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Modelling business processes with links to ISO 9001

By

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Modelling business processes with links to ISO 9001

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Abstract

This work in the domain of quality management and business process design looks at how the requirements of the ISO 9001 standard for quality management systems are designed and implemented in business. It is the aim of the research reported in this thesis to support manufacturing companies when modelling a Fulfil Order Process by identifying the links to the ISO 9001 quality standard and highlighting potential impact from any changes in the process or the standard during a redesign project. It does so by presenting a modelling technique, named $IDEF_{9000}$, which will enable companies to take a systemic perspective of a Fulfil Order Process identifying all relevant links to ISO 9001.

A research strategy based around the experiences of companies when designing business processes with links to ISO 9001 was adopted. In-depth case studies carried out by the author showed that simply documenting what an organisation does to satisfy the various elements of ISO 9001 is still one of the most common approaches adopted. This results in a process-oriented character only at the documentation stage. It is the result of limited guidance on how to integrate the requirements of ISO 9001 in business processes. The work proceeded by exploring the domains of business processes, the use of systems thinking to explain business processes and the relevance of ISO 9001 requirements from a process-based viewpoint. A set of criteria was developed to identify activities, information and other flows controlled by ISO 9001 to design a Fulfil Order Process in a manufacturing company. This provided the context for the development of the modelling technique $IDEF_{9000}$, which is an enhanced version of $IDEF_0$, and its validation by review and by use in two manufacturing companies.

The originality of this work lies in the identification and emphasis by the author of the need to take a systemic view of business processes when designing or redesigning a process-based ISO 9001 quality management system. Also, criteria for a technique to address the modelling of a Fulfil Order Process were identified. Furthermore this contribution to knowledge includes the identification of links between ISO 9001 requirements and a holistic Fulfil Order Process. This led to the development of further criteria for modelling such a business process showing the links to ISO 9001. $IDEF_{9000}$ represents an improved modelling approach that fulfils the identified criteria and permits the systemic design or redesign of a Fulfil Order Process while establishing the links controlled by the ISO 9001 quality standard.

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Finally I would like to express my thanks to the companies which willingly allowed themselves to be part of this research, for their time and sincere efforts. In particular, let me thank Sarah, Joe and Steve for their support.

Author's Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award.

During the period of the research the author was employed in two different companies. TQU – Transferzentrum für Qualität und Umwelt (part of the Steinbeis-Foundation, Germany) and Cooper-Standard Automotive UK Sealing Ltd. partially funded this study. The research described in thesis were the results of work undertaken solely by the author.

Relevant seminars and conferences were attended at which a number of papers were presented. The conferences and training courses included:

- *World Class Manufacturing – "Lessons from Europe"*, Unit for Productivity Growth and Development, Port Elizabeth Technikon, South Africa 11-12 April 1996;
- *DGQ/EOQ Quality Auditor Training*, (German Society for Quality/European Organization for Quality), Ulm, Germany, 2-6 September 1996;
- *EFQM Assessor Training*, Ulm, Germany, 9-11 December 1996;
- *TQU-Symposium - Integrierte Managementsysteme in der Praxis - Ganzheitliches Denken, Entscheiden und Handeln*, TQU Ulm, Germany, 16-17 April 1997;
- *4th EOQ Forum - the Evolution of Quality - Quality in Integrated Management*, Park Lane Hotel, London, UK, 13-14 March 1997;
- *12th International Trade Fair for Quality Assurance*, Sinsheim, Germany, 12-15 May 1998;
- *BPR2 Workshops - Process Based Change in Small and Medium Sized Enterprises*, MABS - University of Plymouth, UK, 22 April – 17 June 1999;

- *Systems and process design,* MSc. Module MOT 502, University of Plymouth, UK, 18-19 November & 17 December 1999;
- *Total Quality Management,* MSc. Module MOT 504, University of Plymouth, UK, 11 May & 15-16 June 2000;
- *Ford Production System,* Ford, Cologne, Germany, 30-31 January 2001;
- *Ford Supplier Advanced Lean Manufacturing – Commodity Focused Workshop Phase 4,* Ford Lean Manufacturing TCM Department, Plymouth, 12-16 March 2001;
- *Ford Production System - Phase I&II,* HOSCA Consultancy, Plymouth, 2-3 April 2001;
- *43^{rd} Annual Conference of the Operational Research Society (OR43),* The University of Bath, UK, 4-6 September 2001.

The following publications were produced from the research:

Gingele, J., Integriertes Management erschließt Potentiale (Integrated management creates potential). *Proceedings of the 12^{th} International Trade Fair for Quality Assurance,* Sinsheim, Germany, 12-15 May 1998;

Gingele, J., Childe, S.J., A business process view of the design of quality systems – specification of a tool. *43^{rd} Annual Conference of the Operational Research Society (OR 43),* The University of Bath, 4-6 September 2001;

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Signed ____________________

Date 19/12/2001

1 Introduction

The work reported in this thesis was carried out during a five-year research project with the objective of developing an approach that supports the design and redesign of business processes with links to ISO 9001.

During the first half of this part-time research project the author was employed as a senior consultant at TQU – Transferzentrum für Qualität und Umwelt (part of the Steinbeis-Foundation, Germany) and conducted industrial projects in the field of quality and production and operations management. In the remaining stages of this research the author was working on a part-time basis in the motor industry for Cooper-Standard Automotive UK Sealing Ltd. as a Lean Enterprise Co-ordinator. The Manufacturing and Business Systems research group (MABS) and the Department of Mechanical and Marine Engineering at the University of Plymouth supervised this research.

The objective of this chapter is to introduce the development of this research work entitled "Modelling of business processes with links to ISO 9001". It describes the background to the current situation in the domain of quality management systems and business process design with the focus on the ISO 9001 quality standard. The research question will be introduced together with the subsequent objectives and the concepts which support this research. These concepts lie in the domains of business processes, systems theory and the ISO 9001 quality standard. The chapter concludes by presenting the contribution of this work to knowledge and a summary of the structure of this thesis that describes the research undertaken by the author.

1.1 Background

As organisations are increasingly focusing on flexibility, innovation and processes there appears to be a need to assess current approaches to the implementation of the ISO 9000 requirements. The ISO 9000 series is an international standard that can be used by organisations to develop and document their quality management system. An effective quality management system allows an organisation to ensure that its products and services consistently conform to customer's requirements. The actual requirements for a quality management system are described in the standard ISO 9001:2000 (Quality management systems – Requirements) (ISO, 2000b) and organisations can be audited against these requirements to become ISO 9001 registered.

With over 400,000 certificates granted by the end of December 2000 (ISO, 2001) even its keenest supporters were surprised how quickly this standard achieved world-wide acceptance. However ISO 9000 has had some very bad press. Much of the work undertaken in the field of ISO 9000 quality management has focused on complying with ISO 9000 requirements to get or maintain a certified quality management system which in many cases has resulted in very high levels of record-keeping and form-filling. Critics such as Seddon (1998) reported it as being an expensive and in many cases, an irrelevant and inappropriate system for many businesses. The commonest criticism is excessive bureaucracy and the inflexibility it generates (Karapetrovic *et al.* 1998b). Jonker *et al.* (1998) further argue that due to the lack of a proper methodology, the integration of such models remains difficult.

Much of the development in the field of quality management has tended to focus on the design and documentation of quality management systems without taking the business processes of an organisation into account. A business process can be described as a chain of events or activities which are independent of departmental structures of an organisation to provide a desired output its customers. This concept will be examined in a later chapter.

Harrington *et al.* (1997), Mertins *et al.* (1999), Tranmer (1996), Renfrew (1997), Hesterwerth (1998) and others have emphasised the need for quality management systems to be built around the business processes to keep the system efficient and lean. Hoyle (1998a) and Karapetrovic (1998a) have also stressed the importance of understanding ISO 9001 quality management systems from a systems viewpoint. The domain of business process design/redesign has recognised the need for process-based quality management systems and it was argued that during the design of business processes greater consideration to the requirements of the ISO 9001 standard was needed. This would result in quality management systems becoming more of an integral part of the business. Therefore, despite the thorough understanding of business processes, the author contends that work needs to be carried out to help organisations to design/redesign their business processes with an emphasis on the requirements of ISO 9001.

The research is restricted to an investigation of the design of quality-based business processes that support the product and/or service cycle. It does not consider the implementation stage or the documentation of a quality management system. Exceptions are made where the quality of the design can only be properly evaluated after the implementation stage. This limitation will allow the author to focus on improving the way to design and re-design business processes.

This thesis refers to the ISO 9000 series, which is still the most widely used term for this standard. However organisations which seek registration to the 2000 version of this standard need to address the quality management systems requirements published in ISO 9001.

The term ISO 9000 is also used in cases where no further indications are given as to which of the 1994 criteria (ISO 9001, ISO 9002 or ISO 9003) were applied. Throughout this thesis reference to ISO 9000 indicates the standard in general, whereas the use of ISO 9001 refers to the specific requirements.

1.2 The Research Question

With the focus on developing the current theory of the design of business processes taking into account the requirements of ISO 9001, the following research question has been raised:

> *How can a process model be best drawn to establish links between business processes and ISO 9001?*

This research is firmly embedded in the management of production activities that transform inputs into products to fulfil customer orders. The research will concentrate on an operating business process. To answer the research question the following also need to be addressed:

- to define a business process, in particular a Fulfil Order Process, and describe it from a systems viewpoint;
- to identify and characterise the requirements of the quality standard ISO 9001:2000;
- to develop a set of criteria which need to be addressed by an appropriate modelling technique to model a business process to show the links to ISO 9001:2000.

1.3 Research aim

The aim of this research is to support manufacturing companies in modelling a Fulfil Order Process showing the links to the ISO 9001 quality standard. By using the proposed modelling technique practitioners should be able to take a systemic perspective of a Fulfil Order Process and identify all relevant links to ISO 9001. The links should highlight any potential impact from changes in the process or the standard and should be given special attention during a redesign. As it is important that the production and operations management practitioners are provided with a set of concepts, tools and techniques, the outcome of this research must provide a contribution beneficial to them. The research methodology applies the five key needs described by Thomas and Tymon (1982) to guide this work and contribute to new knowledge. The research outcome should therefore:

- be generally applicable to allow practitioners designing/redesigning a Fulfil Order Process within an organisation to show the links to the ISO 9001 quality standard (*Descriptive Relevance*);
- help the practitioners to successfully design/redesign a Fulfil Order Process and maintain the links to the requirements of ISO 9001. When introducing ISO 9001 the findings of the research should aid the practitioners in establishing the links between ISO 9001 and the activities of a Fulfil Order Process (*Goal relevance*);
- be easy to operationalise and implement (*Operational validity*);
- be more than simple common sense to the practitioners (*Non-obviousness*);
- be available at a point in time when the practitioners are required to design/redesign a Fulfil Order Process or when introducing ISO 9001 (*Timeliness*).

1.4 Contribution to knowledge

A first contribution to knowledge of this research has been the identification of a need to take a systemic view on business processes when designing/redesigning a process-based ISO 9001 quality management system. This led to the definition of a business process and the identification of criteria required for a modelling technique to address the modelling of a Fulfil Order Process from a systemic perspective. This was followed by the identification of links between ISO 9001 requirements and a Fulfil Order Process from which the criteria for a technique to model such a process systemically were identified. The proposed modelling technique and its method of use have been validated and were found applicable to the design/redesign of a Fulfil Order Process with links to ISO 9001.

1.5 Structure of this thesis

Chapter 1 introduces the field and background situation in which the research is embedded and leads to the research question. It describes the evolution of this project leading to the work's contribution to knowledge.

Chapter 2 describes the research methodology used to structure this work. An appropriate research methodology has been identified based upon the objectives of this research which focus on the need practitioners might have from this research as discussed by Thomas and Tymon (1982) and on the author's philosophical stance. The Meredith *et al.* research cycle (1989) has been applied and the Descriptive Phase starts with a literature survey and empirical case studies. This is followed by an Explanation Phase during which the modelling technique was conceptualised and developed before it was validated by review and by conducting case studies during the Testing Phase.

Chapter 3 presents a literature survey and describes the empirical research undertaken to investigate current literature concerning ISO 9001 quality management systems and business process design. This chapter explores the major findings and identifies issues of relevance to the research subject area. Two empirical studies during this research recount the findings of the author first whilst observing an organisation operating its ISO 9001 quality management system and secondly participating in the design of a process-based quality management system in a different manufacturing company. The experiences from these case studies are combined with the issues identified during the literature survey to outline the research problem and formulate the research question.

Chapter 4 summarises the common themes of business processes to extend the knowledge considerations for a process-based ISO 9001 quality management system. A definition is given for a business process. The use of systems thinking is explored and the concepts and principles investigated. These are then applied to describe a business process from a systems perspective using the systems parameters proposed by Churchman (1971) and Checkland (1981). This results in the consideration of the concept of a business process as an embodiment of systems thinking.

Chapter 5 considers how the concept of a business process from a systems perspective can be used during the design/redesign of a process-based ISO 9001 quality management system. As this research is situated in the field of production and operations management, the systems parameters for a Fulfil Order Process are discussed. The chapter concludes with the development of a set of criteria that need to be addressed by a modelling technique to successfully describe a process model of such a business process. To support this objective, the concepts of business process design with an emphasis on business process re-engineering (BPR) are investigated.

Chapter 6 describes the evaluation of the current version of ISO 9001:2000 and identifies all requirements of the standard which affect the activities of a Fulfil Order Process. This recognises that for design/redesign the process model needs to be able to show which activities and tasks are linked to ISO 9001. Based on these requirements, a further set of criteria has been developed which address the modelling of a Fulfil Order Process from an ISO 9001 viewpoint.

Chapter 7 describes various modelling techniques and their functionality together with the subsequent selection of the most appropriate based on the criteria discussed in Chapter 5. The modelling techniques discussed are those generally used for modelling processes in manufacturing systems. This chapter continues with a further evaluation of three selected modelling techniques to identify how well they address the criteria as discussed in Chapter 6. For the links of ISO 9001 in a Fulfil Order Process no existing modelling technique explicitly supports the criteria. The modelling technique called $IDEF_0$ has been selected on the grounds of its easily adaptable syntax and semantics to the criteria.

Chapter 8 looks at the development of an extended version of $IDEF_0$, named $IDEF_{9000}$ by the author, to model a Fulfil Order Process identifying the links to ISO 9001 and addressing the two sets of criteria. The name $IDEF_{9000}$ refers to the ISO 9000 series, which is still the most widely used term for this standard even though organisations which seek registration to this standard must address the quality management systems requirements published in ISO 9001. This chapter concludes with a description of how $IDEF_{9000}$ may be used and provides a set of guidelines.

Chapter 9 describes the work undertaken to validate the proposed modelling technique $IDEF_{9000}$ and its method of use as part of an approach to meet the needs of practitioners.

Practitioners reviewed the concept of $IDEF_{9000}$ before it was validated using a case study approach and during application to design/redesign ISO 9001 quality management systems at Teignbridge Propellers Ltd. and WeldcraftServices.

Chapter 10 concludes by evaluating the work undertaken and the contribution to knowledge that has been developed from this thesis.

The work has generated new knowledge by identifying the need to take a systemic view of business processes when designing/redesigning a process-based ISO 9001 quality management system. This leads to the identification of criteria which a modelling technique needs to address if being used to model a Fulfil Order Process. A second contribution to knowledge has been the identification of relevant links between the requirements of ISO 9001 and a holistic Fulfil Order Process. This formed the solid foundation for the development of criteria which a modelling technique needs to address when being used to model a Fulfil Order Process which shows the links to ISO 9001. This final chapter identifies potential areas for future research and proposes ways in which they may be developed.

1.6 Summary

This first chapter introduces the work reported in this thesis by describing the background to ISO 9001 quality management systems. The overall aim of this research is to contribute new knowledge to support the design/redesign of future process-based ISO 9001 quality management systems and to address some of the requirements of manufacturing companies.

In the following chapters the author describes the research undertaken, with the next chapter describing the research methodology used to structure this work.

2 Research Methodology

This chapter will describe and justify the research methodology used in this research. In identifying an appropriate research methodology the objective of this research will be discussed focusing on the needs that practitioners might have. The philosophical stance of the researcher within this work is described. Based on the researcher's paradigm and the nature of the research problem a research methodology will be described applying a three-phase research cycle of Description, Explanation and Testing. The remainder of this chapter will explain the research cycle in greater detail together with the research methods used during each phase.

2.1 The objective of this research

The research is intended to support practitioners in modelling a Fulfil Order Process showing the links to the ISO 9001 quality standard. With the proposed modelling approach the practitioners should be able to take a systemic perspective of a Fulfil Order Process and highlight all relevant requirements of ISO 9001 so that any potential impact from changes in the process or the standard become apparent.

The research work is related to the field of Production and Operations Management (POM). Production and Operations Management is concerned with the way organisations produce goods and services and with the management of people, processes, technology and other resources (Armistead *et al.* 1996; Armistead *et al.* 1997). Considering operations as transformation processes, they can be seen as converting sets of resources (inputs) into goods and services (outputs). *Transformed resources* may be raw materials or information which are converted into final goods or services by *transforming resources* such as facilities or staff (Armistead *et al.* 1996). Filippini (1997) and Sower (1997) are among those who report that recent developments in POM show an increasing interest in quality and in particular quality control, ISO 9000 and Total Quality Management (TQM) when compared with a previous study carried out by Meredith *et al.* (1989). Assuming that a Fulfil Order Process is essential to a manufacturing organisation and that POM interacts with other disciplines such as quality and ISO 9000, the research outcome must provide a contribution beneficial to this field. The research findings will therefore need to be assessed for usefulness to practitioners. This objective needs to be supported by an appropriate research methodology that guides the researcher through the entire research project. For the selection of an appropriate research approach an initial understanding of what practitioners consider useful and practically relevant is required.

2.2 The needs of the practitioner

The following five key needs which any useful POM research should satisfy are described by Thomas and Tymon (1982). Their framework describes the practitioners needs as *descriptive relevance, goal relevance, operational validity, non-obviousness* and *timeliness*. These five key needs will be addressed in the validation of the new knowledge.

Descriptive relevance will assess how well the findings of the research have addressed the problems encountered by the practitioners in a particular context. The research needs to consider whether it is relevant to any practitioner with a specific type of organisational problem. Descriptive relevance is often referred to as external validity (Campbell *et al.* 1963) and can be generally described as how well something reflects and fits reality.

Goal relevance will assess how successfully the practitioners can apply the findings of the research and meet their organisation's objectives. It should also answer how relevant the new knowledge is to supporting these practitioners when applying the outcome of any research work.

Operational validity will evaluate how easy it is for the practitioners to use and implement the new knowledge in their specific circumstances.

Non-obviousness will question how "meaningful" the research outcome is. Non-obviousness will assess to what degree the "contribution to knowledge" was an improvement on the method or knowledge that is already used by the practitioners.

Timeliness will question the research with reference to the applicability of new knowledge at a particular point in time. New knowledge should be available and relevant to the practitioners at the time of generation.

The framework of Thomas and Tymon (1982) as described above will be used to assess the research project to meet the key needs of practitioners. The research outcome should therefore

- be generally applicable to practitioners designing/redesigning a Fulfil Order Process within an organisation focusing on showing the links to the ISO 9001 quality standard (*Descriptive Relevance*);
- help the practitioners to successfully design/redesign a Fulfil Order Process and maintain the links to the requirements of ISO 9001. When introducing ISO 9001 the findings of the research should help the practitioners in establishing the links between ISO 9001 and the activities of a Fulfil Order Process (*Goal relevance*);
- be easy to operationalise and implement (*Operational validity*);

- be more than simple common sense to the practitioners (*Non-obviousness*);
- be available at a point in time when the practitioners are required to design/redesign a Fulfil Order Process or when introducing ISO 9001 (*Timeliness*).

Before selecting an appropriate research methodology that will support the research work that fulfils these needs, the following sections explain the philosophical position of the researcher.

2.3 Research Philosophy

To answer the research problem an appropriate research methodology needs to be chosen. The research methodology that comprises the complete research process is dependent on the chosen outlook of the researcher (Hussey *et al.* 1997). The term paradigm is referred by Hussey *et al.* (1997) as

> *"...the progress of scientific practice based on people's philosophies and assumptions about the world and the nature of knowledge."*

The research paradigm impacts on how the research should be best conducted. The personal paradigm of the researcher and their belief will determine the entire research design. This design includes a plan explaining the information sources used to answer the research question and also outlines a strategy for methods used to collect and analyse the data (Emory, 1985).

The two alternative research paradigms *positivism* and *phenomenology* which are described by Hussey *et al.* (1997), Easterby-Smith *et al.* (1991), Gummesson (1991) and many others reflect the two extremes of a continuum. Morgan and Smircich (1980) classify the following six stages of the continuum from extreme objectivity to extreme subjectivity (see Figure 2-1).

Approach to social sciences **Positivist**					**Phenomenologist**
reality as a concrete structure	reality as a concrete process	reality as a contextual field of information	reality as a realm of symbolic discourse	reality as a social construction	reality as a projection of human imagination

Figure 2-1: Different assumptions about the nature of reality (Morgan *et al.* 1980)

The work of Hussey *et al.* (1997) and Creswell (1994) was used to classify the two main research paradigms (see Table 2-1) and should simplify the different terminology used by various authors.

Positivistic	Phenomenological
Quantitative	Qualitative
Objective	Subjective
Rationalism	Existentialism
Scientific	Humanistic
Experimental	Interpretive
Realism	Nominalism
Determinism	Voluntarism

Table 2-1: Classification of the positivistic and phenomenological research paradigm

Creswell (1994) identifies five assumptions which can be used to explain research in general and to distinguish between the different paradigms. The *ontological, epistemological, axiological, rhetorical* and *methodological* assumptions relate to the entire research and need to be addressed by the researcher at the beginning of a research study. *Ontology* is the most important of the five assumptions as the remaining ones follow from the initial perception of what is meant by *reality*.

To be able to argue which paradigm the researcher will adopt for this research work, the following criteria about the researcher's preunderstanding, training and experience must be addressed.

2.3.1 Preunderstanding of the research project

Preunderstanding is the researcher's knowledge, insight and experience prior to engaging in a research project (Gummesson, 1991). Gummesson uses the term preunderstanding in a wider sense than just knowledge. Knowledge is usually obtained from intermediaries such as literature, reports, lectures or the experience of others. Preunderstanding also includes the researcher's attitude, commitment and personal experience.

The preunderstanding for this research problem comes from two main aspects of the researcher's previous responsibility in a company which included consultancy work for other companies implementing ISO 9001 quality management systems in their organisations. During this time the researcher was involved with a large number of quality management systems which were developed with only loose consideration of the organisation's structure and its business processes. Furthermore the documentation of the quality management system did not reflect the unique business situation of the organisation and the structure chosen for the quality manual was often identical to the one in the ISO 9001 standard. With ISO procedures and policies written in a generic manner the workforce perceived the quality manual as being "out of touch" and not reflecting what really matters in the company. In many cases the approach to the quality management system did not allow the identification of which documents were relevant to whom and who had to consider what to comply with the standard. Both, company officials and their workforces often got frustrated with an ineffective quality management system leading to disillusionment and increased bureaucracy.

The implementation of ISO 9001 quality management systems further developed the researcher's preunderstanding in systems thinking and the concepts of business process modelling. By taking a system's view, the quality management system was understood as part of an overall system within the organisational environment. The interrelationship of a quality management system with other systems includes the exchange of information and objects in the form of inputs and outputs. The design of quality procedures and working instructions was mapped showing the flow of activities and information addressing some of the concepts of business process modelling.

Additionally the researcher's involvement in an activity-based ISO 9001 environment with a previous employer included ownership of ISO 9001 controlled business activities and conducting regular audits of the quality management system. To continuously improve the quality management system, the researcher was responsible for maintaining one section of the standard by keeping track of to whom a particular section was relevant and who might require training or support. The training and support aspect also included the teaching of methods or techniques which were defined by the company as necessary to comply with the standard.

Observations and direct participation during these projects led the researcher to conclude that organisations do not adequately address the links between their business processes and the requirements of the quality standard. There seems to be a need to implement the quality standard in such a way that the links between ISO 9001 and the business processes can be established to maintain compliance to the requirements if changes occur in the process or the standard. The perception about the situation prior to the research study itself contributed to the researcher's paradigm about the subject.

2.3.2 Ontology

According to Gummesson (1993) the researcher must take a stance on the ontological and epistemological assumptions on which the research is founded. The two extreme positions of ontology, which can also be referred to as realism (objective) and nominalism (subjective), are about:

> *"Whether the object of investigation is the product of consciousness (nominalism) or whether it exists independently (realism)". (Remenyi et al. 1998)*

Ontology deals with either a reality *out there* which is independent of the researcher (quantitative view) or a reality that is constructed by the individuals involved in the research situation (qualitative view) (Creswell, 1994). With a quantitative view an observer maintains his objectivity of the subject under study by separating what is being studied from its context and its environment. This results in an objective and singular reality external to the observer and is experienced by everyone in the same manner. To maintain objectivity quantitative observations, records or measurements must be obtained.

The opposite end of the ontological continuum refers to reality as being subjective and not absolute. Individuals involved in the research study form a personal construct about what happens in any given situation. People construct their own worlds and give meaning to their own realities (Easterby-Smith *et al.* 1991). This leads to multiple realities amongst those involved as the way they perceive information does not usually follow a common structure. Knowledge and understanding which are in the constructs of the researcher can not be independently verified or transferred.

An extreme subjective ontological stance would exclude any contribution towards the research by others as it only reflects the individual's perception of the subject. Similarly an extreme objective stance would seem to deny any direct involvement of the researcher in the study as personal interpretation and perception is not scientific and therefore not valid for the research.

An organisation and its business processes are perceived as a complex system which undergoes constant change. Due to the human interventions of the workforce, a business process is also called a Human Activity System. This type of system only exists through the perceptions of the people involved in it and represents an intellectual construct of reality rather than real-world activities (Checkland, 1981). Such social settings lead to difficulties in controlling variables which is why the control of effects is seldom relevant in a non-positivist research approach (Remenyi *et al.* 1998).

Based on the preunderstanding and the nature of the problem, the paradigm adopted by the researcher for this work therefore takes a qualitative position but also accepts some external reality. It assumes that there is an external reality in which people and businesses operate. This reality needs to be understood by observations and requires an understanding about the subject gained from applying a qualitative research approach.

2.3.3 Epistemology

The epistemological question deals with the nature of the relationship between the *knower* or *would-be knower* and what can be known. The answer to this question is constrained by the answer already given to the ontological question (Denzin *et al.* 1994). Both the epistemological and the ontological stance will affect the research methods and tools that the researcher can apply to answer the research problem.

Positivists believe that only those phenomena that can be measured and explained by causal relationships between their elements can be accepted as being valid knowledge. Therefore the researcher should remain distant and independent of that being researched. On the other hand phenomenologists attempt to understand the world by interacting with those they study (Creswell, 1994). The two extreme positions of epistemology can also be referred to as positivism (objective) and anti-positivism (subjective).

This research is concerned with observing and explaining situations involving people and activities. To better understand the business processes with regards to the ISO 9001 standard the research is based on people and their perceptions rather than on *hard facts*. Meredith *et al.* (1989) explain this type of study as *interpretivism* as the researcher focuses on meanings and interpretations rather than behaviour. It is relativistic in nature, as facts are not considered independent of the theory or the observer.

2.3.4 Axiology

The distance between the researcher and what is being researched is governed by the onto-logical and epistemological assumptions. Taking an objective stance about the subject under study the quantitative researcher needs to remain independent from the actual research domain. By applying appropriate methods for data gathering and analysing, results can be obtained that are value-free and unbiased. The development of causal relationships often leads to the deduction of theories, valid explanation and axiomatic conclusions. Qualitative research on the other hand keeps the researcher close to, deeply involved and playing an integral part of the research domain. The results from such an approach are value-laden and biased as they are due to the researcher's observations and interpretations obtained in the field.

With the qualitative position of this research the researcher becomes an integral part of the field. As some bias is inevitable in observations the interpretation of the gathered data needs to be validated.

2.3.5 Rhetoric

The rhetoric assumptions deal with the language used in the research. There is a distinction between the formal, impersonal style used by the quantitative researcher and the more informal, personal style applied in qualitative research. The quantitative approach uses value-free data and accepted definitions for developing concepts and conclusions. Qualitative studies take a narrative and personal approach to describe observations that evolve during a study and explain a phenomena (Creswell, 1994; Creswell, 1998).

This research is firmly embedded in qualitative research but also accepts some external reality in that the rhetoric style will reflect both stances. The observation and interpretation in this research leads to discussion of the findings more from an informal and personal viewpoint. The use of models and questionnaires to develop and validate the findings follows a formal and impersonal style.

2.3.6 Methodology

The research methodology which comprises the entire process of a research study needs to reflect the four assumptions about the ontological, epistemological, axiological and rhetoric stances (Creswell, 1994). With a quantitative paradigm the researcher takes a deductive approach testing theories and hypotheses which are set at, or before, the beginning of a study (Gill *et al.* 1991). A qualitative approach uses the reverse of deduction as it discusses the meanings and understanding of the subject in order to explain a phenomenon. Contrary to the deductive logic that moves from a general stance to a particular instance in order to support existing theory, induction moves from a particular case to a general statement by providing a rich picture of information about a particular phenomenon.

The first part of this research is seek to explain the phenomena by observing and interpreting the domain to gain a thorough understanding (induction). Findings will be used for the development of an improved approach to resolve some of the problems encountered during the observations and validated in a particular case (deduction). This research process can therefore be described as an *induction-deduction sequence*.

The following two sections discuss the Meredith *et al.* (1989) research cycle and framework for selecting research methods in order to develop a soundly based research approach.

2.3.6.1 The Research Cycle

The research process is about organising the investigation, collection, interpretation and analysis of data and information. This is influenced by many variables and situations that are not foreseeable. Emory (1985) states that even though clearly laid out stages in the research design might be skipped and/or need revisiting at a later stage, the concept and sequence of a research process is helpful when planning research.

Meredith *et al.* (1989) suggest that all research investigations within the field of Production and Operations Management can benefit from using a repetitive ongoing cycle of *Description, Explanation* and *Testing*. The three stages might be seen as the main elements of a research process which need to be continuously revisited and Meredith *et al.* (1989) point out that in practice the stages are rarely as clear as proposed. During the research process the stages might be addressed in a different order or activities from different stages might be included to progress with the research. Even though research might not strictly follow the proposed sequence this research cycle as seen in Figure 2-2 provides a useful and well tested structure on which to base a research methodology.

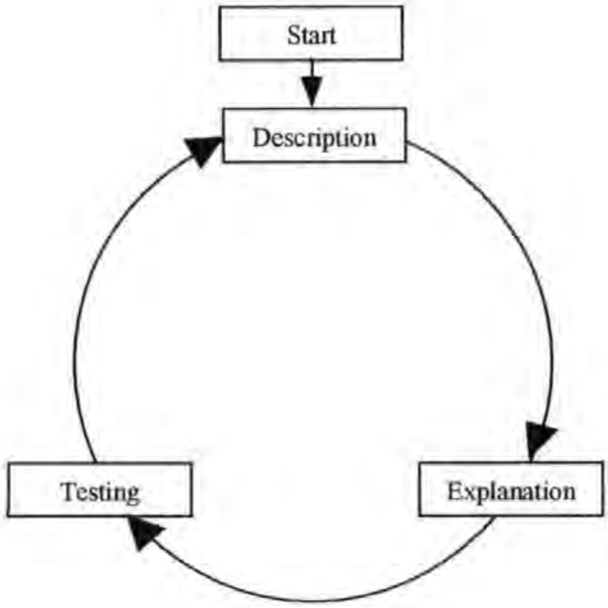


Figure 2-2: The Meredith *et al.* Research Cycle (1989)

In the Description Phase the current preunderstanding and literature relevant to the research topic are addressed in order to form a picture of the area under study. This phase can also be described as the problem definition phase in which groundwork to establish the focus for the research is undertaken. Here the research question is refined accordingly.

The Explanation Phase provides an opportunity to develop frameworks, concepts or models to explain the phenomena under study. A result of this phase may be the proposal for the generation of new knowledge. It is also described as the prescriptive conceptualisation phase which justifies the relationship between variables (Filippini, 1997).

During the Testing Phase new knowledge generated in the Explanation Phase is validated. This process reflects the success in answering the research question and meeting the objectives of the research problem. Depending on the outcome of the validation, this phase may be the point for starting further cycles with refined knowledge and/or a modified problem definition (Meredith *et al.* 1989).

In this case, the researcher understands the research as a continuous learning process about the phenomenon itself and about the special knowledge of theories, methodologies, techniques and other skills which are required to enable him to satisfactorily complete the research. This is similar to the Kolb *et al.* (1979) experiential learning cycle of *concrete experiences, observations and reflections, formation of abstract concepts and generalisations* and *testing implications of concepts in new situations*. As learning can start at any point, Kolb *et al.* (1979) suggest that the individuals might emphasise particular elements of the cycle depending on particular circumstances. For this research such an iterative but informal process of learning supports the researcher in the principle of understanding. This allows the acquisition of additional knowledge about the phenomena from different viewpoints and learning about different research methods through repetitive literature studies or other means.

