when it is issued into production. Information about the conditions of the process and the metal at that specific process is recorded on the lot ticket at each stage of the process. After each operation the information is captured into an information system and used for progress and quality analysis.

According to Hulett Aluminium management, the most urgent business priority at the time of investigation was eliminating customer dissatisfiers. Customers are not satisfied with the erratic quality that is being supplied. Material is often produced to incorrect dimensional specifications. In certain cases the quality within a product varies, for example the thickness or the width may not be consistent. Similarly, certain parts of a reel conform to specification while remaining portions do not conform. The introduction of new machines, products and customers has emphasised the traditional problems associated with “getting the process under control”, that Hulett Aluminium has faced for many years.

A key factor causing the production of poor quality products is that operators are not receiving adequate information to set-up, control and monitor the machine. When a customer has a specific need or a certain product is identified as being profitable to produce, a detailed product specification is developed. An example of a detailed product specification is shown in Appendix A. The detailed product specification is a description of the attributes that are crucial for the customer to use the product successfully. For each stage of the manufacturing process product coordinators define the customer requirements that are crucial for the customer to process the product in his plant. Each product has different requirements that must be achieved. Once the customer's requirements are understood and some trials are done, a detailed product quality plan is produced and the product is approved for commercial volumes.

The product recipe, which is an abstract of the detailed quality plan, is compiled to supplement the lot ticket and standard operating procedures. The product recipe describes the actions necessary to produce a product, which meets the quality requirements specified in the detailed quality requirements. **The challenge is to get the right elements of that information (product recipe) to the shop floor at the right time, without flooding the operator with excessive details, but making sure the operator gets the critical information that he needs.**

There are several difficulties in using the existing mechanisms to get the information to the operator. Some of the known factors highlighted by management are as follows:

- Lot tickets do not give a total understanding of what needs to be done. Lot tickets only give instructions about the dimensions to which a product needs to be manufactured.
- Standard operating procedures (SOP's) are supposed to indicate how a product should be manufactured.
- SOP's and technical standard practices are voluminous, out of date and not operator friendly.
- Operators' set-up the machines for the correct conditions based on information they remember and their experience.
- Sequencers use information from the lot ticket and rules from memory to generate sequence lists.

- There is a culture of considering the process of aluminium production an art.
- Current manufacturing practices do not support the production of a detailed requirement at each stage (product quality plan) of the manufacturing process.

The last point mentioned above is a result of problems not being identified and corrected at the source. After each operation, visual inspections are performed and information gathered through instrumentation or manual measurements, and recorded on the lot ticket. Due to several factors, these checks are not very reliable and require the product to undergo a rigorous inspection at the end of the process to confirm if quality requirements are met. If defects are found then the history of the process steps are traced. Investigations to trace the history of process steps are tedious because the information is paper-based and not well coordinated.

There are several perspectives on possible solutions to make the elements of the product recipe available to the shop floor. Hulett Aluminium management have realised that information technology can play a key role in improving the situation and have tried in the past to improve the situation through the introduction of technology. The following section will review some historical developments regarding the provision of information systems at Hulett Aluminium.

1.3 Historical Remarks Regarding the Implementation of Information Systems at the Aluminium Plant

There have been difficulties in supporting information system needs in the Batch Process Aluminium Rolling Industry with standard enterprise resource planning (ERP) package solutions. These difficulties are caused by the complexities of a highly competitive and complex business environment. Today's business environment demands shorter lead times, the ability to introduce new products more rapidly and the ability to respond to customer service and product requirements more rapidly. To meet these competitive requirements, manufacturers have to adopt a whole range of philosophies, methods and techniques to gain or sustain the advantages they have over competitors (Boar, 2001:1-40). Beach *et al.* (2000:319-320) state that with the complexities caused by the present business environment the notion of a single "best practice model" which can be applied across all industries, products and business environments is now more of an illusion than a reality.

Kumar and Hillegersberg (2000:23-41) write that a key premise of ERP systems is the underlying, sometimes unstated, but often implicitly promoted notion that the reference models in ERP systems embody the best business practices. They further elaborate that the reference models supposedly reflect preferred business models including data and process models as well as organisational structures, and there can be considerable mismatches between the actual country, industry, and company and the specific best practices and reference models embedded in ERP systems. While at the abstract level the idea of “universal” best practices may be seductive, at the detailed process level these mismatches may create considerable implementation and adaptation problems. Kumar and Hillegersberg (2000:23-41) also indicate that the future trends in ERP would be a collection of domain specific, third party components plugged into a thin backbone supplied by a key ERP vendor. Supporting the organisations business processes with information systems that embody the chosen philosophies is normally a critical success factor for sustaining competitive advantage. The inadequate solutions provided by standard ERP packages force manufacturers down the path of developing customised solutions. The successful design, implementation and deployment of information systems is inseparable from successful design of the business processes.

Hulett Aluminium has tried to meet its information systems requirements with standard ERP packages over the past five years. These attempts were not very successful because the standard packages did not adequately meet the business requirements. Through many stops and starts the approach of implementing package solutions was abandoned and the company has since adopted an approach of customised development. To cope with the increased volumes Hulett Aluminium recently upgraded the order capture and lot ticket generation processes through customised development. Hulett Aluminium still faces a huge backlog of information system needs, that revolve around the support of the actual production of rolled aluminium. The production process requires a vast amount of information and knowledge in the form of process instructions, test instructions, set-up parameters and inspection criteria. The production process also generates large amounts of data, which is needed to investigate problems, monitor performance and refine the process. The manual, uncoordinated, paper-based systems are proving to be very cumbersome to work with in a company that is assimilating many new customers and products. The present informal paper-based systems are hindering the process of improving quality and

getting the process under control, and therefore makes the requirement for supporting the production process with appropriate technology the most urgent need at present.

In the past Hulett Aluminium have tried to support the production process with information systems using traditional approaches to systems analysis and design. According to the engineering manager Torr (2001) these attempts were not successful for the following reasons:

- There was a tendency to focus on optimisation and automation (technical issues) instead of first measuring, then understanding and finally controlling through IT (learning).
- There has always been a tendency to be more sophisticated than the users could appreciate or the business was ready to support.
- Point solutions introduced at particular machine centres were poorly integrated with the remainder of the plant systems and slowly fell into disuse.

An organisation's technology assimilation is often a difficult process that needs to be carefully managed through the various phases of growth until the technology is successfully introduced (Gibson and Nolan (1974:8), Cash *et al.* (1983:78-81) and Robson (1997:39-40)). The challenges introduced in each maturity phase are different and require different management approaches to ensure success. Mingers (1995:19) argues that all these types of failures can ultimately be seen as failures in expectation, i.e. the final information system did not in some way meet the legitimate expectations of the stakeholders. He further states that information system failures ultimately occur as a result of the limitations in conventional (hard) information system (IS) analysis and design methodologies. Traditional approaches to information systems design have attracted a considerable amount of criticism recently because of their lack of attention to social, political and cultural issues. The positivist, objectivist assumptions with which traditional approaches are underpinned make them inappropriate for analysing or modelling production systems on the shop floor at Hulett Aluminium, where there are many stakeholders with potentially divergent interests. The critics of the hard approaches suggest the use of interpretive approaches like soft systems methodology (SSM) to gain a rich understanding of the softer issues (more than logic and facts) that affect the problem before identifying appropriate information systems requirements to improve the situation (Jackson (1991:39-41); Mingers (1995:44-46); Checkland and Holwell (1998:155-158)).

Hence there is a requirement for more effective business process modelling approaches.

1.4 Research Goals and Sub Goals

The main aim of this research project is to establish if it is possible to formulate an integrated methodology to assist business analysts define and communicate business process models to object oriented developers.

To accomplish this research goal, the following sub goals are necessary.

- 1) Investigation into business process modelling (BPM) and its relation to information systems provision.
- 2) Investigation into organisational learning in general and soft systems methodology (SSM) in particular.
- 3) Investigation into unified modelling language (UML) based business process modelling approaches, and the approach suggested by Eriksson and Penker (2000) in particular.

The formulated methodology will be applied to the problem at Hulett Aluminium with the aim of defining a business process that improves delivery of quality information to production process employees. The proposed design will be communicated in UML to the development team at Hulett Aluminium.

1.5 Research Methodology

Robey (1996:400-408) indicates that research aims determine both the theoretical foundations and the research methods, whereas theoretical foundations also determine the research methods (See Figure 1.1).

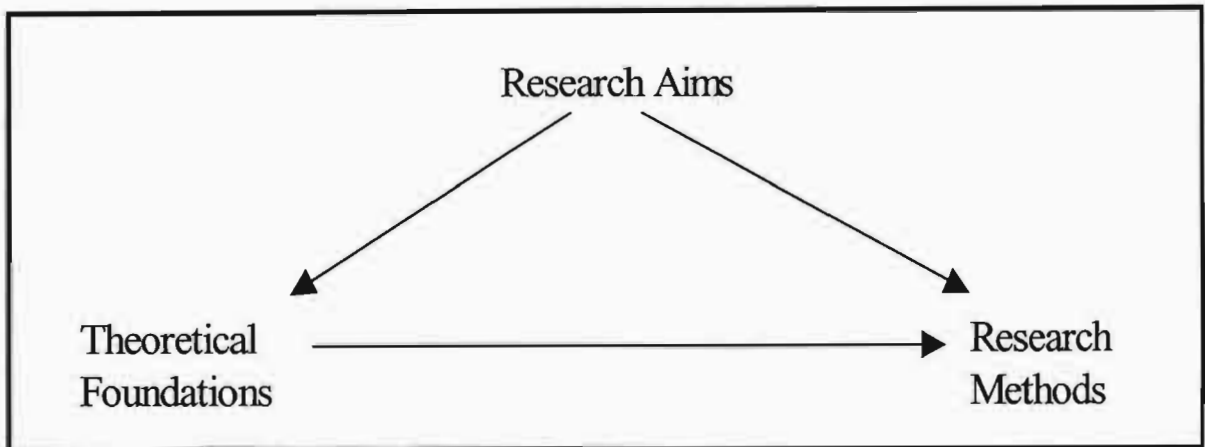


Figure 1.1 A triad for the Justification of Research (adapted from Robey (1996)).

Hulett Aluminium employs the author, and the research work will influence the development practices of the company as well as the theory in the fields of business process analysis and modelling. An approach of action research will therefore be followed in this research project. Checkland and Holwell's (1998:22-28) framework for action research shown below in Figure 1.2 will be used.

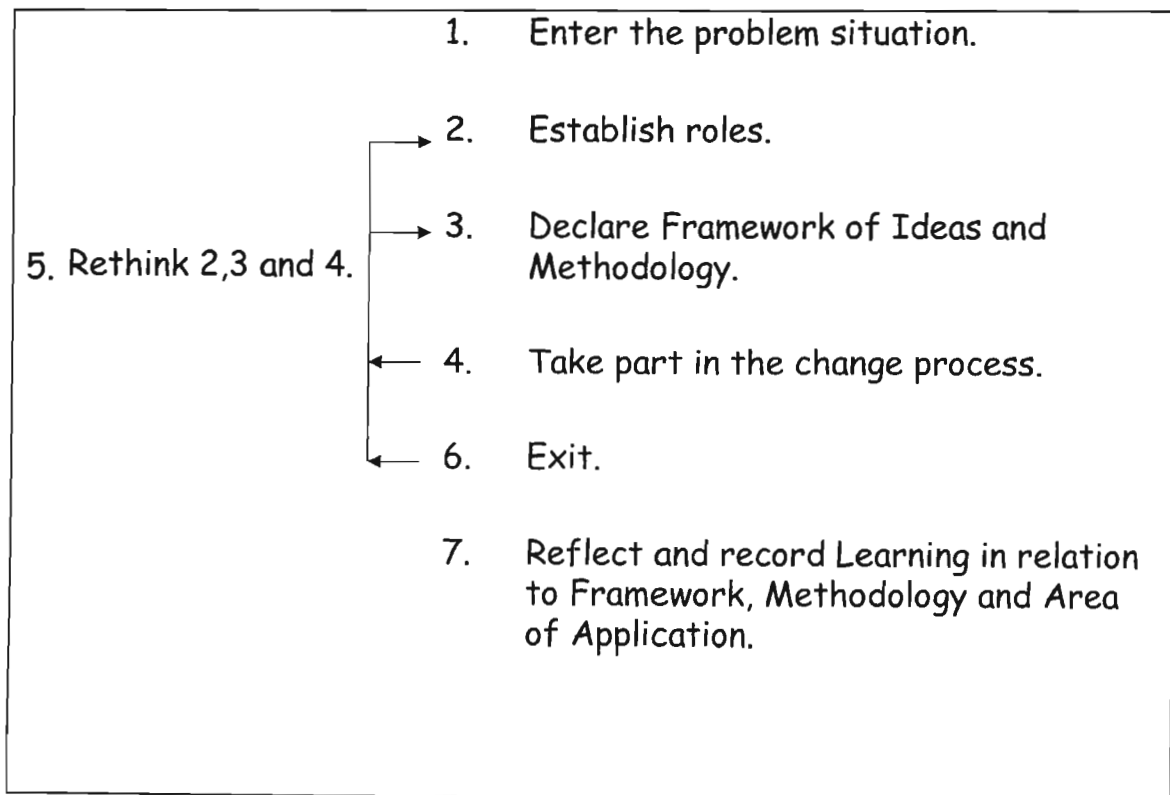


Figure 1.2 A process for action research (adapted from Checkland and Holwell (1998:27)).

The steps of the process illustrate that the framework of ideas, relevant to solving the problem, will be investigated. These ideas will be combined into a suitable approach that can be used to participate in the process of change. After intervening, there will be reflection on the learning that is generated by the intervention, by reflecting on the framework of ideas, methodology and area of application.

Business process modelling is a complex activity, involving various stakeholders with views that do not necessarily coincide. In line with Rose (1997:250), Ackermann *et al.* (1999:196) and others, this research acknowledges the social dimension of the problem situation and the multiplicity of interpretations related to it. It is essential, therefore, to investigate the influence of social theory on business analysis and modelling. SSM is regarded as a valid social science research tool to explore the social aspects influencing a problem situation (Rose, 1997:250). The chosen methodology therefore creates a need to incorporate techniques for SSM to better understand the situation.

1.6 Significance of the Research

An aim of this research is to define a business process that will improve delivery of critical product information to operators working at the production process. To achieve this the current frameworks for business process analysis and modelling will need to be improved. Traditional business process modelling approaches emanate from software specification and design techniques. These techniques focus on the technical features of the software product and offer the analyst no support in understanding and surfacing the softer issues that affect a problematic situation. Successful business engineering is brought about by paying considerable attention to softer issues of cultural change, motivation and communication of the total vision (Parnaby, 1994:503).

Hulett Aluminium is a major component of the aluminium cluster chain in South Africa. Recent figures quoted by the CEO of Hulett Aluminium, indicate that for every five tons of aluminium that is converted by Hulett Aluminium's customers into value added exports, one job is created. The quality and cost at which customers of Hulett Aluminium receive metal determines how competitive they are against other suppliers. The production process is the primary process that determines the quality and is the second most important factor influencing the cost, after raw material costs. Improving the quality produced by

operators will reduce customer dissatisfiers as well as improve the cost (minimal rework), which will influence the competitiveness and growth potential of the aluminium cluster chain

1.7 Overview of the Structure of the Dissertation

An overview of the thesis is presented in Figure 1.3

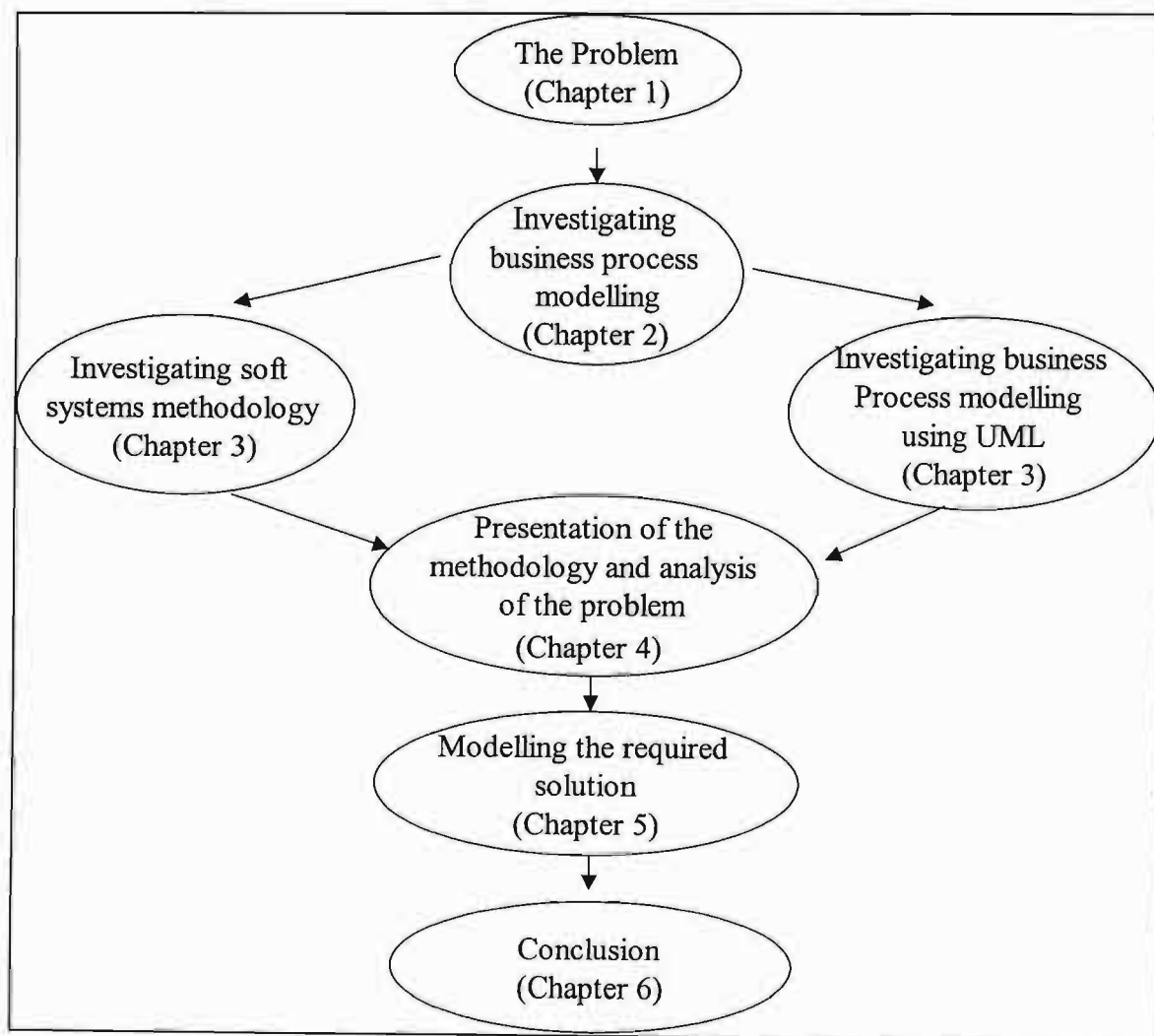


Figure 1.3 Overview of the structure of the thesis.

Chapter 1 provided the necessary background to the research project. Chapter 2 will provide an analysis of current approaches to business process modelling. Chapter 3 will investigate the benefits that soft system methodology techniques may provide in analysing problematic situations and providing a process to determine acceptable solutions. Chapter 3 will also investigate the possibility of representing the model in unified modelling language, to provide a basis for the subsequent delivery of software using an object-oriented approach. Chapter 4 will present a proposed methodology, with justification, for analysing and modelling the required business processes that will lead to improving the delivery of critical product information to operators at the production process. Chapter 4 will also present an analysis of the problem situation. Chapter 5 will discuss the development of the UML models to communicate the proposed business model to the developers. An evaluation of the case study will conclude Chapter 5, followed by Chapter 6, which concludes the thesis with directions for future research.

CHAPTER 2 Analysis of Current Research and Practice of Business Process Modelling

2.1 Introduction

Producing business process models is one of the most complex activities in information systems development. In recent years many different business modelling approaches have been proposed, to deal with this complexity. The most important approach that has been receiving attention in recent years is the “process-driven modelling” technique, in which the business is analysed in terms of main business processes (Herzum and Sims, 2000:428).

A business process is commonly referred to as “a set of logically related tasks performed to achieve a defined business outcome.” Business process modelling can be defined as the process of determining functional activities for the whole or part of an enterprise, either as an as-is model of the current situation or a to-be model of the proposed situation (Tam *et al.*, 2001:144). The term enterprise modelling is used when business process modelling is performed for the entire organisation (Nuseibeh and Easterbrook, 2000:40). Researchers often use the term business model to refer to both the process and data models. The literature on process modelling indicates that the term has its origins in the technical design of information systems. The terms process modelling and business process modelling are used in the literature to refer to the same activities. From the available literature it is apparent that there are no significant differences in the expected aims, objectives or outcomes of process modelling and business process modelling. More recent papers use the term business process modelling. In this report the terms business process modelling and process modelling refer to the same activity and may sometimes be used interchangeably.

There can be many different objectives for modelling business process. Generally, business process modelling is a fundamental activity that is necessary to support business process improvement initiatives, provide a platform to guide the installation of suitable information

systems or provide insight into the business operations to allow strategy development. When business process modelling is done for each of these intentions, specific modelling approaches and representation techniques are used.

This chapter will explore the reasons for producing business process models, but will focus specifically on how business process models can improve the chances of delivering information systems. The chapter concludes by evaluating the strengths and weaknesses of the techniques presently being used to produce business models. The following section provides an overview of how business process models support process improvement programs, strategic planning and the provision of information systems.

2.2 Business Process Models in Business Improvement

The struggle of business has always been and remains the quest for competitive advantage. Those who build, compound and sustain competitive advantage win; those who don't, lose. Competition is all about advantage and the business process is the unit of evaluation, design and improvement through which advantage is gained (Boar, 2001:3-11). Producing business process models is central to the activities responsible for improving the efficiency of the business, in order to extend or maintain advantages over competitors. One of the roles played by business models in these improvement initiatives is to increase the understanding of current mechanisms. This understanding is crucial for analysing what needs improvement or changing. The other role a business process model serves is to convey the design of the proposed business process to facilitate constructing, extending, revising or redesigning processes.

Over the last decade several business improvement initiatives have emerged, which force businesses to evolve and adjust to meet the requirements of changing business environments. The indications are that the improvement initiatives will continue to grow in importance. According to Peppard and Rowland (1995:10).

"In the past, economic winners were those who invented new products. But in the twenty-first century sustainable competitive advantage will come out

of new process technologies and much less out of new product technologies.”

There are two general approaches to improving an organisation's performance. One approach is the Japanese method of Kaizen, associated with the just in time (JIT) and total quality management (TQM). Kaizen is based on the principle that many small incremental developments will accumulate into substantial gain (Bond, 1999:164). The other approach is business process re-engineering (BPR) (Hammer and Champy (1993)). BPR is concerned with fundamental redesign of business processes. BPR is also closely related to Simultaneous Engineering (SE) and Time Compression Management. Table 2.1 is a summary of these approaches. It highlights their focus areas and gives an indication of some of the modelling techniques used. Table 2.1 also illustrates that the improvement philosophies shown are process oriented and depend on process models to investigate opportunities for improvement and the proposal of new process designs.

	Focus	Improvement		
		Scale	Process focus	Techniques
Total Quality Management (TQM)	Quality Attitude to customers	Continuous Incremental	Simplify Improve Measure and control	Process Maps Benchmarking Self-assessment Statistical Process Control (SPC) Diagrams
Just-In-Time (JIT)	Reduced inventory Raised throughput	Continuous Incremental	Workflow/ Throughput efficiency	Visibility Kanban Small Batches Quick set-up
Business Process Re-engineering (BPR)	Process Minimise non-value added	Radical	"Ideal" or streamlined	Process Maps Benchmarking Self-assessment Information System (IS)/ Information Technology (IT) Creativity/out of box thinking
Simultaneous Engineering (SM)	Reduced Time to Market Increased quality	Radical	Simultaneous R&D and Production development	Program teams Computer Aided Design (CAD)/Computer Aided Manufacture (CAM)
Time Compression Management (TCM)	Reduce Time (time = cost)	Radical	Eliminate time in all processes	Process Maps Benchmarking

Table 2.1 Business philosophy comparisons. Adapted from Peppard and Rowland (1995:16).

Representing process activities in diagrams provides a clearer explanation of a process than is possible through a verbal description. Diagramming techniques also emphasise sequence, dependencies, inputs, outputs and control elements. Over the years a number of

modelling techniques have emerged. A discussion of the most popular process modelling techniques follows in the paragraphs below.

IDEF0 (Level 0)

The IDEF0 process modelling technique was developed by the US Department of Defence (DoD) in the 1970s. IDEF0 stands for International DEFinition. IDEF0 originally started as a software development technique, but has since become widely accepted as a general process modelling technique. Peppard and Rowland (1995:172) and Kettinger (1997:64) indicate that the IDEF0 mapping standard is frequently used in BPR initiatives. IDEF0 is a high level mapping technique, which identifies activities with the four major components of inputs, outputs, controls, and mechanisms.

The IDEF0 modelling technique assumes a top-down approach to process modelling, where each subsequent process model is broken down into a more detailed version of the original process model. The IDEF0 standard prescribes that processes be decomposed into component activities. Boxes are used to represent these activities. Individual activities of a process are interrelated by flows of information. “Input” information enters activities from the left, while “output” information leaves activities from the right. “Control” information enters activities from the top and “mechanism” information enters the activities from the bottom. Collectively all these inputs and outputs into activities give an indication of the circumstances or conditions which govern the transformation. The analyst is therefore forced to consider these aspects for each activity in the process.