2.3.6.2 Selection of an appropriate research method

To be able to find the right answers for the research problem, a research method which is one part of the overall research methodology must be selected. Writers such as Gill and Johnson (1991) and Meredith *et al.* (1989) have put forward frameworks for research method identification to support the process of selection from the range of methods available. The selection of appropriate research methods is constrained by the epistemological and ontological stance of the researcher and the research problem itself (Denzin *et al.* 1994).

The framework constructed by Meredith *et al.* (1989) distinguishes between two dimensions. The first dimension describes the epistemological structure of the research process from *rational* to *existential* and the second dimension indicates the origin and nature of information gathered from *natural* to *artificial* shown in Figure 2-3.

A purely *rational* viewpoint assumes any generated knowledge is independent of the observer, while with an extreme *existential* view the distance between the observer and what is being observed is reduced. In the latter case, knowledge generated is the individual's experience from interacting with the subject and its environment. The second dimension differentiates reality between a *natural* extreme, where information is derived empirically and an *artificial* extreme where reality is interpreted and reconstructed.

ONTOLOGY

NATURAL → ARTIFICIAL

EPISTEMOLOGY		**Direct observation of object reality**	**People's perceptions of object reality**	**Artificial reconstruction of object reality**
RATIONAL	**Axiomatic**			reason/logic/theorems normative modelling descriptive modelling
	Logical Positivist/ Empiricist	field studies field experiments		prototyping physical modelling laboratory experimentation simulation
	Interpretive	action research case studies	historical analysis delphi intensive interviewing expert panels futures/scenarios	conceptual modelling hermeneutics
EXISTENTIAL	**Critical theory**		introspective reflection	

Figure 2-3: A framework for identifying research methods (Meredith *et al.* 1989)

Together with the philosophical assumptions made earlier, the research methods which are proposed by the Meredith *et al.* framework (1989) addressing the *natural* and *existential* end of the continuum are seen as appropriate methods to form part of the research methodology for this work. Information generated from such an approach cannot be independent and unaffected by the researcher's interpretation and others involved in the study. This research will therefore focus from an ontological viewpoint on both the *direct observation of object reality* and *people's perceptions of object reality* and on the *interpretive* perspective from the epistemological stance. The primary research methods will be case studies, Action Research and interviews.

2.3.7 Conclusion

The qualitative stance that has been chosen by the researcher stems from the description of a personal interest, the philosophical assumptions and the research domain itself. The researcher does not deny the value of the positivist approach when studying natural philosophy such as physical science but it is necessary to go beyond positivism when explaining problems of people and organisations. This leads to the ontological assumption that there is an existing reality which can be discussed providing that each individual involved has a construct about it. The philosophical assumptions for this research are summarised in Table 2-2.

Assumption	Question	Positivistic versus phenomenological viewpoint	This researcher's position
Ontological	What is the nature of reality?	Assumption whether the world is objective and external to the researcher or socially constructed and subjective	Nominalistic and qualitative position
Epistemological	What is the relationship of the researcher to that being researched?	Concerned with the study of knowledge and what is accepted as being valid knowledge	Observing and explaining situations rather than objects; being involved in what is observed
Axiological	What is the role of values?	Concerned with values; differs between a value-free/unbiased and a value-laden/biased nature	Some bias inevitable in observations; validation of research to reduce bias
Rhetorical	What is the language of research?	Concerned with the language of research which varies from a formal and impersonal style to informal and personal	Rhetoric style will reflect each stance; Formal and impersonal for models and questionnaires; Informal and personal for interpretations and observations
Methodological	What is the process of research?	Concerned with the process of research which varies from a deductive view (testing theories and hypotheses) to an inductive form (observation and explanation of a phenomenon)	Induction-deduction sequence; explaining a phenomenon by observing, understanding and interpreting (inductive) the research domain before validating (deductive)

Table 2-2: Quantitative and qualitative assumptions as identified by Creswell (1994)

The remainder of this chapter explains the research methodology used in this research and describes in detail the research process and the methods applied. It is there to structure and support the research study, to produce the new knowledge that will fulfil the needs discussed in Section 2.2 and is aligned with the philosophical position of the researcher.

2.4 Research Methodology used during this research

Following on from the previous sections that described the researcher's preunderstanding and understanding about the subject, the philosophical position and the needs of the practitioners, the objectives of the research can be summarised as:

- to review the current work undertaken by organisations with reference to the implementation of the requirements of the ISO 9001 quality standard into their organisation (Chapter 3);
- to identify the current approaches available to the implementor of the ISO 9001 quality standard and to critically evaluate those approaches with reference to a business process-oriented organisational structure (Chapter 3);
- to identify the criteria for a modelling technique to reflect the requirements ISO 9001 in a Fulfil Order Process (Chapter 4-6);
- to develop a useful modelling approach to implement the findings derived from the research (Chapter 7-9).

To address the above research objectives, the chosen structure of the research methodology is based on the research cycle as described in Section 2.3.6.1 and shown in Figure 2-4.

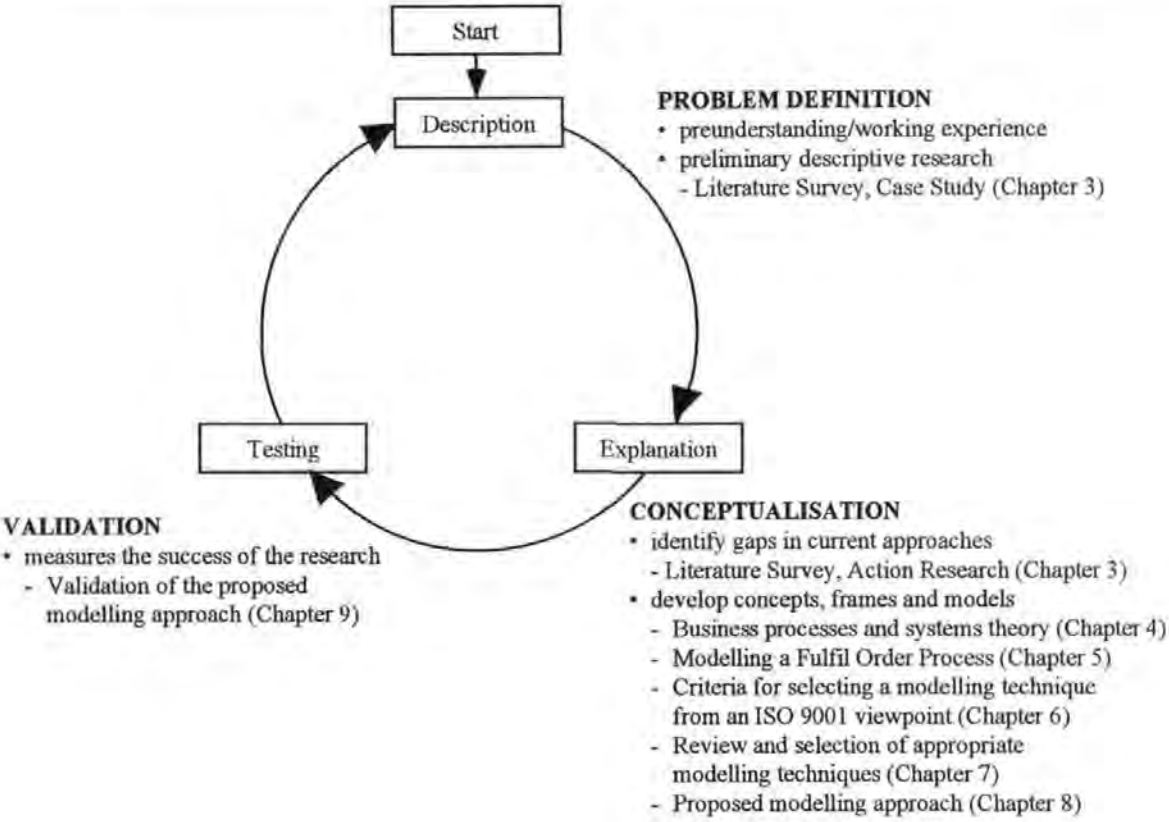


Figure 2-4: The Meredith *et al.* (1989) Research Cycle adopted for this research

2.4.1 Description Phase

In the Description Phase the research problem was addressed and defined. The research activities in this phase were to explore the subject and to develop an understanding about the phenomenon. The problem definition of this project was determined mainly through empirical research based on personal experience, observations gained from a case study and from literature surveys.

2.4.1.1 Literature Survey

An initial literature survey was conducted to investigate the subject area and gain a sound understanding of the phenomenon. This survey included a review of the development of the ISO 9001 standard and the identification of the different concepts for implementing ISO 9001 quality management systems as described in Chapter 3. The literature survey also included information gained from the experiences reported by practitioners working in the field.

From this initial understanding further investigations were carried out in the form of participatory observation using the case study approach.

2.4.1.2 Use of Case Study

The case study approach has been chosen to complement findings from the initial literature study by observing the phenomenon in its real-life context and concentrating on specific instances to create proposals for further studies. Case studies are seen as a useful research method to provide a rich data source of the observed allowing *how* and *why* questions to be addressed (Meredith *et al.* 1989; Yin, 1994). Gummesson (1991) describes the case study approach as a general research tool to add value to the body of knowledge while Meredith (1998) and Eisenhardt (1989) concentrate on case studies for theory building.

The principal concern is to establish the case study design that will define the phenomena under study (Yin, 1994). This case study concentrates on the implementation approach of the ISO 9001 quality management system within the organisation of the case company to better understand the phenomenon of this research. The main objective for this case study was to obtain evidence on how the organisation designed and implemented its ISO 9001 quality management system. The adopted field role can be characterised as a *participant as observer* which focuses on gaining access to the subject in the form of social intervention (Johnson *et al.* 1999). This allowed the researcher to gain knowledge about the structure of the quality management system itself as well as about its effectiveness by observing the workforce as they operated the system. The researcher could observe the daily issues experienced by the people and their actions and interactions which an external observer might have missed.

The advantage of using close observations to gain a full understanding leads to potential bias and subjectivity and needs to be addressed in order to satisfy the standards of competent research (Meredith, 1998). The use of multiple and independent measures is known as *triangulation* and improves the validity of the research and minimises bias. Easterby-Smith *et al.* (1991) distinguish between four categories of *theoretical, data, investigator* and *methodological* triangulation. Validity for this case study has been improved by using multiple sources of evidence and different methods of data gathering. Various kinds of evidence such as documents, records, manuals and interview transcripts which belong to the category of *data triangulation* have been evaluated, while the application of different methods such as semi-structured interviews and participant observation can be referred to *methodological triangulation*.

The literature survey and case study provided information and observations about ISO 9001 quality management systems, the design and implementation of such systems and the problems faced by practitioners. During the next phase the research concentrated on reflecting on the information and observations gathered in order to provide new knowledge to support practitioners linking the requirements of ISO 9001 to a business process.

2.4.2 Explanation Phase

The understanding gained from the Description Phase was reflected upon. The current approaches revealed issues that affected the effectiveness of the design and implementation of ISO 9001 requirements in organisations. A further literature survey discussed in Chapter 3 was carried out and investigated current thinking on ISO 9001 from a business process viewpoint. In addition to the literature survey the researcher was directly involved in a project to design and implement an ISO 9001 quality management system in another manufacturing based organisation. The research method used was Action Research.

2.4.2.1 Use of Action Research

This research method was used to further the knowledge about the design and implementation of ISO 9001 quality management systems in a process-based context. During a period of eight months the researcher was involved in the project on a part-time basis.

Action Research can be seen as a variant of case study research (Gummesson, 1991; Westbrook, 1995). With Action Research however the researcher not only takes an active part in the subject but the findings will also be used for theory building and generating new knowledge. This approach requires the role of a full participant rather than that of an independent observer.

Meredith *et al.* (1989) and Gill and Johnson (1991) identify Action Research as an important approach to research in business and management which serves both the concerns of the practitioner and the contribution to knowledge. By combining research and practice very valuable and relevant research findings can be generated. The main objective for conducting Action Research is being involved in a specific problem which is relevant to the organisation, making changes and monitoring the effects. Such a close relationship enables the Action Researcher to learn about the organisation and gain a thorough understanding based on different perspectives and interpretations of the changes that are occurring. This arrangement makes it important for the researcher to be aware of the impact of his own presence. Rapoport (1970) reported three dilemmas a researcher faces when conducting Action Research.

The three dilemmas relate to *ethics, goal* and *initiatives*. Ethical dilemmas hit the Action Researcher in a number of ways during the project. There might be issues with the type of product or service an organisation provides (products for warfare, products tested on animals etc.) or the principle of confidentiality between management and its workforce or competitors. With the statement made earlier that an Action Research project needs to serve the purpose of producing something useful and relevant for the organisation and at the same time lead to the contribution of knowledge, the Action Researcher faces the goal dilemma of coping with this joint responsibility. The initiative dilemma refers to the role the Action Researcher needs to play when using this type of research. Gummesson (1991) argues that many projects labelled as Action Research do not fulfil the requirements of research and should be associated more with consultancy work. Gill (1986) refers to the consultancy approach as where the client usually presents a problem which is diagnosed by a consultant who then applies a definitive approach or packaged method to solve the problem. With an Action Research project both parties usually present a problem statement and mutually agree goals. A joint diagnosis stage leads to an increased involvement and commitment of both parties which follows on to the implementation stage which is primarily carried out by the client with the support of the Action Researcher. Another major difference between the two approaches is that the Action Research leads into an evaluation stage where the work is jointly reviewed if new problems occur. This is followed by the publishing of the approach undertaken.

The dilemmas of role and goal were particularly important in this case as the researcher supported an organisation in its quest to establish a process-based ISO 9001 quality management system. A mutual agreement about the outcome of this project was settled between the organisation and the consultancy where the researcher was employed at the time. The consultant's approaches would only be used if the company found them appropriate. In all other cases, recommendations by both parties would be taken into account and mutually agreed to achieve the desired outcome of the project. During the entire project the researcher/consultant and the client were jointly involved in the project. This way the researcher/consultant and the practitioners could learn from each other and develop their competence. With this arrangement the role of the researcher as a consultant was reduced to only providing specialist knowledge about ISO 9001 and business processes and avoiding entering the situation with a preconceived set of theories suggesting a pre-defined solution.

The observations made during the project were recognised by the researcher as being subjective. To understand whether specific observations had a wider interest in other situations the researcher often exchanged his experiences with colleagues and others who were not part of the client company. As part of the validation the practitioners involved in the project approved the transcripts of all meetings and workshops as part of the data triangulation.

2.4.2.2 Development of new knowledge

The information gained from the Description Phase and the set of issues identified after completing the Action Research approach provide the focus for the next part of this research. It required undertaking a further literature search to uncover ideas that could be applied to the problem situation. In-depth knowledge had to be gained about systems theory and business processes (Chapter 4) before developing a set of criteria for modelling a Fulfil

Order Process (Chapter 5). Further criteria were developed to allow ISO 9001 requirements within a Fulfil Order Process to be shown (Chapter 6). This was followed by selecting an appropriate business process modelling technique (Chapter 7) based on those criteria. These criteria led to the development of an enhanced approach for modelling ISO 9001 links in a Fulfil Order Process as discussed in Chapter 8.

The proposed modelling technique was developed from direct observations during the Action Research activities, the conducted case study and other cases in literature. The next phase of the research methodology was to determine whether the new knowledge satisfied the five needs of practitioners as well as the specific criteria that had been defined for the modelling technique.

2.4.3 Testing Phase

The modelling technique developed in the Explanation Phase was validated in two stages. The principal aim of the Testing Phase was to establish whether the proposed new knowledge met the needs of practitioners and the specific criteria set for this research. The five needs of the practitioners were described above in Section 2.2 and the specific criteria for the modelling technique are discussed in Chapter 5 and 6. The two stages during which the modelling approach was validated can be described as a review by practitioners and by use of the modelling approach in two manufacturing companies.

2.4.3.1 Validation by review

During this stage of validation the researcher was particularly interested in a general feed-back on improving the modelling approach. Practitioners were presented with a manual on how the modelling approach should be applied including an explanation about its general purpose. The practitioners who carried out the review were independent of the research project. The *validation by review* included academics involved in the field of POM, managers and practitioners from industry. They were asked to work through the manual and give their feedback about the concept of the modelling technique without actually applying the modelling approach itself. The review was carried out in several steps to allow improvements to be included with each version of the modelling technique. This allowed the researcher to get useful information and opinions on how the proposed approach met some of the needs of practitioners before validating its use.

2.4.3.2 Validation by use

During this stage of validation practitioners who had not been participants in the development stages of this research applied the proposed modelling approach during the implementation of their ISO 9001 quality management system. In order to keep an independent stance, case studies were initiated to ensure that the modelling approach was tested without significant influence by the researcher. Apart from an initial introduction and explanation of the modelling approach there was no interference in the actual application of the technique. This should ensure that all knowledge was derived from the use of the modelling technique and not from the researcher directly.

The practitioners' experiences of using this modelling approach were recaptured as part of the case study research. This information was then used to establish whether the five needs of practitioners which derived in Section 2.2 were met, to support establishing the links between ISO 9001 and a Fulfil Order Process as well as the specific set of criteria defined for the modelling technique.

2.5 Chapter Summary

This chapter has described the research methodology applied when conducting this research. The research methodology was developed to satisfy the five needs of practitioners and was grounded in the ontological and epistemological stance of the researcher.

Within the continuum of the quantitative and qualitative paradigm, the viewpoint for this research work is towards a nominalistic perspective. This is based on the assumption that while there is an external reality in which people and businesses operate it is difficult to control, repeat or predict situations within such a Human Activity System from a positivistic viewpoint. It is therefore necessary to understand and explain the situation using the perceptions and observations of the people involved. This is supported by qualitative research. From an epistemological stance it can be described as interpreting the situation, which is best researched by participatory observations, direct involvement, qualitative data and triangulation.

Based on this philosophical position the research methodology was developed around a three-phase research cycle. During the Description Phase of this research a literature survey and case study findings relating to the design and implementation of ISO 9001 quality management system provided a solid background knowledge which was also supported by the researcher's preunderstanding about the subject. The first part of the Explanation Phase reflected upon the findings from the previous phase and led to the use of Action Research during which a quality management system focused on a process/activity context was implemented. This was followed by the development of a modelling technique to help practitioners in their efforts to establish and show the links between ISO 9001 requirements and business processes. The Testing Phase involved the validation of the proposed modelling technique and was carried out in two stages. While during the first stage the concept to develop the modelling technique was reviewed, the second stage validated the modelling approach by use in manufacturing companies. The practitioners' observations and experiences with the modelling approach were evaluated in respect of the discussed needs of practitioners and the criteria set for the modelling technique.

3 Quality standards and their implementation

As part of the research project, a literature survey was undertaken. This was to investigate current literature concerning ISO 9000 quality management systems and business process design.

The literature survey encompasses the development of quality from quality control to quality management and the role of the ISO 9000 quality standard. The approaches used by organisations to design their quality management systems to comply with the requirements of the ISO 9000 standard will also be examined together with an initial empirical analysis using case studies. This chapter explores the major findings of the literature survey and identifies issues of relevance to the research subject area.

The design of an effective quality management system goes beyond merely complying with the ISO 9000 standard to allow an organisation to achieve, sustain and improve quality economically. The following are considered in this literature survey:

- *Design of quality management systems – fulfil order process ISO 9000 implementation;*
- *Business Process Design – quality-oriented business processes.*

The investigation is restricted to the ways of designing quality-oriented business processes that support the product and/or service cycle. It does not consider the implementation stage or the documentation of a quality management system. Exceptions are made were the quality of the design can only be properly evaluated after the implementation stage. This limitation permits the researcher to focus on improving the way to design and redesign *business processes. The research question that evolved from this part of the research will be stated at the end of this chapter.*

3.1 Design of quality management systems

What becomes apparent to practitioners when reading literature about ISO 9000 for the first time is the vast number of different quality terms. In fact the quality standard is supported by a separate part (ISO 9000 "Quality management systems – Fundamentals and vocabulary") (ISO, 2000a) which explains the many terms used in the field of quality management. While the 1987 version of the ISO 9000 standard used the terms *quality system* and *quality management system*, only the former term was adopted in the 1994 update. The year 2000 version of the standard introduces the quality standard, and used the term *quality management system*.

In 1994 a *quality system* was defined in ISO 8402 (Quality Management and Quality Assurance – Vocabulary) (ISO, 1994) as

> *"the organisation structure, procedures, processes and resources needed to implement quality management".*

Furthermore ISO 8402 states that *quality management* incorporates

> *"all activities of the overall management function that determine the quality policy, objectives and responsibilities and implement them by means such as quality planning, quality control and quality improvement within the quality system" (ISO, 1994).*

The newly introduced ISO 9000:2000 "Quality management systems – Fundamentals and vocabulary" (ISO, 2000a) which supersedes ISO 8402 does not include a definition for a *quality system* but defines instead a *quality management system* as

> *"a management system to direct and control an organisation with regard to quality"*

and a *management system* as

> *"a system to establish policy and objectives and to achieve those objectives".*

From the definitions above a *quality system* can be described as a means which allows an organisation to achieve and improve quality. The *quality system* enables the organisation to implement the quality policy and to accomplish its quality objectives. This is, in principle, what a *quality management system* accomplishes in the 2000 version of the quality standard. Hoyle (1998b) argues that the two terms *quality system* and *quality management system* have been used interchangeably throughout the literature. Authors including Harrington (1997), Adams (1995), Ho (1995) and Gupta (1996) have consistently used the term *quality management system* over the years. The term *quality management system* as defined in ISO 9000:2000 is used throughout this research work including the discussions which refer to the previous version of the ISO 9000 standard.

3.1.1 From quality control to quality management

What is known today as *quality management* is the combined efforts of *quality control, quality improvement* and *quality assurance* (Hoyle, 1998a). The current ISO definition states that *quality management* incorporates

> *"coordinated activities to direct and control an organisation with regard to quality. Direction and control with regard to quality generally includes establishment of the quality policy and quality objectives, quality planning, quality control, quality assurance and quality improvement" (Quality management systems – Fundamentals and vocabulary), (ISO, 2000a).*

In the 1960s and 1970s when industry was predominantly technically oriented, quality was very much restricted to production, inspecting product quality, with little consideration of the importance of quality from an economic point of view (Seghezzi, 1998). This gradually began to change during the mid 1960s as the importance of quality to other departments, particularly research and development, became apparent and led to the evaluation of what we today call *quality assurance*. The definition in ISO 9000:2000 "Quality management systems – Fundamentals and vocabulary" (ISO, 2000a) states that *quality assurance* is

> *"part of quality management focused on providing confidence that quality requirements will be fulfilled".*

Quality assurance activities do not control quality but establish the extent to which quality has been controlled. The corresponding ISO definition (ISO, 2000a) refers to *quality control* as the

> *"part of quality management focused on fulfilling quality requirements".*

During the 1970s quality was usually the domain of a few specialists working in the quality department of the company. The specialists received their training from courses offered by specialist quality institutions such as the British Institute of Quality Assurance (IQA), the American Society for Quality (ASQ) or the German Society for Quality (DGQ), attendance at quality conferences or through membership of one of the many quality associations. This produced a very introverted quality community.

Seghezzi (1998) describes the great upheaval from *quality assurance* to *quality management* in the 1980s, as the inspection of product quality was no longer considered to be sufficient. Customers asked increasingly for capable processes and Adams (1995) reports how technical departments began to recognise the opportunity for further development in terms of organisation and leadership. It has been argued that this development was a turning point for quality as it was no longer solely a technical task but clearly a management responsibility requiring a holistic approach. Seghezzi (1998) defines the following four factors for driving the change to *quality management:*

- *Just-in-time* which no longer allowed companies the time to sort out deliveries but required defect free goods;

- *Internationalisation of trade* which resulted in unknown quality behaviour by new suppliers;

- *Regulations by the EU-Commission* to remove technical, non-tariff related trade obstacles to create a common EU internal market;

- *Removal of non-tariff trade barriers world-wide* as proposed by GATT (General Agreement on Tariffs and Trade) and later the WTO (World Trade Organisation).

The newly acquired instruments (see list below) facilitated this change (Seghezzi, 1998):

- *Harmonised models,* such as ISO 9000 systems for both quality assurance and quality management needed to be comparable and transparent to support the development of transparent management systems;

- *Quality Audit* for monitoring, a new form of assessment was needed;

- *Certification* to show evidence of the existence of a working quality management system a new instrument, the certificate, which is granted by independent institutions, was necessary;

- *Documentation* required by the standard, which can be made accessible to customers and administrative bodies.

Adams (1995) reports that the development of total quality management required all elements of quality management systems to be linked together with the existing functional and process-based structures to form the system. The graphs in Figure 3-1 show that the *quality management system* took over from the *quality assurance*. There is clear evidence that the ideas of *quality assurance* and *quality management*, with which the majority of companies currently deal, form part of a higher level approach described as Total Quality Management (TQM).

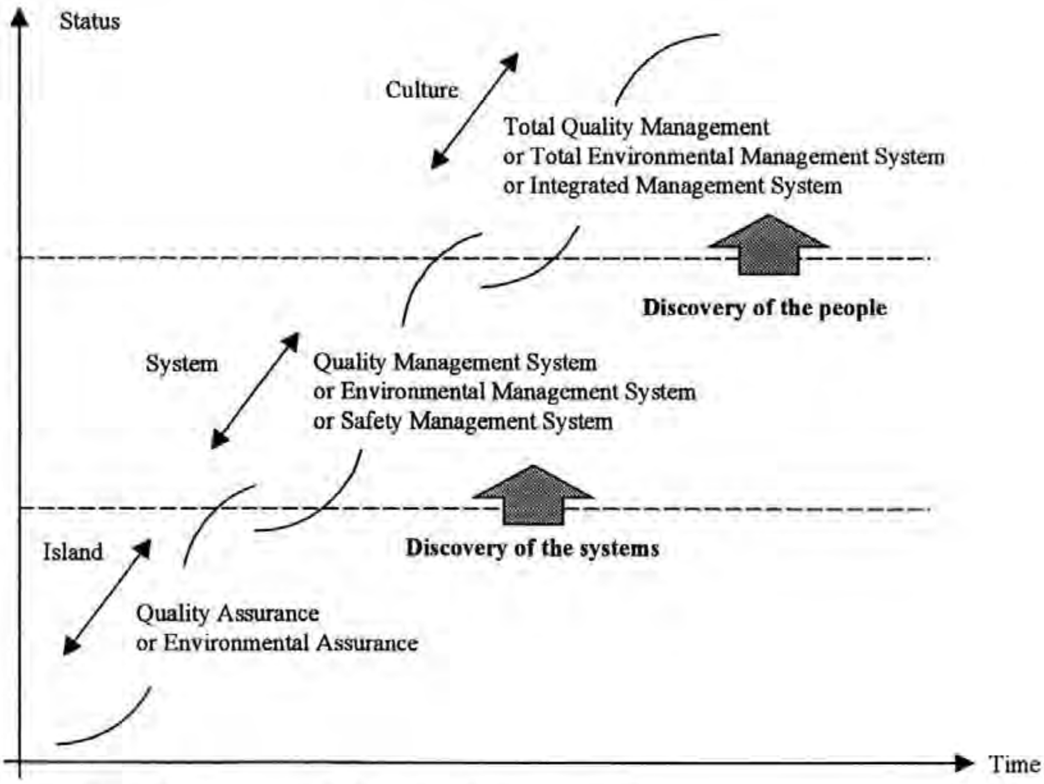


Figure 3-1: Development of quality (Adams, 1995)

The following summary by Voehl *et al.* (1994) shows the relationship between the terms discussed:

> ***Quality control*** *concerns the operational means to fulfil quality requirements.* ***Quality assurance*** *aims at providing confidence in this fulfilment, both within the organisation and externally to customer and authorities.* ***Quality management*** *includes both* ***quality control*** *and* ***quality assurance****, as well as the additional concepts of quality policy, quality planning, and quality improvement.* ***Quality management*** *operates throughout the* ***quality system****. These three concepts – quality control, quality assurance, and quality management – can be applied in all parts of an organisation.*

3.1.2 The origin of ISO 9000

The ISO 9000 series provides a recognised standard for a quality management system for most organisations. One principle of the standard is that a quality management system provides a sound basis for an organisation to demonstrate its ability to consistently provide products and services that meet customer requirements. The standard ISO 9001:2000 is used for certification/registration and contractual purposes by organisations seeking recognition of their quality management systems. As ISO 9001:2000 has a close relationship with ISO 9004:2000 (Quality management systems – Guidelines for performance improvements) (ISO, 2000b) they were both revised together (2000) by the International Organization for Standardization (ISO) as a *consistent pair*. ISO 9004 focuses on guidelines for those organisations whose management wants to go beyond the requirements of ISO 9001 and make improvements on a continual basis. Organisations cannot get certification for working to ISO 9004 guidelines.

Progress in the field of quality was originally dominated by the military and in 1959 the American Department of Defense issued the first national standard for quality programs, MIL Q 9858-A. This was followed by the Allied Quality Assurance Publication (AQAP) of NATO in 1968 and a British defence standard Def Stan 05-08 in 1970. The British Standard

Institution (BSI) published BS 5750 in 1979 based on the UK and NATO standards. In 1984 BSI revised its BS 5750. Growing commercial and international interest in the subject led ISO to adopt BS 5750 with minor syntactic differences as a full international standard, the ISO 9000 series. This was first available in 1987. The second edition of ISO 9000 was published in 1994. This version which is now superseded by ISO 9001:2000 can be grouped into the following four main categories:

1. ISO 9000-1/2/3/4 – "Quality management and quality assurance standards"; these supporting documents provided an introduction to the standard and guidelines for the selection, use, and application of the ISO 9001/2/3.

2. ISO 9001/9002/9003 – "Quality systems"; these models were the "heart" of the quality system standard and applied to organisations which seeked ISO 9000 registration for "contractual" purposes. Depending on the nature of the business the organisation would apply the most appropriate of the three models.

3. ISO 9004-1/2/3/4 – "Quality management and quality system elements"; also provided guidance for the organisation wishing to implement an ISO 9000 quality system for its inherent benefits. They supported implementation of a quality system and were not subject to any assessment.

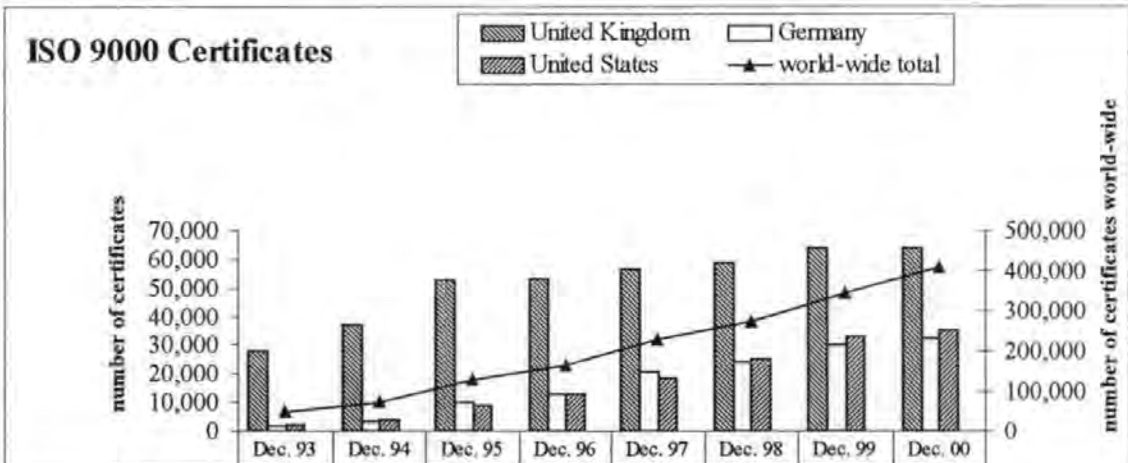
4. ISO 10011-1/2/3 – "Guidelines for auditing quality systems"; the continuous evaluation of the performance of the quality system is another essential element of the ISO 9000. These guidelines incorporate documents for auditing and assessing a quality system.

A full harmonisation of the main standards within the ISO 9000 series was introduced in the year 2000. The three standards ISO 9001, ISO 9002 and ISO 9003 were revised and integrated into ISO 9001:2000. The *consistent pair* ISO 9004:2000 and ISO 9001:2000 can be used by an organisation for the continual improvement of its quality management system. Both standards are based on the same process-based quality management system which also allows an easier alignment with the EFQM Excellence Model (European Foundation for Quality Management) (Green, 2000). ISO 10011 is currently under development and will be superseded by ISO 19011 (Guidelines on Quality and/or Environmental Management Systems Auditing) and will also include guidelines for auditing both types of management systems.

This research work refers to the ISO 9000 series, which is still the most widely used term for this standard. However organisations which seek registration to the 2000 version of this standard need to address the quality management systems requirements published in ISO 9001. The term ISO 9000 is also used in cases where no further indications are given about which of the 1994 criteria ISO 9001, ISO 9002 or ISO 9003 were applied. Throughout this thesis, the reference to ISO 9000 indicates the standard in general whereas ISO 9001 is used when actual requirements are referred to.