ASME (American Society for Mechanical Engineers) notation

ASME is a process modelling technique that originated in manufacturing and has since found wider acceptance in office and service environments (Peppard and Rowland, 1995:173). ASME models the process steps against an analysis of the process step. This method provides a distinct advantage over the rest of the techniques because it has built into it an evaluation of whether a step is value adding or not, as indicated in Figure 2.1. The chart provides a powerful focus on those areas that should be minimised to improve overall process efficiency.

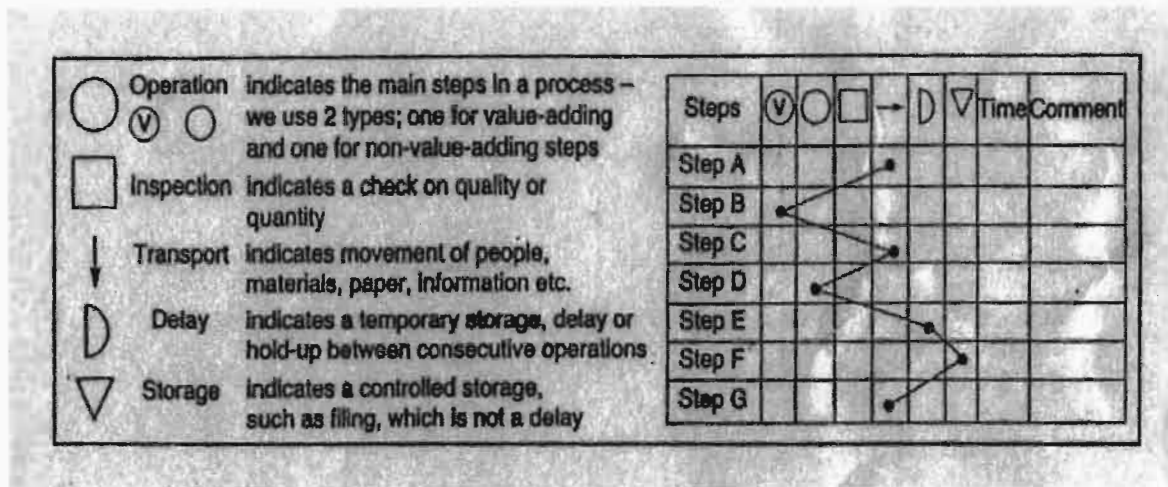


Figure 2.1 ASME mapping standard (Peppard and Rowland, 1995:173).

Event-Driven Process Chains

Event-driven process chains (EPCs) are an alternative approach to modelling business processes. EPC is a graphical business process description language introduced by Keller, Nuttgens and Scheer (Aalst, 1999:3). The ERP vendor SAP and Prof Scheer’s ARIS approach use EPC’s to model business processes (Aalst, 1999:1).

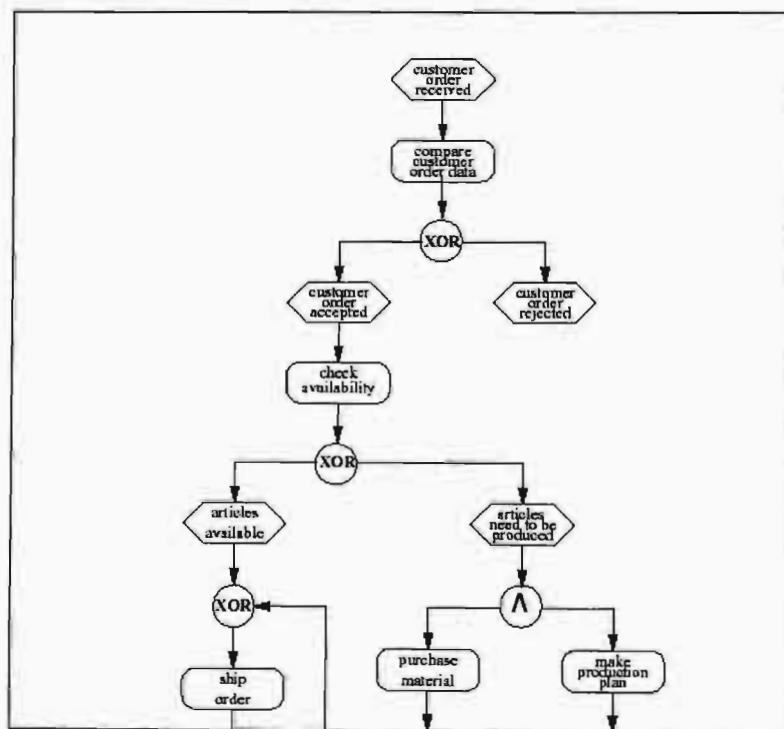


Figure 2.2 Modelling of a business process using EPC. Adapted from Aalst (1999:5).

The EPC methodology inherited the name from the diagram type shown in Figure 2.2. Such a diagram shows the control flow structure of the process as a chain of events and functions, i.e., an event-driven process chain. An event-driven process chain consists of the following elements:

- **Functions:** These are the basic building blocks. A function corresponds to an activity (task, process step), which needs to be executed;
- **Events:** Events describe the situation before and/or after a function is executed. Functions are linked by events. An event may correspond to the post-condition of one function and act as a precondition of another function; and
- **Logical connectors:** Connectors are used to connect activities and events. The use of connectors ensures the flow of control is specified. There are three types of connectors: (and), (exclusive or) and (or).

A Flow Chart

Flow-charting provides a view of the relationships between the different activities within the entire process. Once a flowchart is represented, an analysis of the process is performed to identify the following:

- Each activity within the process;
- Who performs the activity;
- How long it takes for the activity to reach completion;
- What is the delay (if any) in performing the activity;
- Which previous activity (if any) does the current activity depend on in order for the activity to take place and ultimately for the process to reach completion;
- Any frequent problems with the specific activity, for example if a certain activity is always very slow; and
- Whether any value has been added for the customer by the completion of a specific activity.

The strength of flow charts lies in the ease with which they can be used to understand the steps of a process.

Many forms of information must be integrated to adequately describe the processes. Process modelling languages developed over the years differ in the extent to which their

constructs highlight the information that is necessary for each of the process improvement techniques. The above summary illustrates that process modelling techniques and representations usually present one or more different perspectives. For a particular study a combination of the various techniques best serve the interests of the process improvement program.

The most important ways in which process-modelling techniques assist process improvement programs are as follows:

- The model acts as a basis for improving the current business process structure and operation;
- The model or the modelling process identifies the changes necessary to the current business to implement an improved business process model; and
- The model shows the structure of an innovated business. The model in this case becomes the basis for the action plan.

Models produced during the change programs play vital roles in the subsequent activities of introducing change. In recent times technology has become the crucial enabler of introducing change, making the models useful in the provision of suitable information systems. The above modelling techniques can be used to provide an understanding of the tasks of the process by emphasising dependencies, required inputs and outputs of the task. These modelling techniques, however, will not provide sufficient insight into the assumptions that process designs are based on, and therefore will not be very effective in supporting the definition of suitable solutions. The symbology used by these techniques is also not a standard amongst developers and will therefore not be able to directly support software delivery.

2.3 Business Process Models in the Analysis of the Operations of a Company

Peppard and Rowland (1985:7) and Kettinger (1997:64) suggest that business process modelling be preceded by value chain analysis. Value-chain analysis was developed by Michael Porter in 1985 (Porter and Millar, 1985:149). Porter introduced value chain analysis as an alternative approach to strategy formulation. Value chain analysis looks

internally at processes to identify competitive opportunities. This is done by analysing the value adding process. Porter's initial strategy formulation tool, the "Five forces model" calls for an analysis of the business environment to counteract the threats. Value chain analysis calls for the identification and modelling of business processes to understand the scale (how many departments do they cross), scope (how simple or complex) and the contribution a process makes to the value a customer is willing purchase. Identifying and understanding processes using value chain analysis is complicated by the fact that processes cross functional-boundaries.

Kettinger (1997:64) prescribes the use of value chain analysis to discover re-engineering opportunities while Peppard and Rowland (1985:9-13) suggest the use of value chain analysis as a framework to understand all the operations of a business. According to Peppard and Rowland (1985:9-13), value chain analysis is a general model of business that helps that analyst categorise and assess all the operations of the business. The process of categorising and assessing all the processes of a business is a way of ensuring that the entire business environment is established as the context to guide process modelling. Value chain analysis also has the benefit of emphasising the primary value adding process of the business to the analyst.

Value Chain analysis requires that businesses are analysed in terms of primary activities and support activities. Primary activities are those activities directly involved with adding value to inputs and transforming them into goods or services desired by customers. These include:

- Inbound logistics;
- Operations;
- Outbound logistics;
- Marketing and sales; and
- Service.

Support activities are those activities necessary to support or enable the effective functioning of the primary activities. They include:

- Firm infrastructure;
- Human Resource Management;
- Technology development; and

➤ Procurement.

The identification and subsequent modelling gives the analyst an understanding and appreciation of the value adding process and the competitive opportunities open to the organisation (Robson, 1997:48). Value chain analysis is also a way of ensuring that the functional organisation supports business level strategy. Value chain analysis is therefore used to identify those activities that are not contributing value to the customer. These non-value adding activities are natural candidates for business process re-engineering. Value chain analysis also emphasises those activities that are directly responsible for the value adding process; these activities are natural candidates for improvement programs.

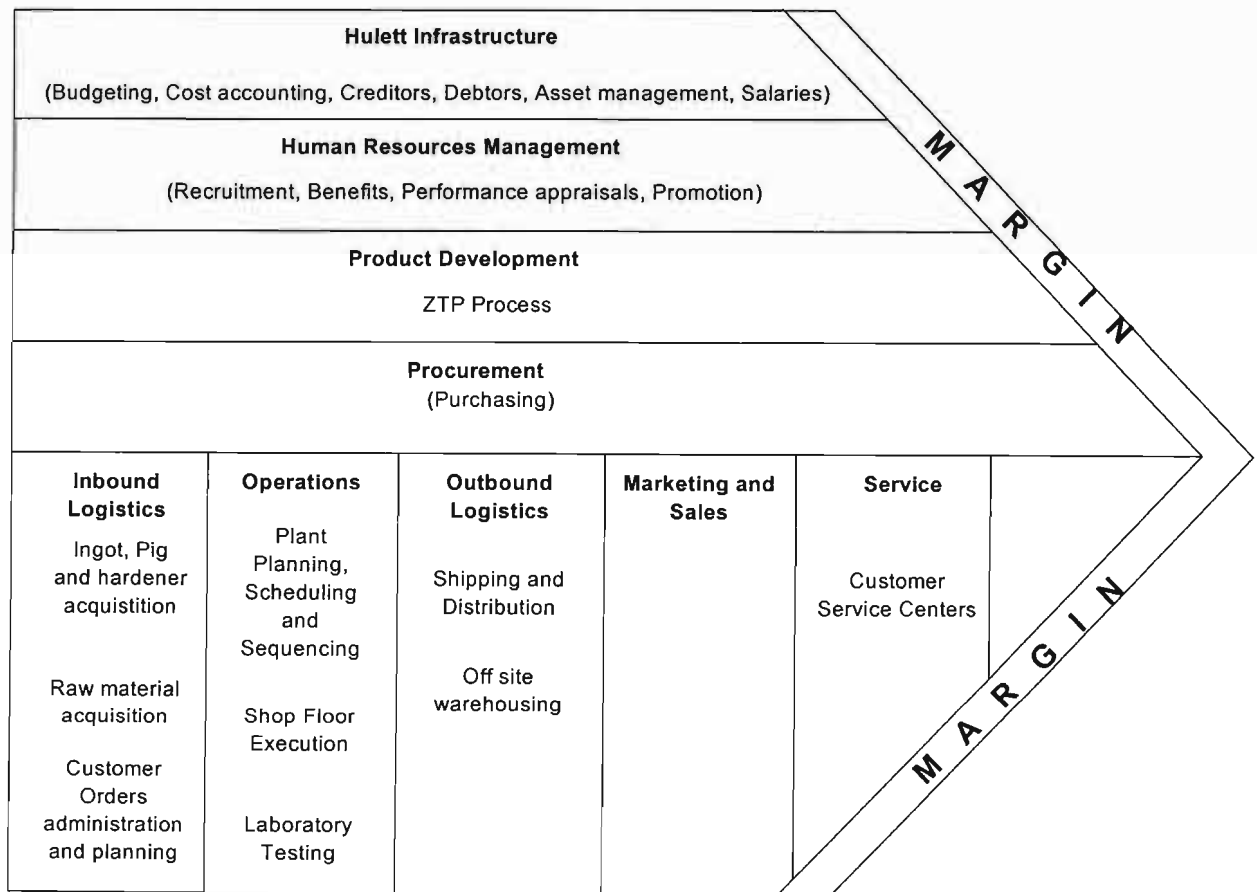


Figure 2.3 Operationalisation of Porter's Value Chain Model for Hulett Aluminium.

Figure 2.3 illustrates the primary and secondary processes of Hulett Aluminium in the format of Porter's Value Chain Model. The primary processes are shown in the vertical columns of the diagram. Primary processes are used directly in the production of rolled aluminium for customers. As indicated in Figure 2.2 the production process is described as

Shop Floor Execution and is part of the primary value adding process. The term shop floor execution is used because of the links to the planning and scheduling. Secondary processes are those processes that do not directly provide value to the customers of Hulett Aluminium. They simply support the primary activities of the aluminium plant. Such processes are procurement, human resource management, Finance, etc.

2.4 Business Process Models in the Delivery of Information Systems

The business requirements or expectations of an information system are captured through a planning process called information systems (IS) strategy planning. This process documents the specific requirements that need to be met by information systems (Robson, 1997). The process and data architectures portions of the plan have a direct influence on the deployment of software. The process architecture defines the major processes of the enterprise and the functions that comprise the processes. The data architecture identifies the enduring, stable data entities or business objects with their relationships that constitute the enterprise.

The business process and data architectures are normally compiled for the entire business. These models are used to guide traditional approaches to information systems deployment by serving as a framework for the conceptualisation, planning and delivery of concrete information systems projects (Jacobs and Holten, 1995:96). The process and data models assist business analysts and developers to transform vague ideas into consistent specifications for information systems. There are many instances of organisations trying to deploy information systems without well-defined business process and data models that explain the context of these information systems. These organisations attempt to specify and model information systems requirements in a fragmented way or on a project-by-project basis. The problems with approaching information systems requirements on a project-by-project basis have been widely reported (Scheer and Hars (1992:166-171); Weston (1999:835); Popkin (1999:1)). According to these authors, the absence of a description of the business context (business model) leads to the following problems:

- The delivered software systems are difficult to maintain, enhance and evolve. Normally projects approached in isolation have an overlap in scope, which leads to a duplication of functionality;

- Information systems that are hard to access and retrieve data from because data modelling is approached on a project-by-project basis leading to a duplication of entities and a fragmented design;
- Unsatisfied business stakeholders, as the deployed software does not conform to the “big picture” of enterprise needs and solutions; and
- Poorly integrated business processes caused by duplication of functionality.

A business model needs to contain the requirements and goals of the enterprise that have been defined in a holistic manner. This holistic definition of the goals and needs is necessary to ensure that different business, technical and social viewpoints are reconciled to arrive at one consistent statement of the needs that is acceptable to all stakeholders. The business model contains the organisation structure, the business rules that affect its operations, the goals, tasks and responsibilities of its constituent members, and the data that it needs, generates and manipulates. The enterprise model is an expression of the behaviour or expected behaviour of an organisation in terms of organisational objectives and associated tasks, concepts and resources (Nuseibeh and Easterbrook, 2000).

The process and data models are normally achieved through business modelling activities that make use of process and entity-modelling approaches. These approaches are used in the specification of information systems. The domain/entity model involves identifying, naming and relating the concepts (objects or entities), (Scheer and Hars, (1992:167-171); Jacobson *et al.*, (1999)). The process models involve identifying major processes, their activities, goals and the entities or objects that are used to achieve these goals.

Process and data models add many tangible benefits to the successful delivery of information systems. Scheer and Hars (1992) and Jacobson *et al.* (1999) write about the need for common terminology to facilitate learning and exchange of knowledge. The team structure of information systems projects comprise of many individuals, often with differing interests. This generally includes developers, customers and stakeholders. The data (domain) model provides common terminology in the language of the customer to facilitate sharing of knowledge amongst the team members. Jacobson *et al.* (1999:119) state that in order to capture the correct requirements and aim development toward the right systems, a good understanding of the business context is needed. The process and

data models are meant to provide a platform for subsequent information systems analysis. Jacobs and Holten (1995:96) write about the decision making process that is required to evaluate possible alternatives to solve problems during systems analysis and design. Business models facilitate decision-making and conceptualisation by acting as a framework that is referenced to guide the transformation of vague ideas into concrete information systems. Technology provides many opportunities but at times technology can be installed without introducing business benefit. According to Popkin (1999:1) the successful exploitation of technology requires information technology (IT) infrastructure to be aligned with business models. The act of modelling assists the alignment and therefore allows the successful exploitation of IT (Popkin, 1999:1).

2.5 Traditional Approaches to Business Process Modelling used in the Provision of Information Systems

This section discusses the most prominent techniques used to produce business process models. Since software specification techniques provide a means for representing and reasoning about the various aspects of a process, these techniques became natural, well-established choices for business modelling. The two most prominent techniques used to model the business are data modelling (or entity relationship modelling) and function modelling (data flow diagramming) (Bond (1999:165)). These techniques are based on two complementary aspects of analysis, which originated during the structured analysis and design era. Entity relationship diagrams model the static aspects of a system while DFD model the dynamic aspects of the system. A number of similar diagramming techniques have been developed over this period. Although the various techniques use different charting symbols the fundamentals usually remain the same. Conger (1994:227) and Bond (1999:169) suggest performing entity modelling before the function modelling although this is not a strict rule or established practice.

Conger (1994:27) claims that structured analysis was the first well-documented, well-understood method of describing application problems. Structured analysis and design follows the architectural notion that “form ever follows function”. The functions of an information system are the processes that transform application data. In structured

analysis, processes with required input and output flows are modelled. Process oriented analysis using structured analysis is based on systems theory, which in turn is based on the systems models. System models assume that inputs are fed into processes to produce outputs and there is some sort of feedback to prevent the system from “running down” (Conger (1994:27)). The modelling process is top-down, where the original specification is gradually broken down into more detail through hierarchical decomposition. In structured analysis of complex information systems, self-contained small sections of the information systems are analysed separately then integrated to produce a unified system. These small systems comprise a hierarchy of system components. Each component of the system, regardless of level, has its own inputs, processes, outputs and feedback. At the lowest level of the hierarchy are the elementary components, which can no longer be subdivided and retain their system characteristics (Conger, 1994:28).

The structured analysis approach provides heuristics, guidelines, and diagram sets for dividing an information system into a hierarchically decomposed system of components. The first assumption made by structured analysis is that the analyst is most interested in functions or processing that need to happen. The second assumption is that the problem will be treated in a top-down manner. Top-down analysis implies that the external interfaces are first analysed, then the high level functions, then the next level functions until the elementary functions are arrived at, that is the simplest level of activities. The scope is defined at the highest level. The scope of the project is documented in a context diagram. The context diagram defines the interactions of the system with the external world (Conger, 1994:229). A context diagram also depicts the scope of a project using a circle to define the system, squares to define the external entities and directed arrows to indicate data flows. Conger (1994:232) compares structured analysis to a video camera with a zoom lens. At a distance the item being examined is abstract and fuzzy. It has shape but no details. This is normally the context diagram. As we zoom in to reveal more detail we generate each subsequent DFD.

2.6 Evaluation of Traditional Approaches to Business Process Modelling

Since the emergence of computers, authors have been reporting a high incidence of unsuccessful information system projects. Although there are a number of reasons for this, many of the failures are due to information systems not meeting the legitimate expectations of stakeholders. A number of authors also highlight that these failures are a result of the lack of attention to the social context in which the new system will have to operate (Stowell (1993:95); Galliers (1994:165); Mingers (1995:21); Omerod (1995:292) Nuseibeh and Easterbrook. (2000:43)). According to these authors the traditional approaches used in eliciting requirements for the business process model do not allow for the understanding, and accommodation of stakeholder concerns. Each business process has many stakeholders. Stakeholders have different goals and objectives because there is generally a difference in perspective of the environment they would like to work in and the tasks they think are necessary. The situation of multiple stakeholders with different views of a situation makes eliciting requirements a difficult process because the techniques that are used only accommodate one valid view of reality (Nuseibeh and Easterbrook (2000:41)). In certain situations there might be conflicting requirements, which requires negotiated agreement which only comes through shared understanding of the situation (Ackermann *et al.*, 1999:262).

Nuseibeh and Easterbrook (2000:43) claim that the traditional techniques and tools do not allow the modelling and analysis of requirements in a social context in which the final information system will have to operate. These authors feel that traditional techniques focus on specifying new functionalities of the system instead of modelling the problems, objectives and the social setting. Modelling and understanding the various perspectives naturally allow a suitable solution to emerge. Nuseibeh and Easterbrook (2000:43) go on to say that understanding and resolving the conflict and disagreement amongst the stakeholders is important.

According to Mingers (1995:20), traditional tools are inadequate for eliciting requirements because they focus on providing technical solutions to what may be complex social,

organisational, and communication problems. He suggests that this is probably caused by focussing on the technical aspects of design, by analysing data, data flows and system functions. Mingers (1995:20) also indicates that traditional software specification techniques are inadequate because they are based on the following assumptions:

- Existing processes are effective and focus on computerising them;
- The users know what they want and that eliciting user requirements is a straightforward, mechanical process; and
- There is some objective reality out there that can be observed and captured.

Many authors believe that these assumptions are wrong and inappropriate for designing information systems because the multiplicity of issues associated with individuals (Stakeholder) needs are ignored (Mingers, 1995:20). When understanding stakeholder terminology, concepts, viewpoints and goals, the business analyst is concerned with understanding the beliefs of stakeholders (epistemology) and what can be agreed on objectively. The traditional software specification techniques do not empower the business analyst with techniques to understand, interpret, analyse and validate the information gathered. Mingers (1995:20) claims that interpretive techniques offer more opportunities for understanding the meaning stakeholders attach to their objectives, goals and preferences. Interpretative techniques argue that our actions and conversations are not open to simple objective recording by an outside observer.

Traditional approaches are also criticised because the artefacts do not comply with the object-oriented development paradigm, which is based on the UML. Since the emergence of the object-orient paradigm, the object management group (OMG) has introduced standards for a modelling language (UML) and a standard for the software development process called the unified rational process. These standards have become widely accepted and many vendors provide support for artefacts produced in UML as well as the unified rational process. Since the adoption of the object-oriented paradigm, developers have been forced to work with artefacts generated through the use of structured analysis and design techniques. Besides the differences in the language constructs, the models are not naturally used within the unified rational process. Eriksson and Penker (2000) have recently published an approach to business modelling with UML. Eriksson and Penker (2000:9) claim that the UML has managed to decrease the semantic gap between those who analyse and design systems and those who program them. Eriksson and Penker go on

to predict that having the model represented in the same language that developers use will decrease the semantic gap between business analysts and information systems analysts, as well as provide the following additional benefits:

- Using object-oriented techniques, the modelling concepts and structures used in the business model can be the same as those used in the analysis model and implementation models. This provides the ability of enabling traceability of business requirements all the way to the code; and
- The trend for re-use within system development is leaning more toward high-level re-use through architectural frameworks or patterns, instead of simple code re-use. Using a standard notation for business process modelling helps the move towards re-using patterns.

Traditional software specification techniques have served business analysts for decades. Although these models have many valuable uses in the delivery of information systems, they can be an inaccurate representation of the true needs of stakeholders if they are produced using traditional software specification techniques. The models can also be difficult and cumbersome to use in the object-oriented development paradigm.

2.7 Summary and Conclusions

This chapter emphasises the important role business process models serve in providing a framework and platform to guide the installation of suitable information systems.

A review of the most popular approaches to business process analysis and modelling reveals that business process modelling techniques do not emphasise the analysis techniques that are used. Hence, there is no separate identification of the analysis and modelling techniques. This creates the impression that there is a focus on modelling rather than analysis. The recording of business process models is therefore only an objective recording as seen through the eyes of the analyst. A richer point of view is necessary.

This lack of seeing situations within social settings disregards the multiple perceptions that influence the interpretation of problems and potential solutions. Many researchers highlight the lack of attention to softer issues and the inability to treat the implementation environment as a social setting. The researchers identify these limitations as important

factors, which result in many information systems projects failing to address the real needs of a situation. (Galliers (1994:165); Ormerod (1995:292); Mingers (1995:21); Nuseibeh and Easterbrook (2000:43)).

The techniques that have been reviewed have the ability to define the tasks of a process, inter-dependencies of tasks within a process and the required inputs and outputs for each task. Each of the techniques reviewed in this chapter emphasise a different aspect of a process, and therefore have different modelling advantages and disadvantages. ASME's feature of evaluating each step as value adding or not gives the technique a unique advantage over the rest of the modelling techniques. An analysis of Porter's value chain analysis shows that the technique is able to identify business processes in the context of their contribution to the organisation's value adding process. Value chain analysis provides a comprehensive reference model for business functions to ensure all activities of a business are considered. The techniques also confirmed that the production process is a primary activity that has a direct impact on the value adding process.

Conversely, Eriksson and Penker (2000:15) indicate that one of the limitations of present process modelling techniques is that they do not produce artefacts that are able to naturally support developers. This is the case because the modelling languages used by business modelling techniques are not a current standard amongst developers. Although IDEF0 and DFD have origins as software specification techniques, they have emanated from structured analysis and design, which has been superseded by object-oriented approaches.

The following chapter reviews SSM and UML business process modelling to establish whether these techniques can address the limitations of current business analysis and modelling which are highlighted in this chapter. Several researchers concur that business analysis and modelling techniques in use need to be supplemented by other techniques to address their analysis and modelling limitations. Mingers (1995:21) and Galliers (1994:165) suggest the use of SSM as the enquiry process to elicit, communicate and confirm aspects of the business process model. Eriksson and Penker (2000:15) recommend the use of UML to model business processes in order to make business models more usable to developers.

CHAPTER 3 Suitable Techniques for Analysing and Modelling Business Processes to Support Developers Following an Object-Oriented Development Approach

3.1 Introduction

Research into business process modelling techniques has emphasised the important role business process modelling serves in providing a platform for the subsequent delivery of suitable information systems. Despite this important role, there are shortcomings in the traditional software specification techniques that are being used to analyse and model business processes.

The previous chapter shows how these techniques offer limited analysis support to the business analyst in complex situations, e.g. when there are many stakeholders with different perceptions of problematic issues and potential solutions. Software specification techniques that are used to model business processes also do not allow a holistic enquiry, or focus on the softer issues that may affect the improvement of the situation. Generally software specification techniques are geared towards defining and expressing software constructs instead of human activity systems. In addition to these analysis shortcomings, present business process modelling techniques produce artefacts that are conducive to a structured analysis and design development process as opposed to object-oriented development process.

This chapter investigates the relevance of Soft System Methodology's techniques. This chapter also investigates if these techniques are capable of providing a rich analysis of the problems affecting the delivery of critical product information to the production process. It is hoped that the process of SSM will allow an acceptable solution to emerge. The chapter initially discusses the factors that have led to the emergence of SSM. A presentation on the nature of SSM will follow explaining the techniques and processes entailed by SSM. A number of researchers have already tried to precede information systems development projects with SSM. An analysis of these attempts is presented thereafter.

Unfortunately SSM models will not be acceptable to developers due to the use of modern object-oriented development practices. As discussed previously in the report the preferred business process modelling language to support object-oriented development approaches is the UML. Hence, suitable UML business process modelling techniques will be investigated in the remainder of the chapter.

3.2 Factors that Contributed to the Emergence of Soft Systems

Methodology

Galliers (1994:164) indicates that, in order to successfully design or re-design business processes there needs to be:

- Participation, so that there is buy-in and agreement on the appropriate solution;
- Significant learning about the issues that could affect the implementation of a solution;
- Formulation and understanding of the various alternative solutions that stakeholders recommend; and
- Agreement amongst stakeholders on the required activities to enable a relevant system to improve the situation;

Parnaby (1994:503), Ormerod (1995:280) and Weston (1999:836) claim that paying considerable attention to these softer issues of cultural change, motivation and communication of the total vision, are essential factors to ensure the final systems are “what” stakeholders really want. Hence, meeting the legitimate requirements of stakeholders is crucial to successful business engineering.

The realisation that complex situations are characterised by actors with different points of view and interpretations of reality has led to softer approaches to requirements analysis being preferred to the more traditional requirements analysis techniques in complex situations. Soft systems methodology (SSM) is an example of an interpretive soft approach to understanding complex situations, which is being used to improve the requirements determination process (Galliers (1994:164-165); Platt and Warwick (1995:21); Mingers (1992:86,1995:45)). Checkland’s soft systems methodology is a problem-solving framework designed specifically for situations in which the nature of the

problem is difficult to define (Sinn, 1998:442). SSM is an iterative, systemic process that allows for a structured, organised, and holistic approach to problem identification and structuring. Bulow (1989:35-41) succinctly summarises SSM as follows:

“SSM is a methodology that aims to bring about improvement in areas of social concern by activating in the people involved in the situation a learning cycle which is ideally never ending. The learning takes place through the iterative process of using systems concepts to reflect upon and debate perceptions of the real world, taking action in the real world, and again reflecting on the happenings using systems concepts. The reflection and debate is structured by a number of systemic models. These are conceived as holistic ideal types of certain aspects of the problem situation rather than accounts of it. It is taken as given that no objective and complete account of a problem situation can be provided.”

SSM is based on soft systems thinking, which emerged as a result of dissatisfaction with the development and limitations of hard systems thinking (Checkland 1999:A6-7). Lane and Jackson (1995:225) indicate that soft systems thinking seeks to extend the sphere and application of systems ideas to problem situations in which objectives are ill defined and systems too complex to model mathematically.

The development of SSM started at the university of Lancaster by Gwilym Jenkins and Peter Checkland around the mid 1960s. Jenkins was disenchanted with the lack of contact with the real world and started research by applying systems engineering approaches to situations where there was no clear definition of the problem. Jenkins did this through action research and found that these application of systems engineering approaches to ill-defined situations failed. Systems engineering is a goal seeking or goal meeting approach. Systems engineering approaches include information systems development techniques and other hard approaches from the area of operations research. These approaches are concerned with meeting defined objectives in the most efficient, economic and elegant way, instead of actually defining the objective that has to be met (Rosenhead, 1989:72). SSM emerged through this process of action research as an alternative to systems engineering, to define the objectives of the system that have to be met. (Rosenhead

(1989:73-74); Checkland (1999:128)). The problem-structuring, goal-formulation process of SSM makes it possible for systems engineering methods to bring about improvement. Similarly, this research project hopes that a combination of SSM and UML business modelling will result in a business process model of the business requirements, which can support developers following an object-oriented approach.

Checkland acknowledges the influence of Geoffrey Vickers' work on "appreciation" and "appreciative systems" has had on the development of SSM (Stowell, 1993:97). Vickers believed that human beings selectively make judgments of their experience of the world individually and in groups. Judgments of fact ("what" is the case), and judgements of value (is this acceptable or unacceptable) are made, as relationships and are maintained over time. With time, action is also taken to balance relationships in line with judgements. Checkland and Scholes (1999:A41) indicate that SSM can be seen as a systematic learning process, which articulates the working of "appreciative systems" in Vickers' sense.

Since its emergence, SSM has evolved into a flexible, problem-solving framework. The following section discusses the key ideas, which have led to the development of SSM and how the process of SSM can be applied.

3.3 The Nature of SSM and its Philosophical Foundations

Four key ideas shape SSM (Checkland, 1999:A7). The first idea is to see the problematic situation as a situation which involves people taking purposeful action that is meaningful to them, instead of focussing and thinking of some system in the real world that needs repair or improvement. Treating a problematic situation in this way requires the modelling of human activity systems as sets of linked activities, which together can exhibit the emergent property of purposefulness. These ideas have led to ways of building such models.

The second idea is that many interpretations of the declared purpose are possible. This means that for any situation a large number of human activity systems are possible. To explore a situation through model building, the perspectives or viewpoints

(Weltanschauung) from which the situation will be explored, need to be chosen. This makes it possible to explore a situation from technical, social or political viewpoints.

The third idea, which shapes SSM, is that in order to model purposeful activity, it is accepted that there are two world-views for each model. The first world-view is the perspective that makes a chosen model relevant, while the second worldview describes the model content of the relevant activities that leads to achieving the purpose.

The fourth idea is to move away from working with an “obvious” problem that requires a solution, to a situation that some people for various reasons regard as problematic. Improvement of the situation is brought about by solutions that emerge through the learning and appreciation that occurs, as the developed models are used to explore the situation. These ideas have led to the emergence of SSM as an organised learning system.

All these thoughts have led to SSM taking its present format presented in Figure 3.1. This figure shows that, initially there is finding out about a perceived real-world problem situation (technical, cultural and political). This is followed by formulating relevant purposeful activity models. These models are then used to debate the situation by comparing the models with reality to seek:

- a) Changes which could improve the situation that are regarded as both desirable and culturally feasible, and are
- b) accommodations between conflicting interests, which will enable action to be taken that improves the situation, which is
- c) followed by taking action in the real world to improve the situation.

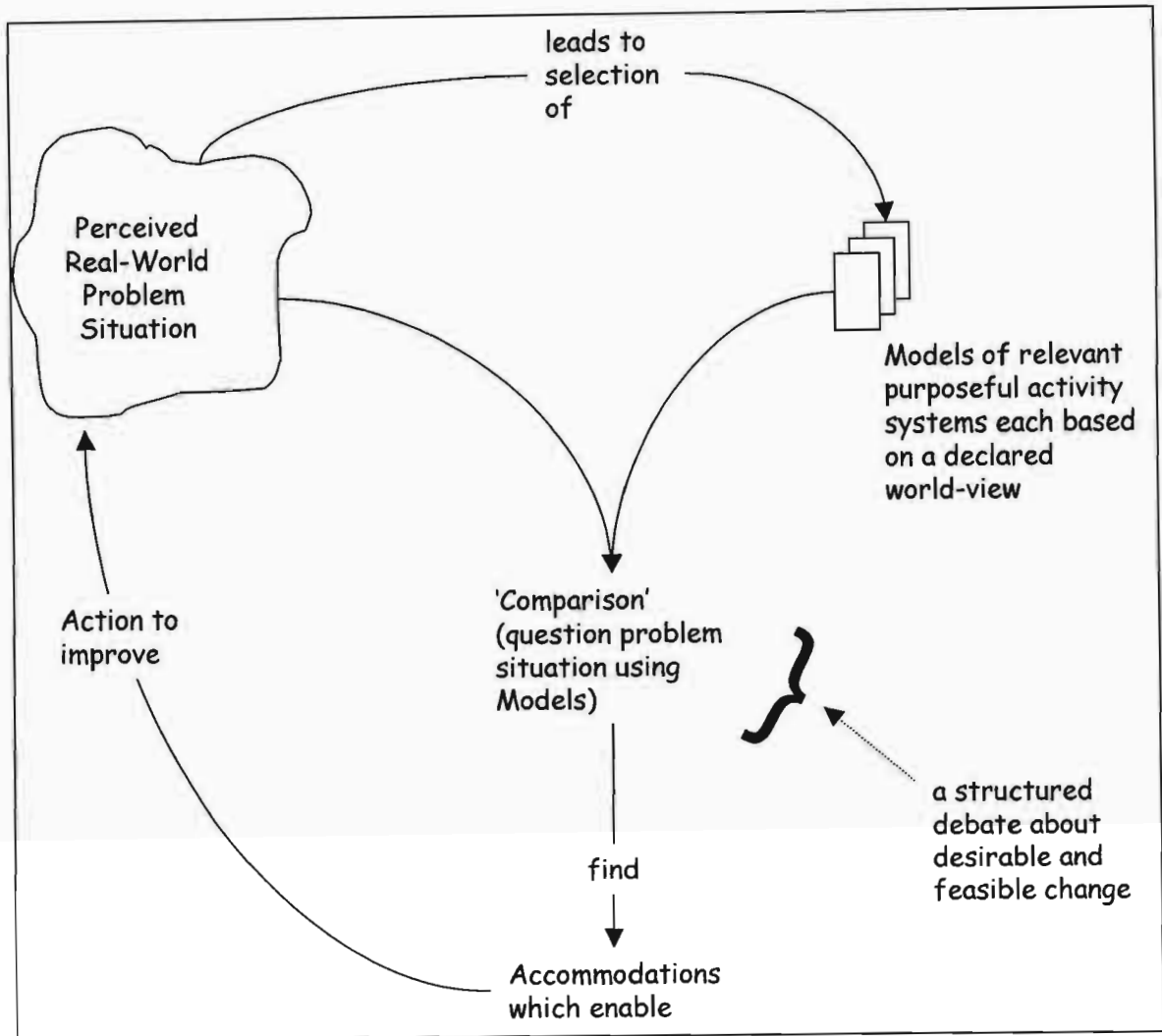


Figure 3.1 The enquiring learning cycle of SSM (Checkland, 1999:A9).

There are many ways of applying the techniques of SSM within a process. The following section discusses the most popular approaches.

3.4 The Process of SSM

Although the process of SSM is outlined in distinct stages, Checkland emphasises that the stages merely provide a guideline to the types of thinking that should be occurring instead of a strict guideline of sequential steps to follow (Sinn, 1998:442). SSM was initially presented in 1981 as a seven-stage model (see Figure 3.2). The original model also has a line separating the systems thinking about the real world from the real world. This division emphasises what is necessary in a systems study in order to claim that SSM has been used.

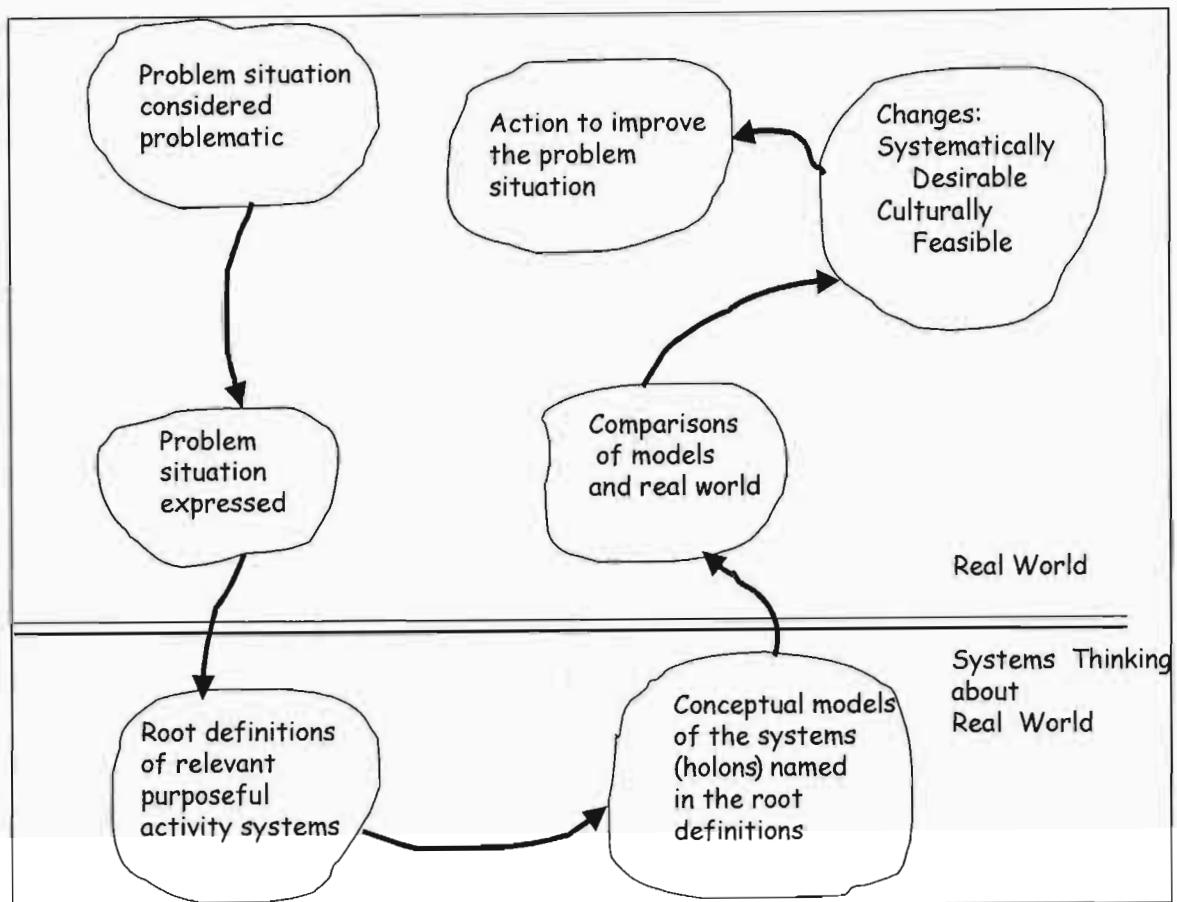


Figure 3.2 Seven Stages of SSM Mode one (Rosenhead, 1989:84).

The model presented in Figure 3.2 shows that the first two stages involve entering the problem situation, finding out about it and expressing its nature using rich pictures. This allows for only the relevant activity systems to be chosen from the defined activity systems for further exploration. According to the seven-stage model, root definitions of systems relevant to improving the problem situation are constructed in the third stage. Each of the root definitions embodies a particular world-view. The construction of root definitions leads to the fourth stage where conceptual models of these root definitions are built. The next stages are used to structure further questioning of the situation by comparing the conceptual models with real-world activities (stage five). This is done to define changes, which could improve the situation. Changes meeting the criteria of ‘desirable in principal’ and ‘feasible to implement’ are selected as possible candidates for improving the situation in stage six. Stage seven then takes organised action to improve the problem situation, completing one cycle.

The original seven-stage model has since been revised because it gives the impression that SSM is a mechanistic, prescriptive process that has to be followed systematically. Over the last twenty years, SSM has evolved into a more sophisticated and representative model of the real world. The revised version of SSM has two streams of enquiry namely, cultural and logic based streams of enquiry (depicted in Figure 3.3). According to Checkland and Scholes (1999:A36) there are two idealised ways of using the process of SSM. Checkland refers to the idealised ways of using the process of SSM as Mode 1 and Mode 2. Mode 1, according to Checkland is methodology driven, intervention oriented, sometimes sequential and is often used as an external recipe. Mode 2, however, is situation driven, interaction oriented, always iterative and used as an internal recipe. For an application at Hulett Aluminium's production process, SSM would be used more as an external recipe (mode 1), while there will also be a requirement to use SSM as an internal recipe (mode 2). This proposed use of the techniques supports Checkland's and Scholes (1999:A36) suggestion that a typical implementation includes both mode 1 and mode 2 uses of SSM.

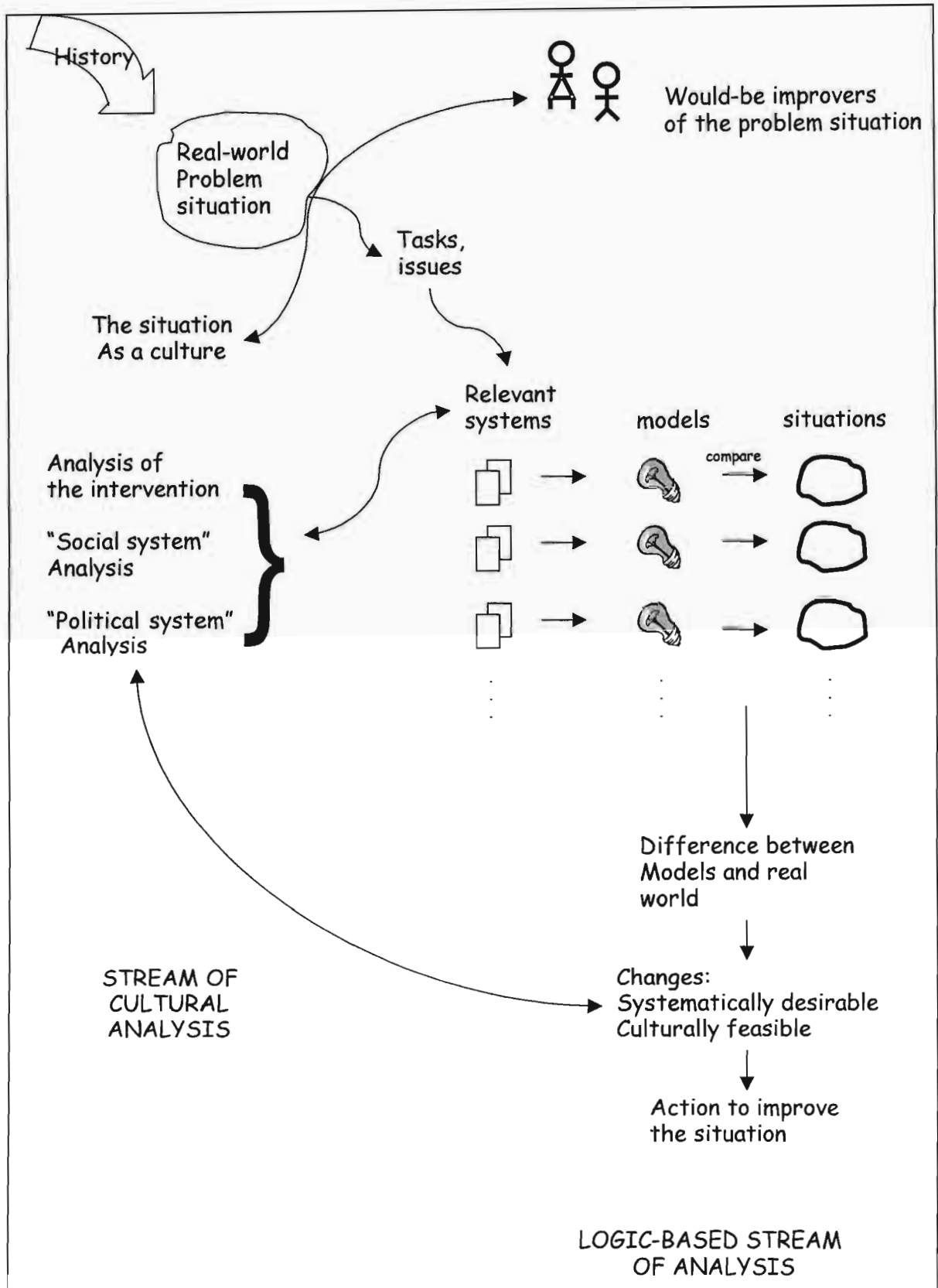


Figure 3.3 Process of SSM (Checkland and Scholes, 1999:29).

3.5 Techniques in SSM

Although there are a number of ways of applying SSM as a process, the individual techniques can also be used in isolation or with other techniques. Mingers and Brocklesby (1997:491) often suggest using the individual techniques of SSM in their discussion of approaches aimed at combining techniques from different methods in a single intervention. These individual techniques of SSM are analysed in the following sub sections.

Rich Pictures

Finding out about the problematic situation using SSM has always been characterised by building pictures to describe elements of structure, process and relationships between structure and process. According to Checkland (1999:A16), picture building encourages holistic rather than reductionist thinking, by conveying the complexity of the situation at a glance. Pictures more easily convey the social and cultural issues in a situation, which are necessary to describe the complexity of interacting relationships. Pictures are also easier to read than written descriptions because they can be read in parallel, while written descriptions can only be processed serially (Checkland, 1999:A16). Rich pictures normally guide the analyst into exploring the technical, social and political issues that affect the problematic situation.

Analysis one (i.e. analysis of technical issues) is concerned with understanding the stakeholders, by trying to be as holistic as possible about the problem situation. Banville *et al.* (1998:19) observes that the problem cannot be seen independently from the problem owners (Stakeholders), because the problem is not an autonomous reality, but a construction that stems from the interaction between one or more stakeholders and the reality upon (problematic situation) which they wish to act to modify it to their advantage. This observation by Banville *et al.* (1998:19) indicates that the identification of the stakeholders aids in understanding and pinpointing the problem.

Analysis two and three, known as social and political analysis is concerned with understanding the commodities through which power is embodied. 'Commodity' is the metaphor proposed by Checkland to make the topic more approachable so that organisational members are able to discuss it openly, because there are normally

difficulties in approaching this issue. It is necessary to understand the impact the various commodities have on the situation or could have on the situation. Power is exercised by some stakeholders to influence other stakeholders in problematic situations. According to Checkland (1999:A20), in social interaction, all people have an understanding of how to influence other people, to cause things to happen, or to stop possible courses of action the groups or its members are trying to take.

Rich pictures and analysis techniques one, two and three could provide good insight into the real needs of stakeholders in the production process, because the stakeholders come from different cultural and social backgrounds, which cause them to have different interpretations of the problems and required solutions. Stakeholders of the production process also spend a large proportion of their lives at work and the relationships between various groups must impact the activities of the production process. Checkland (1999:A16) indicates that pictures are a better means of recording relationships than linear prose.

CATWOE

The mnemonic CATWOE was developed to expand the idea of the transformation process (T) and Weltanschauung (W). CATWOE is used as a tool for presenting multiple perspectives of the problem. The elements of the transformation process include (Platt and Warwick, 1995:20):

- Customers (those who are affected by the process);
- Actors (those who perform the process);
- The Transformation process itself;
- The Weltanschauung (world view);
- The Owners (who can stop the action); and
- And the Environmental constraints.

The act of understanding and analysing the elements of the transformation process is often referred to as CATWOE analysis. Checkland and Scholes (1999:A22-A23) indicate that root-definitions that are constructed without CATWOE analysis are often “bald” and not rich enough. There can be more than one CATWOE analysis of a problem situation from different viewpoints

Root Definitions and Conceptual Models

Checkland (1999:221) identifies two distinctly different types of root definitions, namely, primary task and issue-based. Primary task root definitions are structured and closely resemble the kind of systems defined by hard systems methods. On the contrary, issue-based root definitions do not describe tasks that have been “institutionalised in an organisation department or section, or an organisation as a whole”. The core of the root definition is the transformation process in which a defined input is transformed into an output. Rosenhead (1989:86-99) and Checkland (1999:A22-A24) caution against confusing the element to be transformed with the resources needed for the execution. Conceptual models are constructed based on the human activity implied by the root definition. Only verbs or verb phrases in the root definition should be used in the construction of the model. The conceptual models are used to structure and encourage debate among decision makers, after finding out about the problem situation. When SSM is used in mode 2, the conceptual model technique is not compulsory in the analysis of the problem situation. Normally the purpose of comparing models with the real world is to generate a coherent debate, out of which will come ideas for improving the ‘what’ and / or ‘how’ of current practice. Through the process, a solution that is culturally feasible and acceptable to all stakeholders emerges. Root definitions and conceptual models appear to be good techniques that allow an organised enquiry into the various perspectives that stakeholders have of problems or solutions in the production process.

Since SSM’s emergence as a problem-structuring tool, there have been many attempts to link the process of SSM to approaches that facilitate information system provision. The following section provides an analysis of the various ways that SSM has been used to improve the delivery of information systems.