3.1.3 International acceptance and distribution of ISO 9000

The introduction of the ISO 9000 series in 1987 was a success from the start. There being no official database of certified companies the ISO Central Secretariat undertakes an annual survey called "The ISO survey of ISO 9000 and ISO 14000 certificates". It gives an overview of two of its most popular standards, the quality standard ISO 9000 and the environmental standard ISO 14000. Excerpts of the Tenth cycle up to the year 2000 (ISO, 2001) are shown in Figure 3-2 and includes the three countries with the highest number of granted certificates. The survey backs up an earlier statement by Harrington *et al.* (1997) that "despite the many critics the ISO 9000 standard is here to stay" as the figures show a continuing strong growth.



	Dec. 93	Dec. 94	Dec. 95	Dec. 96	Dec. 97	Dec. 98	Dec. 99	Dec. 00
United Kingdom	28,096	36,825	52,595	53,099	56,696	58,963	63,700	63,725
Germany	1,534	3,470	10,236	12,979	20,656	24,055	30,150	32,500
United States	2,059	3,960	8,762	12,613	18,581	24,987	33,054	35,018
number of countries	60	75	96	113	126	141	150	158
world-wide total	46,571	70,364	127,349	162,701	226,299	271,847	343,643	408,631

Figure 3-2: ISO 9000 certificates - ISO Tenth cycle, (ISO, 2001)

Note: ISO Central Secretariat reports a problem with the figures for the UK for Dec 99 which requires a readjustment of 1,900 (see original report for further details).

Europe still has the highest number of ISO 9000 certificates but the Far East is continuously closing the gap. The two main contributors to the Asian development are China with the highest increase of 10,548 certificates followed by Japan with 6,765 certificates for 2000.

3.1.4 Different types of a quality management system

Organisations need to decide on the kind of quality management system they want to implement. Harrington *et al.* (1997) argue that organisations have six options (see Table 3-1) and as each approach has advantages and disadvantages they need to be carefully evaluated by each organisation.

Option 1	An informal quality management system.
Option 2	Their own documented quality management system based on their past experience and their present needs.
Option 3	A quality management system that reflects the requirements imposed on them by their customer.
Option 4	A quality management system that meets the requirements defined in the ISO 9000 series.
Option 5	A quality management system certified to the ISO 9000 specification.
Option 6	A complete quality management system that meets the needs and expectations of all the stakeholders and includes the minimum requirements defined in ISO 9000, allowing the organisation to be certified to the ISO specification.

Table 3-1: Different types of a quality management system (Harrington *et al.* 1997)

In addition Hoyle (1998a) summarises the following four approaches to ISO 9000 implementation.

- Simply following what the standard dictates;
- Documenting what you do in response to the requirements of ISO 9000;
- Limited documentation of the business processes to meet the requirements of ISO 9000;
- Creating an integrated management system that covers all processes and where relevant, addresses the requirements of ISO 9000.

The following sections address each of the above in turn.

3.1.4.1 "Following the standard" method

This method documents the activities that are required by the standard and generates a quality manual that addresses each element of the standard in the sequence in which they are presented, regardless of their relevance to the business. Many companies gain no real benefits from this type of quality management system and unsurprisingly remain unconvinced of the potential benefit obtained from a strict compliance with the requirements of this standard (Griffin, 1995). Barrett *et al.* (1996) describe the development of ISO 9000 and its certification scheme as creating an excuse for many companies to approach quality from a point of view of mere compliance, and suggest that too many quality management systems are solely built to conform to standards rather than excellence. In a similar vein Carley *et al.* (1996) observe that

> *"under ISO 9000 poor quality products or services can be manufactured and offered as long as it is done consistently and documented procedures are followed".*

The adoption of ISO 9000 leads in many cases to disillusionment in those companies. They are led by certification bodies to believe that documentation is the key factor and it need only mirror the published requirements of the standard (Dean, 1997). Shillito (1995) argues that

> *"where the use of ISO 9000 may have gone wrong is in creating the impression that a prime function of the documentation is for the demonstration of the operation of the management system, usually for the certification body. In reality, the documentation is not the management system. It exists only to assist management. Documentation should be designed for the operators, not the certification agency".*

Many companies are forced to create new organisational units and introduce additional bureaucracy simply to deal with the amount of paperwork generated by an ISO 9000 quality management system (Bokhoven *et al.* 1996; Primrose *et al.* 1996; Barrett *et al.* 1995). Systems implemented this way will fail to provide the user with the transparency needed to better understand its structure (Tranmer, 1996).

Companies often fail to identify the potential for quality management systems to become an important tool in the day to day work of their staff (Bleuler *et al.* 1995). This missed opportunity can lead to frustration in the workforce (Adams *et al.* 1997).

The "following the standard" approach is also called a *bolt-on system* which often consists of a series of related but unconnected parts and is likely to be ineffective if a company merely documents what it does (Hoyle, 1998a). There is evidence that companies even fail in providing compliance to the requirements of the standard. A total number of 15,886 ISO 9000 certificates had been withdrawn up to Dec. 2000 for a variety of reasons. The numbers of withdrawn certificates for the top three countries for 2000 are shown in Table 3-2. The trend in Europe is particularly noticeable in France with 1,170 organisations which decided to discontinue certification because of insufficient Return on Investment, no business advantage or other reasons.

Reasons for withdrawal	**United Kingdom**	**Germany**	**United States**	**World-wide Total**
Organisation failed re-certification audit	435	53	17	2,168
Organisation decided to discontinue certification	386	267	2275	11,417
Organisation ceased activities	192	44	78	1,391

Table 3-2: Number of withdrawn ISO 9000 certificates (ISO, 2001)

There is some concern that the 2000 revision of the ISO 9000 series will not change the current situation quickly enough. Burgess (1998) states that small to medium sized enterprises (SMEs) may find the substantial changes, necessary to get the new version approved, unacceptable given the limitation on management time and other resource constraints. Bendell *et al.* (2000) report a lack of trust in SMEs in models such as ISO 9001 as the benefits and the impact on the business are often too difficult to assess. Both large organisations and SMEs may focus their resources on other management strategies for continuous improvement, Business Process Re-engineering or performance measurement etc.

The comments and feedback about the new standard are in general very positive (Green, 2000; Wilmer, 2000). A proper judgement however will require some time as the organisations are granted a three-year transition period to update their current quality management systems to the new version starting from the date of publication of ISO 9001:2000 (December 2000).

3.1.4.2 "Documenting what you do" method

Documenting what an organisation does will not necessarily create a system but may describe all of its components (Hoyle, 1998a). As long as the implementation of ISO 9000 requirements is seen by many to be satisfied by a documented description which does not reflect the actual organisation, *it is inevitable that "parallel tracks" will be used to successfully manage the essential business functions and others to manage quality, the environment or health and safety* (Hall, 1998).

The usual approach to documenting quality management systems is to write procedures. Tranmer (1996) comments that this tool for communication is not well understood in most organisations. Verbose and complicated procedures are the results of using obscure terminology, confusing the meaning of things and attempting to cover too much in one document. Aberer *et al.* (1997) suggest that many companies demonstrate the first signs of being process-based by presenting their procedures in the form of flowcharts. However, many of them fail to change their functional organisational structure. This becomes evident when evaluating the quality manuals.

Lo *et al.* (2001) propose the use of a business process modelling approach called $IDEF_0$ (Integration DEFinition language 0) to present a quality manual and to document the relevant quality procedures. This method of documentation is seen as an alternative to the conventional way of presenting quality manuals. However this proposed approach only addresses the documentation of the procedures in the quality manual. It overlooks the advantages of the $IDEF_0$ approach to model organisational processes and integrate this with the quality manual. The $IDEF_0$ modelling technique is described in detail in Chapter 7.

3.1.4.3 "Business process" method

This method focuses on the processes that convert customer input into customer output and maps the requirements of the standard onto the process model (Hoyle, 1998a).

Regardless of the requirements of standards, the management system must be built around the business processes to keep the system efficient and lean (Hesterwerth, 1998). As compliance to procedures will achieve little if the processes are not designed and operated to achieve business requirements (Dean, 1997), other aspects from profitability to legislation or environmental protection must also be addressed (Buhlert, 1998). The overall task of quality management systems is not to implement *a jungle of instructions* (Helling *et al.* 1997) but to focus on a target-oriented optimisation of the business processes. Many of these quality management systems based on the ISO 9000 standards have been implemented in the conventional way with conformity as the primary goal. They are therefore structured in the same way as the standard itself (Karapetrovic, 1999), just describing how the organisation responds to the various sections of the standard. Tranmer (1996) states that the common element of quality management systems is simply a process, not a new concept and that

> *"most organisations lack an appropriate tool, first to define the process clearly and, second, to manage documents covering more than a couple of aspects of a process".*

Organisations need a true understanding of business processes and the idea of process management. By adopting the "business process" method the organisation can create a quality management system rather than a quality assurance system. Tranmer (1996) and Renfrew (1997) both argue that a good starting point to design a process-oriented quality management system is to split the processes into the following three distinct types:

- core processes

  which reflect the sequences of events that cause customers to value the product or services;

- supporting processes

  which are tasks ensuring the core processes work effectively;

- assurance processes

  which ensure that an organisation is meeting its operational objectives.

Karapetrovic *et al.* (1998a) argue that an ISO 9001 quality management system needs to be understood from a systems viewpoint which incorporates interdependent processes that use resources to achieve an objective. In the 1994 version of the ISO 9001 standard, the relationships between the 20 sections which made up a quality management system were not obvious and required rearrangement to see the interdependencies. According to the literature this was unfortunately not common practice when developing a quality management system. ISO 9001:2000 is now based on a *process model* which focuses on meeting objectives, rather than documenting processes and claims to address some the issues raised by its critics over the years (Karapetrovic *et al.* 1998a).

3.1.4.4 "Integrated management system" method

There is some confusion in the literature as to what precisely constitutes an *integrated management system*. To some it is a combination or linkage of various standards such as ISO 9000, the environmental standard ISO 14000 and BS 8800/OHSAS 18001 (for occupational health and safety) into one single management system. This approach is based on the objective that *"any organisation has just one management system in the end which must be designed to achieve the organisation's mission"* (Campbell, 1996). Muir *et al.* (1998) claim to achieve this aim by a single integrated standard and propose the idea of QUENSH (Quality, Environment, Safety and Health). The argument is that even if standards complement each other they will always be separate systems and integration will be difficult to achieve. Muir and Renfrew's QUENSH is therefore based on a single *management system standard* which also considers the various requirements of ISO 14000 and BS 8800 using the ISO 9000 structure. The QUENSH revision of ISO 9001 has been established by cross-relating the elements of BS 8800 and ISO 14000 based on the 20 section structure of ISO 9001, using as much of the common ISO-terminology as possible. Critics such as Woolliscroft (1997) argue that such a single standard would simplify current management systems which is probably not appropriate for its stakeholders right now as it might be a step too far for the majority of them. As QUENSH focuses on the strategic management of organisations' key business risks, this approach uses business processes to cross organisational boundaries and to introduce a risk viewpoint (Renfrew, 1997). Renfrew also suggests the establishment of a QUENSH department with QUENSH experts dealing with aspects for products, processes and systems.

In a similar vein to QUENSH, the electronics company Sharp developed its *Integrated Quality Standard – IQS* which enables their dealers to establish a management system according to the company's demands (Henderson, 1997). This approach incorporates

ISO 9001 (quality), ISO 14001 (environment), BS 8800 (Occupational health and safety), BS 7850 (Total Quality Management – draft), MQA (Marketing Quality Assurance), and IIP (Investors in People). Even though this approach is called *integrated* it simply combines all standards in one programme as a set of requirements for all its dealers.

Others (including Ulrich, 1971; Bleicher, 1992; Seghezzi *et al.* 1995; Adams, 1995; Seghezzi, 1996) present integrated management concepts that are not designed around standards. They argue for a holistic approach in which quality or any other requirement can or must be embedded. The premise is that quality, ISO 9000 or any other ISO standard cannot act as a management system unless they consider all aspects needed to run a business. One of the most widely used generic management systems is the *St. Gall Management Concept* developed by Bleicher (1992) which led Seghezzi (1996) to develop his *Integrated Quality Management - IQM* approach.

3.1.5 Empirical analysis during the Description Phase of the research

This part of the chapter introduces the first phase of the empirical research. It consists of a case study of the design and use of an ISO 9001 quality management system considering its organisational structure and its business activities. The aims of this case study are to determine whether the concepts and methods used by the case company reflect what has been portrayed in the literature and to provide initial empirical evidence upon which the research builds.

The case study research plan that was issued to the case company incorporated the following objectives:

- to determine the structure of the ISO 9001 quality management system used by the company;
- to determine the concepts and methods used to design and implement the ISO 9001 quality management system;
- to identify the relationship between the ISO 9001 quality management system and the organisational structure.

The case study includes a general background of the manufacturing organisation together with the development of the quality management system since its introduction. It incorporates a detailed investigation about the structure of the quality management system together with the documentation structure and document control. It also assesses how well the quality management system is incorporated in the business structure of the organisation by using Hoyle's (1998a) four different approaches for implementation.

This case study was carried out by the researcher over seven months whilst working for the case company for three days each week studying the quality management system. The researcher's role could be best described with *participatory observations* as he was fully integrated within the company and the situation was observed and the information recorded as it occurred. Together with the observations, open ended, semi-structured interviews with various people at different levels in the organisational hierarchy enriched the data. Talking to the Quality Manager, Document Controller, Quality Engineers, Product Manager and Team Leaders reflected the different viewpoints and perceptions about the quality management system. All interviewees were sent a transcript of the interviews to enable validation. Additional information for this case study was drawn from the documented quality management system and other relevant internal and external company documents.

3.1.5.1 Summary of Case A

Case A is a first and second tier supplier manufacturing sealing systems for the automotive industry. Its QS-9000 quality system was developed continuously during its nine years existence and met the requirements of ISO 9001. As part of an international organisation operating world-wide, the case company was advised by consultants and experts in the field during the design and implementation stages. The initial findings and the key points of interest of this case study are summarised and discussed below. The full case study is at Appendix 1.

Hoyle's (1998a) description for the different approaches of a quality management system allows Case A's to be described as being somewhere between the method of "following the standard" and "documenting what you do". The functionally based organisation addressed each section of the standard in the sequence in which they are presented, regardless of their relevance to the business. This type of quality management system is also called *section- or sector-based* (Muir *et al.* 1998) as it follows the structure of the ISO 9001 with its 20 different sections.

The interviewees did acknowledge that the documented quality management system was unresponsive to the requirements of their day to day work and due to lack of transparency it involved extra bureaucracy. As procedures and office instructions were controlled and distributed by head office they were written in a general manner and were open to interpretation. Only the standard operating instructions for the shopfloor operations were explicit and clearly specified. With over 100 procedures and office instructions and more than 1,600 standard operating instructions the quality management system had become very complex over the years.

This development is likely to continue, as the organisation had to take on new business due to closures of other sites. Moreover Case A was also implementing an environmental system to comply with the ISO 14000 standard. The option of reorganising the quality management system and designing an integrated quality and environmental management system was not preferred mainly due to lack of resources and the concerns of jeopardising compliance with QS-9000.

In the design of the quality management system Case A did not apply *best practice* methods used in other areas of the company. It only recently changed its way of recording new procedures from pure text to using simple block diagrams. However Case A had used flowcharts to document and improve the workflow on its shopfloor for many years. The only advantage of this approach is that the documentation produced matched the standard and it was therefore easier for the auditor to verify compliance.

From this, the research develops its focus and further specifies the domain to develop a research question and make a useful contribution to the field.

3.1.6 Conclusion of quality management systems literature

As a result of this literature review and the findings of the case study it was concluded that current approaches to the design of quality management systems have the following key weaknesses:

- responding to the requirements of the ISO 9001, by simply documenting what a company does is still one of the most common approaches adopted. Such an approach can lead to increased bureaucracy and the associated additional work due to the minimal cognisance the quality management system takes of the existing organisational structure;

- the design of quality management systems often achieves the process-oriented character at the documentation stage but fails to create the corresponding organisational structure;

- the usefulness of business process-oriented organisational structures has been widely recognised. In the field of quality, the focus remains on the design of a certifiable quality management system, not on an overall systemic view of the entire business.

The conclusion is that a process-oriented approach (which is not limited to one or more standards but to the organisation and its organisational structure) would provide a system that benefits the business rather than merely conforming to the requirements of a standard. The design of business processes to deal with the requirements of standards (in particular ISO 9000) demands further research. In the following sections of this chapter the research concentrates on the domain of business process design and ISO 9000.

3.2 Business process design and ISO 9000

Instead of emphasising the structure of an organisation, business process design attempts to plan and optimise the output of an organisation according to the requirements of the market (Mertins *et al.* 1999). Outputs to customers are delivered by chains of activities which may be seen as business processes. As discussed in Section 3.1.4.3 authors such as Harrington *et al.* (1997), Hoyle (1998a), Mertins *et al.* (1999), and Tranmer (1996) suggest that quality management systems should be aligned with business processes.

3.2.1 Quality-oriented design of business processes

ISO 9001 points out that all work is accomplished through processes. Companies that are ISO 9000 registered describe their operations in many ways, typically some mixture of text and diagrams published in a quality manual. However not every organisation recognises that it operates processes, even if its functions and responsibilities are well understood (Ould, 1995). Harrington *et al.* (1997) argue that a quality management system needs to be built around different levels of processes. The process hierarchy should include macro-processes, processes, activities and tasks. The macro-processes sometimes called *mega processes* are required to conduct the organisation's business objectives. A process is part of a macro-process and usually documented in operating procedures. Activities which form part of a process are usually documented as instructions. The detailed steps needed to conduct an activity are called tasks. Other authors use slightly different terms for example Hoyle (1998b) uses the term *activity* instead of *task*.

Hoyle (1998b) suggests that a business process approach cannot start with the standard or by documenting what to do. It needs to start with a model of the business – indicating business processes and their dependencies. Generally process-oriented quality management system approaches limit their defined business processes to those processes needed to comply with ISO 9000. These processes are often referred to as *quality processes* and do not explain the full story and show the "entire picture" of how an order is processed.

Hoyle starts with definitions of the interfaces of both the business and the quality management system. The *business interfaces* place the organisation in context with its surroundings while the *quality management system interfaces* establish and define parts of the business contributing to the quality management system. Hoyle creates a system model, which involves successive levels of the quality management system including business processes, tasks and activities. During the process identification the functions and departments of the organisation contributing to each individual process will be omitted. Only after creating the system model will they be correlated to the business processes using a *function deployment matrix*. The requirements of ISO 9000 that apply to each process will be associated with the business processes in a similar way as the functions using a *requirement deployment matrix*. After analysing this matrix a company can determine whether there is a requirement for additional tasks or not. For the actual process mapping Hoyle uses block diagrams and ANSI (American National Standards Institute) flowcharts.

3.2.2 Enterprise modelling architectures and ISO 9000

3.2.2.1 ARIS - The Architecture of Integrated Information Systems and ISO 9000

The Architecture of Integrated Information Systems (ARIS) by Scheer (1994; 1998) is a general methodology that facilitates the specification and implementation of information systems (IS) to support business processes. ARIS provides a comprehensive framework for process engineering and management with integrated IS-support for designing, managing, controlling and executing business processes (Scheer *et al.* 1999). It is based on the four connected levels of *process design, process management, process workflow* and *process application*. The top level of *process design* incorporates activities to define, model and analyse the organisation's business processes. To describe all aspects of a business process the ARIS framework applies four descriptive views namely *function, data, organisation* and *control* and three life cycle phases *requirement definition, design specification* and *implementation description*. *Process management* deals with scheduling and monitoring the business processes to collect the correct data and information. The third level of *process* *workflow* transfers the data to its required destination where it is processed with appropriate methods and techniques defined on the fourth level of *process application*.

A software suite named the *ARIS-Toolset* supports this comprehensive methodology (Scheer *et al.* 1999). When incorporating the ISO 9001 quality standard during the modelling of the business processes at the *process design* stage of the methodology, one facility of the software solution is to support the quality management system and generate a quality manual. ARIS might offer a process-oriented solution for the design of an ISO 9001 quality management system. There is however little evidence in the literature that organisations with the intention of *only* becoming ISO 9001 registered have applied the comprehensive ARIS methodology and developed an integrated information system.

3.2.2.2 GRAI Methodology and ISO 9000

The GRAI methodology is considered as an enterprise modelling technique and has been developed to model decision-flow processes predominantly in the domain of production management systems (O'Sullivan, 1994). The two original methods used in the GRAI methodology are the GRAI Grid and the GRAI Net. At a macro level of the model the GRAI Grid shows a diagrammatic process view of the modelled activities of decision making and information flow. The GRAI Grid includes every decision in a production control system in sequence and calls its position within the matrix a *decision centre* (MacIntosh *et al.* 1995). These *decision centres* are then described in detail using GRAI Nets, which also show in diagrammatic form the inputs, resources and other requirements to execute the decisions and activities of the manufacturing system (Carrie *et al.* 1996).

GRAI Quality, which is currently under development (Prof. Doumeingts, private communication, July 2001), will complement the ten other methods in the GRAI methodology tree.

This particular approach will offer a facility to deploy quality procedures and link them to the concerned business processes (Doumeingts *et al.* 2001).

3.2.2.3 IEM - Integrated Enterprise Modelling and ISO 9000

Mertins *et al.* (1999) developed a modelling method based on *integrated enterprise modelling (IEM)*. It is related to the 20 sections of the ISO 9001:1994 quality standard and allows companies to analyse, improve and redesign their business processes. The modelling language is used to create business process models with an integrated quality management system. Predefined reference models are part of a structured model library. A reference model provides predefined model structures that need to be specified and adjusted.

This object-oriented approach models business processes using *product, order* and *resource* as the three main modelling elements of an enterprise. A *product* is either a physical product or service requested by the customer. The action to transform the *product* to its desired state is controlled by an *order* that monitors and checks the use of *resources* to fulfil the customer requirement. *Resources* are either physical or information objects (Mertins *et al.* 2001).

The enterprise model uses predefined models of processes that are based on the requirements of the 20 sections of the ISO 9001 to support the development of a quality management system. Serving as a reference model for process models it should enable adjustment of the model to create a company-specific version. Such reference models are called *process modules* and refer to different sub-processes of the enterprise model. The following three main categories for *process modules* as shown in Table 3-3 are based on Pfeifer's (1993) division of the 20 sections of the ISO 9001:1994 into *process-related sections, process-accompanying sections* and *control sections*.

Management process modules	**Process modules accompanying processes**	**Process modules related to processes**
Top management responsibility (1)	Products provided by the customer (7)	Contract verification (3)
Quality management system (2)	Testing devices (11)	Procurement (6)
Internal quality audit (17)	Testing status (12)	Design control (4)
Corrective and preventive actions (14)	Controlling documents and data (5)	Process control (9)
Training (18)	Identification and traceability (8)	Treatment, packaging, storing ... (15)
	Tests (10)	Maintenance (19)
	Controlling defective products (13)	
	Controlling quality records (16)	
	Statistical methods (20)	

Note: the number in brackets indicates the corresponding sections of the ISO 9001. Mertins uses different terms for some of the individual sections compared to the ISO 9001 standard.

Table 3-3: Process modules based on the 20 sections of ISO 9001:1994 (Mertins *et al.* 1999)

Process modules related to processes are assigned to business processes directly related to the value-adding chain. They support the processing of an order within the organisation. *Process modules accompanying processes* go alongside the process-related modules. They could be employed during various stages within the production process as they refer to indirect production activities such as *testing* or *inspecting*. *Management process modules* concentrate on the development and the documentation of the quality management system.

From a practitioner's viewpoint Mertins *et al.* (1999) suggest the application of the predefined models as inexperienced users might find it difficult to apply this comprehensive and complex approach for the first time. There are potential problems while trying to integrate individual process modules into suitable positions in the enterprise model. This is likely to happen if the users are not familiar with the modelling approach of *integrated enterprise modelling (IEM)*. From case study findings Mertins *et al.* (2001) report that the main benefits of this approach are an improved understanding of the enterprise through the modelling process which crosses departmental boundaries. The application of the model itself led to an increased transparency of the business recognising gaps in communication and documentation within the organisation.

3.2.3 Empirical analysis during the Explanation Phase of the research

The next phase of empirical research consisted of an Action Research case study in the design and implementation of an activity-based ISO 9001 quality management system. It follows on from the findings of Case A and the subsequent literature survey which concentrated on process-oriented approaches to the design of ISO 9001 quality management systems. The aim of this Action Research was to apply the gained understanding and knowledge about business process design and to model an ISO 9001 quality management system which is firmly embedded in the organisational structure of the organisation.

This Action Research includes a general background to the manufacturing organisation (Case B) together with the overall objectives of the case organisation to develop an effective quality management system to support the company commitment to satisfy their customers with quality products. It describes the principal ideas of this approach together with the structure of the quality management system. This includes the tools used to correlate the requirements of the standard with the business activities. Furthermore it discusses the approach to the development of the quality management system together with the company's experience with this new system.

This case study was carried out by the researcher over a period of eight months during which he was working for the case company on two days each week designing and implementing a quality management system. The Action Research approach included a direct involvement in the development of the system. With the intention to firmly embed the quality management system throughout the entire organisation the approach involved a large number of employees and aimed to generate commitment to the system. The data was derived from direct observations and discussions with employees involved in the project during and outside a series of workshops. It also included regular reflections on the findings with the entire senior management team which was involved in the project from the beginning and with independent fellow experts in the field. For validation, the transcripts of the findings were submitted to the process owners of the quality management system. A final copy of this case study was approved by both the General Manager and the leading consultant.

Case B is a paper mill which produces all its products to customer requirements. In order to guarantee a superior quality product, Case B decided to align its quality management system with the requirements of ISO 9001. The results of the initial investigation are summarised and discussed below. The full case study can be found in Appendix 2.

3.2.3.1 Summary of Case B

Case B was chosen because the organisation decided to extend their existing quality management system with the ISO 9001 standard. The company's objective was to implement an effective, process-based quality management system. Using the Hoyle (1998a) description for the different types of a quality management system again, the quality management system could be described as being somewhere between the method of "documenting what you do" and the "business process" method. The business was designed using some of the ideas discussed in the business process literature. As the company retained its functional structure the researcher referred to the defined processes as *key activities* and *activities*. Even if the activities had a horizontal flow they were not defined at start and finish with a customer nor did they cross any departmental borders. The 40 activities defined could be described as parts of complete business processes that were never defined nor mapped. To integrate the requirements of ISO 9001 into the activities a correlation matrix was established to ensure that all 20 sections of ISO 9001 were plotted against all activities. This exercise was based on the experience and expertise of the leading consultant. This did not influence the way the activities were documented as this step was carried out at a later stage.

Flowcharts were used to document the quality management system showing links to other activities which gave the impression of a truly business process-oriented organisation. The format of the quality manual might have given an indication of how the company could evolve and be organised in the future. All flowcharts showed activities. A short description of the individual activity outlined only a general statement of an action and none of them were broken down in greater detail and documented in the quality manual. Two columns at the right hand side of each flowchart gave further information on individual activities including responsibilities. Links from one activity to another across individual flowcharts were marked.

Case B's strictly controlled on-line production control system already incorporated an excellent system to ensure product quality throughout the entire manufacturing process. In terms of ISO 9001 compliance no change was necessary. 50 documents were kept in two separate folders in production. Most of them were in words as opposed to the easier flowchart format. These separately kept standard operating procedures and work instructions were referred to in the quality manual by a reference mark in the flowcharts.

This activity- or process-based approach required new roles within the organisation as the responsibilities for the quality management system were spread throughout the organisation. Ownership meant that individual employees were responsible for reviewing their activities and for ensuring that all documents were relevant and up to date. It also required them to inform and train the people on the activity content and to monitor and assess any improvements carried out on the activity.

Positive feedback was given by the people involved in the project especially about the ownership of activities and the activity-based approach itself. It spread the workload as well as the responsibility across various employees and they felt confident with the new approach. This is because they could identify themselves with the quality management system as it reflected their individual fields of work.

3.2.4 Conclusion of business process literature

One of the key issues in the business process literature is that every activity carried out must have a direct effect on the quality of the business outputs. A quality management system should ideally affect all areas of a business as every process, activity and task has the potential to create errors. The term quality is usually considered in business process design in various different sets of measurements such as performance, reliability or conformance.

Business process related literature recognises the need for process-oriented quality management systems. There is however limited guidance on the design of business processes considering ISO 9001 requirements. Instead of focusing on overall business processes, the design of a quality management system usually consists of a set of separate quality processes. Such quality processes may be designed as part of a complete business process but restricted to the boundaries of the quality management system. To link these quality processes to the requirements of ISO 9001 they are usually correlated after the design stage with an ISO 9001 requirement matrix. Achieving this link is dependent on the expertise and experience of the team designing the system. This is generally only alluded to and insufficiently discussed in the literature. It is unclear how the redesign of a business process is carried out if analysis reveals that it is not conforming to all of the requirements of the standard.

Some enterprise architectures incorporate the automatic generation of a documented quality manual if the requirements of the ISO 9001 standard have been considered during the business modelling. Integrated approaches such as ARIS or GRAI either strive to holistically describe an information system for supporting business processes or to support the decision flow within an organisation by using their comprehensive frameworks. When developing such integrated enterprise models, quality management and ISO 9001 can become part of the entire business. Companies that redesign their organisational structures and apply such frameworks usually have a different set of business objectives and consider that an ISO 9001 certification is not one of the main drivers.

Other approaches offer pre-modelled processes for a quality management system that can be amended for the organisations' individual needs. They are based, for example, on grouping relevant processes into *core, support* and *assurance processes*. Each of the 20 sections of ISO 9001 is linked to either one or more of these three types of processes.

A system needs to be identified to prepare and implement business processes that are not only focused on single requirements such as for quality, environment or any other, but to reflect the whole organisation. The basic requirement is to recognise a quality management system as being the integration of interconnected business processes that cause the fulfilment of customer demands. If the design of business processes with regard to the requirements of ISO 9001 can be improved, quality management systems can be integrated further into the overall business.

3.3 Overall conclusion

The quality management systems literature review highlighted the fact that the majority of ISO 9000 quality management systems are designed to implement a standard set of quality processes. As a result, there is limited guidance on how to integrate the requirements of the standard into the organisational structure of a company. The business process literature review highlighted that business processes can improve through the integration of ISO 9000 requirements to establish a responsive quality management system. From the case studies there is some evidence that an activity- or process-based approach to the design of a quality management system showed improvements when compared with a section-based approach. In terms of responsiveness the activity-based approach gained from the defined activities as its design considered the overall business objectives and structure of the case company.

It was argued that if during the design of business processes greater consideration to the requirements of the ISO 9000 standard was addressed it would result in the quality management system becoming more of an integral part of the business. The development of quality management systems is moving towards process orientation. So far, however, the majority of activity- or process-based quality management systems only define required quality processes and set tight boundaries around the quality management system. Not taking a systemic view of an organisation could lead to the possibility that improvements made to one part of a business process may result in problems in other parts of the organisation. It was argued that someone who is redesigning the process would be able to see where possible conflicts with the requirements of the standard occur. This also applies if the standard changes. Such conflicts could arise where the ISO 9001 requirements "control of documents" or "control of records" would lead to unnecessary administrative tasks, approvals, and paperwork. This might be due to poorly designed processes and procedures which allow the same information to be recorded and kept more than once in different departments of the organisation. In other situations companies cannot fully understand and evaluate the impact of changes to the standard on their processes or vice versa.

What seems to be missing is a modelling approach which does not necessarily document procedures and instructions but supports the modelling of business processes and establishes the links to the requirements of the standard. The next phase of the research will therefore aim to develop the current theory on the design of business processes taking into account the requirements of ISO 9001. The research question that reflects this intention is:

> *How can a process model be best drawn to establish links between business processes and ISO 9001?*

As this research is concerned with management of production activities that transform inputs into products to fulfil a customer's order the research will concentrate on an *operate type* process. In order to answer the research question the following must be addressed:

- to define a business process in particular a Fulfil Order Process and describe it from a systems viewpoint;
- to identify and characterise the requirements of the quality standard ISO 9001:2000;
- to develop a set of criteria which need to be addressed by an appropriate modelling technique to model a business process to show the links to ISO 9001:2000.

It is in this area that the proposed research will add knowledge.

3.4 Chapter Summary

Reflecting back to the initial stages of this research it can be argued that the literature survey was conducted in two main phases. The researcher's preunderstanding and interest in the field led to an early literature review. This was the basis for the design of the case study at Case A. A more refined second literature review followed that led to Action Research at Case B from which the overall conclusion and the research question was developed.

The remaining chapters of this thesis will describe the research carried out to develop new knowledge that will contribute to an improved approach for the modelling of business processes showing the links to ISO 9001.

4 Business Processes and Systems Theory

The previous chapter proposed that process orientation can be a useful approach to the design of a ISO 9001 quality management system. To understand better what is required from a process based approach this chapter will summarise the main themes from the literature before developing a working definition of a business process. The objective of this chapter is to discuss the principles of a business process from a systems viewpoint in the context of a business process model. An introduction to systems thinking including a description of a system classification, the main ideas and various different views of a system will end the chapter.

4.1 Business Process

Organisations can be analysed in terms of their business processes. To understand how business processes may be analysed, it is necessary to define a process. In reviewing the field of business process design/redesign, some common themes emerge. A business process may be seen as a set of activities which:

- transform inputs into useful and effective outputs

  To consider business processes it is necessary to be able to describe specific inputs and outputs. To take input and create output of value to the customer is crucial. A key point is that inputs originate from outside the boundaries of the organisation, and that outputs in the form of goods and services leave the boundaries of the organisation (Davenport *et al.* 1990; Johansson *et al.* 1993; Hammer *et al.* 1995).

- starts and ends with the customer

A business process relates to customers either directly or as contributors to other processes. Anyone, who receives output from the process, either directly or indirectly, is a customer. Customers can be classed as being directly or indirectly affected by the output from the process or as being an internal or external customer in receiving the output (Harrington, 1991; Hammer *et al.* 1993).

- focus on goals

Each process exists to make a contribution to one or more business enterprise objectives. Goals for a business process approach force fresh thinking about both the process structure and the way work is done. Each process should be measured against process goals that reflect the contribution of that process to accomplish the overall business objectives (Harrington, 1991; Hammer *et al.* 1993).

- can be measured to allow feedback and process improvements

Processes should be maintained and improved so that the organisation can enhance its performance level. The inputs and outputs can be measured and monitored for numerous factors such as usefulness, costs or time. A system of measurements and feedback controls helps to establish process effectiveness and efficiency requirements. While process effectiveness is a performance measure for producing the desired output, process efficiency gives feedback on how much resources have been used (Davenport *et al.* 1990; Harrington, 1991; Hammer *et al.* 1993).

- flow horizontally using a hierarchical structure

A process structure differs from the more conventional vertical hierarchy and responsibility in that it shows a dynamic view of how the organisation delivers value. By taking a process approach the structure reflects the way which is necessary to produce value for its customers. Processes flow horizontally and can be disaggregated into hierarchies of smaller processes with increasingly detailed activities (Davenport *et al.* 1990; Harrington, 1991).

- cross organisational (functional) boundaries

Work carried out in organisations generally consists of integrated elements produced by independent organisational units. A business process can be described as being independent of organisational boundaries (cross-functional) as it flows horizontally across several functions or departments linking them together. A process structure should be visualised in order to understand organisational boundaries. Such a structure will highlight the linkages with other processes within the organisation and with customers (Davenport *et al.* 1990; Harrington, 1991; Johansson *et al.* 1993).

- require resources to transform inputs into outputs

The transformation process requires resources to make the contribution to that process. The *transformed resources*, which are usually a combination of materials and information, are converted by *transforming resources*. The two classes of *transforming resources* are facilities such as equipment in general and staff (Slack *et al.* 1995, Armistead, 1990, Rummler *et al.* 1990).

While this list could be expanded it does incorporate the fundamental issues discussed in business process literature. In this study a business process is defined as:

> *"A structured, measured set of activities and flows which are independent of departmental structures and that use necessary resources of the organisation to provide specified output for a particular customer".*

The CIM-OSA standard (Computer Integrated Manufacturing Open Systems Architecture) (CIM-OSA/AMICE, 1989) defines the three fundamental types of business processes as Manage-, Operate- and Support-type business processes. Their relationship is shown in Figure 4-1.

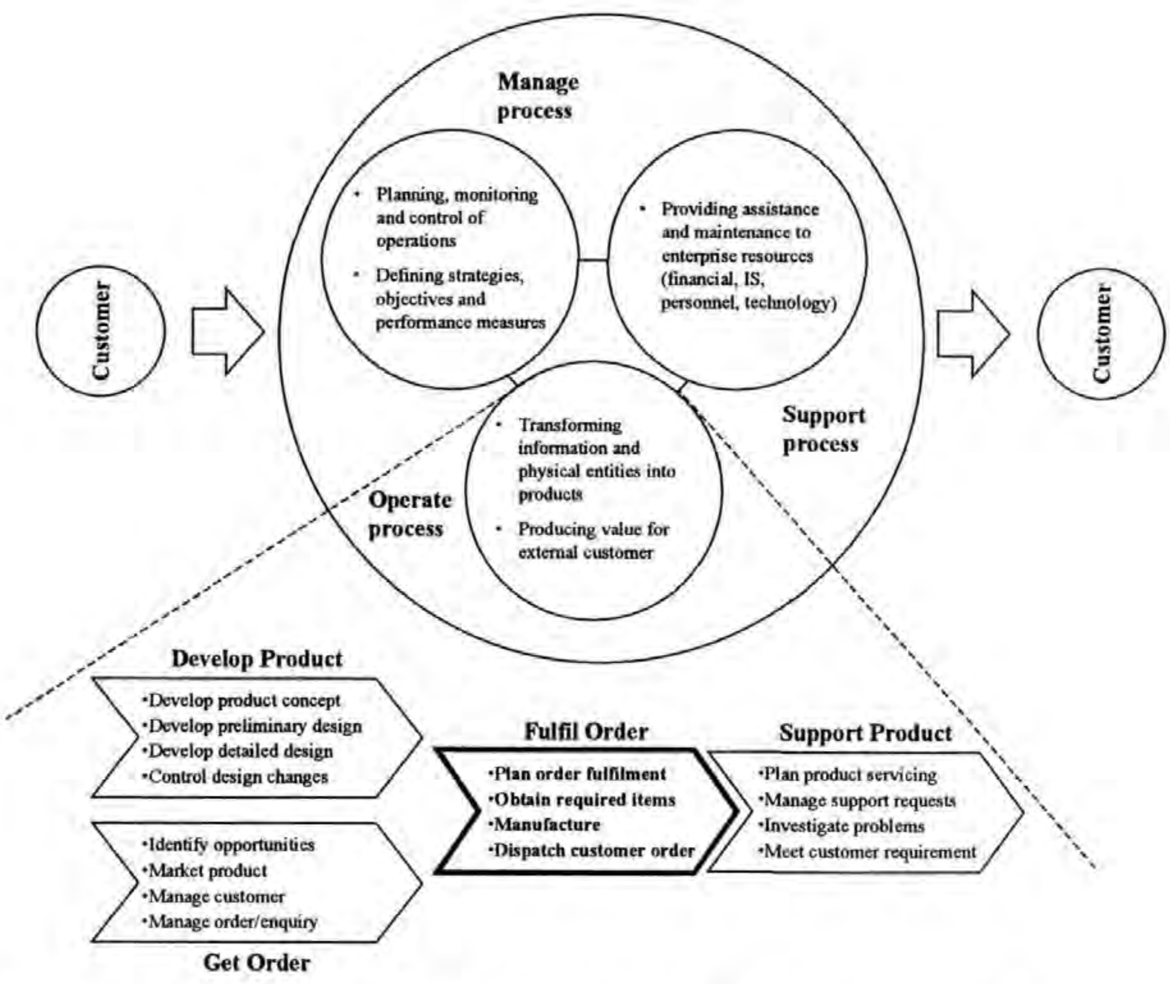


Figure 4-1: Typical operate business processes in the CIM-OSA process model

Management processes are concerned with planning strategy and operations and monitoring performance and are used to manage and control other processes. Operational processes are to develop product, make product and market product. Support processes are mainly concerned with the maintenance and assistance of the operational and management processes (providing, maintaining and assisting enterprise resources) (CIM-OSA/AMICE, 1987; Childe *et al.* 1994).

This research is concerned with management of the production activities that transform inputs into products to fulfil a customer's order. This transformation can be viewed as being an *operate* type of process because it is directly related to satisfying an external customer's requirements by producing direct value. Four types of operate processes are defined and described in Childe *et al.* (1995) and Maull *et al.* (1995a), they are Get Order, Develop Product, Fulfil Order and Support Product. A Fulfil Order Process turns an order into a finished product or service and delivers it to the customer by activities which are performed by employees and machines. Enquiries are turned into specifications, and product orders into products. This will include flow of materials and information that result in the fulfilment of an external customer's order or enquiry. The concept of the order fulfilment process is widely accepted in literature (Chen, 1999; Cooper, 1996; Jackson, 1996; Meyer, 1993).

Maull *et al.* (1995a) state that a number of important ideas associated with the concept of a business process are not made explicit enough. They believe that the use of a business process can be grounded in the discipline of systems. This view is also shared by other authors such as Rummler and Brache (1990) and McHugh *et al.* (1995).

4.2 Basic concept of systems theory

The word *system* has many interpretations and is of a subjective nature. It could be observed simply as a set of entities that interact. A pragmatic definition is that a system is the organised collection of men, machines and material required to complete a set objective. By using Ackoff's (1981) more scientific definition, a system can be described as a set of two or more elements. The interdependence of these elements also forms a behavioural pattern which has effects on the whole. The latter is also true if subgroups of an element are formed. This outline of what a system means can be summarised using Checkland's (1981) definition, namely:

> *A system embodies the idea of a set of elements connected together which form a whole, this showing properties which are properties of the whole, rather than properties of its component parts. (the taste of water, for example, is a property of the substance water, not of the hydrogen and oxygen which combine to form it.)*

Wilson (1984) states that the above definition provides an overall understanding but should be refined by defining different types of systems. In the literature of systems theory types of systems are also referred to as classes of systems.

4.2.1 Classification of systems

A paper written by Boulding (1956) is a frequent starting point when describing systems theory. Boulding's classification of systems shows a concept that incorporates a hierarchy of systems with different complexity. The framework consists of nine different levels as shown in Table 4-1 and comprises systems with greater complexity down to those of being less complex. The hierarchy of systems is useful and gives an understanding of the complexity of different systems. It also explains another concept where a system itself can consist of various other, less complex sub-systems. In General Systems Theory (GST)

Boulding's *hierarchy of systems complexity* is one of the most general theories upon which the more specialised ones have built.

Level	Systems	Characteristics and Examples
9	Transcendental systems	"Inescapable unknowables"; the idea of God; languages and science
8	Socio-cultural systems	Populations of organisms such as man living together as communities; roles, communications and cultural factors expressed in music, art or emotions
7	Man	Individuals are defined as a system; additional qualities to the ones of the animal level are self-consciousness, self-awareness and the ability to communicate by language
6	Animals	Structures where the main characteristics are various degrees of consciousness, behaviour and mobility; with the ability to learn reactions to changes in the environment are more or less instantaneous
5	Lower organisms	"Plant-like" organisms with its main quality of differentiation of system (so-called division of labour) and slow changes in reaction to the environment
4	Open systems	Structurally self-maintaining structures such as cells and organisms in general with the ability to reproduce itself
3	Control mechanisms	Systems with a closed-loop control and a feedback facility such as a thermostat
2	Clockworks	Dynamic systems with a predetermined motion such as the solar system, machines or theoretical structures of physics and chemistry
1	Frameworks	Static structures and relationships such as the arrangement of atoms, molecules or cells

Table 4-1 : Bouldings's Hierarchy of systems (1956)

As work on systems continued, Checkland (1981) developed a set of five classes: *natural systems, designed physical systems, designed abstract systems, Human Activity Systems (HASs),* and *social and cultural systems*. The researcher tried to link the five classes of Checkland with Boulding's nine levels to better understand the boundaries of the different systems.

4.2.1.1 Natural systems

Checkland (1981) claims that systems such as mankind, animals or the planets which make up the Universe are given and cannot be other than what they are, given the pattern and laws of the overall system are not erratic. This suggests that there exists an obvious hierarchy that formed the universe, its components (natural, physical systems) down to single molecules and atoms. Using Boulding's concept of systems hierarchy natural systems can be lower organisms, open systems, animals, and man.

4.2.1.2 Designed physical systems

These systems can be described as objects that were developed and designed to fulfil a human purpose. Systems such as tools, machinery or structures belong in this category. A designed physical system can be described using Boulding's classification as designed clockworks or control mechanisms.

4.2.1.3 Designed abstract systems

Mankind is also capable of designing systems which cannot be built or produced and are only associated with human beings and their understanding. Checkland (1981) defines concepts such as science (mathematics, physics), languages, or ideologies as abstract systems. Such systems are defined by Boulding's as transcendental systems.

4.2.1.4 Human Activity Systems

Human Activity Systems (HASs) can be described as systems which consist of individuals or groups of people carrying out purposeful activities to achieve a set objective. Examples of HASs range from business systems (e.g. organisations) to political systems (e.g. Communism). A socio-cultural system as described by Boulding would be a HAS.

4.2.1.5 Social and cultural systems

Checkland (1981) reports a problem with this category and why it is placed on the boundary between HASs and natural systems. A family, which can be described as a social system will have rational elements such as activities (HAS) but also sets of relationships which occur in a community (natural system).

For the purpose of this work which is concerned with the improvement of activities and flows of a Fulfil Order Process a business process can be viewed as a HAS. A more detailed explanation of the systems characteristics of a business process is presented in Chapter 5 after discussing the most important systems ideas in Section 4.2.2 and systems views in Section 4.2.3.

4.2.2 Systems ideas

There are certain ideas that are common to systems and systems thinking. Among the most important ones are two pairs of ideas described by Checkland (1981) as those of *emergence and hierarchy* and of *communication and control.*

4.2.2.1 Emergence

The idea of *emergent properties* is that a system has a set of properties that only refer to the entire system. These properties would be meaningless at a lower level of the system and would not apply to individual parts or elements (Checkland, 1981). The objective of a system is generally different from the objectives of its sub-systems.

4.2.2.2 Hierarchy

The idea of *hierarchy* is that systems are part of other systems and follow a structure which can be expressed as a hierarchy. While the hierarchical structure of a particular system shows all sub-systems and elements down to the most detailed level, the system of interest itself is part of a superior, larger system. With the idea of hierarchy it is possible to identify and group common elements of interest at the same level of detail and deal with the problem of resolution. The resolution is the level of detail chosen at which activities can be described (Wilson, 1984).

4.2.2.3 Control

For a system to react and adapt to its changing environment control actions are required. This requires measures which include information about the new objectives from the environment. Activities within the system will than have to take control actions to achieve the new objectives.

4.2.2.4 Communication

Means of communication enable the control actions to take place. These means need to be available for the entire system and be connected to all parts within the system and to its environment to ensure undisturbed flow of information.

4.2.2.5 Systems thinking

Systems thinking can be seen as an *epistemology* which forces an observer to view and understand a system as a whole rather than simply analyse its parts. In analytical thinking an observer concentrates on static and structural properties, whereas systems thinking concentrates on the function and the behaviour of the whole system (Skyttner, 1996). This latter view is also called *the systemic view* as opposed to *the reductionist view* which concentrates only on a particular issue within a system.

Checkland (1981) identifies two types of system thinking, *hard* (HST) and *soft* (SST). The main difference is that HST has a given end or an objective as opposed to SST where an end cannot be assumed. This can be further explained in that hard problems are concerned only with the question of *how*. A defined problem will be solved by providing an answer to the *how* question. Soft problems are complex mixtures of both *what* and *how* types of questions (Wilson, 1984). HST is also about deterministic systems, typically *designed physical systems*, which operate in simple predictable ways. In SST the initial action is to understand the situation and answer *what* the problem represents before proposing *how* to solve the problem. SST has a wider scope than HST in that it involves determining what problem to address in a particular situation.

4.2.2.6 Weltanschauung

Weltanschauung is a particular point of view for any kind of situation. The concept defined by this German word translates into *world-view*. It describes any observer's perception of what is observed. Wilson (1984) also calls it

> *"a filter in the head of an observer which has been formed and is moulded by experience, personality, politics, society and the situation".*

A problem which can be referred to as *hard* can be analysed as a designed system (Section 4.2.1) and might be expressed in exact numbers derived from calculations using equations. A single view and common Weltanschauung emerges by taking a hard systems stance and by using a *precise* language such as mathematics which generates *engineering-like* solutions.

The modelling of a *soft* problem which can be described by a HAS is highly problematic. Describing a HAS will always have a multiplicity of objectives and Weltanschauungen and can never be modelled sufficiently in a single account (Checkland, 1981). Such a system may have as many interpretations as people observing the situation. For example, a prison may be seen as a correctional institution, a punishment, or a way of keeping inmates away from victims. To improve or develop the system, the alternative views must be known and a consensus must be developed. Despite the problems in developing HAS, it

> *would seem to be the system type most relevant to improving real-world production systems (Checkland, 1981).*

4.2.3 Systems views

Systems introduced by manufacturing companies can be very complex. Wang *et al.* (1993) states that it is not possible to represent all the components in a single useful model for such complex systems. It would require models of multiple views to address all aspects such as events, conditions, and users of each element of a process. In order to reduce this complexity models are divided into individual views that represent different aspects and can be handled independently (Scheer, 1998). This guarantees a description of every aspect of the business process.

The following four views are widely discussed in the literature and also used within process models such as CIM-OSA (CIM-OSA/AMICE, 1989) or *Architecture of Integrated Information Systems* (ARIS). ARIS was designed to holistically describe an information system for supporting business processes from all views and across all phases of development (Scheer, 1994).

4.2.3.1 Function view

This view contains the description of the function itself, the relationship between functions and subfunctions and the system's boundaries. The function view was described by Ross, (1976) who developed *The Structured Analysis and Design Technique* (SADT). The U. S. Air Force used it in their *Integrated Computer Aided Manufacturing* (ICAM) program. It became a model that describes the functions an organisation performs. The functions can be defined as a set of activities that transform its input into output under the supervision of its controls by using its mechanisms (Meta Software, 1990). In this context the *function view* relates to activities and must not be confused with a *functional view* of an organisation describing traditional functions such as Design, Accounts or Service etc. To avoid confusion in this research the *function view* will therefore be referred to as *activity view*.

4.2.3.2 Data view

The logical structure of data to be used and produced by the functions (activities) is described here. Events such as *order received* are information and are represented by data. This data view is also known as the *information view* as its purpose is to produce an information model that graphically represents the information content and structure related to the system. Although the *function view* shows some sort of information as inputs, outputs or controls of activities it appears only at the level of graphical labels without showing actual information structures (Wang *et al.* 1993).

4.2.3.3 Organisation view

This view represents the organisational structure of the company and the interrelationship between users and their organisational units. The organisational chart is a typical representation of these structures. It also determines the reporting channels within an organisation i. e. the chain of command.

4.2.3.4 Resource view

This view shows resources such as information technology, materials, tooling and other equipment that might both be consumed and produced by activities.

Other views discussed by Wang *et al.* (1993) are a *dynamics view* which is concerned with what the sequences of operations are and a *decision view* which deals with the decision-making which controls the architecture of systems. Scheer (1998) argues that by introducing individual views to reduce the complexity of a system the relationship between these views can get lost due to isolation. Therefore a *control view* is introduced in ARIS to restore the relationship between the different views.

Often overlooked is the most commonly used way of describing business processes namely the *financial, cost view* or the *performance view* (Yu *et al.* 2000) which is used to evaluate projects designs to determine whether they fulfil the set objectives.

4.3 Chapter Summary

This chapter has stated and discussed the most common elements and characteristics of a business process. They can be summarised as a set of activities which will transform inputs into outputs using the necessary resources to fulfil a specific customer requirement. A business process flows horizontally across departmental boundaries and starts and finishes with the customer.

The concept of systems thinking has been introduced and explained for a business process model. A business process and in particular a Fulfil Order Process is about performing activities to achieve defined goals. It can be described as a Human Activity System. By taking a systemic viewpoint the overall understanding of a business process can be improved.

The next chapter will discuss the system characteristics of a Fulfil Order Process in further detail. Based on these specific characteristics a set of criteria will be developed to define what is required to model this operate type process.

5 Modelling a Fulfil Order Process

The previous chapter showed that a systemic viewpoint of a business process leads to an overall understanding of business processes and their relationships in the context of an organisational structure. The objective of this chapter is to develop criteria which need to be addressed by a modelling technique to successfully describe a Fulfil Order Process. In order to achieve this, the details of a Fulfil Order Process will be discussed from a system viewpoint using the parameters for describing a system as proposed by Churchman (1971) and Checkland (1981).

The work in this chapter will also present an overview of the concept of business process design emphasising that the main focus during a BPR project must remain on the business process. This will form the basis for the close of the chapter where criteria will be developed which need to be addressed to model a Fulfil Order Process from a systems viewpoint.

5.1 General process characteristics from a systems perspective

Processes have a number of characteristics by which they and their relationship to one another can be described. The basic ideas of a system as described in Chapter 4 are also embodied in a business process.

A basic concept of a process is the transformation of inputs and resources into outputs. The outputs from one process are the inputs to another process. Each complete business process as a whole can be broken down into smaller components or sub-processes. Such a hierarchical structure consists of different levels of processes each decomposing to sub-processes, activities and individual tasks which allow them to operate. These components can be examined to see whether they add any value (Porter, 1985), and, if so, how much from an external customer perspective. Within each component there are decisions that control how and whether things are done. For a business process to achieve a particular objective some means of control must be established to ensure that the measures for improvement or performance can be met. Therefore a particular area needs to be set to take control. This area usually defines the boundaries of a business process.

A business process does not exist in isolation and interacts with its environment. A boundary may be drawn around a business process to distinguish it from its environment. The boundary has to include the components where decisions are taken and components where decisions are implemented. The boundaries separating the business process from its environment will depend on the perceived purpose of the business process and the corresponding views of those individuals defining the business process.

Interactions (communication) between components and across the boundaries with its environment must be consistent with the perceived purpose of the whole process. The behaviour of one component will affect all those components that interact with it and can influence the ability of the business process to fulfil its purpose. The emergent properties of a business process from a systems viewpoint will also be affected. When analysing, it is imperative to focus on the entire system as the emergent properties are defined only for the entire system and not for its individual components.

To be able to operate and provide the operation task to achieve a specified output a business process requires resources. These resources include both the physical requirements for the process and the human resource of the participants.

The characteristics of a business process have been explained by using the concepts of systems theory. As mentioned in Chapter 4, a business process can be classified as a HAS. Wilson (1984) illustrates that a HAS represents a transformation process which converts inputs into some outputs and can be modelled as a set of activities. This is also a basic concept of a business process. A HAS represents a *system of activities* that can be used to define *what* to change and a *social system* that defines *how* change may be implemented (Wilson, 1984). The purpose of this work is concerned with improving/supporting the way organisations design/redesign a Fulfil Order Process. A business process can be viewed as being a HAS as it represents

> *a set of human activities, linked together so that the whole constitutes purposeful activity (Checkland, 1981).*

5.2 Characteristics of a Fulfil Order Process from a systems perspective

Systems theory discusses various concepts which can be useful for the analysis of a business process and the definition of its environment. Churchman's (1971) consideration of a system in terms of its parameters namely *source, input, process, transformation, output, receiver* and *feedback* is a useful approach. Together with the following set of principles which help organisations to define their business processes, the researcher discusses criteria for the design/redesign of a Fulfil Order Process. The principles were discussed by Maull *et al.* (1995a)

- For each business process there should be a set of specific inputs and outputs (Hammer *et al.* 1995);
- Each process may cross a number of organisational boundaries (Hammer *et al.* 1995);

- There should be a focus on goals and ends rather than actions and means (Hammer *et al.* 1995);
- The boundaries of processes should make sense from an external (customer) perspective (Kaplan and Murdock, 1991);
- Dependencies between processes should be minimised (Kaplan *et al.* 1991);
- All the processes should relate to customers and their needs, either directly or as contributors to other processes (Kaplan *et al.* 1991).

The following definition by Childe *et al.* (1995) of a Fulfil Order Process is used for this research.

> *The Fulfil Order Process contains activities performed by humans and machines. Its principal transformations are product orders into products and enquiries into specifications. It includes the flow of both the material and the information that results in the fulfilment of the external customer order or enquiry. The process constantly seeks to fulfil customer requirements whilst balancing stakeholder requirements.*

To clarify the criteria for a typical Fulfil Order Process the following systems parameters, as shown in Figure 5-1, are described following Churchman (1971) and Checkland (1981) as *source, input, processes and transformation, output, receiver* and *feedback*.

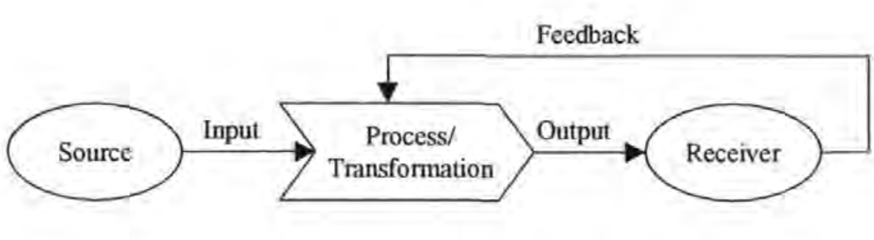


Figure 5-1: Systems parameters from the viewpoint of the process (Churchman, 1971)

5.2.1 Systems parameters of a Fulfil Order Process

5.2.1.1 Source

A source is the origin which is outside the boundaries of a system and provides useful inputs. There are often alternative sources for each input. For a Fulfil Order Process inputs usually originate from various suppliers, customers and other stakeholders.

5.2.1.2 Input

Inputs are those things needed by the process to fulfil its purpose that come from outside the defined system's boundary. Typical inputs for a Fulfil Order Process are information about a product or about a business strategy, preliminary design, product order or supplied items.

5.2.1.3 Transformation

Transformation is the actual conversion of matter and adding value to the input to achieve a desired output. In a Fulfil Order Process a conversion can be explained as the change in shape of incoming materials, the content or location of information or the satisfaction of customers.

5.2.1.4 Processes

This parameter deals with the conversion and the adding of values to inputs in order to generate desired outputs. Processes can be explained as chains of events that are performed to achieve transformation. By studying processes it is possible to show what needs to happen but also what might be able to happen when carrying out the process in a certain manner. Processes can be altered to achieve the same transformation of inputs. This is the basis of re-engineering where the transformation is kept but the process to achieve it will be changed. Plan order fulfilment, Obtain required items, Manufacture, or Dispatch a customer order are typical activities within a Fulfil Order Process. A business process as explained in Chapter 4 can be seen as a system.

5.2.1.5 Output

An output can be anything that will cross the system's boundary into its surrounding environment. Outputs may take the form of objects or information. The former can be a product as ordered while information might leave the system in the form of customer or supplier communication or a request for product development.

5.2.1.6 Receiver

Any party outside the system's boundary that is interested in the output of the system is called a receiver. Outputs should be useful and of value to a particular receiver such as customers and suppliers.

5.2.1.7 Feedback

Information from earlier events will be fed back to influence future choices about sources, inputs, processes, and outputs. Generally feedback can be thought of as a kind of input that comes from a receiver. In terms of a Fulfil Order Process internal feedback might deal with process or product control while external feedback loops might be confronted with customer issues and concerns.

5.2.2 Basic understanding of process design

Process design or redesign became popular when in the early 1990s Hammer (1993) and Davenport and Short (1990) introduced business process re-engineering (BPR). Since then many authors have described the principles of BPR under headings such as *business process design*, *business process redesign*, *business process improvement* or *process based change*.

A more recent BPR methodology discussed by Chen (1999) is based on a review of various existing approaches by Hammer (1993), Davenport (1993) and Johansson (1993) and specifies the following seven phases as important:

1. Visioning: define corporate visions, business goals, organisational structure and business processes;
2. Identifying: identify business processes to be re-engineered;
3. Analysing: analyse and measure an existing process;
4. Redesigning: identify enabling IT and generate alternative process redesigns;
5. Evaluating: evaluate and select a process redesign;
6. Implementing: implement the re-engineered process;
7. Improving: continuous improvement of the process.

BPR is all about change and about redesigning the way that the company does business. Even Hammer (1996) has backed off from the notion of radical change, instead focusing on the need to be process centered. The focus must therefore be on the fundamental business processes and not on departments or other organisational units within an organisation.

In a BPR project, it is important to gain an overall understanding of the relationships between key processes in an organisation (Chan *et al.* 1995) and to find a suitable definition of a business process. With discussing the nature of a business process only at a superficial level, numerous definitions simply quote re-engineering pioneers and their vague definitions of a business process as *a set of related activities that are of value to a customer* (Melao *et al.* 2000). All parts of a business process, the activities, boundaries and resources used in the process need to be understood. The different viewpoints of a business process as discussed in Chapter 4 are useful for achieving a better understanding. They assist the modeller in monitoring the changes introduced to a business process during redesign. Each of the four main views concentrates on a particular aspect of a business process and is of value in business process design.

5.2.3 Systems view of a Fulfil Order Process

The characteristics of a Fulfil Order Process have been identified using the systems parameters (Section 5.2.1). It shows that a Fulfil Order Process is concerned with the process of converting inputs (incoming material, information) to meaningful outputs (finished goods/orders) within the boundaries of the defined system. This transformation is carried out by activities, sometimes referred to as functions. With the main focus of this research based on the design/redesign of this operating type process, its improvement of the overall structure as well as the flow of activities and information is closely related to the principles of BPR as discussed in the previous section.

Design/redesign of a Fulfil Order Process requires an analysis of the activities the organisation must perform, the flows of information and material which these activities generate or require, and the performance requirements of each activity. By taking a function view of the process all required activities and their flows can be shown. While the function view primarily concentrates on activities and tasks, information and their flow of it can also be incorporated when being understood in the context of the description of activities. This is stated by Kueng *et al.* (1996) explaining *activity-oriented modelling approaches* which primarily concentrate on activities as the name implies. The function view associated with *activity modelling* shows information as inputs and outputs of activities on a basic level without showing the actual information structures (Wang *et al.* 1993). An information view represents the conditions and events that exist when data is updated (Gulledge *et al.* 1999). This work concentrates on showing information, data flow and resources only on the level of graphical labels and in the context of activities. Focusing on activities also allows the modeller to analyse them in terms of being value-adding or non value-adding to the overall business, an essential principle in the streamlining process (Harrington, 1991).

It is therefore proposed that the Fulfil Order Process under the discussed limitations can be modelled using a function (activity) view.

5.3 Criteria for selecting a process modelling technique for a Fulfil Order Process

To understand a business process for design/redesign, a process modelling technique which considers the following requirements is required. These requirements were developed by considering the work of Harrington (1991), Franks (1993), Jorysz *et al.* (1990) and Maull *et al.* (1995b).

The technique must provide an

- Easy to use, common language for communication

  An important criterion for the technique must be to present and communicate the view of the modeller clearly so that anyone not involved in the modelling process can easily understand and discuss the process at any later stage.

- Simple syntax and semantics

  Syntax in general describes and represents the format and the rules and regulations set for a modelling technique. Syntax also includes how the concept of a process is presented such as by showing graphics, drawn symbols and various other pictorial elements. A set of rules needs to provide a description of what each individual symbol represents (activities, data entries or resources) as well as the connections and relationships to others. Semantics is concerned with the meaning of symbols and pictorial elements defined within the syntax. Semantic rules should support the interpretation of each type of symbol by means of precise labelling and identification.

- The identification of a systems hierarchy for activities and information

  The process model must be able to show the process at detailed levels. Harrington (1991) proposed a hierarchy of macro-processes, sub-processes, activities and tasks similar to a systems concept in which systems are composed of sub-systems. This requires a process model where each component of a process is identified in the same way so it can be seen in its proper context relative to the other elements.

- A means to define the whole system including its boundaries and the overall goals

  The model must have the ability to present the consensus of the modellers regarding the system boundaries within which the modelling takes place. It is important to distinguish between the system under study and the surrounding environment.

- The description of a process in terms of systems parameters

  The modelling technique needs to be able to represent and distinguish between a number of systems parameters including *sources, inputs, processes, transformation, outputs, receivers* and *feedback.*

  Sources which show information from where about input crosses the system boundaries.

  Inputs which can be divided in the subgroups of *control, resource* or *object*. The modelling technique needs to be able to distinguish between (a) information or objects which control the performance of an activity, (b) objects which are utilised (resources) by activities to complete its functions and (c) objects which are transformed by activities.

  Processes which show individual activities converting inputs into outputs.

  Transformation which shows the actual change of state of an input into an output.

  Outputs that represent processed information or objects needed for subsequent activities to be carried out.

  Receivers who/which are the beneficiary of information about where the output goes beyond the system's boundaries.

Feedback that is any type of information fed back from the receivers to improve future activities.

5.4 Chapter Summary

A Fulfil Order Process has been described from a systemic view and the systems parameters *source, input, process, transformation, output, receiver* and *feedback* have been discussed. They show that a Fulfil Order Process is concerned with transforming inputs (incoming material and information) to desired outputs (product as ordered) for the customer. This transformation is performed by a set of events or activities which can be altered to achieve the same transformation of inputs. A receiver may send information back in the form of feedback regarding the provided output.

An overview of the principles of BPR has also been discussed in respect to the modelling of a Fulfil Order Process. Including the systems parameters, the design or redesign of this process would need to show all required activities, the flow of information and material and the performance requirements of each activity. The requirements of a modelling technique therefore need to have a means to address the systems parameters and to take a function view of the process which shows all required activities and flows. It has also been argued that the information that needs to be shown can also be incorporated in the function view and does not require a separate view.

Having identified the criteria for modelling a Fulfil Order Process, the next stage of the work is to review the ISO 9001:2000 quality standard and identify all relevant requirements for a Fulfil Order Process. Depending on these additional requirements a second set of criteria will be developed to identify and highlight the links to the quality standard.

6 Criteria for selecting a modelling technique from an ISO 9001 viewpoint

The previous chapter developed the criteria for modelling a Fulfil Order Process. A function view of the process needs to be modelled showing the required activities, information and their flows taking a systemic viewpoint. The focus of the following work is to link the ISO 9001 quality standard to this process model of a Fulfil Order Process. This is based on a recognition that for any redesign exercise the process model needs to be able to show the modeller which activities or tasks are linked to ISO 9001 and consequently need special attention.