3.6 Approaches to use SSM in the Provision of Information Systems

The emergence of SSM has influenced a number of researchers to consider ways in which SSM might be used in the analysis and design of information systems (Jones (1992:123-125); Mingers (1992:82-86); Mingers (1995:21-45)). The majority of the research work in this area discusses attempts to integrate SSM with the type of structured development methods that preceded object-oriented technology. Although the OO paradigm has been

established as preferred practices, the attempts to link SSM with structured methods will still be discussed because the integration is more about transferring knowledge between two paradigms. There is also no formalised or popular way of linking SSM with OO development approaches. The main methods that will be discussed below are the Standard Lancaster Method, Front Ending SSM onto structured design methods, Embedding IS methods within SSM, Multiview and approaches that link SSM with OO analysis and design. Pluralist approaches are also a way of integrating soft analysis with information systems design by mixing different soft approaches in IS analysis and design. Pluralist approaches are, however, excluded from the discussion in the following paragraphs, because the discussion of other soft approaches is beyond the scope of this research project.

Standard Lancaster Method

The Standard Lancaster method was developed by Wilson and is endorsed by Checkland (Mingers, 1992:82). This method prescribes the use of SSM to identify the set of activities that must be carried out by the organisation. The first step of the Lancaster method requires the development of a primary task conceptual model to depict the required organisational activities. Wilson advises that conceptual models do not have to be restricted to the defined five to nine activities (In Mingers, 1995:21-29). The step following the definition of the primary task model requires a description of the information, necessary for executing the activities of the conceptual model. For each activity of the primary task model the following are defined:

- The information inputs that the activity requires;
- The information outputs generated by the activity; and
- The monitoring and control information necessary for the measurement of performance.

Defining the information categories normally produces a large amount of different information items. Wilson suggests that similar items be grouped into information categories with a data model depicting the relationships of data items within an information category. The third step of the Lancaster method involves mapping the conceptual information models to actual functional boundaries or roles within the organisation. This mapping results in a role-to-role information flow. Finally, these

requirements are compared to existing information systems to determine new information requirements. The new requirements form the basis of the detailed design and implementation work.

Mingers (1992:83, 1995:25) highlights a number of weaknesses in the Standard Lancaster method. The first weakness he highlights, is the very narrow definition of IS requirements which results from using a single primary task model. According to Mingers, the Lancaster method reduces the organisation to a traditional task-oriented, functionalist view and hence loses much of the richness of the SSM analysis. The author further explains that the Lancaster method does not prescribe a systemic way of determining the information requirements and suggests that the process of information requirements determination seems ad-hoc. He further states that the Lancaster method is also not linked to any formal systems analysis and design methodologies.

Front Ending SSM onto Structured Design Methods

The idea of linking SSM to existing structured design methods was first surfaced by Stowell (In Mingers 1995:27). The basis of Stowell's proposal relates to the similarities that exist between conceptual models and data flow diagrams. Stowell suggests expanding an agreed conceptual model into a detailed data specification using a data flow diagram (DFD). Although there are major differences in the underlying philosophies of the two methodologies, with conceptual models being interpretive while DFD's are objectivist, there are also similarities. In support of Stowell, Mingers suggests that a well-constructed and detailed conceptual model can easily and usefully be converted into a DFD (Mingers, 1992:83; 1995:27).

Embedding IS Methods Within SSM

Miles argues against the front ending or grafting of SSM onto hard methods (In Mingers 1992:84). Miles indicates that SSM should guide the whole process and when appropriate, hard elements should be embedded within it. Miles suggests that instead of converting conceptual models to DFDs, new constructs are added to the conceptual modelling stage. A conceptual flow model and a conceptual data model should be added to the conceptual modelling stage. The conceptual data model is derived from the conceptual flow model and is very similar to the standard entity relationship diagram. Following the process of

SSM, the conceptual models should be compared to real world activities. Flows of entities not present in the real world indicate the need for information systems development while the absence of real-world entities and flows is an indication of possible changes (Mingers, 1992:14; 1995:34).

Multiview

An approach developed by Arvison and Wood-Harper called Multiview, is the most formalised methodology, which combines techniques of SSM with other information systems development techniques (Mingers, 1992:84; 1995:38). Multiview prescribes five stages:

- i. First there is an analysis of human activity systems using SSM to the point of constructing conceptual models.
- ii. A functional and entity model is developed from one of the root definitions using functional and entity analysis (information modelling) techniques.
- iii. Following information modelling is the analysis of socio-technical systems. The purpose of this stage is to bring into consideration important social objectives and values to generate different possible system designs.
- iv. The results of information modelling and socio technical analysis are then used in the design of the human-computer interface.
- v. Finally the technical subsystem is designed.

The incorporation of stages three and four makes Multiview a preferred approach, since the other approaches pay little attention to important issues which are uncovered through the use of SSM techniques. According to Mingers (1992:84; 1995:38) Multiview does, however, have problems in the prescribed way of transitioning from stage one to two. The process of Multiview does not indicate how the new information system was decided on and how the functions and entities relate to the conceptual model (Mingers, 1995:39).

Methods of transitioning from SSM to Object-Oriented Analysis

Lane (1998:9) suggests deriving an object model from the Conceptual Primary Task Model (CPTM) as one way of transitioning from SSM to object-oriented analysis. Lane also suggests identifying the activities from the CPTM that will be supported by information technology. Once the activities that need to be computerised are scoped, candidate objects for the object model can be identified. According to Lane this step should be followed by

steps, which involve enhancing and refining the object model following conventional object-oriented information systems analysis development techniques. Although this approach is simple, Lane (1998:10) indicates that the disadvantage of this technique is that the objective model may not be based on real-world objects. Lane suggests the creation of a very detailed conceptual model, followed by a high-level business object model to support software delivery. Lane is indirectly suggesting the creation of a single view of the business process model.

Another approach suggested by Lane (1998:11) is to identify use-cases from root-definitions, and then follow a use-case centred object-oriented analysis approach. According to Jacobson *et al.* (1992:127) a use-case is a behaviourally related sequence of transactions a user performs in a dialogue with the system. Lane (1998:12), however, has reservations in using his own prescribed approach because root definitions do not have a detailed description of the domain to support the definition of all use-cases. Lane elaborated that root definitions are defined at several levels of abstraction and would sometimes cause very vague use-case definitions.

3.7 Critical Discussion of SSM and Linking SSM and IS

The above discussion shows that many researchers have tried to use SSM to improve the requirements determination process. Although there are benefits, there are also concerns about how the techniques from two philosophical backgrounds are linked without compromising the advantages the individual techniques provide. The validity of these research attempts is also questioned by the emergence of the OO paradigm, as well as the specific problems some researchers have regarding the use of SSM as a problem structuring, organisational learning tool. The following are some of the concerns expressed by researchers:

- Doyle and Wood argue that soft and hard approaches are incompatible, and that although they are both necessary, there is no easy way to incorporate them (In Mingers, 1992:86). These authors suggest that the richness of an SSM analysis is lost by settling on one single agreed activity model and converting to a narrow representation like a DFD to link to traditional IS approaches. Doyle and Wood

argue, like Miles, that the DFD or conceptual model should remain conceptual and under the line to facilitate the debate about different subjective viewpoints.

- Mingers (1995:45) acknowledges that SSM and information systems analysis and design are philosophically incompatible but also indicates that he does not see how the incompatibility is a serious problem because there must be a path toward greater concreteness, which can result in action being taken. The author states that although a final design is then used to take action, the design can change through the design process to accommodate new or changed needs.
- Mingers (1995:45) also explains that, by embedding hard elements into the process, there are advantages to be gained from using SSM as the guiding process for the entire project. According to Mingers, SSM has several advantages over IS approaches because the entire development cycle is based on learning, which is the strength of SSM.
- Broad participation is essential to soft systems thinking, philosophically because it provides justification for the objectivity of the results, and practically because it generates creativity and ensures implementation. Although this is recognised by SSM, the processes entailed by SSM do not prescribe a method of encouraging broad participation. Jackson (1991) argues that soft systems thinkers believe in a consensual social world because they take the possibility of participation for granted and see it as a remedy for so many organisation problems. Perhaps because of its significance, soft systems thinkers play down the obstacles to full and effective participation (Jackson, 1991).
- Flood and Jackson state that SSM's strong interpretive stance prohibits a method for choosing a correct *Weltanschauung* (In Sinn, 1998:447-449). Although comparing the different models helps illuminate the assumptions of the participants, SSM provides no other method except dialogue to choose among the different viewpoints.

An analysis of the criticism reveals that there are many views on the validity of SSM as an organisational enquiry tool, and the appropriateness of linking SSM with IS provision. SSM, however, allows a way of thinking, which guides problem owners (or "stakeholders) towards purposeful action. SSM also encourages the consideration of systems requirements from the perspective of different stakeholders. This style of thinking allows

the business analyst to believe that business processes do not exist “out there” but are constructed in the minds of stakeholders. This is an important factor in understanding the softer issues that affect the problem situation. These benefits of SSM will be valuable to determine the required activities that will improve the delivery of product information to operators. As mentioned earlier in this report, the absence of these features in structured analysis methods has probably led to inappropriate information systems being designed. Due to the lack of attention to softer issues, projects aimed at supporting the production process with suitable information systems have been unsuccessful

Although there are many critics of the research into ways of linking SSM with information systems analysis and design, the critics do not think the linking is unnecessary or a bad idea (Mingers, 1995:48). The critics appear to be more concerned with how the techniques are combined. The information systems modelling techniques discussed above analyse and describe the technical features of information systems instead of the required business architecture, goals, resources, rules and actual work required by the business. Therefore, none of the approaches discussed above appear to provide a comprehensive business modelling approach, which would be able to establish a suitable platform to support the delivery of information systems, following an object-oriented approach. The different views on how to link SSM with information systems analysis and design discussed in this section will, however, provide significant guidance to arrive at a suitable integrated, business analysis and UML modelling approach.

The remainder of this chapter investigates research into UML business modelling approaches, starting with a discussion of the emergence of UML.

3.8 The Emergence of UML

The acceptance of OO development practices during the 1990's resulted in the number of identified modelling languages to increase from less than ten to more than fifty (Bluhme, 2000:1). This wealth of choices among modelling languages made it difficult for developers to choose a language to represent their designs and fuelled the “method wars” (Bluhme, 2000:1). By the mid 1990's the three most popular approaches were Booch, OMT-2 and Object-Oriented Software Engineering (OOSE). According to Bluhme

(2000:1-2), OOSE was use-case oriented and very suited to business engineering, while OMT-2 expressed data intensive applications very well and Booch'93 was good during the design and construction phases of a project. In 1996, the Object Management Group (OMG), a standards body for the object-oriented community, issued a request for the proposal of a standard object-oriented analysis notation and semantic meta-model. UML, version 1.0, was proposed as an answer in January of 1997. There were five other rival submissions. During the course of 1997, all six submitters united their work and presented to OMG a revised UML document, called UML version 1.1. According to Kobryn (2001:11), UML was designed with the following goals in mind:

- It had to be an easy-to-use, semantically-rich modelling language, which included ideas from other modelling languages;
- It had to address the contemporary software development issues of scale, concurrency, distribution and executability;
- It had to provide flexibility to allow the application of many different processes; and
- It had to enable the electronic interchange of models.

The present release of UML is version 1.4. Figure 3.4 shows the planned evolution of UML as well as the history of the emergence of UML.

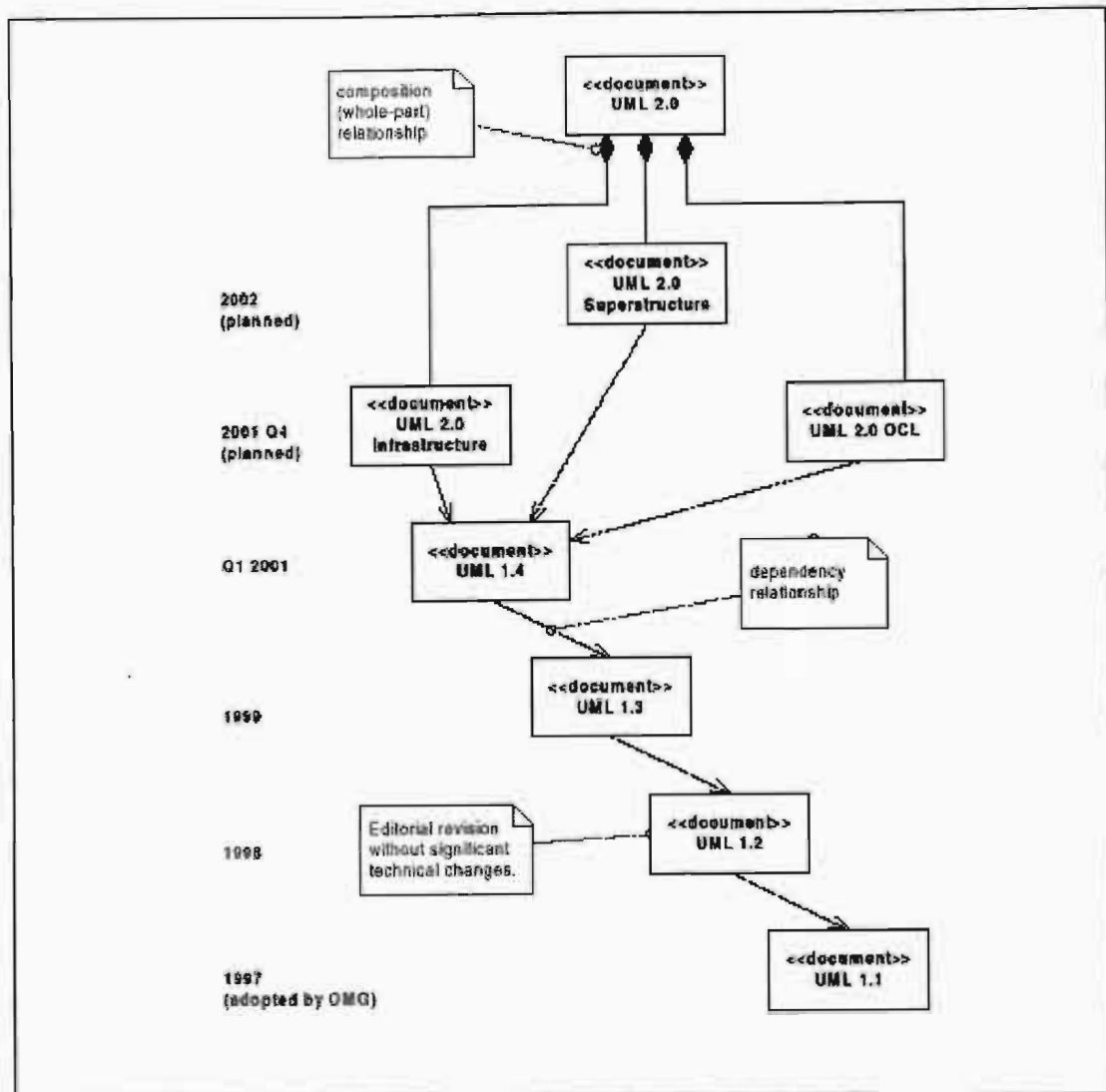


Figure 3.4. Evolution of the UML from Kobryn (2001:12).

UML is considered to be a consolidation of the work of Grady Booch, James Rumbaugh, and Ivar Jacobson (Bluhme, 2000:1-2). These authors were the creators of three of the most popular object-oriented methodologies. According to Kobryn (2001) the basic building blocks of the UML are:

- Model elements (classes, interfaces, components, use-cases etc.);
- Relationships (associations, generalisations, dependencies etc.); and
- Diagrams (class diagrams, sequence diagrams etc).

In terms of the views of a model, UML provides the following nine diagrams to represent static or dynamic aspects of the system:

- **Use-case diagrams** for modelling the business processes;
- **Class diagrams** for modelling the static structure of classes in the system;
- **Object diagrams** for exemplifying class diagrams;
- **Behaviour diagrams:**
 - State chart diagram for modelling the behaviour of objects in the system.
 - Activity diagram for modelling the behaviour of Use-cases, objects or operations.
 - Sequence diagram for modelling interaction and message passing between objects.
 - Collaboration diagram for modelling object interactions.
- **Implementation diagrams:**
 - Component diagrams for modelling components.
 - Deployment diagram for modelling distribution of the system.

These diagrams provide multiple perspectives on the system under analysis or development.

The UML extensions for business modelling contain icons for business modelling with brief specifications on its application, which are difficult to follow (Eriksson and Penker, 2000:66). Use-cases are the central concept for business modelling using the UML. Although the UML does not prescribe a process, the rational unified process (RUP), which is advocated by the OMG, proposes the use of use-cases for business process modelling. This suggested approach by the OMG is considered by Eriksson and Penker (2000:66) and Popkin (2001:1) to be inappropriate for business process modelling. These authors have subsequently suggested alternative approaches to business process modelling using the UML. These authors do not critically evaluate the nine standard views, which illustrates that the major concern is the use-case driven approach rather than the expressiveness of the standard views. Eriksson and Penker (2000:67) simply state that the activity diagram is inadequate for business process modelling and suggests enhancements to the activity diagram. The full set of extensions to the standard UML diagrams will be provided in Section 3.11. Before discussing these extensions, the use-case approach to business modelling and analysis will be analysed.

3.9 Use-Case Approach to Business Process Modelling

Jacobson introduced the use-case technique in his Object-Oriented Software Engineering approach to define functional system requirements (Popkin, 2001:2). Jacobson *et al.* (1992:127) original definition of a use-case, states that a use-case is:

“...a behaviourally related sequence of transactions, a user performs in a dialogue with the system”

The rational unified process proposes the use of use-cases to model business processes (Jacobson *et al.*, 1999:122). Jacobson *et al.* (1999:33) and Esichaikul (2001:29) suggest the definition of use-cases in a structured top-down approach where primary use-cases (major business process) are linked to supporting use-cases through the “depends” and “uses” relationships. Although this approach is consistent with the syntax of defining use-cases, Popkin (2001:2) and Eriksson and Penker (2000:66) do not support the idea of using use-cases to model business processes. Popkin (2001:2) indicates that the definition of a use-case gives the impression that a use-case is an information systems level construct and describes information systems processes, which are subsets of business processes. A use-case also shows processes in a non-sequential way, while the real requirement of business models, illustrated in Chapter 2, is to show both manual and automated tasks in sequence with an indication of inputs, outputs and dependencies with other processes.

These criticisms illustrate that the use of use-cases as a central concept for business modelling has many valid limitations. A significant reason not reflected in the literature review of UML business modelling is that the use of information systems level constructs could force the analyst into considering the technical aspects of information systems before all the elements of the business model are analysed and modelled. Chapter 2 discussed the limitations of structured analysis and design techniques, which focus too early on technical features, that can result in significant business requirements being neglected. The approach of using use-cases will therefore not be considered as a valid technique to present the required production process activities to developers.

3.10 Popkin Approach to Business Process Modelling

Popkin (2001:5) suggests an approach to map enterprise business models with UML systems models. Although the approach is not a UML business modelling approach, it is still analysed because it presents ideas on how the business model can be related to UML information system models. This analysis may influence the decisions taken to arrive at an integrated business analysis and modelling approach, which links SSM with UML business modelling. Popkin (2001:5) suggests that the enterprise business model, in the form of process charts, be used as a starting point to describe any functionality for information systems within the enterprise. Use-cases are created for every enterprise business process, as suggested by Jacobson *et al.* (1999) and Esichaikul (2001:29). For each use-case representing an enterprise business process, an activity diagram is used to express the sequential behaviour of the use-case. Popkin (2001:5) acknowledges that activity diagrams could also be used to represent process charts. This will, however, remove the distinction between business models and information systems models, which Popkin (2001:5) believes is made clear by the use of different techniques. Popkin (2001) does not provide further reasons for the use of different techniques. The use of different techniques can encourage different types of thinking that is required in business modelling and information systems modelling. This will, however, lead to models represented in different languages. Lane (1998:7) indicates that experience has shown that using structured analysis as a front end to object-oriented design often fails due to the limitations of the structured mindset.

3.11 Eriksson and Penker UML Business Modelling Extensions.

Eriksson and Penker (2000:15) believe there are several advantages that are gained when a business model and software model are modelled in the same language. Due to the lack of a well-defined business process modelling approach using the UML, Eriksson and Penker have published the Eriksson-Penker Business Extensions to support UML business modelling. The extensions are based on the existing UML model elements and standard extension mechanisms supported by UML. A detailed description of the extensions is provided in Appendix D. The Eriksson-Penker Business Extensions are also endorsed by the OMG (Eriksson and Penker, 2000). Besides introducing new model elements for business modelling, the Eriksson-Penker business extensions are accompanied by:

- Guidelines on how to approach business modelling;

- Re-usable patterns which encapsulate knowledge and experience of modelling common business problems; and
- an approach that illustrates how the business model can be used to support software delivery, following a use-case centric approach like the unified rational process.

The Eriksson-Penker business extensions make use of the nine predefined standard UML diagrams. The major enhancement to the standard UML diagrams is the unique use of the activity diagram. The activity diagram is renamed in the extensions to an assembly line diagram (Eriksson and Penker, 2000:67). The assembly line diagram is an activity diagram where links are made to information systems or resource objects, which are consumed or referenced during the process. Eriksson and Penker (2000:421), see the assembly line diagram as the point of connection between the world of business modelling and software modelling because it leads to the determination of use-cases.

Eriksson and Penker (2000:421) suggest using a business vision, process, structure and behaviour views to represent the business model. The business vision view describes the goal structure of the business and illustrates the problems that must be solved in order to reach the goals. Besides a written vision statement, a goal or problem diagram is used to model the business vision, using the standard UML object diagram and some stereotypes from the Eriksson-Penker Business Extensions. The business process view represents the activities in the business, the interaction between processes and the resources that are required in order to achieve the goals of the processes. Business process views are modelled using the UML activity diagrams with a set of stereotypes that describe the details of the process. Assembly diagrams are also used to capture the business process view. The business structure view illustrates how the business and related concepts are organised using the standard UML object and class diagrams. The business behaviour view represents the individual behaviour of each important resource and process in the business model. The business behaviour views are accomplished using the following standard UML diagrams: state-chart diagram, collaboration diagram and activity diagram. Eriksson and Penker emphasise that the views should not be seen as separate models, but are different perspectives of one or more specific aspects of the business.

In addition to the Eriksson-Penker business extensions being endorsed by the OMG, the research into UML business modelling illustrates that these extensions are the most comprehensive UML-based business modelling technique available. The diagrams are intended to convey the requirements to developers who want to follow an object-oriented approach to deliver required information systems. The conclusion follows with a summary of the chapter.

3.12 Summary and Conclusions

The chapter discussed the emergence of SSM as a flexible organisational enquiry, goal formulation and problem-structuring tool. The review of SSM shows how the technique is able to structure an organised enquiry into the perceptions of stakeholders and encourage debate about the situation of concern through the use of simple techniques like rich pictures and CATWOE analysis.

The review of current ways of using SSM for business analysis shows that there are several methods of applying the techniques of SSM as well as several ways of linking SSM to information systems analysis and design approaches. Most of the attempts to integrate SSM with information systems provision, which have been reviewed, focus on linking SSM to structured analysis and design approaches. Although structured analysis and design has since been superseded by object-oriented approaches, some aspects of how previous researchers have integrated SSM with business process modelling remain valid, and will be considered when deciding how SSM and UML business process modelling are integrated into a single business analysis and modelling approach.

An analysis of UML based business process modelling techniques shows that the standard UML approach, the unified rational process, the approach advocated by Popkin (2001) and the Eriksson and Penker business modelling extensions are the most popular approaches that exist. The standard UML approach and unified rational process approach of using use-case analysis do not adequately support the needs of business process modelling, while the approach suggested by Popkin (2001) is not a pure UML business modelling approach. The Popkin (2001) approach does, however, highlight that a clear distinction is needed between business process models and software models. The Eriksson and Penker (2000:85)

UML modelling extensions appear to be the most comprehensive UML business process modelling approach that exists. This approach has the potential to provide a basis that will allow developers to follow an object-oriented approach to deliver suitable information systems. The Eriksson and Penker (2000:66-85) extensions are based largely on the standard UML diagrams except for the activity diagram, which has been modified to support business process modelling, and provide a basis for subsequent use-case analysis for information systems requirements. The Eriksson and Penker (2000:59-65) business modelling techniques do not adequately address the analysis requirements for analysing complex situations. SSM supplements the analysis limitations of the Eriksson and Penker business modelling techniques and will therefore have to be preceded by SSM analysis.

The following chapter investigates the integration of SSM business analysis with UML business process modelling following the guidelines of the Eriksson and Penker (2000) business process modelling extensions. This chapter's review of approaches that combine SSM analysis with object-oriented modelling techniques shows that the combinations are not done properly. The attempts at combining do not utilise the outputs of the SSM analysis to formulate a model of the business requirements, before modelling software systems. Hence, the approaches do not emphasise the distinction between agreed activities or specific business requirements ("what") and possible software solutions ("how"). These modelling approaches are therefore software-modelling approaches instead of business process modelling approaches and cannot be used as recipes for performing the integration or as business process modelling techniques.

CHAPTER 4 An Integrated Business Process Modelling Methodology and the Application of its Soft Systems Methodology Components to the Aluminium Production Process

4.1 Introduction

Research into ways of using SSM during the early stages of an information systems project shows that there are many alternative ways of trying to link the delivery of information systems to SSM requirements analysis. The researched techniques, however, are not formulated from a strong theoretical basis and do not adequately address all the concerns highlighted by researchers. None of the researched approaches can therefore be used as a recipe to link SSM activities with UML business process modelling (Eriksson and Penker business modelling extensions). In order to achieve the research goals of this project, the techniques of SSM and UML business modelling need to be combined into a single approach that can be used in one intervention.

The combination of these techniques from different philosophical paradigms was disallowed previously because the paradigms were seen as mutually exclusive and contradictory (Mingers, 2001:241). Recently there are arguments to combine techniques from different philosophical backgrounds in order to deal with the complexity of real-life situations. Similarly, Mingers and Brocklesby (1997:491) and Mingers (2001:240) have discovered that the complexity and richness of real life situations requires researchers to go beyond the use of a single method or methods from a single paradigm. These authors believe that it is necessary to sometimes combine several methods from different paradigms in whole or in part, in order to better represent real-life situations.

Although pluralist research is desirable, Mingers (2001:247) warns that there are a number of feasibility issues that need to be considered. To assist the process of combining techniques, Mingers and Brocklesby (1997:500) and Mingers (2001:250) have published a framework to assist practitioners in formulating valid combinations. According to Checkland and Holwell (1998:23) any piece of research is comprised of a framework of ideas (F), methodology (M) and an area of application (A). The interaction of these

elements is shown in Figure 4.1. In the context of this research project, SSM and UML business modelling techniques constitute the frameworks of ideas that have the potential to propose an improved business model to support the delivery of suitable information systems. This new methodology will improve delivery of crucial quality information to operators at the production process (A).

The combination of these techniques is therefore examined in the light of frameworks provided by Mingers and Brocklesby (1997:495) and Mingers (2001:247) to understand the extent to which the combined approach is valid.

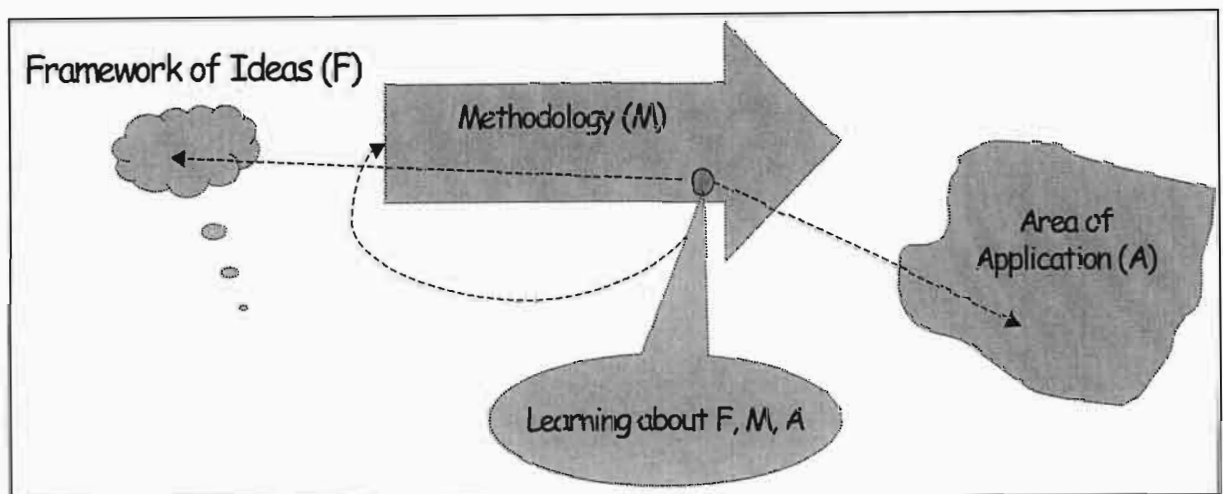


Figure 4.1 The elements of any piece of research (Checkland and Holwell, 1998:23).

This chapter initially presents a justification to combine the ideas (F) as a valid and acceptable Methodology (M). Following the justification and presentation of the methodology will be an application of the methodology to the production process at Hulett Aluminium (A) to propose a suitable business model design that improves the delivery of critical product information to the production process. The experimental implementation will be followed by an evaluation of the case study described in this report. The report has thus far discussed the desirability to combine SSM and UML business modelling; the following paragraphs attempt to establish a feasible combination that can be used in one intervention.

4.2 Justification of the Methodology

The previous chapter researched a number of approaches that link SSM to information systems analysis and design. In addition to the attempts to improve information systems delivery, SSM has also been used to enhance business improvement programs. Petkov and Petkova (1997:3) suggest a methodology for combining SSM with Business Process Re-engineering (BPR). Ackermann *et al.* (1999:202) recommend the use of a number of techniques, including SSM, in order to improve the effectiveness of BPR. There is, therefore, evidence that researchers are already practising multi-method research using SSM, and consider the pluralist approach valid and necessary to deal with the richness of real-life situations. These attempts, however, are not based on any strong theoretical basis like the multi-methodology approach suggested by Mingers and Brockelsby (1997) and Mingers (2001). These authors indicate that the following areas of feasibility need to be considered in the design of multi-method approaches to ensure the combined techniques adequately deal with the requirements of intervention. Mingers (2001:247) identifies the following four levels of problems that can arise when combining methods:

- i. **Philosophical** - Particularly the issue of paradigm incommensurability;
- ii. **Cultural** - the extent to which organisational and academic cultures militate against multi-method work;
- iii. **Psychological** - the problems of individual researchers who are often only comfortable with a particular type of method; and
- iv. **Practical.**

With regards to paradigm incommensurability, Mingers (2001:247) states that the arguments in support of single paradigm research are overstated and that paradigms are in fact permeable at the edges. In addition to these arguments for a single paradigm being weak, Mingers (2001:248) indicates that reality is more complex than our theories can capture and it is quite wrong to insist on a single paradigm to explain reality. With regards to this research project, SSM is necessary to ensure that the views of stakeholders are considered and the required activities are acceptable to all stakeholders. On the contrary, UML business modelling is necessary to explain the required solutions in a language with which developers are comfortable.

The issues of cultural feasibility are beyond the scope of this research project, but based on the arguments of Mingers and Brocklesby (1997:498) and Mingers (2001:248) for pluralist methods, it is assumed that the information systems community encourages multi-method research.

Psychological feasibility is concerned with the cognitive feasibility of moving from one paradigm to another. This research project requires SSM to learn about the different systems of meaning that stakeholders attach to the activities they are engaged in. By increasing the stakeholders understanding, the techniques of SSM improve the “appreciative” systems of the stakeholders involved in the process. With improved “appreciative” systems, there is greater probability of a desirable set of activities emerging, which will improve the delivery of critical product information to the production process. A desirable system existing in the form of some objective reality contradicts the philosophical assumptions of SSM, but is necessary in order to specify a state that will lead to improvement.

Mingers (2001:251) emphasises that the multi-method approach (Methodology) is suggested as a regulatory approach, to guide suitable combinations without the expectation that the approach can be wholly fulfilled in reality. The multi-method approach is being used in this research project to ensure that consideration is given to the range of factors that can influence the situation and to critically evaluate the extent to which the proposed techniques add to the richness and validity of results. Mingers (2001:245) illustrates that any intervention or research is never a discrete event but is a process that has phases, which require different types of activities. Mingers (2001:245) identifies the following four generic phases that comprise the research process:

- i. **Appreciation** is concerned with understanding why the problematic situation exists, who the actors are, accepting that the researchers access to the situation and prior experience will influence what is appreciated or observed;
- ii. **Analysis** is concerned with understanding and explaining the reasons for the information gathered during appreciation;
- iii. **Assessment** is concerned with evaluating alternatives and assessing the results; and

- iv. **Action** is concerned with reporting the research results in order to bring about change.

The proposed methodology is comprised of SSM, which is used as the guiding methodology, and UML business modelling, which is used for its expressive power. Mingers and Brocklesby (1997:491) identify such a combination as methodology enhancement. The combination of SSM and UML business modelling is achieved within the broader framework of conducting action research suggested by Checkland and Holwell (1998:27). Figure 4.2 shows the proposed methodology that will be used. As illustrated in Figure 4.2, there will initially be an analysis of the stakeholders. The stakeholder analysis will be followed by an SSM evaluation of the problem, followed by UML modelling, once there is agreement on the human activity that will improve the situation. The SSM evaluation of the problem will include the following methodological stages and techniques:

- Express the problem situation as experienced, using rich pictures and analyses one, two and three;
- Model the relevant conceptual systems (holons) using CATWOE analysis, root definitions and conceptual models; and
- Compare the models and real world to arrive at an action that is acceptable to all stakeholders and bring about improvement in the situation.

The above three steps equate to the appreciation step, analysis step and assessment step respectively, as defined by Mingers (2001:245).

A widely known limitation of SSM is the lack of techniques required to initiate taking action. This limitation is overcome in this research project by the use of UML business modelling. This step equates to the action stage of the generic research process identified by Mingers (2001:246).

UML business modelling will be initiated by taking the finally agreed conceptual model of the human activities that will bring about improvement, and expanding them into a detailed conceptual data flow diagram. The detailed data flow diagram and the SSM analysis will be used as the basis for the UML models. This approach of arriving at the conceptual data flow diagram from the conceptual model is similar to the standard Lancaster approach discussed in the previous chapter. The proposed methodology uses the detailed conceptual DFD as an input to the UML modelling process, together with the knowledge of the

problematic situation generated by the SSM evaluation. To avoid building poorly constructed models, Checkland (1995:50) suggests that conceptual models should be assembled from phrases that are contained in the root definitions.

The syntactical guidelines and available patterns suggested by Eriksson and Penker (2000) will be used to create the UML views that are necessary to communicate the required business process model to developers. Although there are other views on how to link the techniques of SSM with information systems analysis techniques, an approach similar to the Lancaster Method has been chosen because it is simple to apply, since the SSM evaluation is separate from the information systems analysis and design techniques. The cognitive difficulties expressed by Mingers (2001:248) that can be experienced working between paradigms are therefore avoided. Although the approach is simple, it is however, criticised by Mingers (1995:25) for reducing the problematic situation to a traditional functionalist view, hence losing much of the richness of the SSM evaluation. Due to the action research approach followed in this project this is not entirely true, because the process is continuous and being carried out by the author leading the intervention. This basically means that the SSM evaluation of the problem will be at the back of the authors mind throughout the UML modelling process.

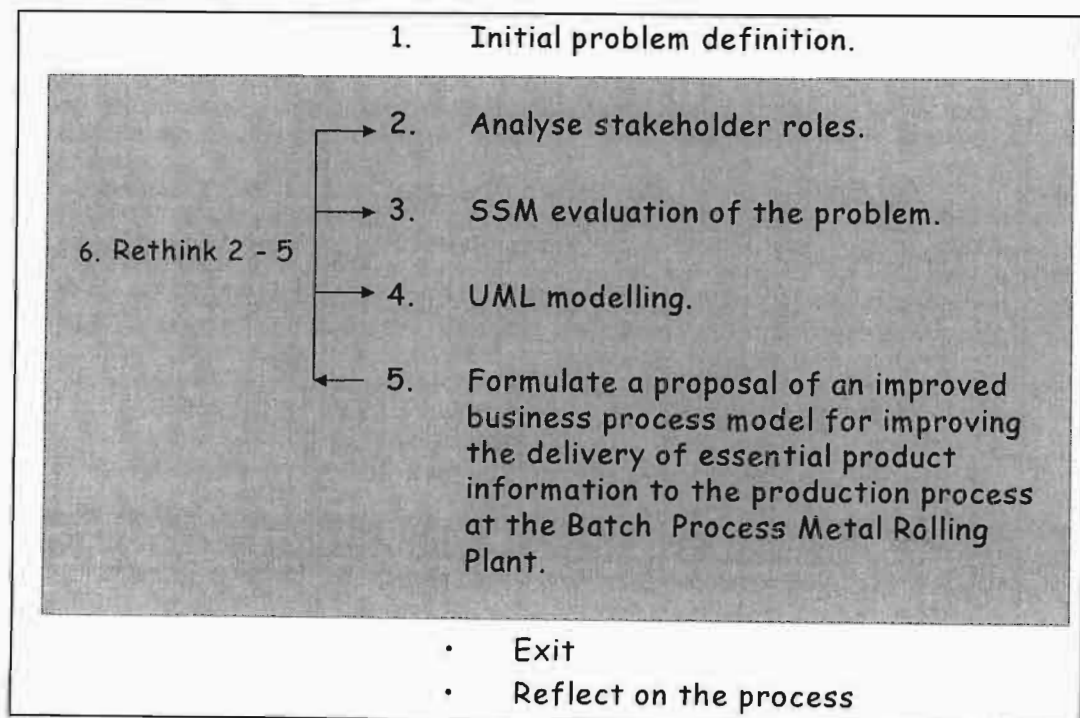


Figure 4.2 Proposed Methodology (adapted from Checkland and Holwell, 1998:27).

Besides being a valid methodology to improve the production process, the methodology has to also be acceptable to the stakeholders who will be affected by its implementation. Thus an important issue is the legitimacy of the methodology, which relates to the likelihood of its successful implementation in practice (Landry *et al.*, 1996:444). The following section discusses the legitimacy of the proposed methodology, which is crucial to establishing if the methodology will be seen as an acceptable approach.

4.3 Legitimacy of the Methodology

The view of legitimacy, supported by Landry *et al.* (1996:446), assumes that the code against which a model (in this case the proposed methodology) is judged for legitimacy is socially constructed, and therefore less stable across time and across organisational actors. There can therefore, be no guarantees for legitimacy since judgement is socially constructed. Although there can be no guarantees for legitimate models, Landry *et al.* (1996:453) define a set of heuristics that can increase the likelihood of obtaining legitimate models. As a way for judging the potential legitimacy of the proposed methodology, the methodology's features are compared with the heuristics suggested by Landry *et al.* (1996:435) in the following paragraphs:

Heuristic 1. The Operations Research (OR) specialist should be ready and willing to work in close cooperation with the strategic stakeholders in order to acquire a sound understanding of the organisational contract. In addition, the OR specialist should constantly try to discern the kernel of organisational values from its more contingent part.

The proposed methodology aims at deepening the understanding of the environment surrounding the production process through the use of rich pictures and CATWOE analysis.

Heuristic 2. The OR specialist should attempt to attain a balance between the level of model sophistication/complexity and the competence levels of the stakeholders.

Rich pictures and conceptual models are simple techniques that use the language of the stakeholders and should be understandable by them. A more precise and powerful representation of the requirements is achievable by UML and is reserved for the developers. The methodology therefore attempts to meet this aspect of legitimisation by matching the sophistication of the stakeholders with the appropriate techniques.

Heuristic 3. The OR specialist should attempt to become familiar with the various logical perspectives and preferences prevailing in the organisation.

The techniques employed in the methodology facilitate the revealing of such logic and preferences within an organisation.

Heuristic 4. The OR specialist should ensure that the possible instrumental uses of the model are well documented.

This aspect of legitimisation is addressed by Section 4.3, which describes the steps of the approach and Chapter 3, which describes why and how the techniques are used.

Heuristic 5. The OR specialist should be prepared to modify or develop a new version of the model, or even a completely new model if needed, that allows one to adequately explore unforeseen problem formulation and solution alternatives.

The methodology is iterative and accommodates several iterations, allowing stakeholders to change their minds and go back to earlier steps in the process.

Heuristic 6. The OR specialist should ensure that the model developed provides a buffer or leaves room for the stakeholders to adjust or readjust themselves to the situation created by the use of the model.

The methodology allows for stakeholders to learn about the factors affecting the problem situation. Through the learning that is generated, stakeholders reach agreement on the most sensible activity that is required to improve the problematic situation.

Heuristic 7. The OR specialist should be aware of the preconceived ideas and concepts of the stakeholders regarding problem definition and likely solutions.

This aspect of legitimacy will be accommodated by generating an initial rich picture about the production process, which will reveal preconceived ideas of problems and solutions to the remainder of the stakeholders.

The above discussion of the methodology's legitimacy provides insight into factors that have been considered to increase the likelihood of the methodology being organisationally acceptable. The remaining sections of this chapter provide an experimental implementation of the SSM components of the methodology to the production process at Hulett Aluminium. The following section provides a more detailed description of the production process at Hulett Aluminium.

4.4 The Production Process at Hulett Aluminium

Hulett Aluminium produces semi-fabricated aluminium for customers located both locally and abroad. Customer requirements are very specific and are determined by the manufacturing conditions in the customer's plant. A popular phrase coined at Hulett Aluminium is "producing a product that works in the customer's plant". This level of customisation makes it difficult to store, maintain and communicate customer requirements and the corresponding manufacturing rules and procedures. Customers are constantly refining their processes and demand tighter quality requirements from Hulett Aluminium. As indicated earlier in the report, the magnitude of the problem has been exacerbated with the introduction of many new products and sales to new export customers. Management has highlighted that operators are receiving inadequate information on product quality to allow them to set-up machinery correctly. To compensate for the lack of consistent information, operators are using information they remember and are making assumptions based on experience. The inadequate information that is being delivered to operators is a

factor causing inconsistent quality that needs to be improved in order to eliminate customer dissatisfaction.

Generally, customer requirements for rolled aluminium products are achieved through a number of process operations. Each process operation directly achieves certain customer requirements or is responsible for getting the metal into a suitable condition for downstream process operations. A grouping of process operations that are responsible for producing a certain quality of product is called a process route. When a lot is issued into production a “lot ticket” accompanies it. An example of a lot ticket is shown in Appendix B. The lot ticket is a printout of the machine route that needs to be followed with instructions per process operation. This tells the operator “which” operations need to be performed at the various production processes.

The sequencer plans a particular process operation. Certain production processes are considered bottlenecks and the objective of the sequencer is to optimise the utilisation of bottleneck processes. Sequencers maximise production process utilisation by ensuring that the production process is fully loaded and there are minimal interruptions for set-ups and preparations. In addition these throughput driven objectives, the sequencer has to also ensure that urgent customer priorities are given consideration, and the required quality conditions for a production process are planned for. An example of a necessary quality condition can be that, in order to process product x , product y needs to be run first. The sequencers communicate the plan for a particular production process by means of a sequence list.

In order to execute a sequence list on a production process, the required conditions for the production process (machine) need to be planned for. Generally the “A” operator leads the rest of the operating crew on a production process. The progressor loads the planned lots on the entry side of the machine, organises the lot tickets and hands them to the “B” operator. The “B” operator inspects the incoming lots for any obvious defects and is responsible for reading and interpreting the NCR (non-conformance reports) from previous operations. The “B” operator is responsible for flagging NCR’s to the “A” operator.

Before processing a particular coil, the “A” operator reads the instructions on the lot ticket, adjusts the mill set-up, if necessary, and records the “start time” of the lot. On completion

of the coil (lot), the “A” operator visually inspects the coil and records the run-time of the lot and other required process information on the lot ticket and machine log. If necessary, the “A” operator will refer certain defects to the product coordinators or process specialist by raising an NCR or stopping the machine. Progressors remove completed lots to storage areas and send completed lot tickets for capturing. Area managers review the performance of production processes daily using information captured from the machine logs, lot tickets and control system. Area managers provide daily feedback to operators on throughput and quality performance.

Customer feedback is received through the sales and marketing teams. Complaints from customers are investigated by Product Coordinators, who upon investigation then take preventative action to ensure the problems do not recur. Generally, after investigation of customer complaints, the operating procedures are revised by changing master lot tickets and standard operating instructions. With the introduction of new machines, new customers and new products, customer returns have increased rapidly, resulting in the elimination of customer dissatisfiers the highest priority at Hulett Aluminium. Management have devised an approach called a product quality plan (Product Recipe or Product Standard Operating Procedure), which requires the monitoring and measurement of critical variables on each process operation to ensure that the variables that influence the achievement of customer requirements on the production process are measured, monitored and controlled. Appendix C contains an example of a product SOP. Essential to this process is the delivery of essential product information to the production process to allow the set-up, control and monitoring of critical variables that influence the products critical quality requirements for the production process. There are several perspectives on what the possible solutions are to “deliver essential product information to the production process”. These different perspectives have prevented any solution from being successfully introduced in the past. An SSM evaluation of the situation follows in the paragraphs below.

4.5 Stakeholder Analysis

The second task of the methodology requires an analysis of the stakeholder roles. The structured interviews with Hulett Aluminium management provided the action researcher with an idea of the decision problem with its associated stakeholders and their specific

roles. A list of stakeholders was proposed during the first workshop. The initial stakeholder list has been modified since the first workshop and is reflected in Table 4.1

1. Operators (“A”, “B” and “Progressors”)
2. Market Managers, Sales Representatives.
3. Area Managers.
4. Process Specialists.
5. Product Coordinators.
6. Sequencers.
7. Customers.
8. Developer.

Table 4.1 Stakeholders identified by all the workshop participants.

Operators are directly responsible for carrying out the production process activities on the shop floor. Market Managers and Sales Representatives in conjunction with Area Managers, Process Specialists and Product Coordinators are responsible for dealing with, and resolving customer dissatisfiers. Sequencers are responsible for the planning of work for the production process and ensuring the decisions made do not violate quality requirements or incur any unnecessary machine stoppages. Product Coordinators are responsible for interpreting the Customer’s requirements into operating instructions and standard operating procedures. In addition to the process design responsibilities, Product Coordinators are responsible for continuously enhancing the product and process design to ensure a better quality product is consistently achieved. Process specialists are responsible for the quality performance of a particular process operation. A Developer assigned to the development of shop floor information systems also participated in the workshop.

All the stakeholders in Table 4.1 except customers can be defined as standard stakeholders, using the terms of Banville *et al.* (1998:18). These standard stakeholders are both affected by and affect the problem, and are participants in the process of “delivering essential product information to the production process”. A customer can be characterised as a “silent stakeholder”. Customers have no direct control over the resources or proposed approaches that are relevant to solving the problem (Banville *et al.*, 1998:18). The

paragraphs below describe the SSM evaluation of the problem, which is the third task of the methodology.

4.6 Creating Multiple Perspectives of the Problem Situation

The third task of the methodology is to carry out an organised enquiry and sharing of the perceptions of the problem and the alternative ways of improving the situation. The SSM evaluation was conducted through a number of workshops. The initial workshop brought together all the stakeholders to discuss the problem and the different views on the issues which are possibly causing the problem. The initial workshop was followed up by workshops with smaller groups of the team to understand specific perspectives in greater detail. A final workshop was used to evaluate the various alternative solutions. At the final workshop, several alternative solutions were compared. Through discussion and appreciation of the alternatives, one of these solutions emerged as the approach which was acceptable to all stakeholders. An account of the workshops follows in the paragraphs below.

At the initial workshop a rich picture was introduced. The rich picture was developed on the basis of individual discussions with stakeholders. This original pictorial summary shown in Figure 4.3 was reviewed and revised during the workshop sessions. The rich picture in Figure 4.3 attempts to show the major structural and process elements of the problem together with the different views on possible solutions to improve the situation. The process of revising the original picture increased the understanding and appreciation the various participants had of the cultural, political and technical issues influencing the problem. The increased appreciation of the various issues allowed the stakeholders to verbalise alternative solutions which could improve the situation. The rich picture encouraged divergent thinking amongst the stakeholders. Each alternative solution recommended by the stakeholders was compared to the activities of the production process and either discarded as an invalid approach or explored in more detail to establish the benefits of the approach.

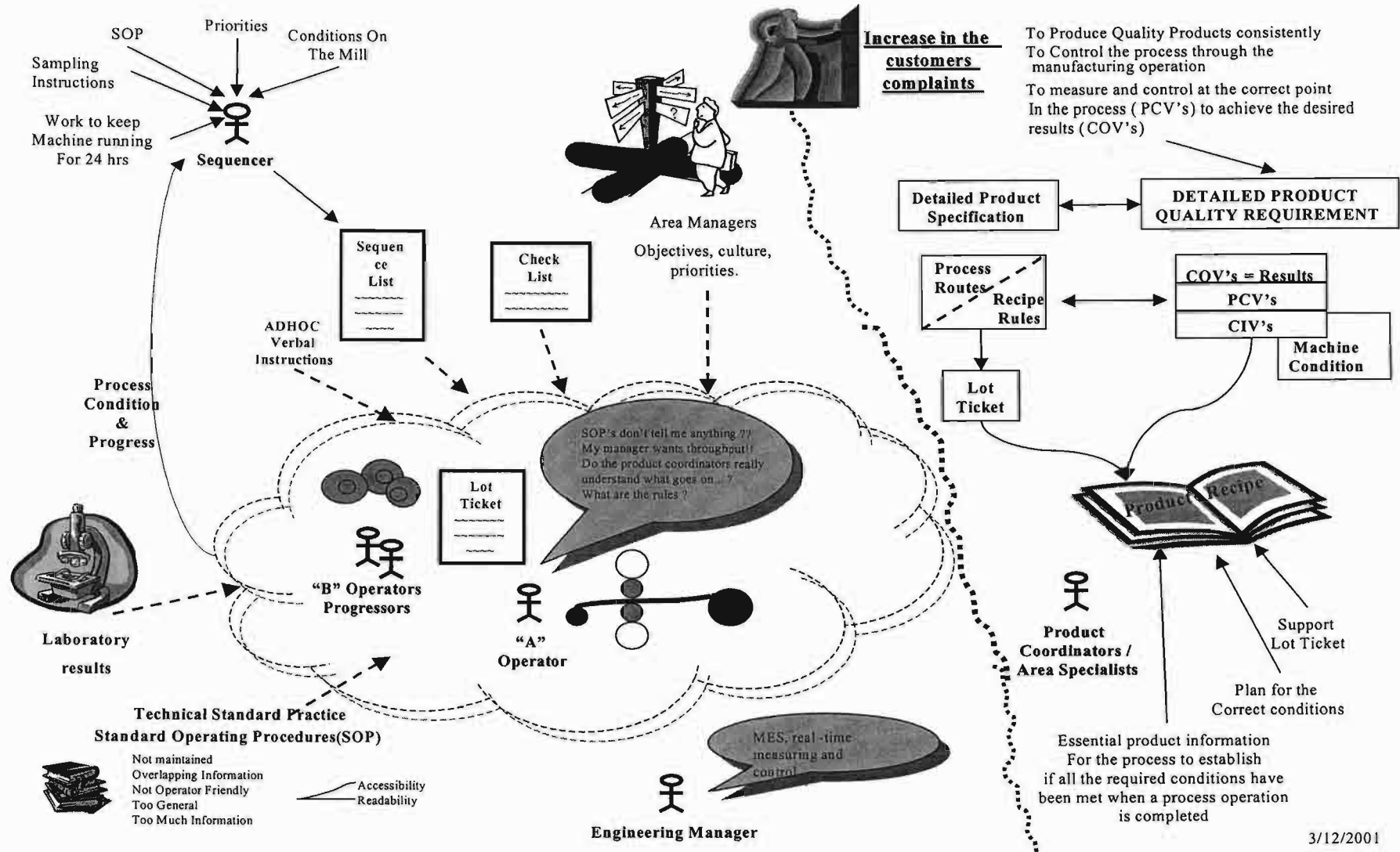


Figure 4.3 A rich picture diagram depicting the main issues associated with delivering essential product information to the production process as perceived by the participants of the workshop.