The following chapter will review ISO 9001 (Quality management systems - Requirements) for its relevance and applicability to a Fulfil Order Process. It will also discuss in what form the requirements of the standard need to be shown in such a model. A second set of modelling criteria will be developed which will address what is required to identify and highlight the links between the quality standard and the activities of a Fulfil Order Process.

6.1 ISO 9001 in a Fulfil Order Process

Figure 6-1 gives an overview showing that ISO 9001 addresses the entire business model and how, when broken down into greater detail, individual requirements of ISO 9001 can be linked to the different parts (operating and non-operating) of the business. In some areas the standard's requirements are more directly relevant to *manage* or *support* processes than to an *operate* process.

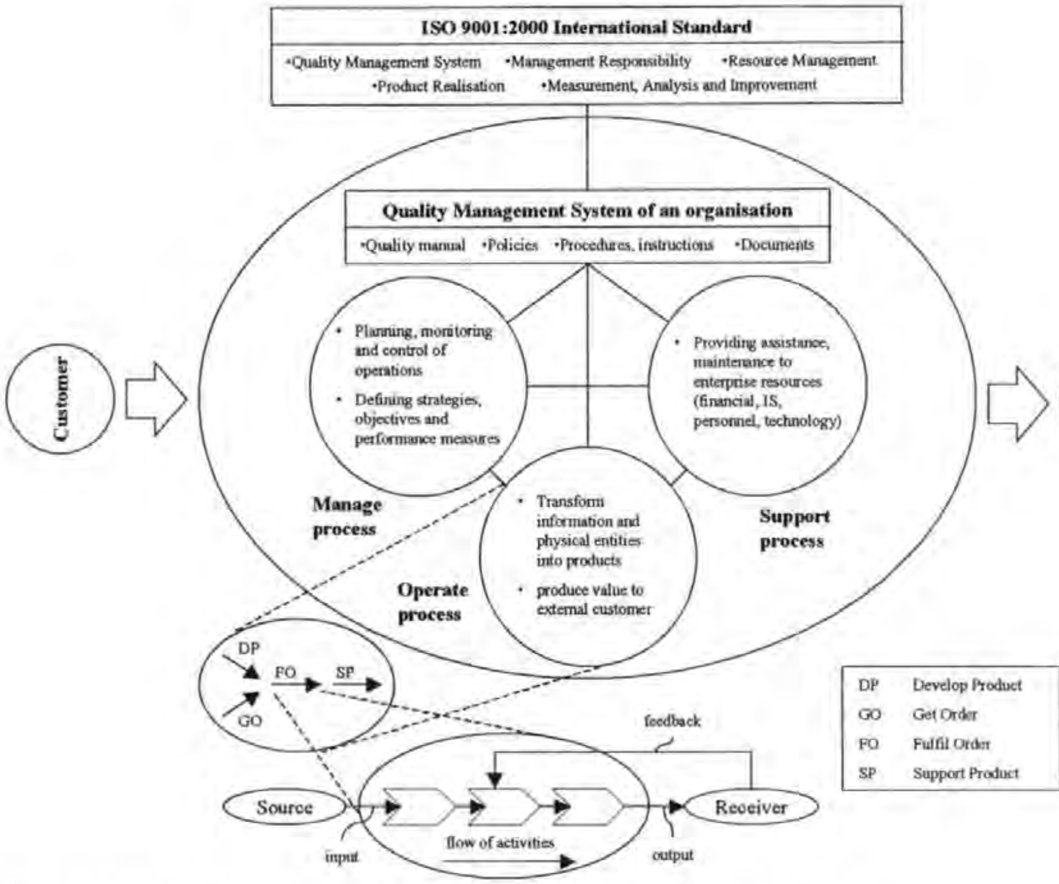


Figure 6-1: Systems model of ISO 9001 and a Fulfil Order Process

6.1.1 Reviewing process of ISO 9001 standard in a fulfil order context

In order to show the links of ISO 9001 in a Fulfil Order Process the relevance and impact of each ISO 9001 requirement needs to be assessed. The standard has been reviewed from a systems and a process viewpoint by the researcher and a full review is included in Appendix 3. To understand the relevance of ISO 9001 in a process context each section of the standard has been reviewed describing the characteristics a Fulfil Order Process needs to provide. The review will assess each section of the standard against whether the requirements can be classified as data, information, resources, objects, activities or others.

The systems parameters described for a Fulfil Order Process from Chapter 5 formed the basis for review of each requirement of ISO 9001 and its role within this process. Each section of ISO 9001 has been assessed by taking a systemic view of the Fulfil Order Process addressing the following questions:

- What kind of input is needed to address each of the ISO 9001 requirements for the Fulfil Order Process;
- What kind of output is needed to address each of the ISO 9001 requirements for the Fulfil Order Process;
- What activities and/or processes are needed by each ISO 9001 requirement;
- Whether other parts of the quality management system outside the boundaries of a Fulfil Order Process are relevant as either a source or a receiver.

Finally the general requirements of ISO 9001 were assessed for when being mapped with a process modelling technique. Considering the requirements of a Fulfil Order Process from a modelling technique viewpoint as described in Chapter 5, the emphasis has been on process identification, process sequence and the dependence between processes and activities. Process identification addresses the need to label all components of the modelling technique consistently. Furthermore the process sequence and the dependence of processes focus on the provision of a sound structure and hierarchy for the process model. These characteristics are relevant for validation and control purposes of the standard and also for its continual improvement elements.

This reviewing process was completed by classifying each link between an ISO 9001 requirement and the Fulfil Order Process. A detailed description has been given in the following three sections.

Appendix 3 shows in its first column all sections and sub-sections of ISO 9001. Column two specifies the strength of linkage between individual sections of ISO 9001 and the Fulfil Order Processes and activities. Column three details the linkages in terms of the requirements of ISO 9001. BSI has granted permission to reproduce a copy of ISO 9001 for use only in this thesis and is included in Appendix 4.

This assessment will allow the research to specify how each requirement of the standard impacts on a Fulfil Order Process. Then criteria for a modelling technique can be specified to address the relevant ISO 9001 requirements and highlight the links within a Fulfil Order Process.

6.1.2 ISO 9001 requirements - directly relevant

Requirements which are considered to be *directly relevant* to a Fulfil Order Process are those such as "Planning of product realisation" (ISO 9001 Section 7.1c) which require activities such as *verifying, validating, monitoring, inspecting* and *testing* etc. that are specific to the product. An example would be "Identification and traceability" (ISO 9001 Section 7.5.3) which requires activities to *identify* the product throughout its production.

6.1.3 ISO 9001 requirements - indirectly relevant

Requirements of the standard that are considered to be *indirectly relevant* to a Fulfil Order Process are usually dealt with in the non-operating/non fulfil-order part of the quality management system. However this part of the quality management system often requires data and information from the Fulfil Order Process. For example an activity in the Fulfil Order Process which uses forms (documents) and records data is indirectly linked to ISO 9001 Section 4.2.3 "Control of documents" and to ISO 9001 Section 4.2.4 "Control of records" if the forms and records are required by the quality management system. ISO 9001 Section 4.2.3 controls aspects such as the *approval of documents for adequacy, ensuring the use of documents with current revision status only,* and *preventing the use of obsolete documents.* In ISO 9001 Section 4.2.4 the standard requires the user to be specific about the *identification, storage,* and *protection of records.* ISO 9001 Section 8.5 "Improvement" which deals with continual improvement of the quality management system is another example of being only indirectly linked to fulfil order activities. Information and data in the form of records or other documents provided by the fulfil order activities are often required by processes in the non-operating/non fulfil-order part of the quality management system to introduce improvements.

6.1.4 ISO 9001 requirements - not relevant

Sections of ISO 9001 considered to be *not relevant* to fulfil order activities are, for example, "Management commitment" (ISO 9001 Section 5.1) and "Design and development" (ISO 9001 Section 7.3). The former includes the establishment of a *quality policy* that is appropriate and communicated company wide. This ISO section would apply to the group *manage processes* rather than *operate processes* as defined in the CIM-OSA standard (CIM-OSA/AMICE, 1989). The latter deals with the design and development of products, including *relevant inputs* and *outputs to the design process, design reviews,* and *the control of design changes.* This ISO section would apply to another of the four operating type processes described as Develop Product (Maull *et al.* 1995a; Childe *et al.* 1995) and is therefore not relevant for this research.

6.2 Criteria for selecting a process modelling technique that can link ISO 9001 to a Fulfil Order Process

ISO 9001 affects a Fulfil Order Process in many different ways. This includes the requirements to perform certain activities, using controlled documents and equipment and providing the quality management system with specific data and information in the form of records and reports etc. In terms of controlling documents and equipment and identifying them to prevent unintended use of any kind the standard requires throughout a unique identification convention. Among other sections of the standard "Control of documents" (ISO 9001 Section 4.2.3), "Control of records" (ISO 9001 Section 4.2.4), and "Control of monitoring and measuring devices" (ISO 9001 Section 7.6) specify in detail what needs to be controlled. A modelling technique needs to show the identification of referred documents or equipment.

As the Fulfil Order Process has been described from a systems viewpoint in Chapter 4 the relevant requirements of ISO 9001 will also be discussed in terms of the systems parameters *source, input, process, transformation, output, resource* and *feedback*. The systems parameters will be used to explain the overall system of a Fulfil Order Process as well as the elements at all levels within this process.

6.2.1 Source related to an ISO 9001 oriented Fulfil Order Process

The boundaries for the system are set around the operate type process Fulfil Order. ISO 9001 affects all parts of an organisation and information from anywhere about ISO relevant inputs that cross the system's boundaries needs to be shown. Suppliers are one of the main sources of these inputs through the provision of required material and information.

Documents in the form of procedures, instructions or blank forms and labels are developed and controlled in the non-operating part of the quality management system. Therefore this part of the quality management system can be seen as another source. Both suppliers and *document production* are outside the Fulfil Order Process system boundaries and therefore need to be acknowledged by the modelling technique as sources.

6.2.2 Inputs of an ISO 9001 oriented Fulfil Order Process

In ISO 9001, material, equipment, personnel and information are considered to be inputs for processes and activities. Activities of a Fulfil Order Process affected by the standard are constrained by inputs in the form of *data* and *information* and *resources*. *Data* and *information* are either processed in electronic form by computers, or come as different types of documents. The documents, which are mostly paper based, convey data and information and can be divided into four classes: *policies, practices, derived documents* and *reference documents* (Hoyle, 1998b).

6.2.2.1 Policies

Policies are documents that define the organisation's approach to achieving set objectives. For the Fulfil Order Process policies are not relevant as they are dealt with within the non-operating part of the quality management system outside the system's boundaries.

6.2.2.2 Practices

Practices are statements that define the details of an operation such as What, When, Where, How and Who and need to be shown by the modelling technique. In ISO 9001 *practices* can be in the shape of procedures, forms, labels or notices.

Control procedures control the work that is carried out within particular activities while operating procedures prescribe how specific tasks are to be performed. Documents that are required by the quality management system must be controlled and control procedures must be established. The standard specifies the requirements in "Control of documents" (ISO 9001 Section 4.2.3) and "Control of records" (ISO 9001 Section 4.2.4). Sub-categories of operating procedures may be inspection procedures or test procedures. Inspection procedures are required for the "Purchasing process" (ISO 9001 Section 7.4.1) and the "Monitoring and measuring of products" (ISO 9001 Section 8.2.4). The former must ensure that purchased goods conform to the purchase requirements while the latter must monitor and measure the characteristics of the product during the production process. Operating procedures must also be established for "Corrective action" and "Preventive action" (ISO 9001 Section 8.5.2 and 8.5.3) to take appropriate actions for eliminating the causes of nonconformities and potential nonconformities to prevent reoccurrence or occurrence respectively. Procedures in general do not cause people to carry out work, they only specify a particular way to perform activities. They may show the sequence of tasks that have defined entry and exit conditions and are needed to execute a routine task. The modelling technique should therefore show that procedures constrain the performance of an activity.

Blank forms and labels can be classed as an *object input* as they are usually transformed by being filled in and completed with data and information. Forms and labels can be seen as being consumed or *used up*, a characteristic of an *object input* while *control inputs* or *resource inputs* are usually *used*. When blank forms or labels are completed (consumed) they become records. Records must be established and maintained where the quality management system requires evidence of conformity. "Planning of product realisation" (ISO 9001 Section 7.1), "Monitoring and measuring of product" (ISO 9001 Section 8.2.4) and "Identification and traceability" (ISO 9001 Section 7.5.3) are typical sections of the standard that require records.

6.2.2.3 Derived Documents

Derived documents are the result of implementing policies and practices and can be further divided into *prescriptive* and *descriptive* documents. *Prescriptive documents* are for example, plans (business plan, quality plan), instructions, or product specifications and need to be shown as *control inputs* by a modelling technique as they contain requirements. In "Planning of product realisation" (ISO 9001 Section 7.1) the organisation must specify all requirements (activities, resources etc.) which are needed for a product. This specification can be referred to as a quality plan (ISO, 2000b). Instructions such as work instructions define specific tasks, when they are to commence and when to be completed. "Preservation of product" (ISO 9001 Section 7.5.5) requires that the conformity of the product is ensured during internal processing and delivery. The organisation might issue instructions to identify, handle, pack, store and protect finished products in a certain way and complete it on a particular date. (A procedure might clarify in detail how to complete individual tasks).

Descriptive documents are discussed in Section 6.2.4 where they are classified as *outputs*.

6.2.2.4 Reference Documents

Hoyle (1998b) describes the fourth type of document as *reference document*. Documents of this nature often only include information without giving instructions. A list of approved suppliers including names and addresses or other data is an example. Where reference documents must be used by an activity they can affect the way it is done. A procedure or other type of practice often refers to the reference documents necessary to complete an activity. Engineering drawings, purchase orders or government regulations may be among the requirements of "Planning of product realisation" (ISO 9001 Section 7.1) which belong to this category. ISO 9001 would usually require such documents to be identified and controlled. In some instances reference documents can also be classed as *resource inputs* where they give guidance and support an activity. Examples could be the use of *Yellow Pages* or the *World Wide Web* which would not become controlled documents. Both classes of inputs are legitimate and, at this stage, it is only important that the modelling technique be able to distinguish between *control* and *resource inputs*.

Resource inputs in general are any kind of physical requirement, including human resources, that is utilised by activities to perform their functions. ISO 9001 states that if work affects product quality it needs to be carried out by personnel that are appropriately educated, trained or are experienced and qualified for the job ("Human resources", ISO 9001 Section 6.2). This requirement applies to any activity involving quality and should therefore not be interpreted any differently for any of the tasks and jobs carried out within an organisation. The required levels of qualification within any organisation vary immensely. It ranges from being able to read work instructions and complete a job accordingly to being able to use complex computerised measuring and test equipment.

The modelling technique needs to be able to show qualified personnel as the human resource that is required for certain activities. Procedures may include information about who is entitled to carry out certain tasks or what qualifications are required. Forms also often state who is authorised to sign off or approve products or components. Examples where ISO 9001 requires qualified personnel within a Fulfil Order Process are "Purchasing" (ISO 9001 Section 7.4) which requires *verification activities* relating to conformity of purchased products, and the use and application of monitoring and measuring devices in

"Production and service provision" (ISO 9001 Section 7.5). Included in "Control of monitoring and measuring devices" (ISO 9001 Section 7.6) is a clause that requires the test equipment to be regularly calibrated and adjusted by qualified personnel.

Furthermore the modelling technique also needs to identify physical equipment that affects the quality of work. Not only is the control of monitoring and measuring devices by qualified personnel important but also the devices themselves need to be identified.

Another example where the Fulfil Order Process needs to consider ISO 9001 is when controlling "Customer property" (ISO 9001 Section 7.5.4). Customer property such as any type of machinery, tooling or measuring equipment that is used or facilitates the completion of an activity needs to be shown as a resource and must be identified as being Customer property.

6.2.3 Processes and transformation in an ISO 9001 oriented Fulfil Order Process

As discussed in Chapter 4 the systems parameter *transformation* itself is the actual conversion of matter to achieve the desired output. Processes are needed to achieve this transformation. ISO 9001 is concerned with tasks and activities that achieve the transformation. The remainder of this section therefore focuses on the systems parameter *processes*.

Besides ISO 9001 controlling activities by the use of procedures it also asks for additional activities to be considered during the product production phase in a Fulfil Order Process. Additional to *making product* which is a key activity within a Fulfil Order Process, ISO 9001 requires many different activities such as *validating, verifying, monitoring, identifying, testing, inspecting, handling, packing* and *storing*. "Planning of product realisation" (ISO 9001 Section 7.1), "Purchasing" (ISO 9001 Section 7.4), "Production and service provision" (ISO 9001 Section 7.5) and "Control of nonconforming products" (ISO 9001 Section 8.3) are among those which directly specify particular activities to be performed. Activities such as *recording* data and information and the *filing* of documents are required by sections such as "Monitoring and measurement of product" (ISO 9001 Section 8.2.4), "Control of nonconforming product" (ISO 9001 Section 8.3) and "Analysis of data" (ISO 9001 Section 8.4).

Each of these activities may incorporate various sub-activities to complete a job. The sequence and flow of these activities and sub-activities are critical to the performance of the Fulfil Order Process. A modelling technique needs to address this requirement by showing the hierarchy of activities and their decomposition.

6.2.4 Outputs of activities in an ISO 9001 oriented Fulfil Order Process

Outputs in general can be described as processed information or objects and often act as input for subsequent activities. Processed information that derives from measurements or assessments is documented as records and may be written up in reports. It can therefore be classified as being descriptive. A *descriptive document* can be defined in general as containing results and information on any kind of achievement. As described in Section 6.2.2, forms and labels once completed may become records and are transformed from being inputs to outputs. Depending on the type of information included, prescriptive documents might be used as inputs in the form of a specification or a procedure. The use of a checksheet for an activity *to set up a machine* is an example of a form transforming from an *object input* to an output. As the original checksheet might need to have certain machine parameter settings recorded or given specifications checked it changes is status and acts as a *control input* for a subsequent activity such as *start producing parts*.

The quality management system with its need for continual improvement requires reliable data and information to ensure the suitability and effectiveness of the overall system. Therefore the organisation needs to determine, collect and analyse appropriate data ("Analysis of data", ISO 9001 Section 8.4). This requires activities in the Fulfil Order Process to provide data and information which can be used to achieve continual improvement. The requirements are only indirectly relevant to the Fulfil Order Process. "General requirements" (ISO 9001 Section 4.1) of the "Quality management system", "Planning" (ISO 9001 Section 5.4) and "Management Review" (ISO 9001 Section 5.6) as part of "Management responsibility" and "Competence, awareness and training" (ISO 9001 Section 6.2.2) of "Resource management" all indirectly rely on such data. It also impacts on "Planning of product realisation" (ISO 9001 Section 7.1), "Measurement, analysis and improvement" (ISO 9001 Section 8) as well as on "Improvement" (ISO 9001 Section 8.5). Regardless of where the improvements and the redesign will be implemented, be it within the Fulfil Order Process system boundaries or outside, relevant data from activities within the Fulfil Order Process needs to be provided to make them happen in the first place.

6.2.5 Receiver of an ISO 9001 oriented Fulfil Order Process

Similarly to the *source* a receiver is outside the defined boundaries of a Fulfil Order Process. The product as ordered crosses the boundaries of the Fulfil Order Process to the external customer and will include all required information such as inspection records, quality reports and process capabilities. In terms of supplier communication there will be an exchange of documents relevant to the "Purchasing process" (ISO 9001 Section 7.4.1) which includes *requests for quotes* (RFQs) or purchase orders etc. Suppliers and any other stakeholders who have an interest in the outcome of the Fulfil Order Process can therefore also be seen as receivers. The Fulfil Order Process also provides the quality management system with data and information to ensure compliance with the ISO 9001 standard. This includes the provision of reliable data for continual improvement efforts (ISO 9001 Section 4.1 or 8.5). Therefore that part of the quality management system outside the boundaries of the Fulfil Order Process can generally be classed as a receiver.

6.2.6 Feedback of an ISO 9001 oriented Fulfil Order Process

Feedback can be thought of as a kind of input that comes from a receiver. The plans for improvements established in the non-operating part of the quality management system can be seen as an input based on feedback from within the organisation and information from the customer to improve future activities. Requirements for such improvements are stated in sections “Quality management system” (ISO 9001 Section 4), “Management responsibility” (ISO 9001 Section 5) and “Measurement, analysis and improvement” (ISO 9001 Section 8).

6.3 Conclusion

This chapter has discussed the criteria which, in addition to those necessary to model the basic Fulfil Order Process as described in Chapter 5, are required to demonstrate its links with ISO 9001. The requirements for a modelling technique for a Fulfil Order Process as listed in Chapter 5 were:

- Easy to use, common language for communication;
- Simple syntax and semantics;

- The identification of a systems hierarchy for activities and information;
- A means to define the whole system including its boundaries and the overall goals;
- The description of a process in terms of systems parameters.

To these we can now add the specific requirements of a modelling technique to incorporate ISO 9001.

- To show activities and clearly identify the ones which are controlled by the ISO 9001 quality standard. A *function view* of the Fulfil Order Process is required which will allow it to show activities, an activity's dependence on other activities and its flow. The modelling technique needs to identify and distinguish between activities that are constrained by the standard and those that are not, either graphically or by some other means of identification.
- To identify and distinguish information and objects that are linked to a requirement of ISO 9001 from those that are not. Where data and information are classed as different types of documents such as practices, derived documents, or reference documents the modelling technique needs to be able to label them accordingly. This may also include referring to sources within the quality management system that originate documents. This applies similarly to objects such as goods (material or consumables) which need to be identified.
- To show information and the flow of information. As with the hierarchy of processes, the modelling technique needs also to decompose information to the different levels of detail. The focus of this research lies in showing information and its flow to allow the activities within the Fulfil Order Process to be redesigned. Consequently information

will only need to be shown as graphical labels, not including the content and structure of information. Therefore the modelling technique does not need to show a separate *information view*.

- Any form of information, be it electronically or paper document based, must be shown as different types of input to an activity. The different types of inputs have been identified as *control inputs, object inputs* or *resource inputs*. This requirement also applies to feedback. Documents that are transformed from inputs to outputs and include the processed information that is required by the standard need to be identified.

- To decompose activities and information to the level of detail necessary to link them to individual requirements of ISO 9001. The modelling technique needs to describe a hierarchy that composes systems from subsystems.

- To set system boundaries in order to identify any source or receiver within the quality management system or with external stakeholders affected by ISO 9001:2000 inputs or outputs.

- To show resources that are required by the activity and to identify the ones that are linked to the standard. The different types of resources required to be shown by the modelling technique have been defined as human resources and equipment.

- All relevant elements such as inputs, outputs and resources within a quality management system need to be controlled and identification is usually achieved by a document numbering convention or other forms of unique labelling systems. The modelling technique needs to refer to the various conventions of identification and show individual identity codes.

6.4 Chapter Summary

The requirements of ISO 9001 have been reviewed for their relevance and applicability within a Fulfil Order Process. Each requirement of the standard has been classified as *directly relevant, indirectly relevant,* or *not relevant* within a Fulfil Order Process. All relevant requirements have been explained in detail and use the systems parameters *source, input, process, transformation, output* and *feedback*. The findings of this review identified that, as with modelling of a Fulfil Order Process, the requirements of ISO 9001 need to be modelled as activities, information and their flows. However in order to satisfy the requirements of the practitioners to see which elements of a process need special attention during redesign, the criteria needed extension. A further set of criteria specified that ISO 9001 controlled activities and information need to be identified and shown differently in the Fulfil Order Process model. This is also required for the flow and decomposition of both activities and information.

The requirements for modelling a Fulfil Order Process showing the links of ISO 9001 have been discussed in detail by developing two sets of criteria as described here and in the previous chapter. The following chapter will review various modelling techniques from within the BPR domain for their ability to address both the criteria to model a Fulfil Order Process taking a function view and also the identification of the links to ISO 9001.

7 Review and selection of appropriate modelling techniques

This chapter will review various modelling techniques and their functionality with respect to depicting a Fulfil Order Process and showing the links to ISO 9001:2000. A literature survey provided the basis for selecting appropriate techniques to model processes in the field of manufacturing systems. Based on this initial filtering, the chapter is divided into two main sections. The first part reviews the selected modelling techniques against the first set of criteria discussed in Chapter 5 for modelling a Fulfil Order Process. This is followed by a review of the techniques and their ability to show the links to ISO 9001:2000, using the second set of criteria as discussed in Chapter 6. Before discussing the various techniques some important aspects of what a model represents and the purpose of a modelling technique are introduced.

7.1 Models and modelling techniques

Modelling can be seen as either the description of a situation or an activity in order to form models. The modelling process in general can produce different kinds of models and there is a concern that modelling can become an end in itself (Wilson, 1984). It is therefore important to select an appropriate modelling technique and develop a suitable model that shows the relevant aspects. A brief description of the terminology is given in the following sections.

7.1.1 Perspectives on models

A model can be defined as a simplified representation or abstraction of reality (Meredith, 1993; Weaver, 1995) as most often reality is too complex to be understood without the help of models. Reality is often studied indirectly through a model, rather than directly, with the objective to develop new knowledge and without the negative implications of costs, time or safety when manipulating the real subject itself (Peterson, 1981). Models are commonly categorised as *iconic, analogic* and *analytic* (Ackoff, 1981) with Wilson (1984) adding *conceptual* as a fourth category.

7.1.1.1 Different types of models

Iconic models – these usually exactly represent the reality of objects. Examples can be full scale or miniature versions of turbine blades used to simulate aerodynamic behaviour or other physical objects to collect information about the intended design.

Analogic models – represent the reality by using a different approach that is constructed to allow the simulation of representative behaviour of a situation. The pH scale is one example of an *analogic model*. It is an important indicator of the hydrogen ion concentration in water. Its range goes from 0 (strong acid) through 7 (neutral) to 14 (strong alkali). Another example is the Richter scale, which measures the intensity of earthquakes.

Analytic models – are a representation of the mathematical, physical or logical properties of a subject usually at a high degree of abstraction. For example in the absence of frictional drag, an object near the surface of the earth will fall with the constant acceleration due to gravity g (9.81m/s^2). With the velocity (v) increasing by 9.81 m/s each second the speed at any time (t) can be calculated from $v=g \times t$.

Conceptual models – are of pictorial or symbolic nature and usually represent qualitative subjects. They tend to be used to describe and explain attributes, properties or meanings of situations, activities or flows by using various symbols. According to Meredith (1993) *conceptual models* can be ambiguous as the model might be conceptual or may be a model of a concept. In manufacturing *conceptual models* are often used in showing the layout of machines, the flow of material and more recently the flow of information (O'Sullivan, 1994). A drawing of a Human Activity System (HAS) as discussed in Chapter 4 can be classified as a *conceptual model* being of a qualitative nature.

7.1.2 Perspectives on modelling techniques

Summarising Wilson's (1984) and Checkland's (1981) descriptions, a technique can be interpreted as the application of a precise and specific approach or manner of producing a standard result. In other words a technique that incorporates a set of guidelines can be used to carry out a particular exercise and solve a problem. For modelling business processes an appropriate technique may need to show activities, information or resources and map the flow of a process.

Modelling techniques are often characterised by the language, concept or graphical tool which they apply. The language can be classified as being *formal*, *semiformal* or *informal* (Kokolakis *et al.* 2000). A characteristic of a *formal* modelling technique is the representation of a model in mathematical terms whereas *semiformal* techniques use a set of rules to apply a defined concept. Modelling techniques classed as having an *informal* language would use, for example, unstructured sketches to describe a model. In the field of business process modelling most of the modelling techniques are based on diagrammatic techniques using a *semiformal* language. They describe processes by using simple symbols, lines and words to display pictorially the activities/information and the sequence of individual operations within a process.

7.2 Selection criteria for reviewing modelling techniques

A variety of methods are used for process modelling within business process re-engineering. The literature search identified a number of studies, among them surveys carried out by O'Sullivan (1994), Kettinger *et al.* (1997), Kota *et al.* (1998) and Kokolakis *et al.* (2000). They all use similar categories grouping the techniques into either functional, data (information), dynamic, simulation, flow or decision (process logic) modelling. This list may not be exhaustive but covers the most widely used, well documented and referenced modelling techniques in the process modelling of manufacturing systems. It is also representative of the various different approaches.

From this list an initial selection was performed excluding all techniques which do not focus on the two main criteria defined for modelling a Fulfil Order Process as discussed in Chapter 5. The two criteria are to model functions and to show the flow of activities and information. All of the selected modelling techniques have been proposed by the studies mentioned above to be suitable in business process redesign and support the different stages of a redesign project when being used for documenting, analysing or redesigning existing processes. The following modelling techniques are reviewed below:

- Action Workflow (Section 7.3.1);
- Petri Nets (Section 7.3.2);
- Role Activity Diagrams (RAD) (Section 7.3.3);
- Flowcharts (Block diagrams, ANSI Flowcharts, Functional Flowcharts, HIPO) (Section 7.3.4);
- Data Flow Diagrams (DFD/SSADM) (Section 7.3.5);

- Object Oriented Modelling (OOM/Use Case) (Section 7.3.6);
- IDEF suite ($IDEF_0$, $IDEF_1$-$IDEF_4$, SADT, NIDEF, NIAM) (Section 7.3.7).

Much work has been done by various researchers on the improvement of the selected modelling techniques. Enhancements range from developing drawing support via computer software also called *paper based software supporting tools* (Bal, 1998) to extending a modelling technique's rules of syntax and semantics to widen or refine its application. Enhancement of techniques is generally developed to resolve a specific problem. This normally does not change the basic principles of the original technique. The emphasis of this review therefore lies in discussing these fundamental principles and the basic concepts of the selected modelling techniques and excludes the numerous variants. It is not the intention of this chapter to fully explain each modelling technique under investigation, for that the reader is referred to other literature. It is however necessary to explain the structure and the basic principles of the modelling techniques so that the review can be fully appreciated.

The following characteristics of each modelling technique have been reviewed based in the criteria defined for a Fulfil Order Process as defined in Chapter 5. They are summarised as:

- Easy to use, common language for communication;
- Simple syntax and semantics;
- The identification of a systems hierarchy for activities and information;
- A means to define the whole system including its boundaries and the overall goals;
- The description of a process in terms of systems parameters.

7.3 Review of modelling techniques supporting the criteria for a Fulfil Order Process

7.3.1 Action Workflows

Action Workflow is an approach for the design of workflow management systems. The main focus of this approach is the workflow elliptical loop (Medina-Mora *et al.* 1993) as shown in Figure 7-1. The loop represents the interaction between a customer and a supplier (performer). Kethers *et al.* (2000) explain the interaction starting with the *request phase* (preparation) where the customer asks for an action to be performed by the supplier. This is followed by the *commitment phase* (negotiation) where the two parties agree on the conditions of satisfaction. The *performance phase* deals with the supplier satisfying the request of the customer which is finally agreed and accepted in the last phase which is the *evaluation phase* (acceptance). Each workflow loop between a customer and a supplier can be joined with other workflow loops to complete the business model. The supplier in one workflow loop can be a customer in another workflow loop. The primary workflow, the largest loop is centred on the map surrounded by its secondary loops (Maull *et al.* 1995b).

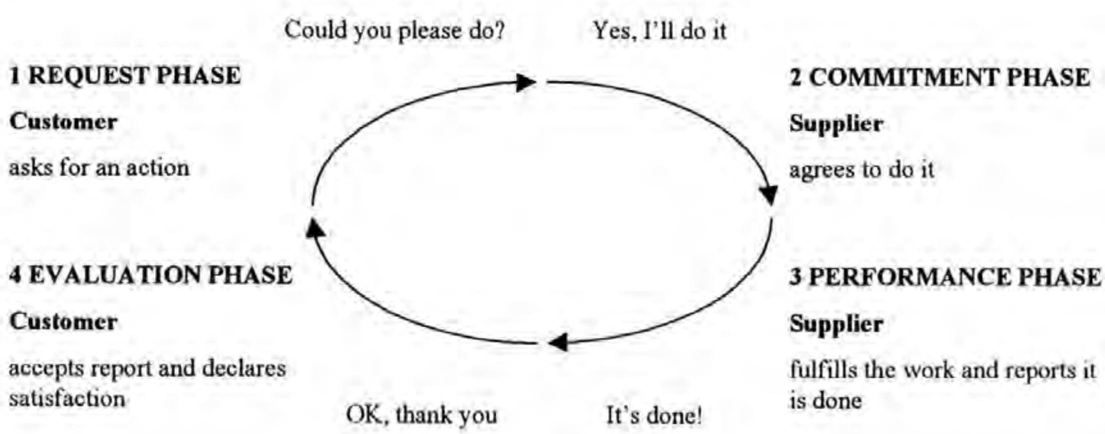


Figure 7-1: Example of an Action Workflow (Schäl, 1998)

7.3.1.1 Use and common language for communication

In terms of clarity, Action Workflow models are reported to be well structured and thus easily read (Kethers *et al.* 2000). However, due to a complex and ambiguous semantics (see next section) models may become highly personalised and difficult to communicate to others.

7.3.1.2 Syntax and semantics

The syntax for the design of a model is reported to be fairly simple (Maull *et al.* 1995b; Kethers *et al.* 2000). The Action Workflow approach provides a simple syntax for designing the model by drawing elliptical loops that are divided into four quadrants representing four sequential phases of an interaction between two parties.

Kethers *et al.* (2000) state that there is however a lack of exact semantics. There seems to be no clear definition of a link between a primary and its secondary workflows or what the object of the workflow specifies.

Also the model cannot take into account several parties (Kueng *et al.* 1996) and sometimes may not be able to "show" the responsibilities and role of a customer or a supplier. Furthermore the workflow semantics does not indicate which activities can occur in parallel or if there are conditional or alternative actions. Maull *et al.* (1995b) state that the modelling of Action Workflows is rather subjective and heavily dependent on the world-view of the modeller. Depending on the modeller's understanding of the process and the modelling goals it would therefore make the communication of such highly personalised models difficult.

7.3.1.3 Systems hierarchy for activities and information

The Action Workflow approach does not support process hierarchies. At each particular phase of the four activities further interactions can be introduced by drawing secondary workflow loops. While these extra loops may be important to clarify the interaction they may result in over complex models. This is because the Action Workflow approach does not use different hierarchies to allow decomposition.

7.3.1.4 Overall system boundaries and goals

Since this approach focuses on the relationship between a customer and a supplier, the main emphasis is on the customer and on achieving customer satisfaction. Therefore, this approach may not be appropriate for modelling business processes with objectives other than customer satisfaction. According to Maull *et al.* (1995b) it may be argued that system boundaries exist between the primary Action Workflow and its environment. There is however no explicit rule about boundaries.

7.3.1.5 System parameters

Maull's *et al.* (1995b) report indicates that the transformation of inputs into outputs is not apparent within Action Workflow models. It can therefore be suggested that other systems parameters such as source or receiver cannot be addressed either, while Maull *et al.* argue that the activities which are performed in the customer/performer relationship can indirectly refer to a source or receiver. Within the four-phase based communication between the two parties involved the actual activities (processes) are not modelled as the focus is on the commitment between the customer and supplier.

7.3.2 Petri Nets

Petri Nets may model the flow of information or other resources within a system and are specifically designed to model systems with interacting concurrent components (Reisig *et al.* 1982). Where two components do not interact they may occur independently and there is no need to synchronise them. When synchronisation is required it can be modelled with Petri Nets. The concept of a Petri Net is based on *places, transitions* and *arcs* and consists of four parts: a set of places (P), a set of transitions (T), an input function (I), and an output function (O).

While *places* represent the possible states of a system, *transitions* represent points where the system changes state and are referred to as events or actions. Two types of nodes make a Petri Net graph. Graphically, a *place* is denoted by a circle and a *transition* by a rectangular bar. An *arc* is an arrow leading from a *place* to a *transition* or from a *transition* to a *place*.

Most theoretical work on Petri Nets is based on the formal definition of Petri Net structures and based within mathematics. The diagrammatic form of Petri Nets is called a *bipartite directed multigraph* as it allows multiple links of arrows between transitions and places. As the arrows are directed it is a *directed multigraph* and because an arrow can be drawn from a place to a transition or vice versa it is called a *bipartite multigraph* (Peterson, 1981). Peterson's example of a simple machine shop (Figure 7-2) illustrates the events and conditions shown in Table 7-1.

The conditions are:	The events would be:
1. The machine shop is waiting	1. An order arrives
2. An order has arrived and is waiting	2. The machine shop starts on the order
3. The machine shop is working on the order	3. The machine shop finishes the order
4. The order is complete	4. The order is sent for delivery

Table 7-1: Conditions and events of a Petri Net

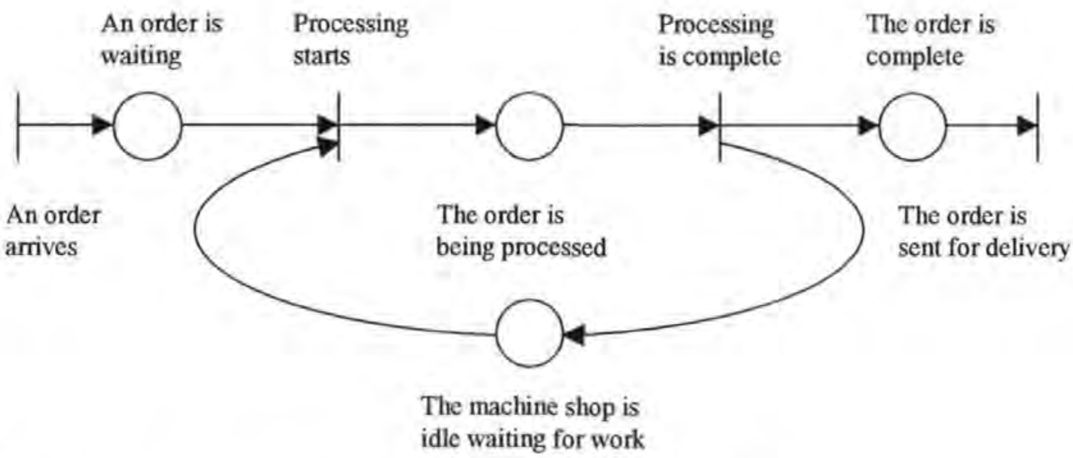


Figure 7-2: Petri Net example – a machine shop (Peterson, 1981)

A change of state (from one place to another) is caused by the *firing* of a transition. Token(s) which resides at places indicates that an event has occurred. Tokens which are referred to by black dots and move around within the system denote the current state. The *firing* is caused by the conditions of the input place, denoted by the tokens available. After firing, tokens will be transferred from the input places of a transition to the output places of the transition. The firing of a transition is to be considered as an instantaneous event (Peterson, 1981). Events are therefore called *primitive events* as the length of time to perform a transition is not considered. Figure 7-3 shows the four seasons (spring, summer, autumn, winter) as the conditions of the system. The current condition or state of the system is marked by a black dot (token). When an event (start of the summer) occurs the token is fired and moves to the next season leading to a new state of the system. The number of states the system can be in, and thus the number of tokens, is strictly limited by the logic of the diagram that the modeller shows. Petri Nets are mainly used to develop the logic of control systems and make particular use of the token to show the current state of a system at a particular moment.

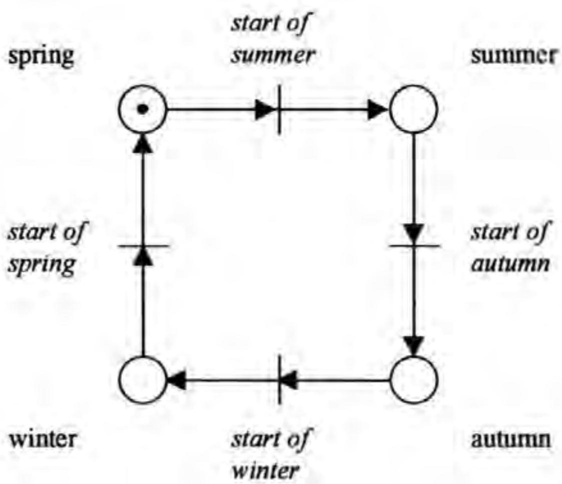


Figure 7-3: The four seasons and their changes (adapted from Reisig, 1982)

7.3.2.1 Use and common language for communication

Petri Nets are a mathematically rigorous modelling framework for discrete event dynamic systems. A useful illustration of the Petri Net theory can be achieved only with a graphical representation. Its wide range of application has been reported by many authors and Narahara *et al.* (1985) were among the first to apply Petri Nets in manufacturing systems.

7.3.2.2 Syntax and semantics

A simple set of symbols allows a Petri Net to be easily understood and analysed. The four major symbols (circles, bars, arrows and tokens) allow complex systems to be modelled and controlled by the number and distribution of tokens. Using all the components a diagram can be drawn that describes the dynamic aspects of a system through the movement of tokens between places. Petri Nets do not specify the boundaries of a system. The lack of systems boundaries will make it difficult to define which components need to be considered for modelling and Peterson (1981) describes Petri Nets as being generally studied in isolation without communication to the outside world.

7.3.2.3 Systems hierarchy for activities and information

A transition or an event can be understood as an activity as it is carried out to move from one state to another. Activities can only be carried out if all incoming statuses include a token. In Petri Nets activities are not linked to each other as the connection is achieved through the status.

Within Petri Nets there is no apparent mechanism to decompose activities or information. Reisig (1982) suggests that a class of Petri Nets *predicate event-nets* supports the process hierarchy. When considering the time required to fire a transition the event is no longer called *primitive* (instantaneous) but *nonprimitive*. Peterson (1981) discusses the possibility of decomposing such *nonprimitive* events into two primitive events (*nonprimitive* event to start, *nonprimitive* event to finish) and an extra place (*nonprimitive* event occurring). A box is often used to represent *nonprimitive* events. This however extends the syntax and semantics of Petri Nets and introduces extra complexity to the modelling. The review of Petri Nets carried out by Maull *et al.* (1995b) suggests that the graphical version of Petri Nets does not support process hierarchies as such. Activities, their flow or information cannot be seen in Petri Nets at all and the only signal that something has or has not happened is the firing of tokens along the connections.

7.3.2.4 Overall system boundaries and goals

Petri Nets do not consider formal systems boundaries and interaction with the outside world can be established by either using *external* places or transitions. Being placed in the outside world they would fire tokens to communicate and interact with the Petri Net. In either way Petri Nets do not allow systems boundaries to be defined. As Petri Nets clearly indicate the change of state within the modelled system the achievement of goals and objectives can be monitored through the movement of tokens.

7.3.2.5 System parameters

Inputs and outputs are not shown in Petri Nets. The input function relates to a transition depending on the state of the (input) place it is originating from. Transition takes place when all states are *correct* and transforms an input to an output. The successful completion of the transition is shown as a new state in the output (receiver's) place. An arrow pointing from a transition to the place indicates the output function. Due to the lack of systems boundaries external sources and receivers cannot be consistently modelled with Petri Nets. As information is not shown in Petri Nets feedback loops cannot be modelled unless a customer sets a state like *order confirmed* that can be shown.

7.3.3 Role Activity Diagrams

Role Activity Diagrams (RADs) model which individual or group (agents) within the organisation is responsible for each stage of a process. Developed from the logic of Petri Nets which is explained in Section 7.3.2 RADs show the roles, refer to the activities and relate to their interaction and all information which must be communicated between agents as labelled links. As the emphasis is not on showing the activity itself but on producing the output an activity box is shown in black (Ould, 1995). These activities which are connected by vertical lines represent different states. How the output is achieved is not important within RADs.

An activity takes inputs (entities) and transforms them into outputs (entities). A horizontal arrow indicates an input that crosses the boundaries of the role from an external event. A role groups all those activities that pursue a common objective or interest. Ould (1995) describes a role as a set of activities carrying out a particular responsibility. As each role is independent of other roles they communicate through *interaction*. Phalp *et al.* (1998) describe an *interaction* as a second type of activity within a role as it is carried out in sequence with another activity (activities) in another role (roles). An *interaction* is depicted by a small clear square joined by a horizontal line. Figure 7-4 shows an example process.

This modelling technique describes each role by means of rounded and shaded rectangles surrounding activities. As a person may carry out more than one role, roles are not dedicated to individuals. The end of each role is marked with a clear ellipse indicating that the objective of this particular role has been achieved. Where a choice or decision, termed as *case refinement*, needs to be made before reaching the next state the original line is split into two starting with downward facing triangles. A set of vertical paths starting with upward facing triangles shows activities that are carried out concurrently. In RAD terms this is called a *part refinement*.

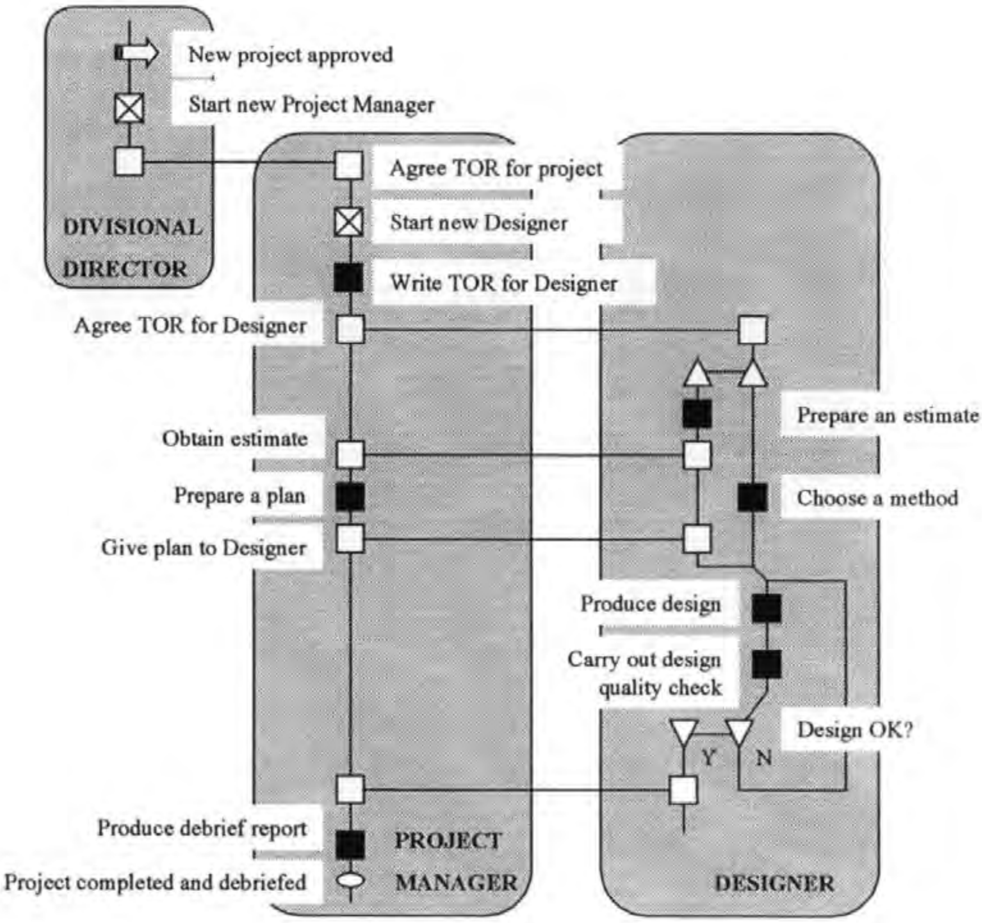


Figure 7-4: Example of a Role Activity Diagram (Ould, 1995)

7.3.3.1 Use and common language for communication

Role Activity Diagrams are valuable as representations of current processes and offer both formality and understanding as the users can identify themselves as being part of the model. Ould (1995) and Kawalek (1996) report that Role Activity Diagrams can be helpful as a communication tool between individuals involved in a study.

7.3.3.2 Syntax and semantics

Maull *et al.* (1995b) report that due to the relatively large number of symbols the design of Role Activity Diagrams is complex. The syntax shows only which activities need to be carried out to complete a role without detail about how the activity is performed. The syntax lacks to draw exact systems boundaries and focuses only on role boundaries (i.e. boundaries are drawn around responsibilities). A horizontal arrow is the only indication of an external event. This has implications for the systems hierarchy (see following sections) as the decomposition of a business process is not possible and is also crucial for the definition of the starting and finishing points of a business process. The semantics of Role Activity Diagrams is complex too. Phalp *et al.* (1998) report that some authors prefer to explicitly label the state of a role which makes the semantics clearer. Even if labelling helps to improve understanding of the situation it makes the diagrams larger which may have reverse effects in terms of clarity and understanding.

7.3.3.3 Systems hierarchy for activities and information

RADs do not allow the decomposition of activities and information into various different levels of detail. However there are reports of users decomposing activities which according to Maull *et al.* (1995b) might reveal other roles including their decomposed activities and tasks or even communication with roles not shown in the diagram. It can therefore be argued that this modelling technique does not have a concept to consistently decompose activities or information, as its main focus being on roles.

7.3.3.4 Overall system boundaries and goals

As mentioned in a previous section the syntax of RAD does not consider formal systems boundaries and only explicitly sets the boundaries around roles. From the perspective of a business process which includes various roles and its activities the process boundaries can therefore not be determined. However through the flow of events across a number of roles an overall goal can be achieved. Each role has a starting and finishing point which represents when the overall objective of the role has been achieved with each state representing the achievement of a single activity.

7.3.3.5 System parameters

Within RADs inputs, outputs or transitions are not explicitly present (Maull *et al.* 1995b). The process is represented by sequential stages within a role or through their interaction across other roles and shows a sequence related to time. As the systems boundaries cannot be defined it is not possible to determine an external source, receiver or the feedback from it for the overall modelled process.

7.3.4 Flowcharts

Flowcharts are a graphical description of an existing process, a system or parts of it using simple symbols, lines and words. The different shaped symbols are used to represent operations, data and flow directions for the definition, analysis or solution of a problem. They also show the sequence of a process and its activities, its decisions, iterations and loops. All the symbols are connected by one-way arrows. The flowchart is one of the oldest design tools available and may take many forms. They are often classified as either *logic (programming) flowcharts* which show the sequence of steps in a procedure or *system (data) flowcharts* which show the relationship between the components of a system. Harrington (1991) explains four different types of *logic flowcharts* which can be used as key tools to design and analyse business processes. The four main types are *Block Diagrams, American National Standards Institute (ANSI) Standard Flowcharts, Functional Flowcharts* and *Geographic Flowcharts*.

Other types of flowcharts such as *system flowcharts* often use their own sets of symbols and unique notation. Before more sophisticated modelling techniques such as object-oriented modelling etc. were introduced *system flowcharts* were very popular in the field of computer programming and systems design. They concentrate on taking an information view of the system and the flow of information through the system. Symbols show through which medium data is introduced to the system, how it is processed, which data media are used and how this data is displayed. In the *system (data) flowchart*, an entire program run or phase is always represented by a single processing symbol which, together with the input/output symbols, show the path of data through a problem solution.

7.3.4.1 Block Diagrams

The Block Diagram is the simplest type of flowchart. The boxes represent activities which are connected by arrows showing the sequence in which those activities occur. The direction of flow of a block diagram is either drawn vertically from top to bottom or horizontally from left to right. The Block Diagram in Figure 7-5 starts and ends with a terminator symbol (rounded rectangle) which shows the entry and exit points of a process. Block Diagrams are often used to give a general overview on a non detailed basis. To show responsibilities the syntax is extended by an annotation symbol which is drawn as a rectangle open on one side. A dotted line with an arrow pointing away from the activity refers to the annotation. It allows the modeller to assign a person responsible for a specific activity and to document other important information. Decomposition of activities may be possible by creating a new diagram illustrating a more detailed level. There is however no defined mechanism to decompose them consistently.

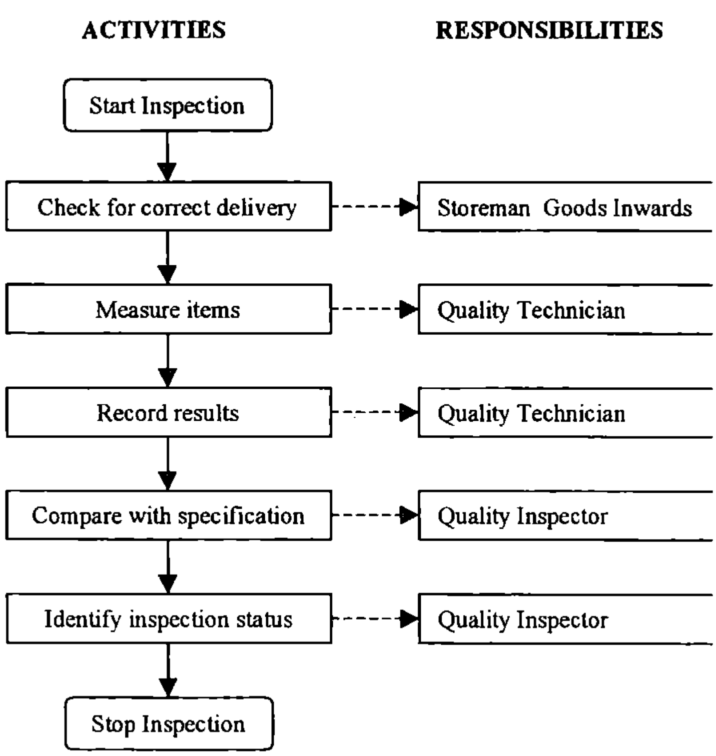


Figure 7-5: Block Diagram including annotations

Harrington (1991) reports that Block Diagrams can also include some communication flow illustrated by drawing communication arrows between departments in an organisational chart.

7.3.4.2 ANSI Flowcharts

Flowcharts of this type go far beyond the use of simple Block Diagrams. They use a larger number of symbols and allow the modelling of a more detailed view and analysis of the process or system. However with a larger number of symbols comes the difficulty of maintaining the same meaning for everyone using this type of flowchart. The symbols are listed by ANSI/AIIM MS4 (ANSI/AIIM, 1987), ISO 6829 (ISO, 1983) and also by ANSI/ISO 5807 (ANSI/ISO, 1985). Although many symbols have been proposed, only a few seem to be found suitable for modelling virtually all processes or situations. The basic and most common symbols are summarised in Figure 7-6.

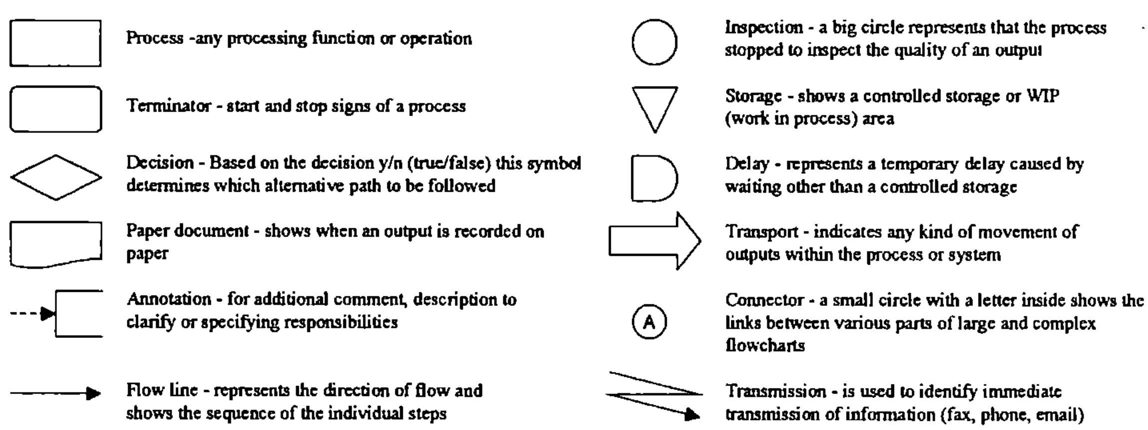


Figure 7-6: Standard Flowchart symbols (ANSI/AIIM, 1987)

To interpret the ANSI Standard Flowchart presented in Figure 7-7 extra conventions are often helpful. While every operation box (rectangle) can have several inputs, there is only one line leaving a box. This might restrict the modelling of business processes where an output might be required as input to more than one subsequent activity. A decision box (diamond) which usually incorporates a simple *question* however must always have some outputs which are preferably labelled with *yes/no* or *true/false*. Logic decisions often introduce loops that can either go forward or backward. To avoid confusion the convention is to draw all loops going clockwise. A forward loop goes down on the right hand side while a backward loop goes up on the left-hand side. Mapping complex processes easily results in large flowcharts which cannot be fitted on one page. A connector symbol (small circle) is used and represents the link to flowcharts on separated pages.

The flowchart seen in Figure 7-7 shows a final assembly process. It is interesting to note that the flow of material (product) or other objects (test report) cannot be seen or modelled using this technique.

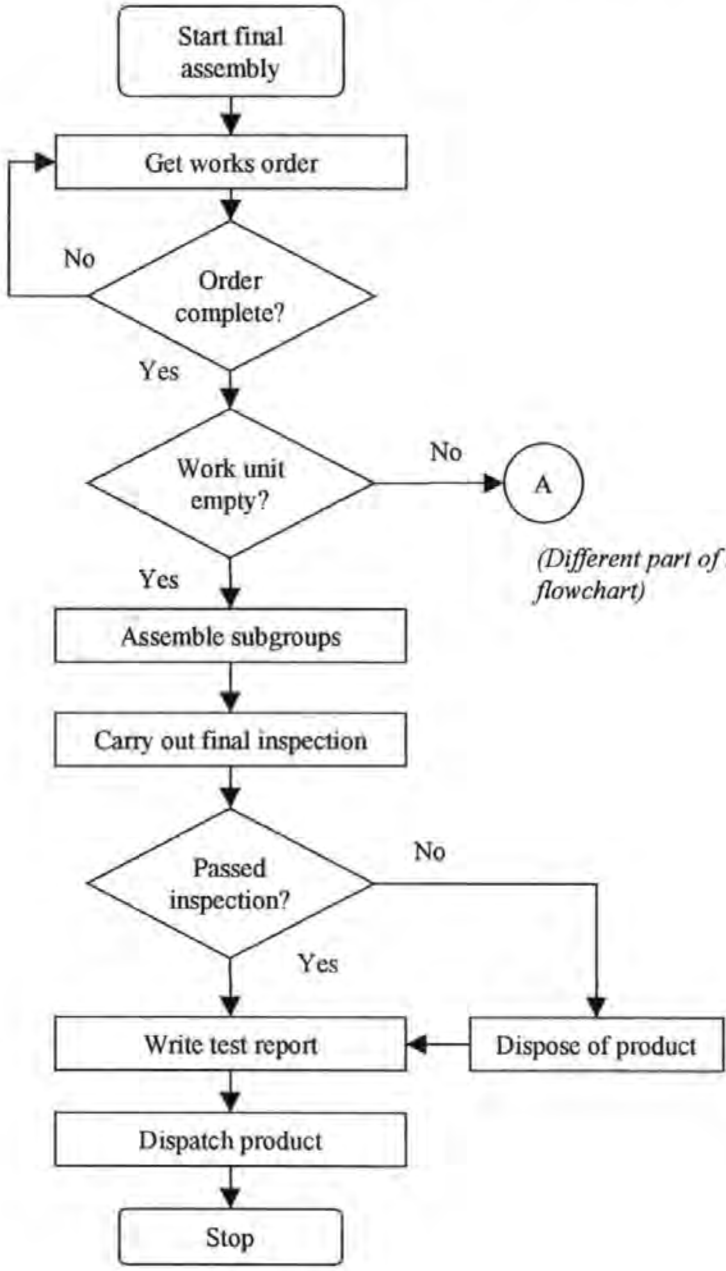


Figure 7-7: Example of a Standard Flowchart

7.3.4.3 Functional Flowcharts

Functional Flowcharts are Block Diagrams or ANSI Standard Flowchart which diagrammatically show the flow of activities through different functional departments or work units within an organisation. This allows a graphical representation of the responsibilities and the involvement of different departments of individuals. Harrington (1991) states that this type of flowchart also allows time to be recorded. For example, it allows individual cycle times to be monitoring to evaluate a ratio of value to non-value adding times of a specific process.

7.3.4.4 Geographic Flowcharts

Geographic Flowcharts are for analysing the physical flow of activities within a given geographic layout of an organisation. Two of the main specialised charting aids are *Flow Process Charts* or *Clerical Procedure Charts* and *String Diagrams.*

7.3.4.4.1 Flow Process Charts

Procedure Charts have long been used by work study practitioners. This type of flowchart is used to realise the most efficient way of doing work by establishing the times required to carry out activities and standardising working procedures (Johansson *et al.* 1993). There is a whole family of Flow Process Charts which can be highly complex (Mason *et al.* 1987). The simplest version uses five symbols (Figure 7-8) based on the recommendations of ASME (American Society of Mechanical Engineers). They show the flow of activities within a process either by using vertical flowcharts or by showing the physical flow on a scaled organisational layout. The only difference between the ANSI symbols used in this review is that ANSI prescribes a rectangle rather than a circle to represent an operation and a circle rather than a square to identify an inspection. Such charts form the basis for determining the ratio between value and non-value adding operations or highlighting possible bottlenecks shown by increased delays and work in process.

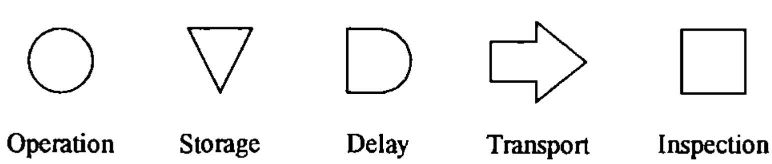


Figure 7-8: Flow Process Chart: standard symbol (based on ASME)

7.3.4.4.2 String Diagrams

String Diagrams (Figure 7-9) show the movements of people, documents or material on a scale layout plan. The line shows the tracking from process step to process step highlighting any unnecessary transport caused by poor layout or a badly thought through working sequence.

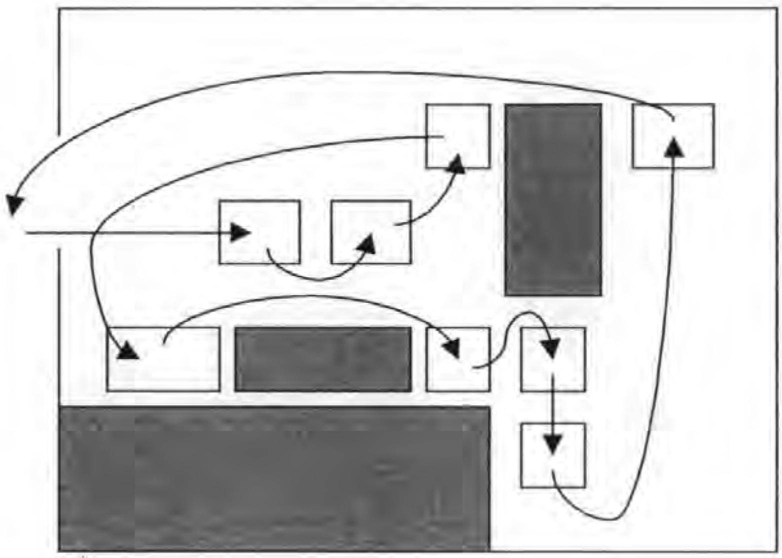


Figure 7-9: String Diagram

7.3.4.5 HIPO Charts

A HIPO (Hierarchy plus Input Process Output) Chart describes an entire system and was developed for computer systems design (Bingham *et al.* 1992). It provides an overview of a system showing its different parts by breaking down the inputs, outputs and the processes involved as seen in Figure 7-10. HIPO Charts consist of three main elements, the *Visual Table Of Contents (VTOC), overview diagrams* and *detail diagrams*. The *Visual Table Of Contents* shows graphically the different levels of the system, and the hierarchical relationship between its elements. High level overview diagrams represent the input, output and the required processes for each system element. Each overview diagram can be expanded by a detail diagram which follows the same convention but shows a greater level of detail. Where additional detail is required each level of a HIPO Chart can be extended with a narrative description at the bottom of the diagram.

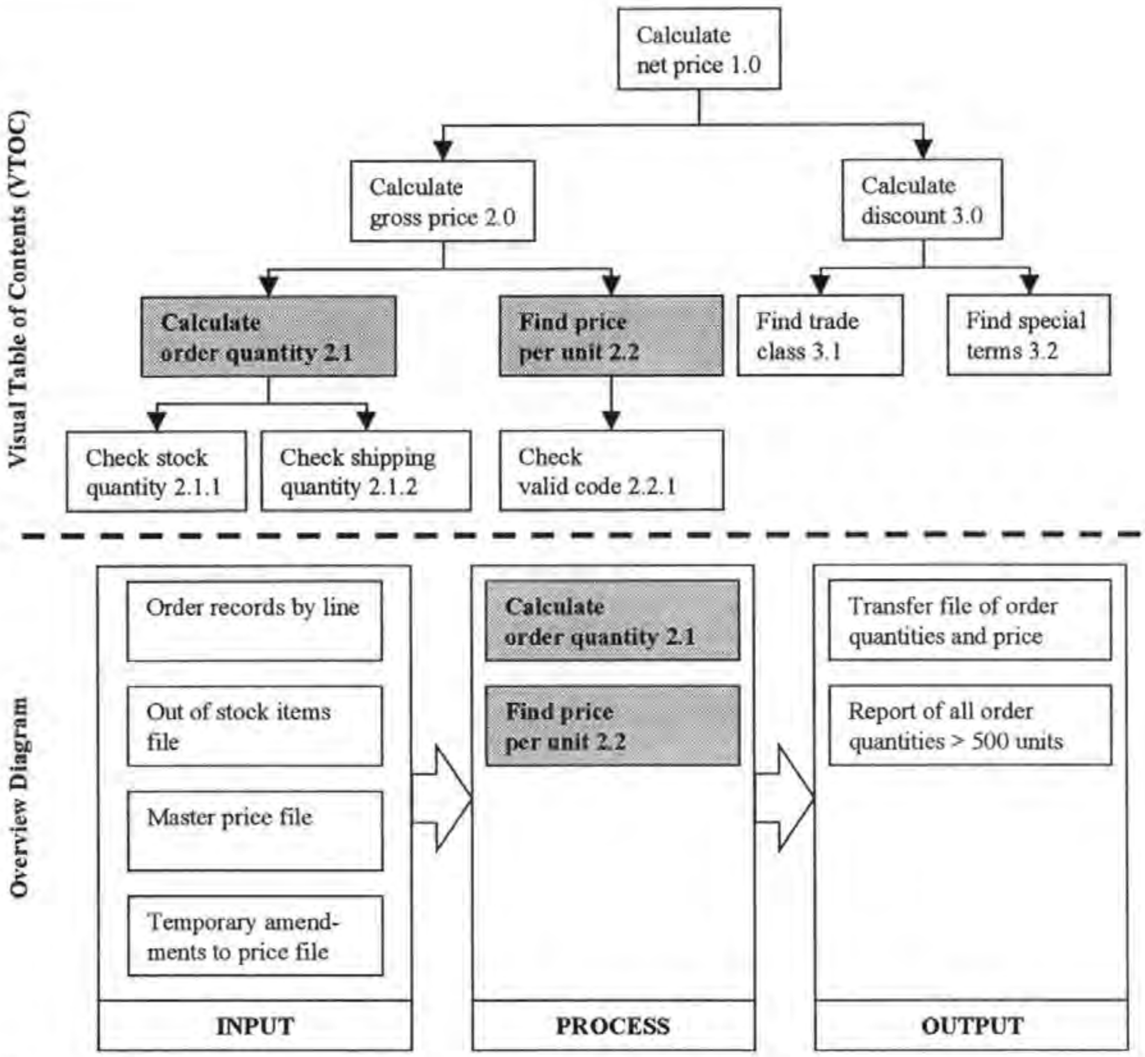


Figure 7-10: HIPO Chart example (Bingham *et al.* 1992)

7.3.4.6 Conclusion of ANSI Standard Flowchart

With the various types of flowcharts described a more detailed review of the ANSI Standard Flowchart follows. This most commonly used type of flowchart appears to be the most appropriate one for addressing the criteria set for modelling a business process as defined in this research.