The rich picture shown in Figure 4.3 conveys the following themes:

- The first theme conveyed, is the quality drive initiated by management, which is seen by management as the key approach to eliminate customer dissatisfiers.
- The second theme shown in the rich picture is the issue of delivering product information through existing mechanisms like the lot ticket, technical standard practice, sequence lists, check lists or standard operating instructions.
- The third theme is the overwhelming amount of information and number of sources of information that are necessary to guide the operators and sequencers.
- The fourth theme is the product recipe alternative to deliver essential product information to the production process.
- The fifth theme is the Engineering manager's view of how essential product information can be delivered to the production process to guide the operator to produce better quality.

These themes were discussed at the initial workshop. The rich picture's cartoon-like presentation facilitated the sharing of perceptions. In addition to sharing perceptions of the solution, all the major themes and relationships between the themes were conveyed at a glance giving stakeholders a holistic presentation of the problem and management's intention of solving the problem.

4.6.1 Management's Intentions

In defining the root definitions, the elements of the mnemonic CATWOE were considered. As discussed in Chapter 3, the mnemonic CATWOE stands for the following:

- | | |
|-------------------------------|--|
| ➤ Customers. | Those who are affected by the process. |
| ➤ Actors. | Those who perform the process. |
| ➤ Transformation process. | The conversion of input to output. |
| ➤ Weltanschauung (world view) | Worldview, which makes this T meaningful in context. |
| ➤ Owners | Those who could stop T. |
| ➤ Environmental constraints | Elements outside the system which it takes as given. |

The following is a CATWOE analysis and root definition of management's intention.

C	Customers, Downstream processes.
A	Sequencers, Operators, Product Coordinators, Marketing/Sales.
T	(input) Critical customer/product quality requirements, process route. (transformation) Understand the influence each process has on the critical customer requirements and which variables need to be controlled to achieve the critical quality requirements. (output) Formulate a plan (product recipe) to achieve the critical customer requirements, that clearly indicates for each of the processing steps, the necessary process conditions that must be available (critical input variables (CIV's)) and the variables that need to be controlled (process control variables (COV's)) to achieve the desired critical output variables (COV's).
W	Control the process through the manufacturing operation, by measuring and controlling at the correct point in the process to achieve the desired customer / product requirements.
O	Company management.
E	Product coordinators have the ability to relate critical customer/product requirements to the variables that influence them, at each process operation.

Root definition: *To produce quality products consistently, requires a system that translates critical customer product requirements into a plan (product recipe), which specifies the necessary conditions that need to be created and the specific variables in the manufacturing process that need to be controlled with their control standards to ensure the requirements are achieved at each stage of the manufacturing process.*

Figure 4.4 A root definition and CATWOE analysis of management's improvement plan to eliminate customer dissatisfiers.

Following the discussion of management's intention, the workshop proceeded to discuss reasons for the situation and possible solutions to improve the situation. Stakeholders were asked to identify key issues of concern regarding the introduction of the product recipe. The participants were encouraged to generate ideas of several types along the three

different perspectives of Soft Systems Methodology, mode two (Checkland, 1999:A19-A20)

- Ideas on the *technical* side of introducing the product recipe to assist in the control of critical variables of the process that influence critical customer requirements.
- Ideas related to the *cultural* analysis of delivering essential product information to the production process. These concern:
 - ✓ Various roles,
 - ✓ Various norms, and
 - ✓ Various values of the stakeholders responsible for generating and using the product recipe.
- Ideas related to the *political* analysis of the issues affecting the conformance to the product recipe, revealing power relations and processes in which differing interests reach accommodation.

This approach provided insight into different viewpoints that existed regarding alternative solutions and limitations in existing procedures. These ideas are reflected in Table 4.2.

Technical issues

1. Deliver relevant information to a machine center at the right time, to enable the operator to achieve critical customer/product requirements.
2. Need to manage the workflow of the data throughout the production process, so that the data is maintainable, traceable and does not rely on people keeping the data in memory.
3. There should be a rule to allow the monitoring of what has happened or what is happening on a certain lot.
4. Need to store information about the process conditions to allow consistent, easy ways of accessing the information to investigate queries and refine the process.
5. Need to monitor the appropriate variables real-time at each process against product recipe criteria and raise alarms to notify the operator when any deviation is detected.
6. Get the right elements of the data to the shop floor at the right time, without flooding the operator with excessive details, but making sure operators get the critical information they need.

Cultural issues

7. Reward systems are throughput-driven, not quality oriented.
8. No culture of sticking to the rules.
9. Standard operating procedure seen to be more of a guideline than a fixed rule. Operators believe the process is an art, not necessarily a science.
10. Too many holes in the understanding of the process, can't give operators concise feedback on why certain practices are wrong.
11. Some operators are throughput-driven and feel free to change rules.
12. Some operators have the mentality of "what can I get away with?". Provided that they have an excuse, operators are not interested in being proactive in highlighting problems.
13. Some operators are not passionate about the company objectives. These operators don't believe there is anything in it for them.
14. Area managers bend rules to reach throughput targets. This situation causes confusion about what the rules are.
15. Standard operating procedures are seen as a helpful tool.
16. There are no fixed rules to prevent incorrect practices being followed because the rules are disregarded, and Product Coordinators cannot conclusively convince area managers and shop floor that certain practices are wrong.

Political issues

17. Operators feel that the product recipe cannot accommodate every condition of the process and certain decisions have to be left with them.
18. Certain operators know more about machine conditions than is documented in standard practices. This knowledge can be used by them to sabotage the assumptions with which the product recipe is drawn up.
19. Operators feel that management is prescribing without understanding the difficulties operators will have in following the prescribed ways of working.

Table 4.2 List of issues raised by stakeholders with regards to introducing the product recipe.

At the first workshop, through discussion of the above issues, stakeholders were already starting to suggest alternative solutions that could lead to improvement. The alternative

ideas on appropriate action were fundamentally different and it was decided that the alternative approaches would be investigated in follow-up workshops. Follow-up sessions were held to analyse the perspectives of operators, product coordinators and the engineering manager. The operators thought that the current lot ticket could be extended to cater for the additional information, while product coordinators felt that the product recipe should accompany the lot ticket as an additional set of instructions. The engineering manager could not see how a manual system would work and suggested that a Manufacturing Execution System (MES) be considered.

During the follow-up workshops with stakeholders the different viewpoints were analysed using CATWOE analysis and root definitions. Root definitions express the essence of the purposeful activity that is required to improve the delivery of critical product information to the production process. The following paragraphs contain the CATWOE analysis and root definitions derived from these workshops.

4.6.2 Operators (“A”, “B” and Progressors) and Sequencers viewpoint

C	Customers, Downstream processes.
A	Sequencers, Operators, Product Coordinators, Process Specialists, Planning staff.
T	Include critical product information (“How”) with the instructions on (“What”) to do on the existing lot ticket systems.
W	Process is not scientific, provide more information to support the operator. Lot ticket always accompanies the piece of metal and has to be consulted by the operator.
O	Company management.
E	Operators are able to constantly and consistently read and carry out the instructions on the ticket.

Root definition: *A system that adds critical product information to the lot ticket instructions to guide the operator on what to do, as well as how to do what is required.*

Figure 4.5 A root definition and CATWOE analysis of the Operator’s and Sequencer’s viewpoint.

4.6.3 Product Coordinators viewpoint

C	Customers, Downstream processes.
A	Sequencers, Operators, Product Coordinators, Process Specialists.
T	Present critical product information to the production process by introducing a Product Standard Operating Procedure (PSOP), which is product specific and contains only the essential product information that is required (Operator has the ability to change or influence) by the Operator or Sequencer to plan or produce the product on a particular machine.
W	The product SOP is new as a concept and will evolve. To support its evolution a manual, stand-alone system is the most flexible.
O	Company management.
E	The additional information on the product recipe gets referenced by the operators and sequencers when planning or producing the product. The administration of the product SOP's could cause complications because of the overlap of information in other existing systems.

Root definition: *A system is required to elicit, structure and present critical product information that is required or necessary for operators and sequencers to have, as a PSOP.*

Figure 4.6 A root definition and CATWOE analysis of the Product Coordinator's viewpoint.

Through the application of the methodology, the Action Researcher has learnt a considerable amount about the problem and presents his perspective as the Action Researcher's. This perspective was very similar to that of the Engineering Manager and these perspectives were merged and are presented in Figure 4.7 as the Engineering Manager / Action Researchers viewpoint.

4.6.4 Engineering Manager / Action Researcher's viewpoint

C	Customers, Downstream processes.
A	Sequencers, Operators, Product Coordinators, Laboratory operators, Process specialists, Area Managers.
T	Present the Operator or sequencer with critical product information electronically to allow him to plan a sequence list or set up the machine correctly. At the end of processing or on demand, present the operator with all the accumulated information about process control variables (PCV's) and critical output variables (COV's) against the control standards to allow the Operator to decide if a coil should progress to the next operation.
W	Allowing a coil to progress to the next operation is not a totally scientific decision. The Operator's evaluation is necessary. At times all the information that is necessary to decide if a coil should progress to the next operation is not available at the end of a process operation. The presentation of required information to plan or set-up the machine can be made more effective with appropriate information technology. The evaluation of actual results against controls is tedious to do manually and needs to be supported with information technology.
O	User company management.
E	There is a combination of manual / automatic machines. The process is not entirely scientific as yet and sub-optimal decisions would have to be allowed, making the Operator's visual assessment and sometime manual overriding of the systems advice is necessary.

Root definition: *A system is required to present essential product information to operators and sequencers when requested, in the right context without overloading them, to support the sequencers to plan a batch of lots on a specific machine, help the operator create the right conditions before running a product and assist operators in the set-up, control and final releasing of a specific lot to ensure the quality requirements specific to the operation being performed on the product are achieved.*

Figure 4.7 A root definition and CATWOE analysis for the Action Researcher's viewpoint.

4.7 Emerging Solutions

The CATWOE analysis and root definitions define the different viewpoints in greater detail and clarify the reasons for different perspectives on appropriate action that could improve the situation amongst the stakeholders. The final workshop discussed the advantages and disadvantages of the alternative approaches. The operator's and sequencer's perspective on using the existing lot ticket system was the simplest approach but was not considered as an effective solution because the product coordinator, engineering manager and action researcher felt that using the lot ticket to convey essential product information would change the focus of the lot ticket and make presentation and delivery of the lot specific information more difficult.

The stakeholders felt that the product coordinator's perspective on introducing a PSOP was a valid interim step to acquire, organise and document information, but this was not an effective sustainable approach to assist the operator and sequencer plan or create the required conditions to run a lot. The action researcher and engineering manager could not see how the new approach would be manageable without the introduction of appropriate IT to assist with the planning, set-up and releasing of lots. The approach suggested by the action researcher / engineering manager was elected as the best solution to pursue. The participants all noted that this approach was the most ambitious and risky but was a more consistent and sustainable approach. A conceptual model of the emerging solution to deliver critical product information to operators and sequencers follows in Figure 4.8 below.

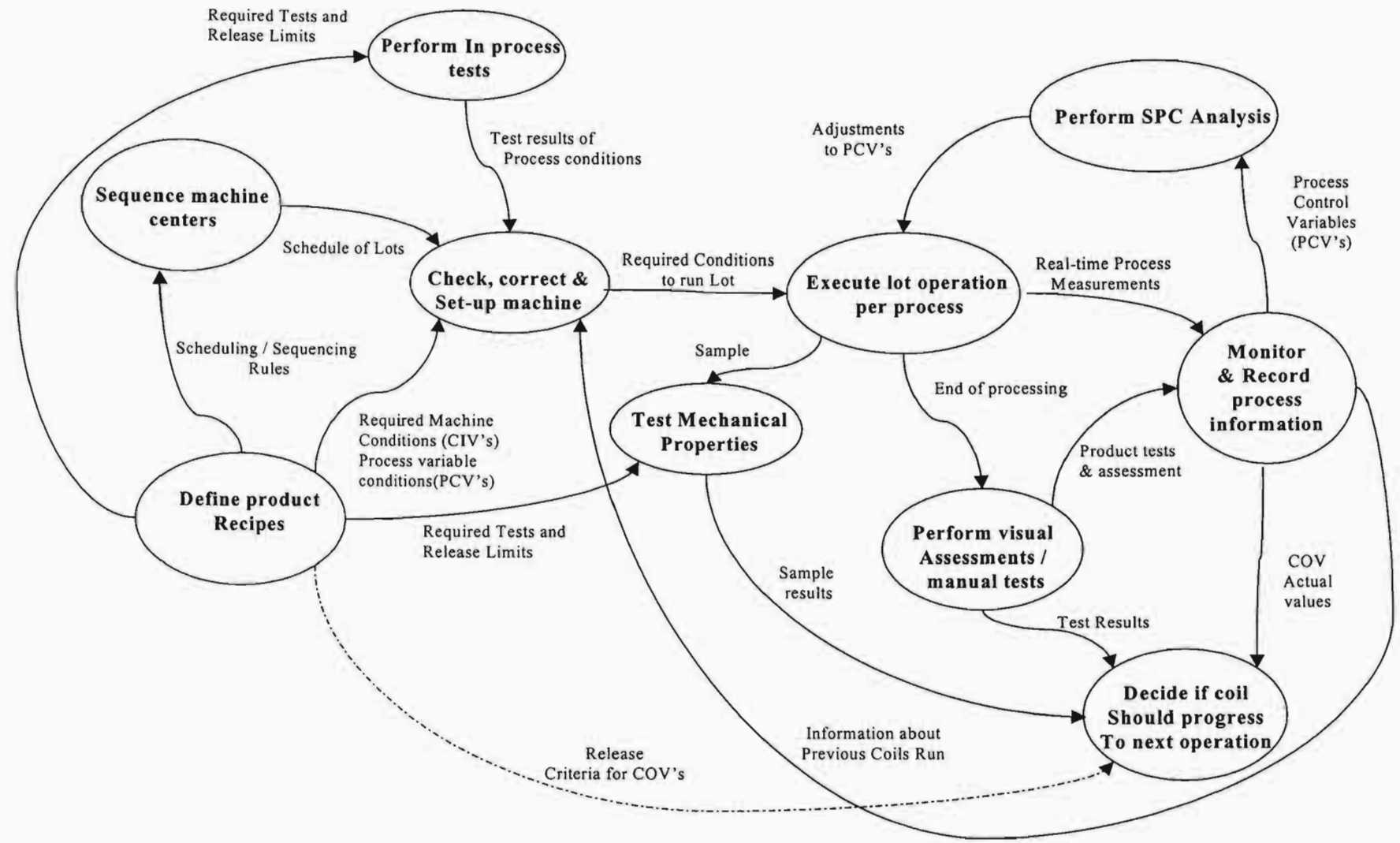


Figure 4.8 Conceptual model for the delivery of essential product information to the production process.

An evaluation of the conceptual model in Figure 4.8 is as follows:

Effectiveness: Besides telling the operator what conditions are necessary and target set-point values for PCV's, the process has to be monitored to notify the operator of any deviations

Efficacy: The process meets the objectives of aiding the operator through set-up, execution and finally releasing of the coil. The process also caters for the interim where sub-optimal decisions and manual overriding will be necessary.

Efficiency: The prescribed activities are based on an integrated solution where the availability of information in the correct context at the right time will make operators, product coordinators and sequencers more productive in their efforts to eliminate customer dissatisfiers.

The conceptual model in Figure 4.8 is different to normal conceptual models as it has flows of information and influences also represented. This makes the conceptual model a closer representation to a dataflow diagram, proposed by Prior (in Mingers, 1992:83).

In summary, the author has used SSM to develop a rich understanding of the issues surrounding the problem and has reached agreement on the activities and concepts that future information systems will need to support. The conceptual model represented in Figure 4.8 contains more verbs than are described in its root definition to which it is linked. This may at first seem as if it contradicts Checkland's (1995:51-53) guidelines for model validation. This, however, is not the case as the conceptual model had to be expanded to provide details of the information flows as well. A detailed conceptual data flow model is necessary to support the UML Modelling process.

Figure 4.8 indicates that the product recipe criterion needs to be defined first. The scheduling and sequencing rules from the product recipe will be used to guide the creation of sequence lists for a specific machine. Prior to running a sequence list the operator will ensure that the correct conditions exist on the machine centre. If necessary, required in-process tests may have to be performed. Once the correct conditions have been established the operator may proceed in the execution of the lot. While processing the lot, the operator would need to

monitor specific process control variables (PCV's) to ensure that the lot is being run at the correct conditions. When the coil finally finishes the operator will evaluate the surface and condition of the coil to establish if it can progress to the next operation. At times the final releasing of the coil will only be possible when lab results are available.

4.8 Summary and Conclusions

The chapter discussed the customised methodology designed to support business analyst through the analysis and modelling of complex, messy situations. The customised methodology aims to assist the analyst in defining and modelling business process requirements. These requirements are intended to guide object-oriented developers towards installing suitable information systems.

The individual techniques of the methodology were reviewed against Mingers and Brocklesby (1997) and Mingers (2001) multi-methodology framework to establish how the techniques support the analyst through the specific challenges inherent in process improvement programmes. Reviewing the combination of SSM and UML business process modelling against the multi-methodology framework clarified how the individual techniques of the methodology support the business analyst through the four generic phases of the research process described by Mingers and Brocklesby (1997:494).

The previous chapter shows that reducing the SSM analysis to a traditional functionalist approach is a popular concern of many researchers who have investigated the combination of SSM with information systems analysis and design techniques. This review has emphasised and clarified the cause of the researcher's concerns. The review also highlights how the suggested approach in this chapter ensures that the richness of the SSM analysis is not lost during the UML business process modelling.

The chapter also presented an application of the methodology's SSM components to the production process at Hulett Aluminium. The experimental implementation shows how the techniques of SSM improve the stakeholder's appreciation of the issues causing the problem.

It also encouraged debate about possible solutions to improve the situation. In addition to the required system and set of activities that are needed to improve the delivery of critical product information to the operators, the SSM analysis also allowed a number of other issues to surface, which that could affect the implementation. The identification of these issues has helped to determine and reach agreement on the final solution that will lead to improvement. Many of these issues however, are aspects of change management that will have to be resolved prior to the introduction of any information systems. The experimental implementation shows how SSM can be used to identify cultural (norms) and political (power) issues that are able to affect the implementation of improvement programmes thereby providing supporting evidence to the claims of Petkov and Petkova (1997:12) and Ackermann *et al.* (1999:202) that SSM can be used to enhance business process re-engineering (BPR).

The following chapter focuses on UML business process modelling activities of the methodology.

CHAPTER 5 Business Process Modelling of the Production Process in an Aluminium Plant with UML

5.1 Introduction

This chapter is devoted to expressing the production process activities, which stakeholders expect in a number of views. These views are necessary to communicate the needs through to software developers following an object-oriented approach. Modelling the business process requirements is the final activity of the proposed methodology discussed in the previous chapter. Each view of the production process will focus on a particular aspect and is described through various diagrams. The following views are presented in this chapter.

- Business vision view;
- Conceptual view;
- Business process view; and
- Business behaviour view.

Although the chapter presents these views sequentially, the modelling was not strictly sequential, as previous views had to be revisited as the modelling progressed. The chapter begins with a description of the business vision view, followed by a business structure view shown by a conceptual model. These views are followed by the business process views and business behaviour views. The following section describes the business vision view which was the first view developed.

5.2 Visions and Goals

The business vision view shown in Figure 5.1 illustrates the relationships between the overall goal of Hulett Aluminium and the problem being tackled in this research project. Eriksson and Penker's (2000:283) business goal decomposition pattern was used to represent the goal model. The intent of the pattern is to allow high level business goals which focus on the reasons for doing things to be broken down into more specific goals that focus on the "how's". Figure 5.1 shows how the overall goal of "Eliminating customer dissatisfiers" is broken down into specific sub-goals. One of the sub-goals that is necessary to eliminate customer dissatisfiers is to improve the delivery of critical product

information to operators in the production process, to allow operators to produce better quality. The goal of this research project is to find an acceptable solution to achieve this. An acceptable solution that will result in improving the delivery of critical product information to the operators has emerged through the application of SSM. This solution is described in the previous chapter and modelled as a sub-goal in Figure 5.1, attached to the goal of “Improving the delivery of critical product information to the production process to allow operators to produce required quality consistently”. The sub-goal is expressed using the content of the root definition of the required system captured in Figure 4.8 of the previous chapter.

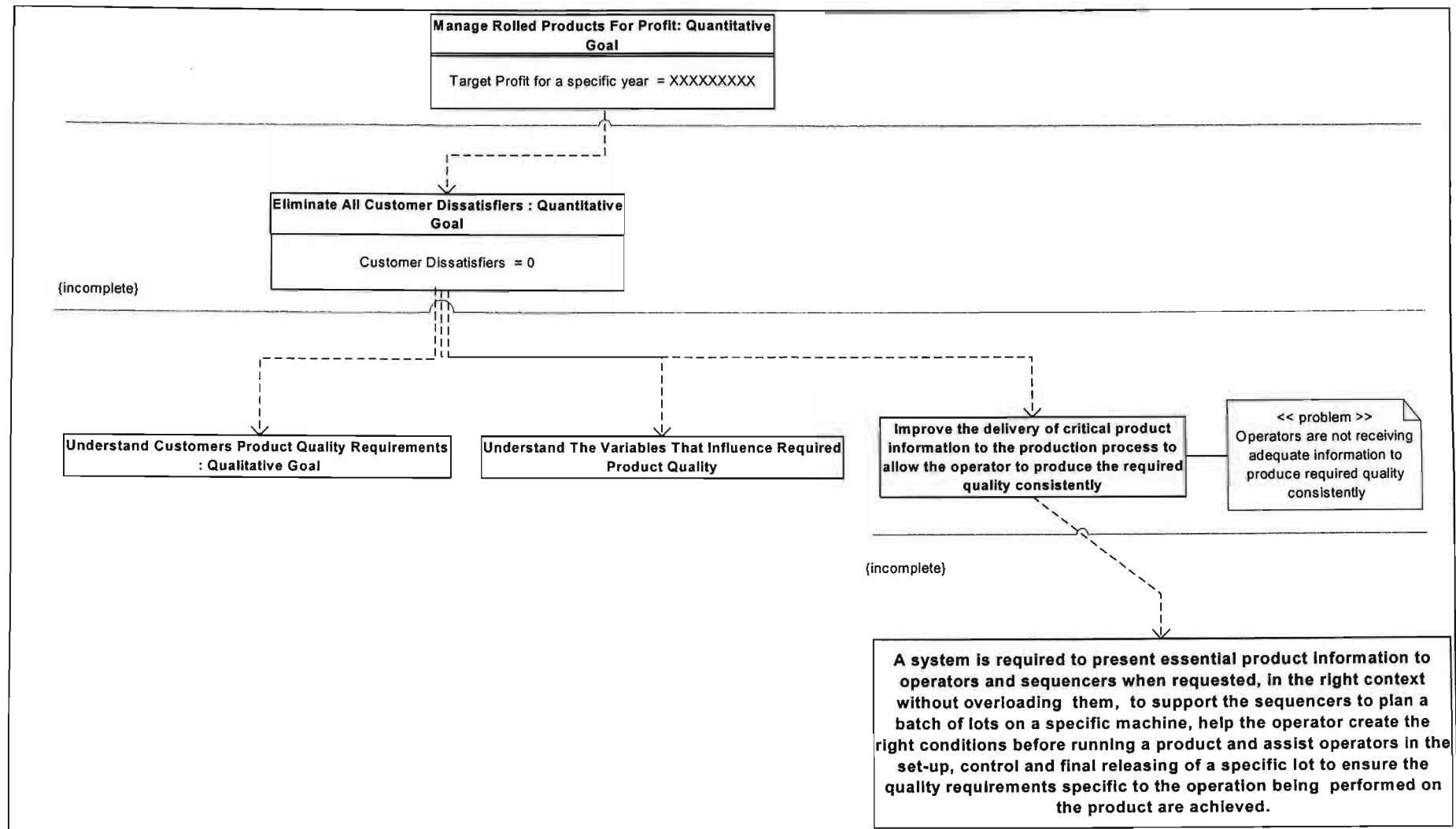


Figure 5.1 Goal model showing the goal hierarchy relevant to improving the delivery of critical product information to the production process.

5.3 Conceptual View

The conceptual view is the second model produced during the modelling process. The objective of the conceptual model in Figure 5.2 is to complement the goal model discussed above. The conceptual view shown by Figure 5.2 illustrates the key concepts that are important for modelling the production process part of the business. Isolating the concepts to only those that are relevant to the production process is a subjective choice. The concepts shown in Figure 5.2 include concepts from the surrounding business context to improve the readability of the model. According to Biemans *et al.* (2001:123), completeness of a model is directly related to the modelling objectives and a model can therefore never be considered complete because it is an abstraction and simplification of reality. The conceptual model conveys the architecture of the production process by showing how the concepts are related.