While Block Diagrams allow a simple overview of a process and are often used at the start of a modelling exercise a detailed analysis of a process cannot be achieved. On this basis Block Diagrams are regarded as not suitable to satisfactorily model all requirements of a Fulfil Order Process. This is also true of Functional Flowcharts even though they consider functional departments and show movements among them by introducing an additional dimension. The two examples of Geographic Flowcharts have no means for decomposing activities or information and are therefore not considered for a more detailed review. HIPO Charts are predominately applied to assist the design of programming languages rather than in the structured systems analysis of business processes. The use of different types of diagrams documenting the different levels of a system results in a more complex syntax and is regarded as a major disadvantage.

7.3.4.6.1 Use and common language for communication

ANSI Standard Flowcharts allow a good visual representation of even complex processes to gain consensus between all participants. The diagrammatic flow allows communication of the logic of a process to people at all levels (Mason *et al.* 1987). However due to some problems with its syntax and semantics new users may find this technique difficult to use due to different possible interpretations of the flowcharts (Maull *et al.* 1995b).

7.3.4.6.2 Syntax and semantics

The syntax of this type of flowchart uses a large number of symbols. Even with the description of the symbols in a standard (ANSI) there is concern that they can be interpreted differently and have different meanings depending on the modeller's understanding or background. Flowcharts quickly become complex and lose their ability to clarify a process. One reason is that all flowcharts are modelled at the same level and do not have a simple way of treating different levels of detail (Mason *et al.* 1987). Decomposition of activities is possible but not specifically defined in the syntax. Maull *et al.* (1995b) point out that if a common set of rules is agreed between everyone involved in a flowcharting exercise the semantics can be simple. This simplicity however is threatened by the lack of defined process hierarchies for this type of flowchart.

An annotation symbol linked to a particular activity allows extra information to be shown about an activity. However this can increase the number of symbols and arrows in the diagram dramatically. While large flowcharts may be split over many pages they are linked through connector symbols which are often difficult to identify. As there are no properly defined system boundaries one has to assume that all connected charts are parts of the same system.

7.3.4.6.3 Systems hierarchy for activities and information

ANSI Standard Flowcharts do allow the decomposition of activities into various different levels of detail. A subordinate flowchart would have to have a defined start and finish point and requires all inputs and outputs to complete the transformation. There is however no clear convention of how to model such decomposition. The main issue according to Maull *et al.* (1995b) is the difficulty of maintaining consistency due to the lack of systems boundaries. Zgorzelski *et al.* (1996) argue that due to the shortcomings in decomposition of activities and processes, traditional flowcharts do not allow the modelling and analysis of processes and systems to a satisfactory level of detail.

In order to decompose ANSI flowcharts a new set of rules would be required. The lack of system boundaries is a plausible explanation why information is neither branched (decomposed) nor bundled (aggregated).

7.3.4.6.4 Overall system boundaries and goals

The syntax of flowcharts does not refer to set formal systems boundaries. The absence of a proper convention may often lead to the introduction or modification of rules to overcome this problem. As explained in the previous section the lack of overall system boundaries leads to other difficulties such as the definition of systems hierarchies. As each flowchart has a defined start and finishing point which is indicated by a *terminator* symbol, specific goals can be set.

7.3.4.6.5 System parameters

In terms of systems parameters, flowcharts only show the transformation of inputs into outputs by referring to the process and activities involved. With the systems boundaries missing neither the source of inputs nor the receiver for outputs can be modelled consistently. An ANSI Standard Flowchart has some serious shortcomings in terms of modelling a business process from a systems viewpoint.

7.3.5 Data Flow Diagrams

Data Flow Diagrams (DFDs) are widely used in structured systems analysis and in the design of information systems (IS). A DFD is centred on the concept of data and is a useful diagramming technique for depicting the flow, the transformation and the storage of data within a system. DFDs may be either *logical* or *physical*. The *logical* or *essential* type depicts what a system should do. It does however lack the physical characteristics of a system. The *physical* or *transitional* type describes how a system or its processes and procedures are carried out. Bingham *et al.* (1992) report that the *logical* type is the more powerful of the two as its focus is to give the reasons why a process is performed and also what is carried out. This type of DFD does not consider any limitations imposed by physical devices. According to Kubeck (1995) this is one reason why the logical type might be more useful during business process redesign. It is however often easier to start modelling the physical system first.

The components of a DFD are the *processes*, any *external entities* that interact with the system, *data stores* that can hold data of any kind and the *data flow* which connects them. Various notation styles have been developed since De Marco (1978) and it was Gane and Sarson (1979) who made this technique popular. This review uses the symbols explained in Lejk *et al.* (1998) together with a simple physical Data Flow Diagram presented in Figure 7-11 showing part of a meeting room booking process. In Figure 7-11 the components of a DFD are identified in italics.

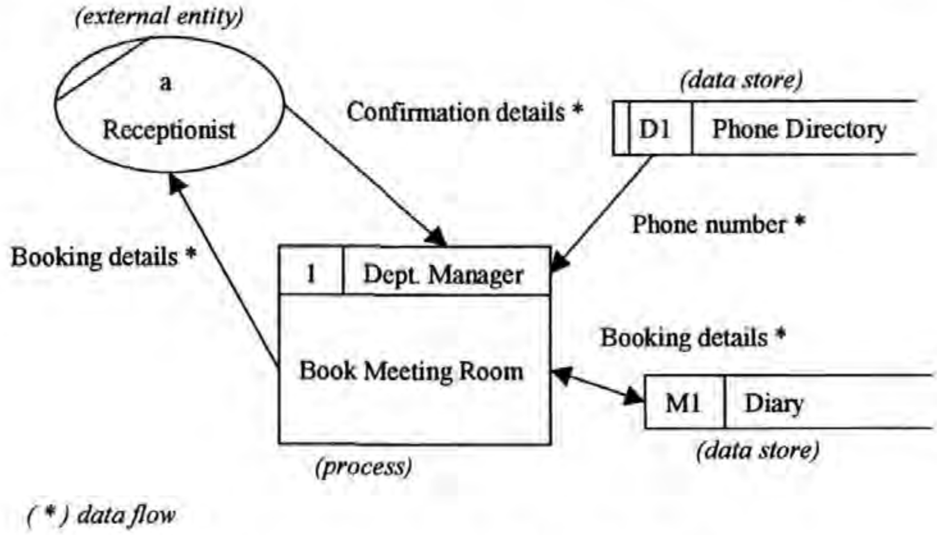


Figure 7-11: Booking a company meeting room – physical DFD

Processes are depicted as rectangles and show what the system does. They are used to show activities that transform data. The activity can also include making a decision. In the top left corner the number in the small box identifies the activity and the box to the right gives extra information where or how the activity is performed. The main box gives a description of the activity itself starting with an imperative verb.

External entities are the sources and receivers of data from the system and located outside the systems boundaries. They may be people, organisations or parts of an organisation or other systems which are represented by an ellipse. A small letter is used to uniquely identify each *external entity*. Where required a *duplicate line* within the ellipse gives evidence that this entity has been used more than once within the system under review.

Data stores contain data which are retained in the system. An open-ended rectangle describes the content or repository of data with the left box showing a reference code. This code consists of the type of data used followed by a unique identifier. DFDs may distinguish between four different types of data: *D* (computer held data), *M* (manually held data), *T(M)* transient data store which is a temporary store where data is held and read only once (Maull *et al.* 1995b) or *T* which is the computerised version of the transient data store. A *duplicate line* at the left end of the rectangle reflects a multiple occurrence of a data store within this DFD.

Data flows show the data in motion and are represented by lines with arrowheads indicating the flow. Data flow is only permitted between *processes*, between a *process* and an *external entity* or between a *process* and a *data store*. This means that all data flow is triggered by or for processes. Single and bi-directional arrows can be used and must be labelled with meaningful descriptions.

The decomposition of Data Flow Diagrams allows the modelling of a system to the required level of detail giving full consistency with all higher levels. A *process* is decomposed into its subordinate processes and activities showing the *data flows* and *data stores* at this level. To ensure consistency the decomposed Data Flow Diagram is identified by a decimal extension of the higher level identifier. It must also ensure that all data flow into or out of the process in the higher level diagram is shown in the lower level diagram. Lejk *et al.* (1998) suggest that decomposing DFDs to level 3 gives, in the majority of all cases, enough detail without the need of more levels. At the lowest level the DFD technique uses textual descriptions called *elementary process description (EPD)* to write exactly what happens at this level to avoid ambiguity and incompleteness.

7.3.5.1 Use and common language for communication

Data Flow Diagrams depict the movement of data within a system and form a useful technique to discuss the objectives of a particular process or system. Systems analysts are interested in the flow of data, and DFDs simply show the input and output of data, its storage and what happens to data. However they do not consider time nor do they show any material flow. This is because time is considered not to be important when modelling data flow. As the sequence of events is not apparent and the diagrams lack a definite start and finish point it may be difficult to understand it, particularly for new users.

The DFD technique has been traditionally used in system analysis and is one part of the *Structured Systems Analysis and Design Methodology (SSADM)* (Lejk *et al.* 1998). SSADM is a methodology revolving around logical data modelling, data flow modelling and entity/event modelling. It is used by the British government to control all areas of business computer systems development and standardises the IT projects across governmental departments.

7.3.5.2 Syntax and semantics

The small number of symbols (ellipse, rectangle, and lines with arrowheads) used within Data Flow Diagrams provides a fairly simple syntax. Within DFDs proper systems boundaries can be defined which permit consistency in decomposing the system from a context diagram into processes and sub-processes showing the data flow at various levels of detail. A clear and straightforward semantics seems to stem from the ability of expanding processes according to Maull *et al.* (1995b). The set of rules does not consider the sequence of processes and time cannot be shown.

7.3.5.3 Systems hierarchy for activities and information

The conventions of DFD consider the requirements for decomposing processes. Within DFDs processes can be expanded from the top level context diagram to any required level of detail. Logical consistency can be achieved using DFDs if every input and output that is appearing on the higher level diagram is considered at the lower level diagram. As the input and output are in form of data this charting technique also allows the decomposition of information.

7.3.5.4 Overall system boundaries and goals

As discussed in a previous section, the syntax and semantics set for Data Flow Diagrams allow the definition of formal system boundaries. The abstract context diagram DFDs present the scope and the objectives of the system under study. Anything outside the boundaries of the context diagram is beyond the scope of the system.

7.3.5.5 System parameters

The convention defined for DFDs provides the consistent modelling of all systems parameters except inputs and outputs. Data Flow Diagrams show how processes transform inputs to meaningful outputs but have no means of referring to the actual input and output of objects or material. At the top level the context diagram interrelates with sources and receivers of the system from which data is supplied by or provided to respectively. As feed-back is a special form of information that comes from a receiver, DFDs can also model this systems parameter.

7.3.6 Object modelling

Object orientation (OO) is an approach for the modelling of a process or a system by using a set of connected objects. For over 25 years OO has been used by Jacobson *et al.* (1994) and others to describe organisations, and other systems. When used to model organisations a business oriented model describes the structure of objects in a system – their identities, their relationships to other objects, their attributes, and their operations (Rumbaugh *et al.* 1991). Objects represent real events and occurrences that happen in organisations.

There are many different notations for modelling a system using object oriented thinking. The different approaches can be grouped into those that focus internally at the core of a business or system or those that focus externally describing the organisation and the world outside it. Chen (1999) reports that although the internally focused object oriented methods were proposed by Wang (1994) or Jacobson *et al.* (1994) to model business processes little or no evidence of successful implementation projects has been reported. Jacobson *et al.* (1994) refer to the Use Case approach as a useful technique for defining business processes and showing the interactions between the business processes and the external environment. Before reviewing the Use Case model some of the basic principles of the object orientation such as *objects, classes, use cases, object model* and *inheritance* are explained. A simple example can be seen in Figure 7-12 with the individual elements of an *object model* identified in italics.

The focus of the object oriented paradigm is an *object*, which can be any thing in the system under study. Each object belongs to a class of similar objects and is often called an instance of a class. Objects contain both the data (attributes) and behaviour (methods) relating to the data. Its attributes describe the internal information (state) of an object and the behaviour provides information on the object's use. Objects are unique and differ from each other by the different values of their attributes. They are linked to each other and can communicate by sending messages. An object starts performing an operation only when triggered by another object via a *stimulus*. A *stimulus* is an action asking objects to behave in some way. Such a triggered object may need to check its attributes, alter its state or use other objects to start its performance. In the case of communicating with others the triggered object would have to send a *stimulus* itself.

All objects of the same type belong to one *class*. The class description contains information that all objects in the class follow. This information includes the attributes of each object, its use and its possible application within the system. It is the class that specifies what operations on the object can be performed which result in the change of its attributes. As all objects of the same type have the same operation and refer to the class the description needs only to be defined in the class itself.

Objects, classes and their associations define the *object model* of a system. An association relates objects and their classes and always links two objects either instances or classes. This relationship needs to be intact for the *object model* to function. Jacobson *et al.* (1994) describe two types of associations which in general are direct binary relations between two objects. The *acquaintance association* set between two objects is static and highlights the location of one object in relation to another. The *communication association* is dynamic and only active when a *stimulus* is sent between the objects.

With the feature of *inheritance* it is possible to apply and share the behaviour and attributes of one class when defining new classes. *Inheritance* is a relationship between classes where one class is the parent class (superclass, ancestor) of another. The definite direction is that only subclasses can inherit the operations, associations or attributes of their superclasses. Subclasses inherit their ancestor's features and may also have unique features without losing the shared ones. They themselves can pass on their own features to their subordinate classes.

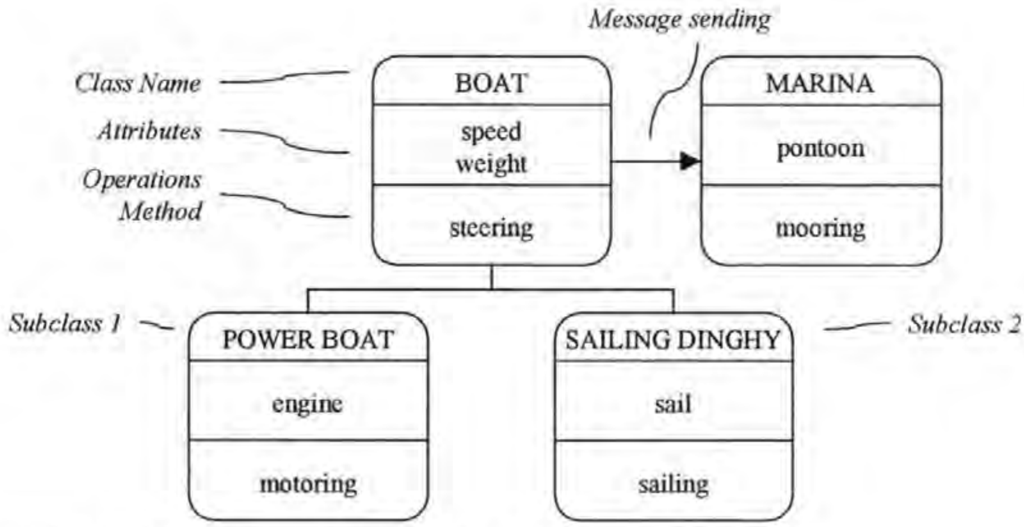


Figure 7-12: Object class, inheritance and information sending

Use Case analysis is according to Jacobson *et al.* (1994) one of the activities at the beginning of object oriented modelling. The syntax is shown in italics in an example seen in Figure 7-13. When applying the Use Case approach in process modelling it will describe the business in terms of what the system can do and how it can be carried out as well as the environment the system is surrounded by. Another way to look at it is that a *use case* (business process) describes a way in which a real-world actor interacts with the system.

To distinguish between the environment and the system under study the boundaries are set around the *business system*. The Use Case approach depicts a *business system* using a rounded corner rectangle which is identified by a description above the symbol. The *business system* shows how business processes (*use cases*) are performed by interacting objects.

Use Cases are employed to define the areas of the business which deal with external customers but do not give a precise picture of the internal structure of an organisation. A *use case* can be described as everything a system will do or be described from a different viewpoint as what an *actor* wants to do with the system. It is shown as a sequence of various transitions representing a possible flow through a system. Where event flows have great similarity they are grouped together. The grouping is referred to as a *use case* class. An ellipse represents a *use class* and its given identifier should express what happens when an instance of a *use case* is performed.

In order to manage large and complex systems the notation of this approach distinguishes between *extend associations* and *use associations*. *Extend associations* describe classes which act as supplements to the basic ones and can be decomposed to show greater detail. The decomposition is to avoid confusion caused by showing additional flow. *Use association* is applied were *use cases* have similar descriptions and therefore overlap. This type of association splits the overlapping *use cases* into their separate parts avoiding redundancy effects.

An *actor* is a user of the system and can be human (customer, supplier) or non-human (machine, supplier's computer system). They represent the role of being part of the environment and are always external to the system. *Actors* are associated with each *use case* of the system in which they interact. They are linked to the *business system* and initiate the business processes (*use cases*). A stick person icon represents an *actor* and lines between them and a *use case* show the association (communication).

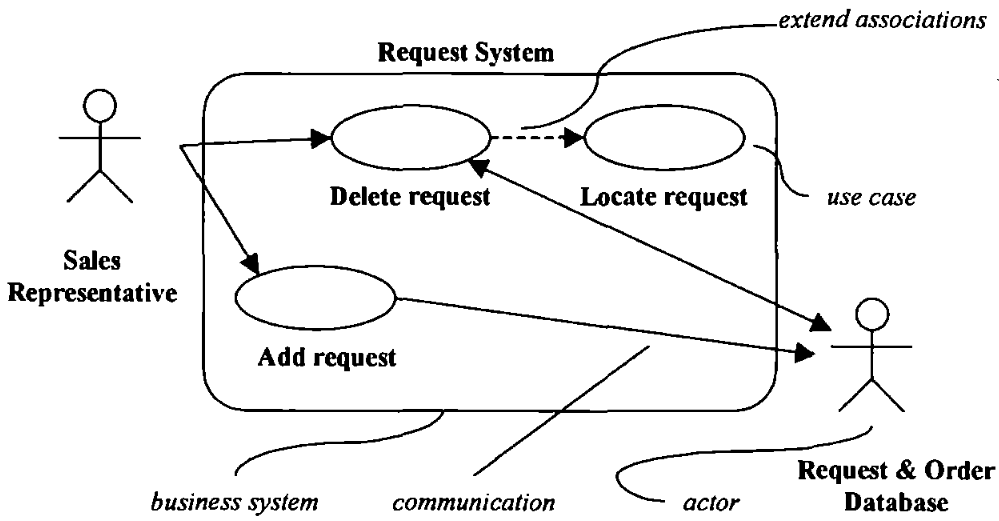


Figure 7-13: Example and notation of a Use Case model

Figure 7-13 shows a sales representative who may add or delete requests using the request system. Deleting a request involves the process of finding the request first. This is shown as an *extended association* between the basic *use case* "delete request" and its augmentation "locate request".

7.3.6.1 Use and common language for communication

Use cases are about capturing high level requirements for the purpose of scoping a project. This technique is about describing what the model will do at a high level. In business process redesign *use cases* are applied to represent how the business is structured in relation to its environment. To review a business system in greater detail the principles of object modelling are applied to identify all participating objects and interactions within each *use case*. This makes the Use Case approach a valuable technique to communicate to others about the requirements of the business and acquire a consensus on how the model will look. However on its own it is not a suitable technique to describe all details of a business process.

7.3.6.2 Syntax and semantics

The Use Case approach depicts only the three main symbols which make the syntax easy to understand. The business system separates the system under study from its environment and forms its boundaries. *Use cases* represent business processes which interact with the external actors. Although the syntax is simple Maull *et al.* (1995b) report that within a Use Case there is no possibility of distinguishing between classes of *use cases* and instances. This is only addressed within the more traditional object oriented methods.

The syntax of the Use Case approach provides a clear and understandable semantics. It does however not consider that instances of *use cases* from the same or a different class affect one another (Jacobson *et al.* 1994). The semantics also lacks the sequence of activities in a process flow which can make it difficult to use in terms of process flow mapping.

7.3.6.3 Systems hierarchy for activities and information

The notation of the Use Case approach allows systems and process hierarchies to be shown. The *extended association* however does not show the internal structure of a business process sufficiently. This is because the purpose of this type of modelling technique is to present a high level scope of the system that is not intended to capture all the system requirements. Maull *et al.* (1995b) also question the logical consistency as the decomposition does not show inputs and outputs at any detailed level. There is no apparent mechanism to decompose information when modelling with *use cases*.

7.3.6.4 Overall system boundaries and goals

System boundaries can be modelled with the Use Case approach. This is depicted by the business system which separates the external actor from the *use cases*. By setting the boundaries the scope and objectives of the system can be defined.

7.3.6.5 System parameters

Modelling with the Use Case technique specifies what the system will do. By considering the environment this approach identifies the sources and receivers of the system. As already mentioned this approach is not meant to model at anything but an abstract level. It does not address the system's inputs, outputs or transformation sufficiently. Modelling with *use cases* also lacks the information flow e.g. feedback from receivers and the details of individual processes.

7.3.7 IDEF

To support its Integrated Computer Aided Manufacturing programme (ICAM) the U.S. Air Force developed a system definition method known as the ICAM Definition (IDEF) methodology (Le Clair, 1982). The IDEF suite of techniques consists of several methods and was designed to deal with complex manufacturing systems. Its original three methods $IDEF_0$, $IDEF_1$ and $IDEF_2$ were developed during the 1970s to address the functional requirements of a system ($IDEF_0$), to capture and analyse the information used in an organisation ($IDEF_1$) and to simulate time related characteristics in a dynamics model ($IDEF_2$) (National Institute of Standards and Technology, 1993). A second and third generation of methods ($IDEF_{1X}$, $IDEF_3$ to $IDEF_5$) within the IDEF family was developed in recent years and is complemented by partially developed methods $IDEF_6$ to $IDEF_{14}$ (Mayer *et al.* 1995). According to Cheung *et al.* (1998) the most important methods for the modelling and analysis of processes are $IDEF_0$, $IDEF_1$, $IDEF_2$, $IDEF_{1X}$ and $IDEF_3$. Before $IDEF_0$ is reviewed in greater detail in this section a brief overview of the methods up to $IDEF_4$ is presented.

7.3.7.1 $IDEF_1$

$IDEF_1$ is the information modelling method of the IDEF family and is concerned with what type of information exists or should be used in an organisation. The modelling technique is developed from entity-relationship models in database systems design and uses entities, attributes and relationships. Information gathered from using $IDEF_1$ can be used as a set of requirements in designing databases (Cheung *et al.* 1998).

7.3.7.2 $IDEF_{1X}$

$IDEF_{1X}$ is a revision of $IDEF_1$ as its application starts after the information requirements of an enterprise are known. This data modelling method is used for designing relational databases (Rasmus, 1992).

7.3.7.3 $IDEF_2$

This method was proposed to model the dynamics of a system and shows the duration and frequency of interactions between function and information based on the aspects of time (Le Clair, 1982). Modelling with $IDEF_2$ would need to take the resources and other requirements into account which could influence the completion of processes. There appears to be no record of this method being utilised to develop a system.

7.3.7.4 $IDEF_3$

The $IDEF_3$ Process Description Capture Method has been developed to acquire an expert's knowledge about the operational aspects of a system or an organisation. $IDEF_3$ is structured to use Process Flow Network (PFN) and Object State Transition Network (OSTN diagrams). A PFN diagram consists of numerous units of behaviour (UoBs) which represent activities, functions or actions etc. and their connections. OSTN diagrams describe and document the state of objects used in the process and relate the change of state to the process (Colquhoun *et al.* 1996). $IDEF_3$ however does not allow a system to be modelled (Plaia *et al.* 1995) as it only captures precedence and causality relations between situations and events.

7.3.7.5 $IDEF_4$

$IDEF_4$ is another method for designing databases. In cases where relational technology ($IDEF_{1X}$) might be insufficient to describe data, $IDEF_4$ uses the object-orientation approach.

7.3.7.6 Other modelling techniques based on the principles of IDEF

Much work has been carried out on the enhancement of IDEF methods. Some of the more popular ones are NIDEF (NIAMized IDEF) and IDEF*. NIDEF combines the concepts of $IDEF_0$'s activity modelling with the principles of the object/role oriented information modelling tool NIAM (Nijsson Information Analysis Methodology) which is primarily used to design relational databases (Zgorzelski *et al.* 1996). IDEF* focuses on the description and development of a comprehensive manufacturing system taking multiple viewpoints which conforms to the CIM-OSA standard. The IDEF* methodology deploys $IDEF_0$, $IDEF_3$ (PFN) and $IDEF_{1X}$ to overcome the problems with the traditional method of creating these models independently (Cheng-Leong, 1999).

Another technique which uses multi-view modelling is the IDEM method (Integrated Design and Modelling) which takes a function, dynamic and information view of the system. The function view is modelled with $IDEF_0$ (Wang *et al.* 1993).

7.3.7.7 $IDEF_0$

$IDEF_0$ is one of the most widely known tools for functional modelling. It is based on the Structured Analysis and Design Technique (SADT) proposed by Ross (1976) and the original manual was published by the US Air Force (1981). In 1993, the National Institute of Standards and Technology (NIST) released $IDEF_0$ as a standard for Function Modelling in FIPS Publication 183 (Federal Information Processing Standard).

$IDEF_0$ models are presented as an ordered series of diagrams and text all of them inter-related to each other. Its graphical representation, as seen in Figure 7-14, consists of a row of boxes called *nodes* which are used to describe functions/activities. The row of boxes starts at the top left corner of the page spreading diagonally to the bottom right corner of the page. Each activity diagram should consist of no less than three and up to six consecutively numbered boxes so as not to overcrowd the diagrams. The text within a box describes an activity and starts with a verb in its imperative (active) form. Arrows are used to represent flows and describe the flow of data and information or real objects between activities. There are four main types of arrows termed *ICOM codes*. An arrow which enters the left hand side of the box is called an *input* (I) and an arrow entering the top of the box is termed a *control* (C). A control has a constraining influence on the transformation of an activity. The activity transforms the input to produce a desired *output* (O) which leaves the right hand side of a box. The fourth type of arrow entering the bottom of the box is called a *mechanism* (M) representing either a person or device needed to successfully complete an activity. This type of arrow indicates where resources are used but not used up. A fifth type of arrow named *call* can be seen as a special mechanism arrow which is drawn out of the bottom of the box. The caller box which is the box from which the caller arrow originates is not decomposed. A caller arrow therefore refers to other diagrams within the same model or to a different model to signify where all details can be found. Each arrow label identifies which box from which diagram is called. As multiple caller boxes may call the same box details may be shared within a model or between different models.

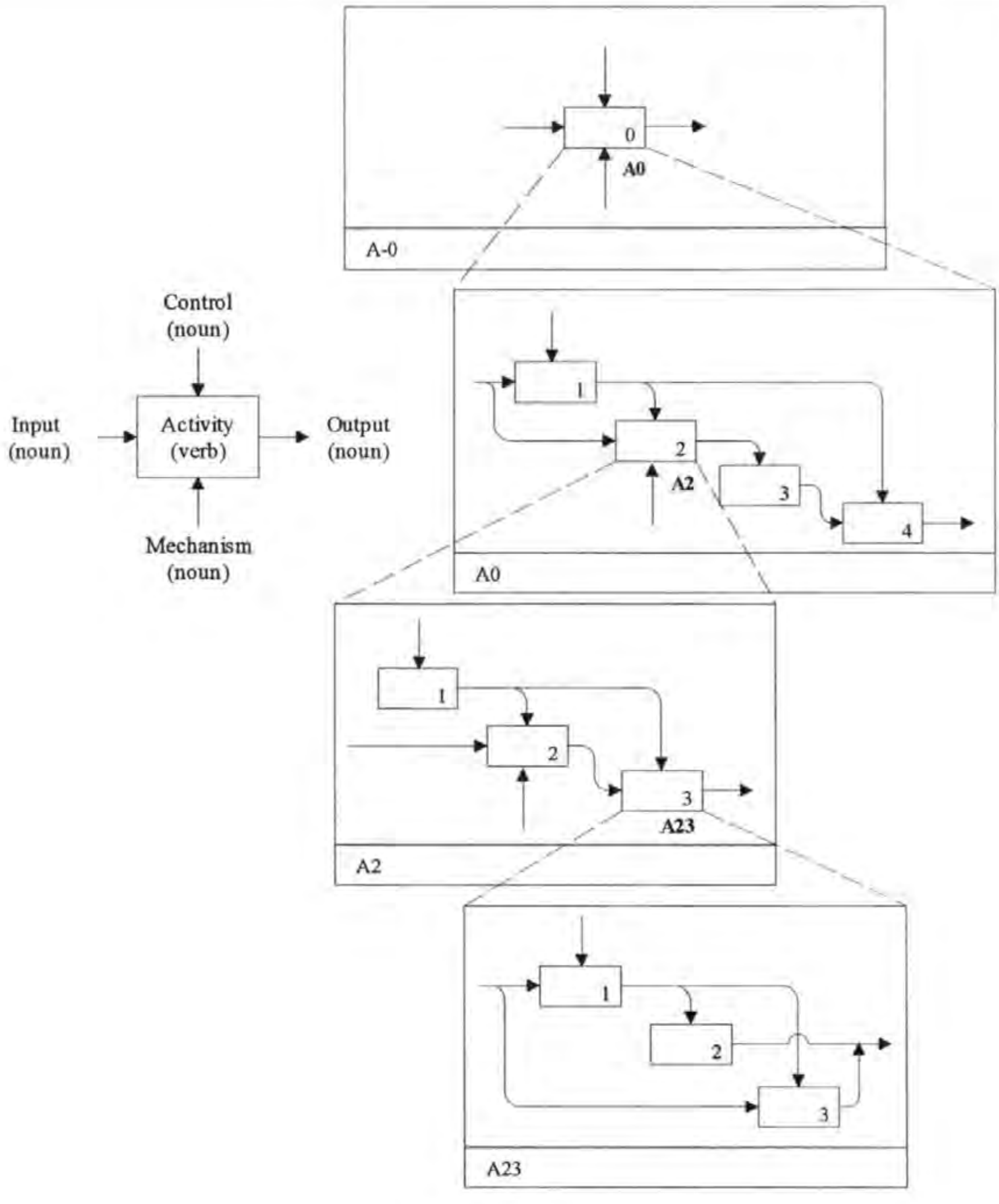


Figure 7-14: Schematic of a set of $IDEF_0$ diagrams

The hierarchy of diagrams is noted by the *node number* which represents where each individual diagram is placed within a model. An $IDEF_0$ model is a top down step by step refinement (Colquhoun *et al.* 1991) starting with the rarely used node A-1 (A-minus-one) diagram followed by the *context diagram* A-0 (A-minus-zero) and a *viewpoint diagram* A0 (A-zero). The A-1 diagram is an optional context diagram which establishes the model within its environment showing all inputs, outputs, controls and mechanisms entering the system. The required top level *context diagram* A-0 at the next level identifies the exact scope and intent of the model and forms the top of the hierarchy of the model under study. An A0 diagram as seen in Figure 7-14 presents a *viewpoint* of the context which the modeller wishes to address and decomposes A-0 into its main processes which are described in the rest of the model. The A0 viewpoint diagram looks like any other detail diagram and shows related sub-processes identified as A1, A2 etc. These sub-processes can be decomposed (nested) to whatever level of detail is required by introducing new diagrams. Constituent activities of A1 keep the notation of their ancestor diagrams and add an extra consecutively digit at the end A11, A12 etc.