The key concepts of the production process are the lot, product process operation and the product machine operation. Through the multiplicity relationships shown in Figure 5.2, a product process operation is capable of being performed on many machines. Similarly, a machine is capable of performing many product machine operations. A lot is issued in production to produce a specific order item for a customer by being processed on several planned lot operations. Each planned lot operation is a specific product machine operation. A product machine operation has to meet specific CIV's (Critical Input Variables) before the operation is allowed to execute. Whilst executing, the lot has to conform to specific PCV's (Process Control Variables) to achieve desired COV's (Critical Output Variables). Irrespective of which machine the planned lot operation is being performed on (Product Process Operation), there are set-up instructions that must be followed as well as in-process and product tests that must be done.

The product data management pattern (PDM) seemed like a likely pattern that could be used to elegantly structure the concepts related to this research project (Eriksson and Penker (2000:247)). This pattern however has no relevance to Hulett Aluminium's product and the product data information that needs to be managed. As illustrated in Figure 5.2, each classification of a product has to conform to detailed quality requirements. In order to achieve the detailed quality requirements, the product requires processing on

one or more product process operations. Each product process operation has set-up, and product and process testing requirements that are independent of the machine on which the operation is performed. While performing a product process operation on a machine there are specific CIV's, PCV's, COV's and standard operating procedures that need to be adhered to, which are pertinent to that machine.

The concepts in Figure 5.2 are shown with associations to other concepts. Simple associations are depicted by lines with multiplicity information. The filled diamonds are used to indicate stronger types of relationships. In UML terms, a filled diamond depicts aggregation, which stands to define ownership, composed of or composition aggregation. This indicates that the whole (side connect to the diamond) owns the parts and the parts live inside the whole (Eriksson and Penker, 1998:90). Figure 5.2 shows several aggregation relationships. The product process operation consists of specific set-up instructions, product and in-process tests that cannot be included as part of another product process operation. An alternative way of reading this relationship would be to say the product process operation consists of specific set-up instructions and product and in-process tests. Similarly, a product machine operation consists of a standard operating procedure, specific CIV's, COV's and PCV's. A schedule for a specific machine consists of specific planned lot operations.

Figure 5.2 does not show generalisation relationships or shared aggregation relationships (empty diamonds) because none of the production process concepts are related in this manner. The conceptual view defines the key concepts and the meaningful relationships that exist between them and can serve as a business entity model as well, except that the many-to-many relationships between concepts are not resolved. The conceptual view is geared toward showing relationships between the concepts (objects) that define the problem space. Having such a precise definition of the concepts allows for the modelling of the production process in further detail. The following section discusses the business process view which was the third view produced during the modelling process.

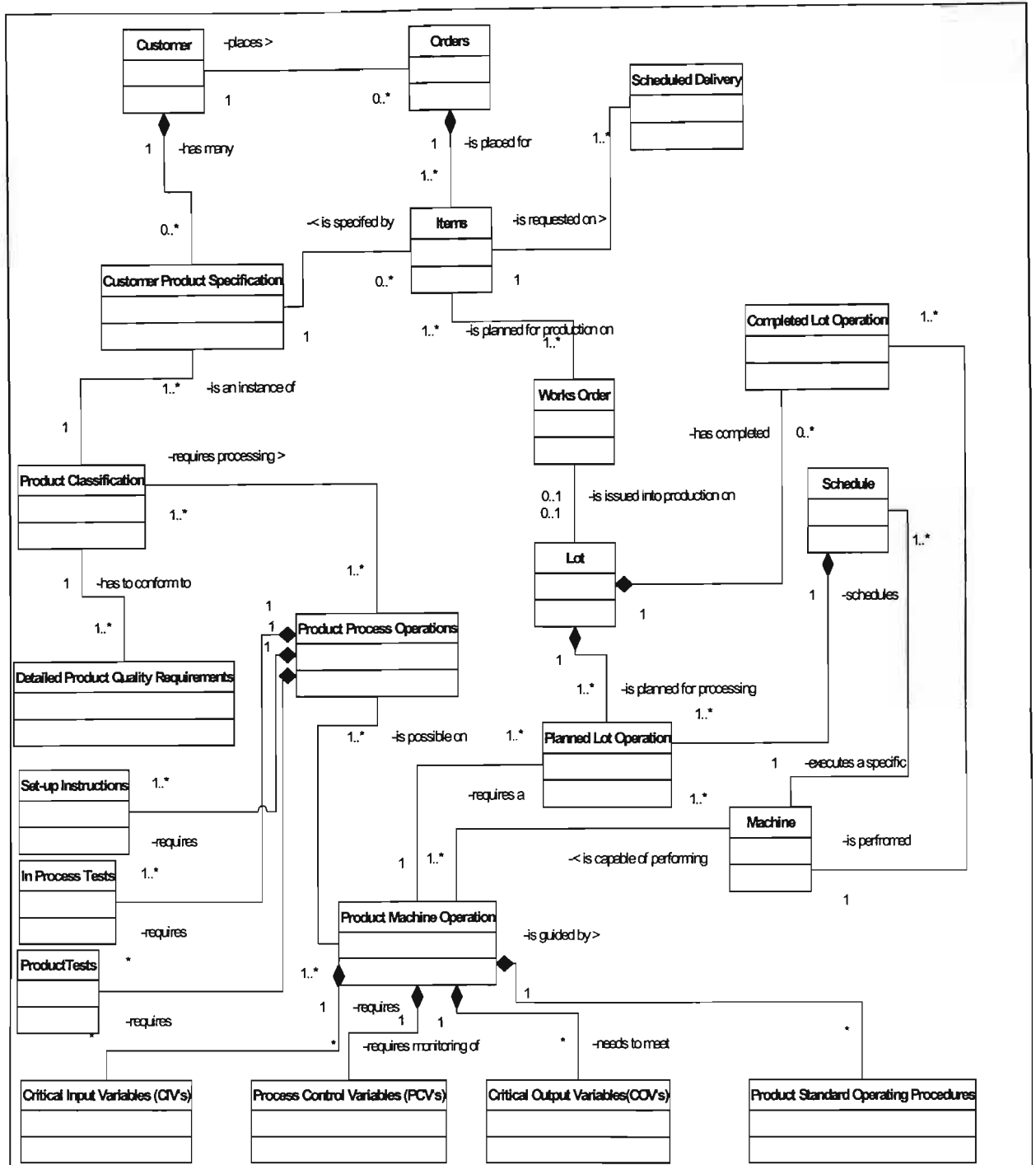


Figure 5.2 Conceptual View of the most important concepts relevant for improving delivery of critical product information to operators at the production process.

5.4 Business Process View

Figure 5.3 illustrates the business process view of the production process. This view focuses on explaining how the production process carries out the visions and goals outlined in the goal and conceptual models. The business process view is created from the conceptual model described in Figure 4.8 of the previous chapter. The conceptual model shown in Figure 4.8 described the components of the required system to improve delivery of critical product information to operators at the production process.

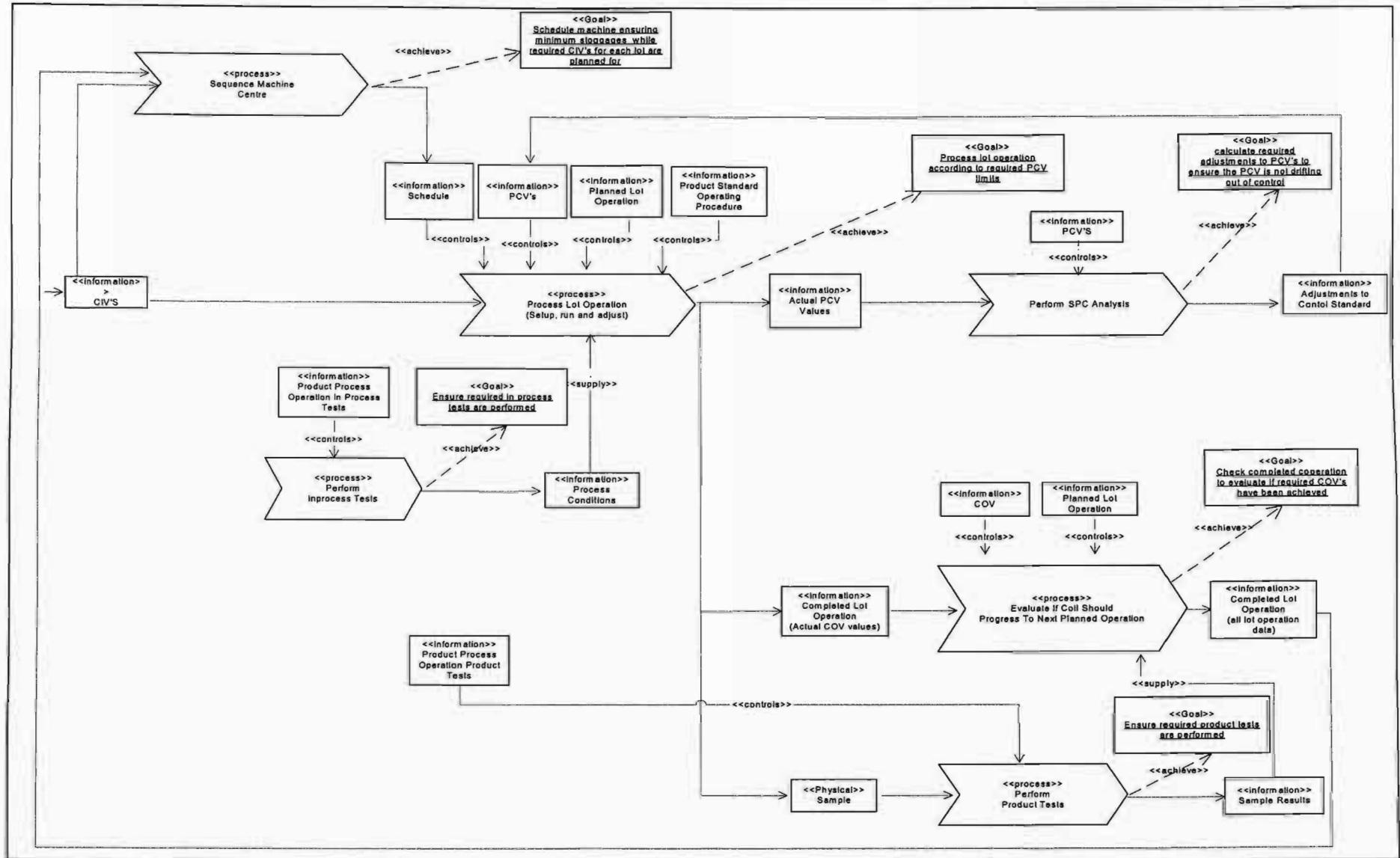


Figure 5.3 The production process at Hulett Aluminium.

The business process view shows primary processes and support processes with dependencies. In addition to sequence and sub-process dependencies, the business process view also indicates inputs, outputs and control information. All of this is necessary for the sub-processes to function. The objective that each sub-process is required to achieve is also shown.

All the information resources except the real-time information are modelled as concepts in the conceptual model. The structuring of the production-process business-process view was achieved through the application of the process layer supply and process layer control patterns suggested by Eriksson and Penker (2000:315-328). The process layer supply pattern assisted in organising the business processes into primary and support processes. The “Process Lot Operation Process” is supported by the “Perform In Process Tests Process”. Similarly, the “Perform Product Tests” process supports the “Evaluate If Coil Should Progress To Next Operation” process. The process layer control pattern helped layer the processes to show how certain processes control other processes. The “Sequence Machine Center” process controls the “Execute Lot Operation” process through the sequence list. The sequence list is formulated by ensuring the required CIV's for each lot are considered and planned for without incurring unnecessary machine stoppages. Process conditions and sample results are supplying objects. The dependency between the process and sample results are stereotyped <<supply>>. The <<supply>> stereotype indicates that these resources are participating in the process without being refined or consumed.

The initial activity of the production process is “Sequence Machine Centre”. This sub-process (activity) results in a schedule being produced, which is used to control the “Process Lot Operation” process. The outputs of the “Process Lot Operation” process are actual PCV values while the lot is being processed, completed lot operation data (including COV information) and samples. The actual PCV information produced while the coil is running is used as input to the “Perform SPC Analysis Process”. This process produces required “Adjustments To Control Standards” which influence the PCV standards that are being used to control the “Process Lot Operation” process. The final step in the production process of a particular coil is to “Decide if the Coil Should Progress to the Next Planned Lot Operation”. The inputs to this process are the completed lot operation results and lab results. These results are compared to the required COV's and planned lot operation

requirements. The output of a single iteration of a production process is a completed lot operation with all the lot's data. This output is fed back to the "Sequence Lot Operation" process and "Process Lot Operation" process that the lot is planned for.

The business process view gives a detailed description of the production process activities that are required. The production process activities are not split up into different functional areas; hence the business process view is not split into functional areas using swim lanes. A more detailed business process view showing the interactions between the processes and concepts of the production process is presented in the assembly line view.

Assembly Line Diagram

Eriksson and Penker (2000:114) suggest the using an assembly line diagram to illustrate what information is used and generated by processes. The assembly line diagram in Figure 5.4 only shows the primary processes of the production process with the interaction each process has with the concepts modelled in the conceptual view. Each interaction is qualified as a read or write. The dark shaded circles indicate a write while the empty, unfilled circles indicate a read. Each read or write is described by the type of information that is read or written.

Figure 5.4 shows that the sequence machine centre process begins by looking at the schedule being executed on the machine, and the available lots requiring processing on that machine. The planned lot operations are scheduled to ensure minimum disruption to the machine and allow for the required CIVs of the lots. The sequence machine centre process results in a schedule for the machine.

The schedule guides the lot operation process. Execution of a specific lot operation begins with an understanding of the planned processing requirements. The processing requirements of the lot determine the conditions the machine has to be in prior to running the planned operation. To establish if the machine is in the correct condition, the conditions of the process are compared to the required conditions of the planned product operation (CIV). The operator may have to change process variables to continue running the lot. Once the planned lot operation is completed, the lot operation results are updated.

When a lot operation ends the completed lot is evaluated to establish if it should progress to the next planned operation. Evaluating if a coil should progress to the next operation requires a comparison of the completed lot results (actual lot COV's) to the required COV's for the product machine operation. A final assessment is returned to the completed lot operation object.

Eriksson and Penker (2000:116) propose that the assembly line diagrams provide the connection between business modelling and software requirements modelling with use-cases. Each interaction between the process and assembly line packages (concepts of the production process) may require a suitable information system. The interactions represented in Figure 5.4 need to be supported with suitable information systems to improve the delivery of critical product information to assist the operators in producing consistent quality. Information systems requirements analysis begins with understanding the requirements for each of these interactions. The assembly line diagram serves as a checklist for developers to ensure that all the correct use-cases have been defined.

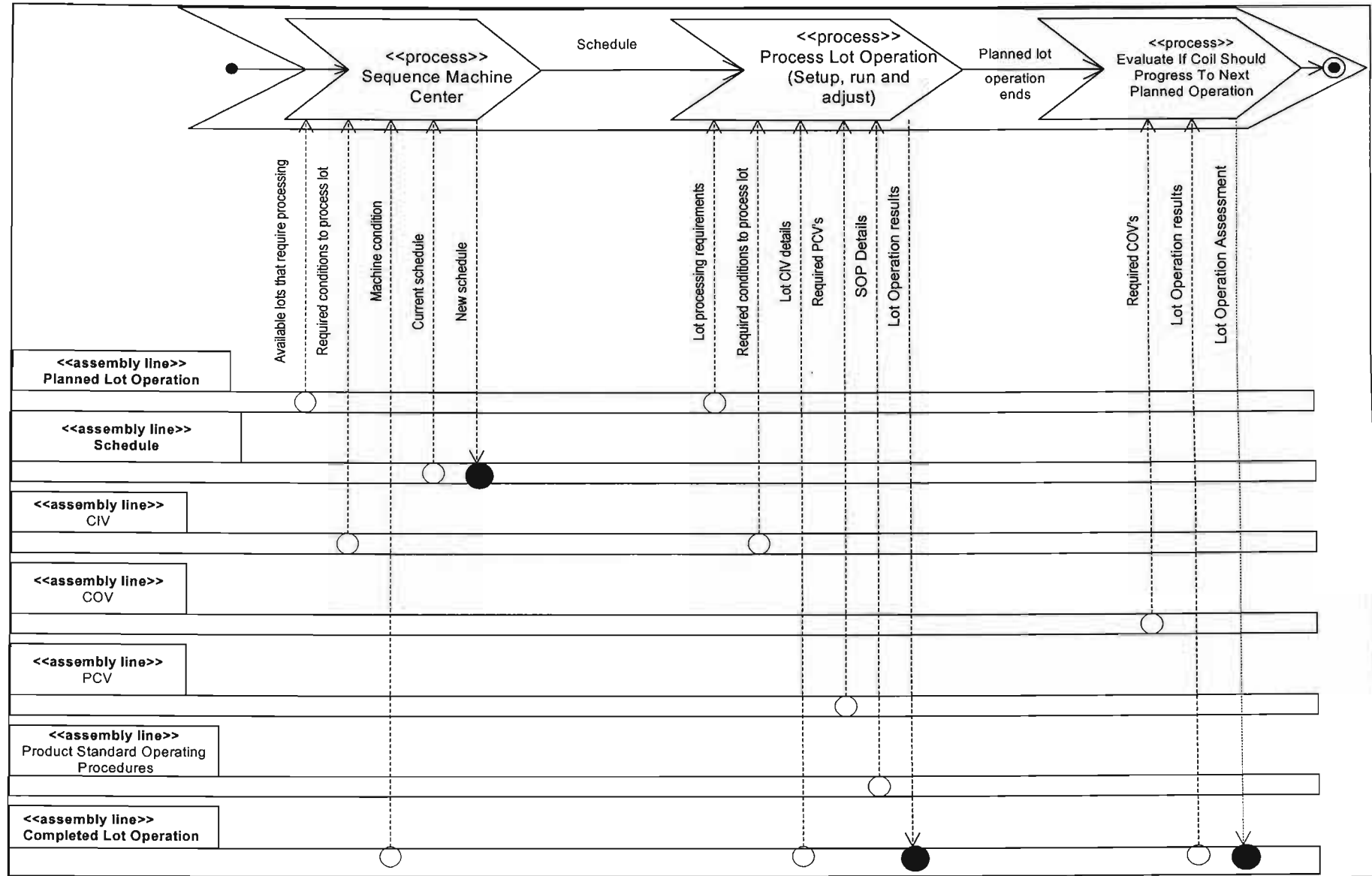


Figure 5.4 Assembly line diagram of the production process.

5.5 Business Behaviour View

The lot is the primary resource that is processed by the production process. Figure 5.5 shows the possible states of the lot and the associated behaviour in each state. The states a lot assumes are: works order awaiting allocation, issued lot, scheduled lot operation, lot in progress, suspended lot and lot closed. The starting state of the lot is works order awaiting allocation, while the final state of the lot is lot closed. The lot-closed state is a result of the lot being scrapped or the final planned operation being completed.

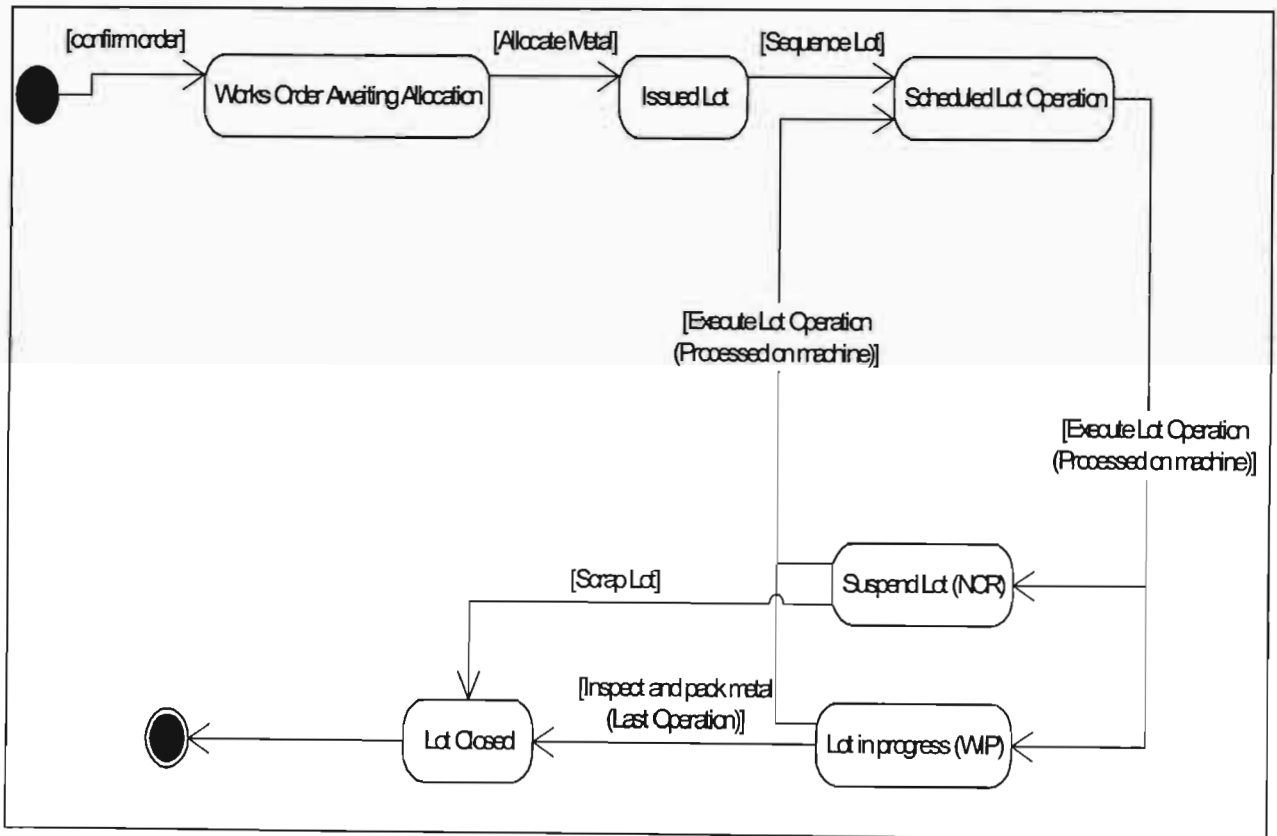


Figure 5.5 State transition diagram of a lot.

5.6 Post Implementation Review and Conclusions

The conceptual flow model provides a framework for the UML business modelling shown in this chapter. The language and concepts of the Eriksson and Penker (2000) business process modelling extensions provided guidelines for constructing the conceptual model and business process views.

In addition to the SSM workshops, further workshops were needed to clarify detailed aspects of the conceptual and business process views. These views of the required production process were shown to developers at Hulett Aluminium. Showing business concepts through standard UML views, using core UML concepts, relationships and elements enhanced the presentation of the business rules and requirements.

The assembly line view provides developers with the total set of use-cases that need to be supported. Through the various views, developers were able to understand how the goals of the surrounding business context were being realised. The conceptual view gave developers a view of the participating objects that are necessary to realise the activities of the production process. Eriksson and Penker (2000:64) indicate that it is incorrect to assume that the business objects reflected in the conceptual view will automatically translate into software objects. Hulett Aluminium developers, however, felt that the conceptual view communicated the primary set of objects or components that were necessary to provide the required software services. This implies, that at minimum, the objects in the conceptual view will be constructed as software objects or components.

Developers felt that the UML business process views give more information about the business than business process views they have been receiving when structured techniques were used for business analysis and modelling. Generally, the developers also felt that the rules are more apparent, and the requirement is more precise and capable of guiding them toward the development of correct systems. This response from developers provides some supporting evidence to the claims made by Eriksson and Penker (2000, 66-130) that there are advantages in having a common language for both the business process model and software models.

The UML models produced in this chapter therefore provide a more effective basis for software delivery following an object-oriented approach than business models represented using structured analysis and design techniques. The business process model provides a basis for developers to begin use-case analysis to define the software features that are required to support the process activity. There are, however, aspects of the approach, which can be improved upon. These will be discussed in the following chapter, which concludes this report and provides directions for future research.

CHAPTER 6 Conclusions

6.1 Introduction

The world of business is imprecise and is often characterised by conflicting views and many vantage points. On the contrary, developers need a view of the world that is precise, consistent and represented by a single model. These differences in assumptions about the world have resulted in information systems delivery being dependant on several types of modelling. This is undesirable.

This thesis has reviewed the limitations of current business process modelling practices. In order to improve the support given to business analysts, the thesis has presented an integrated approach to business analysis and modelling that requires the combined use of SSM and UML based business process modelling. The integration of SSM with information systems analysis and design techniques has been previously investigated by other researchers. The thesis has presented an approach that takes cognisance of, and builds on the work of previous researchers by using the multi-methodology framework to integrate the techniques of SSM and UML based business process modelling. The following paragraphs summarise how the thesis defined the integrated business analysis and modelling approach that was used to define improved production process activities, which will improve delivery of quality information to operators.

6.2 How the Goals and Sub-Goals of this Research were Achieved

The thesis first investigated the current practices of business process modelling in order to gain an understanding of weaknesses and strengths. Chapter 2 presented an analysis of the most popular business process modelling techniques and discussed the various reasons for producing business process models. Although the chapter discussed the broad field of business process modelling, it also focused specifically on modelling approaches to establish a basis for the subsequent delivery of information systems. The chapter showed that present techniques used for modelling business processes place strong emphasis on the technical aspects of the problem situation. This focus appears to be the main limitation of present business process modelling techniques, which originate from information systems

structured analysis and design techniques. The strong technical focus of these modelling techniques does not cater for the acceptance and analysis of different viewpoints or political and social issues that are relevant to understand the problem or specify actions that can lead to improvement. In addition to discussing these weaknesses of present business process modelling methods, the important role business process models play in the subsequent delivery of information systems was also discussed. Chapter 2 emphasised the importance of supporting developers following an object-oriented approach, by representing the business process model in UML. Chapter 2 concluded that the capabilities of traditional business process modelling techniques are inadequate to deal with the requirements of this research project.

In this research project, the production process is viewed as a complex situation with many legitimate stakeholders, from different cultural and social backgrounds. The diverse nature of the stakeholders has caused difficulties in settling on acceptable solutions in the past because the stakeholders have different appreciations of the problems and different perception of potential solutions. This research project's objective, therefore, appeared to be more achievable through the use of SSM and UML business modelling techniques. The second sub-goal of this research project investigated the adequacy of SSM and UML business modelling because these techniques matched the profile of the problem. SSM offered the ability to learn about the production process by allowing a structured, organised enquiry into the various perceptions of the problems and possible solutions.

Chapter 3 investigated the appropriateness of SSM techniques as well as the various approaches to UML business modelling. It also discussed the emergence of UML and showed how UML has grown into the de-facto software modelling language standard. Investigation into UML business process modelling shows that there are only three popular modelling approaches. In this emerging area, the business process modelling approach suggested by Eriksson and Penker (2000) was evaluated as being a more comprehensive and effective approach to model business processes, than the unified rational process or the approach suggested by Popkin (2001). The analysis of SSM shows that there is already significant interest to use SSM to determine information systems requirements. Several approaches that attempt to link SSM to information systems analysis and design techniques were reviewed in the chapter. The review shows that although there is a significant

amount of interest to find suitable ways of linking SSM to information systems analysis and design, there are also several critics who argue against the combination. Chapter 3 concluded that both SSM and Eriksson and Penker's (2000) UML business process modelling techniques complement each other and are necessary to determine a business process model of required production process activities that will facilitate the delivery of quality information to the operators.

Research into the various approaches of linking SSM with UML business process modelling reveals that previous attempts at linking are not based on sound theoretical foundations. The UML modelling languages used in the linking are also not comprehensive business processes modelling techniques. Due to these concerns, the combination of SSM and Eriksson and Penker's (2000) UML business process modelling techniques had to be carefully considered.

Chapter 4, therefore, began with a review of the issues that need to be considered when combining techniques that are underpinned by different philosophical paradigms. The framework suggested by Mingers and Brockelsby (1997; 2001) was used to review the combination of these techniques to ensure the combination is theoretically feasible. In addition to verbalising the proposed methodology, Chapter 4 also discussed how the proposed framework could be made organisationally acceptable to Hulett Aluminium. The framework by Landry *et al.* (1996) was used as a checklist to verify if the approach had a possibility of being an acceptable one to Hulett Aluminium.

Chapter 4 discussed the implementation of part of the methodology. This chapter demonstrated how the techniques of SSM assisted in creating a rich understanding of the different perceptions of issues affecting the delivery of instructions to operators and the different views of possible solutions to improve the situation. The process of SSM allowed for an acceptable solution to emerge. The first fundamental step of establishing what activities are necessary to improve the situation was achieved through the use of SSM techniques. The required system and necessary tasks to enable the system as defined by the stakeholders still had to be modelled in UML to ensure the stakeholder's requirements were effectively communicated to developers.

Chapter 5 applied the remaining activity of the methodology by representing the requirements as a UML business process model. The model of the activities to improve delivery of critical product information to operators was represented in several views. The research project objective of producing a suitable business process model represented in UML was achieved in chapters four and five.

The theoretical contributions of this research project can be summarised as follows:

- The thesis presented a detailed analysis of current business process modelling techniques that are in use. The analysis revealed two areas of weakness. The first is that the current modelling language is not a present standard amongst developers. The second area of weakness identified is that there is insufficient emphasis on analysis techniques and appreciation of the problem.
- Research into techniques that can be used to improve business analysis and modelling identifies SSM as a suitable technique for analysis and Eriksson and Penker's (2000) UML business modelling extensions as the preferred business modelling language.
- The research identified that previous attempts to link SSM with information systems provision were not based on any underlying theoretical foundations. These combined approaches also progress to defining suitable information systems before modelling the required business process.
- To ensure that a comprehensive approach that complies with existing theoretical guidelines is formulated, the thesis proposes an integrated approach for business analysis and modelling, which is based on the framework for combining techniques suggested by Mingers and Brocklesby (1997) and Mingers (2001).

The practical contribution of this research is that it helped Hulett Aluminium define the required production process activities that allow operators to receive sufficient quality information, at the right time and in the right context to enabling them to produce consistent quality. Another important practical outcome of this research project is the UML definition of the required business process, which is intended to allow the developers to pursue detailed analysis, design construction and implementation of suitable information systems. The management at Hulett Aluminium accepted the solution as a sound practical approach that will be planned for implementation. The developers were pleased that the

artefacts provided continuity to the subsequent activities of the software development process.

The main aim of this research project is to establish if it is possible to formulate an integrated methodology to assist business analysts define and communicate business process models to object oriented developers. Based on the experiences at Hulett Aluminium the proposed integrated methodology was able to meet this aim.

6.3 Future Research

Although the thesis has met the defined research goal and objectives, the proposed approach needs to be applied to other areas in order to confirm the benefits of using the approach. Through the application at Hulett Aluminium, several potential areas of improvement and other application areas have become apparent. These potential areas of improvement and application will, however, need further investigation and are discussed in the following paragraphs to provide possible directions for future research.

The software development process needs to be followed up to confirm the specific benefits the business process model provides during the design and construction of the information systems.

Ackermann *et al.* (1999:196) discusses the need to make BPR more effective by supplementing BPR with organisation enquiry techniques like SSM. The use of SSM in this research project illustrates the potential SSM has in being used as a general approach to evaluate the obstacles to successfully introducing change. The extent to which SSM can be used to enhance existing process improvement programs like BPR needs further investigation.

Developers at Hulett Aluminium were happy with the UML business process model, but the absence of an entity model was highlighted. Although developers still persist information to relational databases to allow for the information to be analysed and queried, the Eriksson and Penker (2000) UML business modelling approach does not cater for modelling information requirements. The case tool "Rational Rose" which is used to produce and store software models has only recently announced an enhancement that

allows database modelling using UML. These are indications that the object-oriented community has realised that the relational database is still an important feature of software systems. The Eriksson and Penker (2000) UML business modelling approach should therefore be extended to include models of information requirements for developers to use as a basis for database designs. Extending the conceptual view model is one possibility.

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APPENDICES

APPENDIX A: Detailed Product Quality Requirements

No	CCPPC		CONTROL PROCESS								CRITICAL VARIABLES		
			Casting	Homogenising	Hot Rolling	Cold Rolling	Interannealing	Stabilise Anneal	Multi Slit	Final Slit	Inspect and Pack	Variable Description	Control Standard
Requirement	Description												
1	Gauge Tol.	Gauge Tol.										Cold Mill Passes	+/-2% Roughing passes
													+/-0.05mm on final pass
2	Width Tol.	Width Tol.										Tooling set up	+/-0.50mm for widths<100mm
													+/-0.75mm for widths 100-300mm
3	Formability	Formability										Self Anneal	Self anneal at =>320C
												Final Reduction	Maximum 25% at final pass
												Stabilise anneal	Aim for lower end of spec.
													Produce T/A curves
												Interanneal/Self Anneal	Inert gas interanneal
4	Surface finish	Surface finish										Mill Finish	
5	Straightness	Straightness										Deviation from straight	2.0mm/2m for widths<100mm
												edge	2.5mm/2m for widths 100-600mm
6	Mechanical	Yield Strength(MPa)										Yield Strength(MPa)	220-280MPa. Aim for 225-245MPa
	Properties	UTS(Mpa)										UTS(Mpa)	290-350MPa. Aim for 310-330MPa
		%Elongation										%Elongation	10%. Aim for 14-16%
		Bend Tests(transverse)										Bend Tests	Components to be used as std
													Use more severe bends required.
													No Cracks permitted
7	Chem. Comp.	Chem. Comp.											Present HARP CES Quality - NOT Q
8	Coil Dim.	ID and OD										ID	500mm
												OD	1400mm-1600mm
9	Packing	Straps										Straps through circum.	1
												Straps through eye	3
												Coil Position	Eye to sky
												Slits per pallet	TBA
												Cert. Of Conformance	Yes
10	Microstructure	Free of deformation bands										Deformation bands	None to be present in microstructure
		Grain structure										Grain size	Aspect ratio of less than 3:1

APPENDIX B: Lot Ticket

SHEET MILL LOT TICKET *1907329C34741*		Halett Aluminium Rolled Products (Pty) Ltd		LOT NO 19/07/329C7				
CUSTOMER SAGENRA TRADE CORPORATION (PTY)		TFN 20 FT GP CONTAINER	ORIGINAL COMPLETION DATE 19 July 2002	ORDERED MASS				
ORDER PART 011772B I/I		END USE ROOFING	REVISED COMPLETION DATE 19 July 2002	PIECES				
CUSTOMER ORDER 25284			CONFIRMED COMPLETION DATE 26 July 2002	PLANNED MASS 2,444				
PRODUCT NAME BUILDING COIL PAINTED - PVDF Hazy Grey / Light Grey				MASTER LOT TICKET 34741318049				
DESCRIPTION 0,90 mm (+- 0,08 mm) 3004-H46 1250 mm WIDE								
HOT ROLL DAY SUN	HOT ROLL WEEK 0028	INGOT SIZE 630 X 1400 X 5400	PLANNED START MASS 12,200	ACTUAL MASS 12,930	INGOT NUMBER OCPF5W			
OPERATION	INSTRUCTIONS		PLANNED MACHINE	ACTUAL MACHINE	OPERATOR	DATE	TIME	REMARKS
PREHEAT	"H10" PRACTICE							Temp..... Gauge..... Wght..... Mass.....
HFM	1400 mm x 3,50 mm (+- 0,035 mm) SET TRIMMER TO 1290 mm FOR 1280 mm COLD WIDTH		25031					
SS 1st Rough	3,50 mm ROLL 1 COIL TO 2,00 mm AND B/UP TO 475 mm AND SPLIT FOR ABOVE LOT BAL OF COIL ROLL TO 1,91 mm AND TRF TO LOT No : 03/08/512C8 (5600 KGS)		33401					
All Gas Anneal	INERT GAS INTER ANNEAL		33654					
SS 2nd Rough	2,00 mm - 1,34 mm		33402					
SS Final Pass	1,34 mm - 0,90 mm (+- 0,08 mm)		33407					
TLL 1st pass	SLIT 1250 mm +- 1,50 mm TENSION LEVEL ONLY. DO NOT STAGGER REWIND. I.D 508 mm RECORD LENGTH		34271					
CCL 1st pass	PAINT SPEC No = LINE SPEED = 55-65 OVEN PMT = 216-224°C PRIMER TOP SIDE = CODE REVERSE SIDE = CODE		28011					
CCL Fin pass	PAINT SPEC No = LINE SPEED = 50 STAGGER REWIND = 8 mm MAX FINISH PMT = 249-254°C TOP SIDE = CODE REVERSE SIDE = CODE I.D 508 mm O.D 1094 mm MIN (R 2) O.D 1094 mm MAX B/UP TO mm REFER PC FOR B/UPS (SAMPLING) CUT & IDENTIFY SAMPLES FOR TENSILE TESTING		28015					
Coil Insp	INSPECT PACK PACK FOR EXPORT <i>EYE HORIZONTAL</i>		3412					
All Operations Completed								
FORMAN								
CREATED DATE						APPROVED DATE		
CDEV 21/4/94						REC 2/5/02		

APPENDIX C: Product Standard Operating Procedure

TreadBright Product SOP

Revision – 5th Draft

Revised: 10 December 2001

Page: 2 of 4

TreadBright at S4 Cold Mill 1st & 2nd Smooth Passes

<u>Critical Output Variables</u>	<u>Critical Input Variables</u>	<u>Process Control Variables</u>	<u>Reference:</u>
Surface – Correct brightness when compared to reference samples – free of roll marks, tension scratches and other obvious defects .	Incoming coil temperature < 60°C before rolling	TreadBright checklist completed with all items OK	SOP 3335002-6 Rev1 Checklist sample ??
	Surface free of defects including tension scratches	Auxiliary mill rolls cleaned	
		Coolant condition Temperature 27 – 32°C	
		Exit lube sprays - opened	
		Roll roughness 320 grit finish with Ra 0.028-0.05	Roll card
		Colouring roll penetration 2 deg	
Gauge-within± 0.050mm tolerance	Within ± 0.050mm	Accuracy check before rolling	Gauge trace
		Pass schedule to be exactly as per Lot Ticket to achieve button height	
Flatness – within ±15 l units and with flat target shape		Roll camber + 30 µm	
		Auto AFC Level 5 with Tilt = 0 & Bow = 0	
Tight coil with no line movement	No line movement	Coolant pressure 400 – 450 kPa	Refer SOP 30350012
		Coil centering within 5mm of mill centre line	
		Strapping- minimum 4 straps incl 1 thru eye	
		Welding - At OD 2-3 laps	Refer tension table – currently under review
		Rewind 1.2 – 2.5 kg/mm2	

Revised: 10 December 2001
Page: 3 of 4

Revision - 5th Draft

TreadBright Product SOP

TreadBright at **S4 Cold Mill** **Tread (Final) Pass**

<u>Critical Output Variables</u>	<u>Critical Input Variables</u>	<u>Process Control Variables</u>	<u>Reference:</u>
Surface appearance - correct brightness / reflectivity when compared to standard reference samples Free of Crescent Shadow Streakiness Scratches Roll marks	Check incoming surface for defects Surface brightness as compared to reference samples (go -- no go) Surface to be free of mechanical damage defects including roll marks	TreadBright checklist completed with all items OK Spray levels - Heavy gauge Level 3 Light gauge Level 5 Lube bar - > 1.6mm gauge all 4 valves closed <= 1.6mm gauge - all 4 valves open	SOP 3335002-6 Rev1
		Mill work rolls free of scratches and grinding defects, Ra 0.028 - 0.05 Button length = 28mm min	Roll card
		Coolant temperature: 27 - 32°C Coolant condition: within limits	Daily oil report available on Public Folders
	Incoming coil temperature max 50°C	U/w tension 0.5 - 1.0 kg/mm Max speed 60 m/min Inspections Cut samples to inspect on table from 1 st coil after a roll change and there after every 4 th coil Inspect every coil lead & tail on the mill	

APPENDIX D: Eriksson And Penker (2000) Business Modelling Extensions

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Table A.2 Resources and Rules Extensions

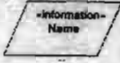





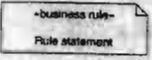
NAME	STEREOTYPE TO	SYMBOL	DEFINITION/DESCRIPTION
Information	Class		Information is a kind of resource. It is the knowledge increment brought about by a receiving action in a message transfer; that is, it is the difference between the conceptions interpreted from a received message and the knowledge before the receiving action. [Falkenberg 1996]
Resource	Class		Resources can be produced, consumed, used, or refined in processes. Resources are either information or things. Things can be abstract or physical.
Abstract resource	Class		An abstract resource is an intangible asset, for example, mathematics, concepts, and so on.
People	Class		A physical resource; specifically, human beings.
Physical resource	Class		A physical resource, excluding people. For example, machines, documents, and so on.
Business event	Signal		A significant occurrence in time or space. A business event is one that impacts the business.
Business rule	Note		Rules restrict, derive, and establish conditions of existence. Business rules are used to specify state of affairs, including allowed business object states.

Table A.3.1 Goal Extensions


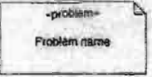


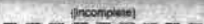
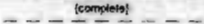
NAME	STEREOTYPE TO	SYMBOL	DEFINITION/DESCRIPTION
Goal	Class		Denote desired states, meaning that goals motivate actions leading to state changes in a desired direction.
Problem	Note		Something that prevents us from meeting goals. Cause, measure, and prerequisite are other stereotype notes that are useful when modeling problems. A cause leads to problems; a problem can be solved if the cause is removed. The cause can be removed if a certain measure is taken and certain prerequisites are valid.
Goal dependency	Dependency		Goals are organized in dependency hierarchies, in which one or several goals are dependent on subgoals.
Contradictory goal	Association		Goals can be contradictory, but must be fulfilled.

Table A.3.2 Goal Extensions

NAME	CONSTRAINT TO	SYMBOL	DEFINITION/DESCRIPTION
Incomplete goal decomposition	Dependency		Goals are organized in dependency hierarchies that are sometimes incomplete.
Complete goal decomposition	Dependency		Goals are organized in dependency hierarchies that are sometimes complete.

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Table A.3.3 Goal Extensions

NAME	INSTANCE OF	SYMBOL	DEFINITION/DESCRIPTION
Quantitative goal	Goal		A goal that can be described with a target value in a specific unit of a measurement (a quantity).
Qualitative goal	Goal		A goal normally described in a natural language. A qualitative goal involves human judgment, in the process of determining whether it has been fulfilled.
Instance of a quantitative goal	Qualitative goal		Both qualitative and quantitative goals can be instantiated.

Table A.4 Miscellaneous Extensions

NAME	STEREOTYPE TO	SYMBOL	DEFINITION/DESCRIPTION
Reference note	Note		A stereotyped note that contains a reference to another diagram or another document.
Business package	Package		Used to package business models or parts of business models.

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Table A.1 Process Extensions

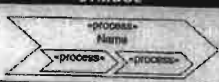





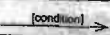
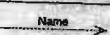
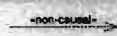
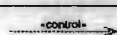
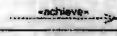
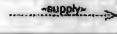




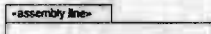
NAME	STEREOTYPED TO	SYMBOL	DEFINITION/DESCRIPTION
Process	Activity		A process is a description of a set of related activities that, when correctly performed, will satisfy an explicit goal.
Activity (atomic process)	Activity		A process might be divided into further processes. If these processes are atomic, they are called activities.
Process start	Start		Starts a process.
Process end	End		Ends a process.
Object-to-Assembly Line	Object		A delivered object from a process to the Assembly Line.
Object-from-Assembly Line	Object		An object that goes from the Assembly Line to a process.
Process flow	Control Flow		A process control flow with a condition.
Resource flow	Object flow		Object flow shows that an object is produced by one process and consumed by another process.

Table A.1 Process Extensions (Continued)

NAME	STEREOTYPED TO	SYMBOL	DEFINITION/DESCRIPTION
Noncausal resource flow	Object flow		Noncausal object flow shows that an object might be produced by one process and consumed by another process.
Process control	Object flow		Shows that a process is controlled by an object.
Goal connection	Dependency		Allocates a goal to a process.
Process supply	Object flow		Shows that a process is supplied by an object.
Process decision	Decision		Decision point between two or more processes.
Fork and Join of processes	Fork and Join		Forks and joins processes.
Receive business event	Signal Receipt		Shows a receive business event.
Send business event	Signal Send		Shows a send business event.
Assembly Line	Package		The Assembly Lines synchronize and supply processes in terms of objects.

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APPENDIX E: Workshop Notes

Agenda	<h2>Workshop –</h2> <p>Delivering essential product information to the production process.</p> <p style="text-align: right;">04 December 2001 8:30 AM to 10:30 AM AMABUTHO Room - Hulett Aluminium</p>	
Meeting called by:	Kosheek Sewchurran	
Type of meeting:	Workshop	
Facilitator:	Kosheek Sewchurran	
Attendees:	Rodney Torr, Craig Smith, Nizaam Davids, Khemlall Sewchurran, Regan Naidoo, Prof Don Petkov, Prof Peter Warren.	
Agenda topics		
5	Welcome and Introductions	Kosheek
5	Discuss Research Project Objectives	Kosheek
10	Discuss Problematic Situation	Rodney / Craig
30	Review Rich Picture Analysis	Workshop
	- Stakeholders	
	- Rich picture	
	- Technical, Social and Political Issues	
5	Break	
30	Discuss different perspectives on the Solutions	Workshop
10	Conclude workshop with general discussion.	Prof Petkov / Prof Warren
Observers:		
Special notes:		

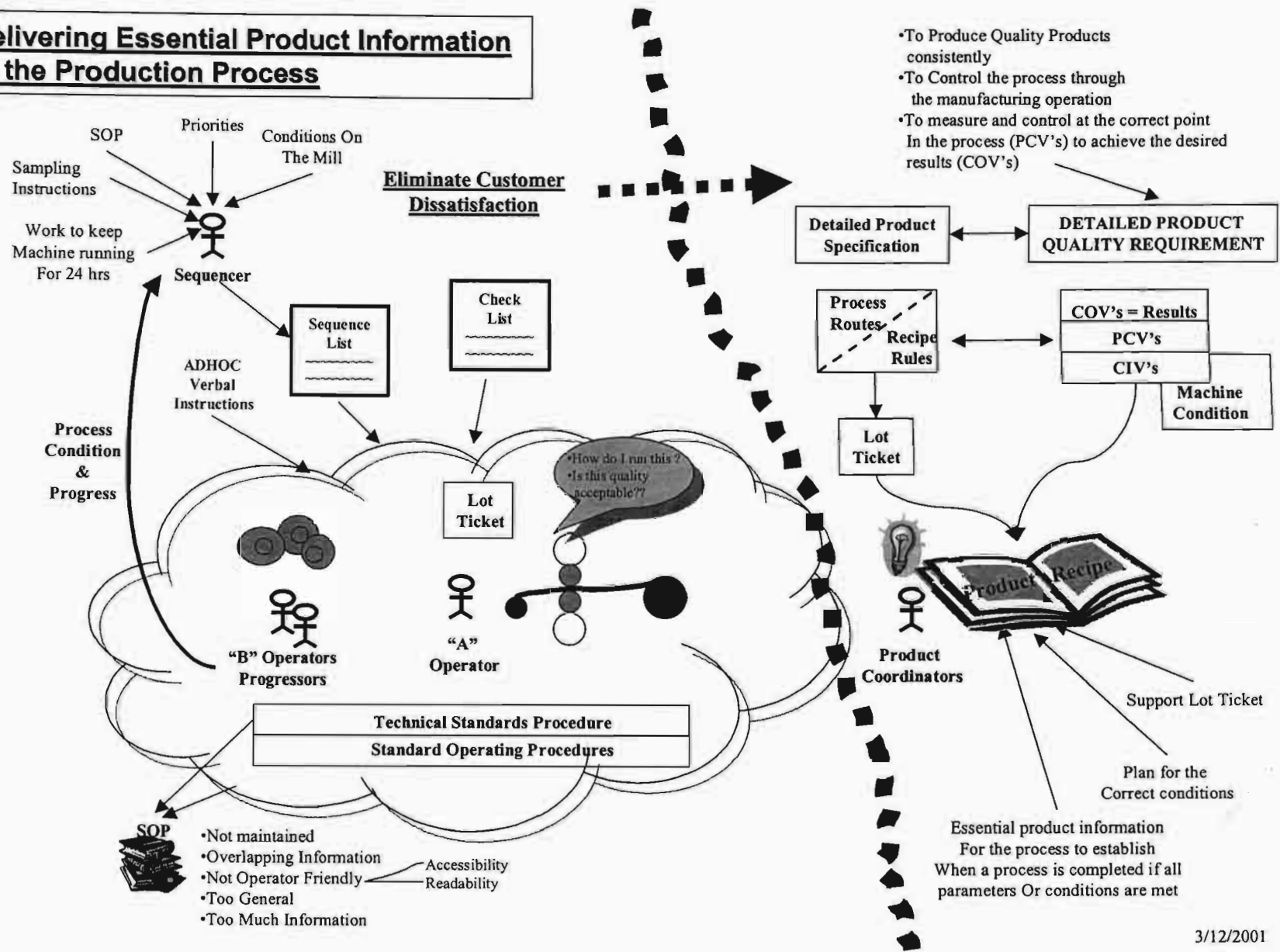
Stakeholders

Those who are affected by the problem or have a vested interest in the potential solutions are:

1. **Hulett Aluminium Senior Management** (Represented by Rodney Torr)
2. **Custodian of the SFES Project** (Represented by Rodney Torr)
3. **Product Coordinators and Process Specialists** (Represented by Craig Smith)
4. **Operators and Production Areas** (represented by Khemlall Sewchurran)
5. **Sequencers** represented by Nizaam David.
6. **Customers**

Stakeholders can be defined as those persons who have a vested interest in some common item. (Banville et al., 1998)

Delivering Essential Product Information to the Production Process



3/12/2001

The Following Important Issues Surfaced During Analysis:

Technical issues

1. Lot ticket gives dimensional instructions, need better support for evaluating COV's.
2. Evaluating if critical output variables (COV's) are within tolerance needs to be appropriately supported by information systems to ensure coil gets evaluated consistently. The effort required to do the analysis manually is unacceptable.
3. It might make sense to query an information system that is monitoring process conditions, to request the status of a specific lot, in order to determine if the lot conforms to the required parameters.
4. Delivering essential product information needs to be an operator friendly process.
5. Essential product information needs to be accessible, operator friendly and intuitive (easy to understand).
6. Overlap of information between product recipe, sequence list and lot ticket.

Political issues

7. Certain operators are throughput driven.
8. Some operators have poor literacy levels.
9. Certain operators predict values, shortcut procedures.
10. Standard operating procedures (SOP) are not maintained.
11. Operators must see the value of the Product recipe.

Cultural issues

12. SOP's do not cater for all conditions of the process. Certain decisions left to operators judgment for example adding a pass to compensate for incorrect incoming gauge.



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