The example shown in Figure 7-15 is a model of a Fulfil Order Process in an anonymous medium sized manufacturing company. The business environment of this company is to produce to order.

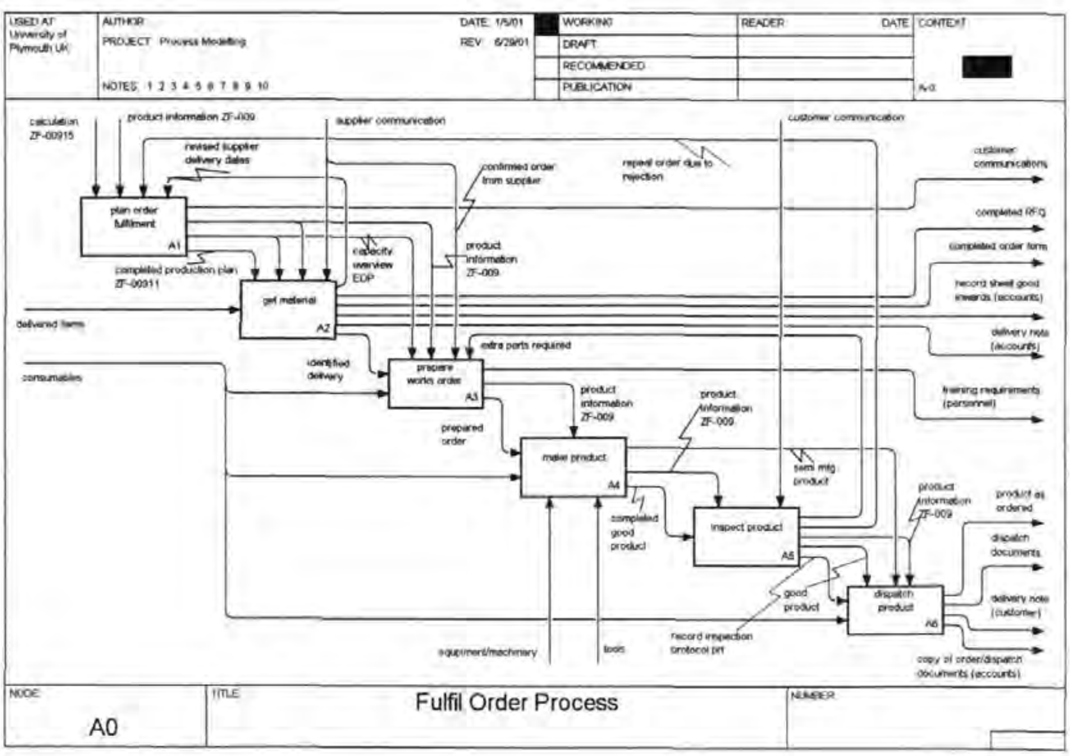


Figure 7-15: Fulfil Order Process

7.3.7.7.1 Use and common language for communication

$IDEF_0$ may be one of the most influential techniques for activity modelling of manufacturing systems and its processes as the method is widely understood and well documented (US Air Force, 1981; Le Clair, 1982; Colquhoun *et al.* 1991). While it is important to develop experience in using this technique, as it is with any modelling method, $IDEF_0$ offers simple diagrammatic graphics. For the presentation and communication this technique is easy to understand even for new users (Colquhoun *et al.* 1996).

Modelling with $IDEF_0$ can however be time consuming especially when mapping large and complex systems even with the support of a software package (Ang *et al.* 1994). In order to keep the consistency of ICOMs at all levels changes made in low level diagrams require the redrawing of all affected higher level diagrams. Although automated tools simplify this, it restricts the applicability of the technique when modelling processes which change frequently as $IDEF_0$ only deals with a static representation of a process (Cheung *et al.* 1998).

7.3.7.7.2 Syntax and semantics

The syntax of $IDEF_0$ is simple and uses only diagrams with box and arrow graphics which represent an activity or a process and the flow of data or objects respectively. The four different types of arrows interrelate with an activity in the form of inputs, controls, outputs and mechanisms (ICOM).

A strict set of syntactic rules requires a unique name and label for each activity and data or object flow and allows the expression of a formal system boundary. This is achieved by showing the top level abstraction of the system using the context diagram (A-0). The technique also allows the decomposition of processes and activities to explicitly show any constituent activities at the required level of detail. Consistency at all levels is maintained as all decomposed sub-processes inherit the associated ICOM components from their ancestor processes and are numbered with a unique identifier. $IDEF_0$ has no means to explicitly model the sequence of activities and does not explicitly show the flow of events but the circumstances in which each activity is able to operate. Representing the sequence of the processes on the page in a logical manner and modelling them as they are performed makes the presentation and analysis much easier.

Maull *et al.* (1995b) report that while the semantics of $IDEF_0$ is relatively simple, due to its syntax the interpretation of detailed process views can be seen as a complex exercise. This however can be overcome by applying the strict rules of the model's syntax. While $IDEF_0$ can show both the flow of data (information) and objects (material) Zgorzelski *et al.* (1996) report a problem with the classic $IDEF_0$ convention when analysing business processes. Both types of flows which are semantically different are represented using the same symbol. In order to show the flow of a real object and supporting information about the object two independent flows, both drawn as simple solid line arrows, must be mapped.

7.3.7.7.3 Systems hierarchy for activities and information

By decomposing processes and activities within $IDEF_0$ a formal set of systems hierarchy can be achieved. The set of rules used by $IDEF_0$ permits the method to cope with complex systems by decomposing the activities to various levels of abstraction providing a manageable amount of detail at all times. The decomposition of high level data and information flow within $IDEF_0$ is also possible. This can be achieved by branching (decomposing) and bundling (grouping) arrows. The consistency of decomposing information is maintained as the decomposed activities inherit all relevant ICOMs.

7.3.7.7.4 Overall system boundaries and goals

Definite system boundaries can be set as $IDEF_0$'s syntax and semantics allows different levels of abstraction to be modelled. This can be achieved by mapping an optional A-1 context diagram showing the environment of the model under study or by using the required A-0 context diagram. With an A-0 diagram it is possible to precisely define the scope of the project including the start and end points of the model. A context diagram reflects the objectives of the modelling which need to be established first. At the A0 diagram level it is possible to specify a certain viewpoint from which the processes will be modelled.

7.3.7.7.5 System parameters

$IDEF_0$ diagrams show how inputs are transformed to outputs within the system. The defined system boundaries show which inputs come from an external source and which outputs leave to an external receiver. The source and receiver themselves however cannot be specifically identified. Within the system's boundary $IDEF_0$ models processes and activities from a function view showing how the transformation is achieved. Feedback coming from an external receiver or as an output from an activity within the system can be modelled in the form of data and information flow.

7.4 Summary of modelling techniques supporting Fulfil Order Process criteria

Table 7-2 gives an overview of how the selected modelling techniques address the criteria set for modelling a Fulfil Order Process. A business process modelling technique that supports the criterion very well is indicated with the symbol "++". The "+" symbol indicates that the modelling technique addresses the criterion only partially.

Criteria for modelling a Fulfil Order Process / **Modelling Technique**	Easy to use/common language for communication	Simple syntax	Simple semantics	Systems hierarchy	System boundaries	Systems parameters						
						Source	Input	Process	Transformation	Output	Receiver	Feedback
Action Workflow	+	++			+	+					+	
Petri Nets	+	+	+						+			
Role Activity Diagrams	+							+				
Block Diagrams	++	++	+	+				+				
ANSI Standard Flowcharts	++	+	+	+				+				
Functional Flowcharts	++	+	+	+				+				
Flow Process Charts	++	++	++					+				
String Diagrams	+	+	+									
HIPO Charts	+	+	+	++	+	+	++	++	+	++	+	+
Data Flow Diagrams	+	+	+	+	++	++			+		+	+
Use Case	++	+	+	+	++	++	+	+	+	+	++	+
$IDEF_0$	++	+	++	++	++	+	++	++	++	++	+	++
$IDEF_1/IDEF_{1X}$	+	+	+		++							
$IDEF_3$		+	++	+			+	++	++	+		+
$IDEF_4$				++	+							

Table 7-2: Modelling techniques supporting the criteria of a Fulfil Order Process

While all modelling techniques require experience and basic knowledge to produce a useful model the majority of them address the criterion for ease of use/common language for communication fairly well. This is often supported by a simple syntax and semantics of these diagrammatic techniques which are based on a semiformal language using graphical symbols and specific rules.

A small and inconsistent set of rules however often permits modellers to develop their own personalised syntax. This makes the communication of a model difficult as it allows interpreting situations differently by taking various viewpoints. The review shows that a simple syntax and semantics does not always specify mechanisms which allow the decomposition of activities and information or the setting of definite boundaries around the system under study.

Chapter 4 described a Fulfil Order Process as a type of a business process. As a business process has been discussed from a systems viewpoint and can be classified as a Human Activity System (HAS), the focus for selecting a modelling technique is how well each technique addresses the systems parameters. The techniques that address all the systems parameters are HIPO Charts, the Use Case approach and $IDEF_0$. These three modelling techniques now form the basis for a second review of how they address the criteria set for showing the links to ISO 9001:2000.

7.5 Review of modelling techniques supporting the criteria for showing the links to ISO 9001 in a Fulfil Order Process

Three modelling techniques were identified as possible candidates to model a Fulfil Order Process from a systems viewpoint. Based on the results from the literature review it can be argued that not one of the selected and reviewed modelling techniques does explicitly support the links to ISO 9001. Table 7-3 therefore reviews whether the concept of each modelling technique can be easily adapted to achieve this. The "++" symbol indicates that the concept of a modelling technique can be adapted in a straightforward manner to support an ISO 9001:2000 modelling criteria. A "++" would be assigned in the case where a modelling technique already addresses a characteristic and the existing notation only needs extending to fulfil the extra criteria. For example a modelling technique which has the means for modelling information requires an extension to differentiate between information which is controlled by ISO 9001 from that which is not. Such an extension could be achieved by using the same graphical symbol for information in a different style.

The "O" symbol is assigned if the convention of a modelling technique does not originally consider address criteria and no straightforward extension is possible. Instead it would demand the introduction of a new set of rules and extra icon(s) to satisfy this requirement. Such a major change is considered to produce a level of complexity at odds with the basic principles of the modelling technique.

Modelling Technique / Criteria for ISO 9001:2000	Show activities and identify the ones controlled by ISO 9001:2000	Identify and distinguish information and objects controlled by ISO 9001:2000	Show information and the flow of information	Show the different types of information; control input, object input, resource input	Decomposition of activities and information; process hierarchy	System boundaries	Show resources linked to the standard	Identify relevant elements using a unique numbering convention
HIPO Charts	++	++	++	O	++	O	O	O
Use Case	++	O	O	O	O	++	O	O
$IDEF_0$	++	++	++	++	++	++	++	O

Table 7-3: Modelling techniques supporting the criteria for showing the links to ISO 9001

7.6 Summary of modelling techniques showing links to ISO 9001

The currently available business process modelling techniques, developed with business process redesign in mind, cannot fully support the task of showing the links to ISO 9001 quality standard. The researcher justifies the decision to select the modelling technique $IDEF_0$ as the most promising approach for addressing the links to ISO 9001 based on the premise that the syntax and semantics can be most easily enhanced. $IDEF_0$ is one of the most widely used method in business process modelling and Colquhoun *et al.* (1996; 1993) report that $IDEF_0$ is well recognised as evidenced by a significant number of publications for modelling functional relationships in manufacturing systems.

HIPO Charts have, in comparison to $IDEF_0$, a more complex syntax as they use different types of diagrams and symbols at different levels of detail when decomposing. They are most commonly used in the initial planning of computer programs, since they concentrate on showing the modular nature of a program but support the understanding of the functions of a system.

The Use Case approach is ideal for modelling on a high level but does not functionally decompose a model showing all levels of detail. As the concept only supports decomposition of activities and information partially it would require a major effort to extend its syntax to comply with the requirements.

7.7 Chapter Summary

This chapter has reviewed the most common modelling techniques which are used to model business processes based on several studies carried out in the field of business process redesign. In the first instance the techniques were assessed for their applicability to model a Fulfil Order Process. This resulted in an exclusion of all those where syntactical limitations did not support the modelling of systems parameters. This is because a Fulfil Order Process has been described from a systems viewpoint and a systemic presentation of it has been seen as a vital criterion for selecting a modelling technique.

The ones that supported these criteria were further investigated in respect of their appropriateness to highlight ISO 9001 criteria. Unsurprisingly none of the modelling techniques completely supported this second set of criteria. Each of the selected modelling techniques was therefore reviewed as to how easily its syntax and semantics could be adapted. For the reasons stated in Section 7.6, $IDEF_0$ was selected to be the most appropriate modelling technique.

The next chapter will propose how $IDEF_0$'s syntax and semantics can be enhanced so that all defined criteria can be shown successfully. Also discussed is how the proposed modelling technique can be used.

8 The Proposed Modelling Approach $IDEF_{9000}$

The previous chapters have identified a set of criteria for modelling a Fulfil Order Process from a systems viewpoint (Chapter 5), specified requirements for showing the relevant links between the activities of such a process to the ISO 9001:2000 quality standard (Chapter 6), and reviewed current business process modelling techniques and their ability to fulfil the defined criteria (Chapter 7). Chapter 7 concluded that while several modelling techniques support the criteria set in Chapter 5 to various degrees, no modelling technique completely satisfies the requirements for showing the links to ISO 9001. $IDEF_0$ *has been identified as the most promising candidate as the base concept can be adapted and enhanced to support the requirements. This chapter will discuss the enhancement of* $IDEF_0$*'s syntax and semantics with reference to the requirements together with a description of how to apply the improved version of* $IDEF_0$ *named by the author* $IDEF_{9000}$.

$IDEF_{9000}$ *reflects in its name an emphasis on identifying ISO 9000 constraints in the design of a business process model.*

8.1 A review of requirements

As argued in Chapter 3 business process modelling literature does not regard showing links to the ISO 9001 quality standard as one of its main priorities. The need for process-oriented quality management systems is acknowledged in this domain but there is limited guidance on how to model business processes considering ISO 9001 requirements and linking the two together. The field of quality management has widely recognised the usefulness of business process-oriented organisational structures. However, the proposed approaches generally focus on the design of a certifiable system and do not take an overall systemic view of the business. The research is required to provide a modelling technique which helps to:

- establish an improved link between the requirements of the ISO 9001 standard and the Fulfil Order Process of an organisation;
- take a systemic perspective of the integration of ISO 9001 in a business process environment;
- implement ISO 9001 in the Fulfil Order Process of an organisation;
- update the Fulfil Order Process of an organisation to conform to the latest version of ISO 9001;
- highlight potential constraints imposed by ISO 9001 during a redesign exercise to maintain compliance to the standard.

A modelling technique addressing the proposals above will support manufacturing organisations to model a Fulfil Order Process and highlight the links to ISO 9001 resolving some of the issues currently encountered. The next sections describe how the proposed approach can be used.

8.2 Enhancement of $IDEF_0$ enabling showing the links to ISO 9001

In Chapter 7 $IDEF_0$ was selected as the most appropriate modelling technique as its concept is thought to be easily adaptable to match the additional criteria. The improvement of the syntax is based on the primary requirement of the research namely to distinguish graphically between controlled and uncontrolled activities, information and objects by ISO 9001. While the syntax of a modelling technique can be adapted in many ways, the proposed design considers the following major aspects to be the most important.

The $IDEF_0$ approach can be thought of as the $IDEF_0$ language itself and the $IDEF_0$ methodology which provides additional procedures for developing and interpreting process models (National Institute of Standards and Technology, 1993). It also includes techniques for data collection, reviewing and documentation. The research concentrates solely on the $IDEF_0$ language and acknowledges the existing generic $IDEF_0$ methodology as valid and appropriate in the proposed modelling approach.

The proposed approach $IDEF_{9000}$ introduces modifications to $IDEF_0$ only where required retaining as much of the technique's well established original principles as possible. This assumes that the new approach can benefit from its association with a well documented and widely acknowledged modelling approach. It can be argued that this may grant the approach a wider application, especially within the current $IDEF_0$ community or when convincing new users to apply this approach by referring to $IDEF_0$'s established and recognised concept.

It can be assumed that the final process model will most probably be documented using a software based solution and the researcher is aware of the numerous possible ways of formatting $IDEF_0$ diagrams highlighting the ISO 9001 links. Instead of applying and evaluating the features of state-of-the-art graphics packages such as different symbols, formats and fonts the researcher proposes one simple notation for the practitioner to use. This is because the primary focus of the research is to enhance the concept of $IDEF_0$ and not to develop syntax based on the facilities of a particular software tool.

The proposal for extending syntax avoids the use of coloured formatting and only distinguishes between a black and white symbol for activities and black arrows with different thickness connecting activities and showing process flow. This will allow easy reproduction where coloured photocopying or printing is not available. For the identification of controlled as opposed to uncontrolled labels by ISO 9001 the text will be formatted in bold as opposed to a regular font style. To avoid ambiguities when diagrams are being reproduced the bold font is also underlined and in italics.

However, during redesign workshops process mapping is often initially documented by hand by drawing on paper, whiteboards or even "Post-it" stickers. This requires an even simpler syntactical approach. Instead of changing the format of the text the labels referring to an ISO 9001 link shall be identified by using the asterisk symbol (*) at the end of the label for ease of reproduction. The use of only one colour remains as mentioned in the previous section.

This chapter will now discuss the extensions in the semantics of $IDEF_{9000}$ together with the syntax adapted for the ISO 9001 criteria which are summarised below.

- To show activities and clearly identify the ones which are controlled by the ISO 9001:2000 quality standard;
- To identify and distinguish information and objects that are linked to a requirement of ISO 9001:2000 from those that are not;
- To show information and the flow of information;
- To show information as different types of input (control inputs, object inputs and resource inputs) to an activity;

- To decompose activities and information and to describe a process hierarchy;
- To set system boundaries in order to identify any source or receiver within the quality management system or with external stakeholders related to ISO 9001:2000 inputs or outputs;
- To show resources that are required by the activity and to identify the ones that are linked to the standard;
- To identify all relevant elements within a Fulfil Order Process using a document numbering convention or other form of unique labelling system.

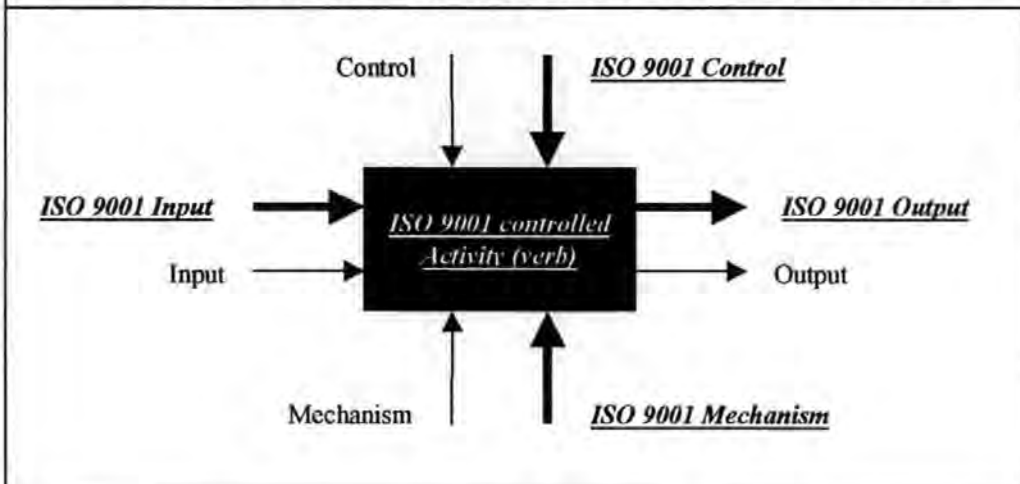
8.2.1 Identification of activities controlled by ISO 9001

$IDEF_{9000}$ needs to show activities and clearly identify the ones which are controlled by the ISO 9001 quality standard. In a traditional $IDEF_0$ activity diagram boxes are used to represent activities of the process being modelled. The box labels are named using imperative verbs.

This enhanced modelling technique for ISO 9001 links identifies and distinguishes graphically between activities that are, or are not, controlled by the ISO standard. A transparent box with a normal black font style represents ordinary activities. ***Using a black box with the font style white, italics, bold and underlined,*** indicates that either this box or a subordinate box or boxes is controlled by ISO 9001 (see Figure 8-1 and Figure 8-2). The emphasis for this rule is where ISO 9001 governed controls are present. Typical controls which rule and constrain how an activity needs to be performed are ISO 9001's control or operating procedures. This extension of the syntax and semantics of $IDEF_0$ does not however apply to inputs (object inputs), outputs or mechanisms (resource inputs) related to

ISO 9001. Such object inputs may be controlled forms, identified goods or inspected components which do not constrain the nature of the activity itself. They only require to be transformed by a particular activity by using certain mechanisms to produce a specific output. The black activity box controlled by ISO 9001 draws the attention of the practitioner to the ISO 9001 control which constrains the activity before starting the redesign.

Extended syntax for ISO 9001 controls when documented with a software tool



Extended syntax for ISO 9001 controls when documented by hand

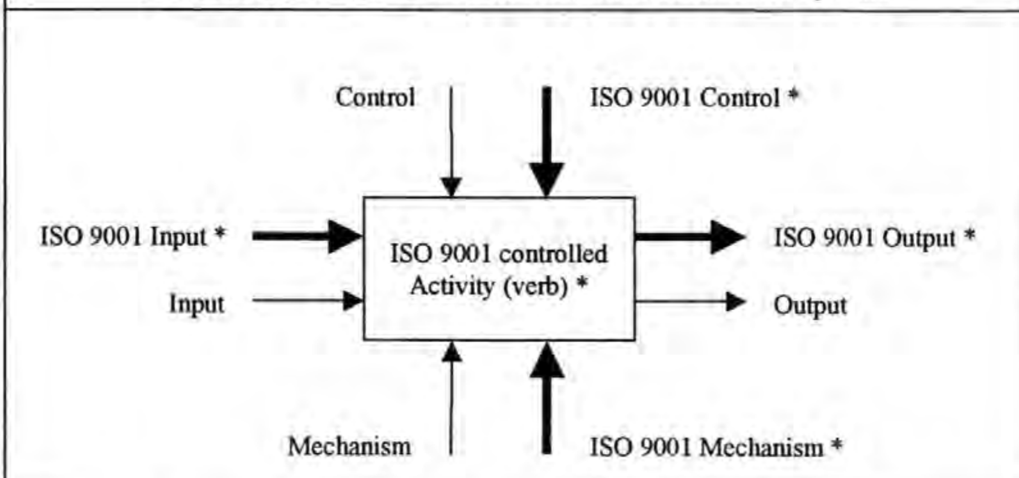


Figure 8-1: Identification of an $IDEF_{9000}$ activity controlled by ISO 9001

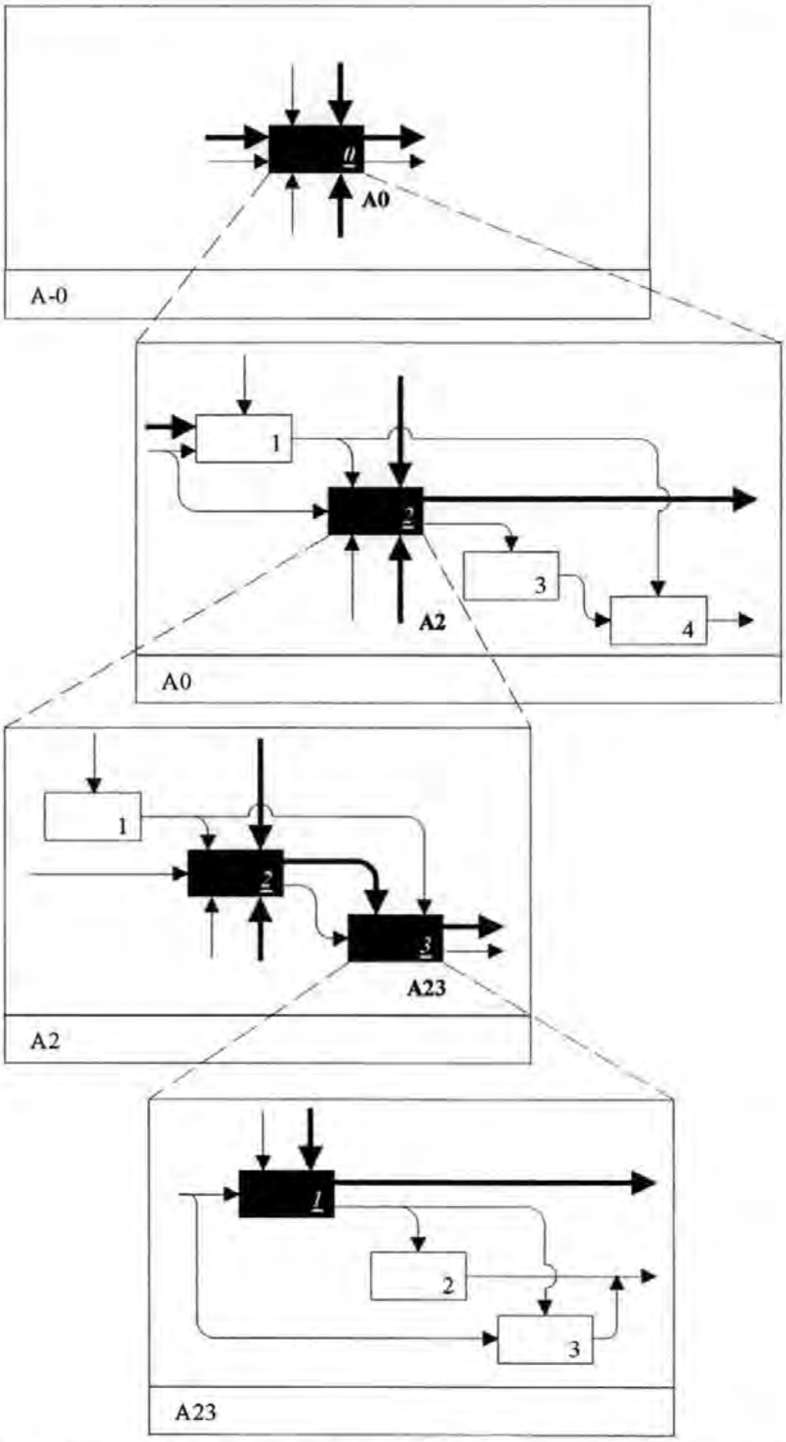


Figure 8-2: Identification of IDEF$_{9000}$ activities controlled by ISO 9001 (decomposed)

8.2.2 Identification of inputs, controls, outputs and mechanisms controlled by ISO 9001

To identify and distinguish information and objects that are linked to a requirement of ISO 9001 from those that are not the modelling technique will need to label them differently. This may also include referring to sources within the quality management system from where documents originate. The syntax proposed for identifying ISO 9001 links is to draw arrows using a heavier "weight" or thickness. For the labelling of arrows controlled by ISO 9001 the font style is changed to ***italics, bold and underlined*** as seen in Figure 8-1. When drawing the process model by hand, arrows and activities controlled ISO 9001 should then be identified by an asterisk symbol (*) or similar.

Some typical inputs, controls, outputs and mechanisms for a Fulfil Order Process from an ISO 9001 standards viewpoint are shown in Figure 8-3. Inputs (object inputs) can be usually classified as being either controlled documents (information and data) or objects. Similarly to the traditional $IDEF_0$ rules, inputs can also become controls where appropriate. An activity always has to have a control arrow regardless of whether controlled by ISO 9001 or not, though they need not always have inputs. Where there is uncertainty if an arrow should be labelled as an input or a control it should be shown as a control.

ISO 9001 governed controls may be split into those that are only required because of an ISO 9001 requirement and those documents or objects which need to be adapted because of ISO 9001. The first category (solely ISO 9001) refers to procedures or documents that an organisation specifically introduced to conform to ISO 9001. The remainder (controlled by ISO 9001) were already applied by the organisation but needed certain amendments to comply.

Typical outputs related to ISO 9001 are completed documents in the form of reports, charts or objects such as inspected and identified goods. Mechanisms which are identified with the new syntax may be customer owned equipment, any measuring and testing equipment or the qualified personnel.

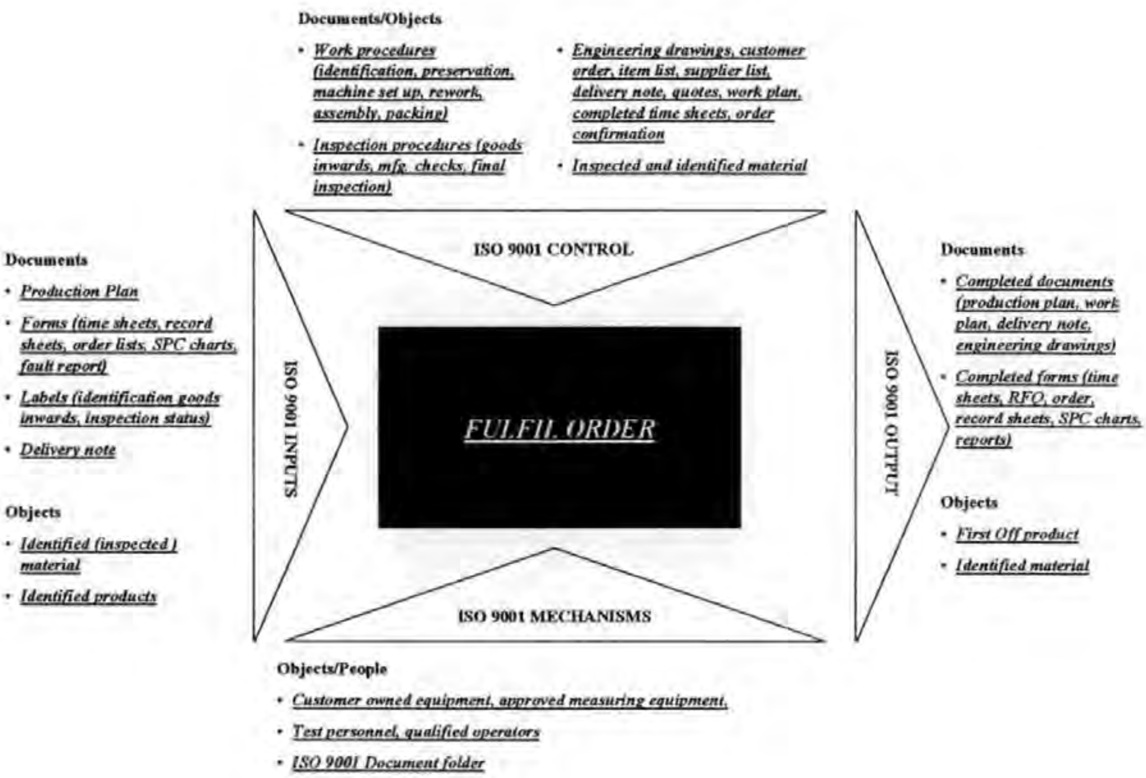


Figure 8-3: Typical governed ISO 9001 arrows of a Fulfil Order Process

8.2.3 Identification of information and the flow of information

The original syntax of $IDEF_0$ already supports the modelling of information and the flow of information. From the discussion in Chapter 6, information will only need to be shown graphically excluding its structure or storage. Therefore no extra information view is required and with the enhanced $IDEF_{9000}$ syntax showing information controlled by ISO 9001 as described in Section 8.2.2 no further amendments are required.

8.2.4 Identification of information as a different type of input to an activity

Any form of information, be it electronically or paper document based, must be shown if it is an input to an activity. The different types of inputs have been identified as *control inputs*, *object inputs* or *resource inputs*. The *control input* is the $IDEF_0$'s original constraint (top of the box), the *object input* is the original input (left side of the box) and the *resource input* is the original mechanism (bottom of the box). This requirement also applies to feedback from outside the boundaries of a defined Fulfil Order Process.

Documents that are transformed from inputs to outputs and include the processed information that is required by the standard need to be identified. This is relevant for example for forms which when being filled in become quality records.

8.2.5 Decomposition of activities and information describing a process hierarchy

To decompose activities into sub-activities to the level of detail necessary and to link them to individual documents or objects controlled by ISO 9001, the modelling technique will use the ability of $IDEF_0$ to describe a hierarchy that composes systems from subsystems. $IDEF_0$'s original facility for decomposing activities needs to be combined with the identification of activities controlled by ISO 9001 as described in Section 8.2.1.

Similarly to the hierarchy of processes, the decomposition of information down to the different levels of detail needs to consider the extended syntax to identify information controlled by ISO 9001 at all levels as described in Section 8.2.2. As there is always concern about overloading the diagrams the arrows should only be branched at the required level of detail. For example instead of drawing all individual *work and test instructions* (control inputs) entering the more general activity *make product* they could be bundled to one arrow labelled as ***Work instruction (ISO 9001 procedure folder PF-Ru)*** and decomposed at the next lower level of the more detailed diagram (see Figure 8-4). This example also shows the source or location of documents and other information on each arrow label. This is required as many ISO 9001 documents have their origin outside the boundaries of a Fulfil Order Process. They need to be shown in the context diagram as entering the system on a high level (bundled) and should be identified as e.g. ***ISO 9001 documentation***.

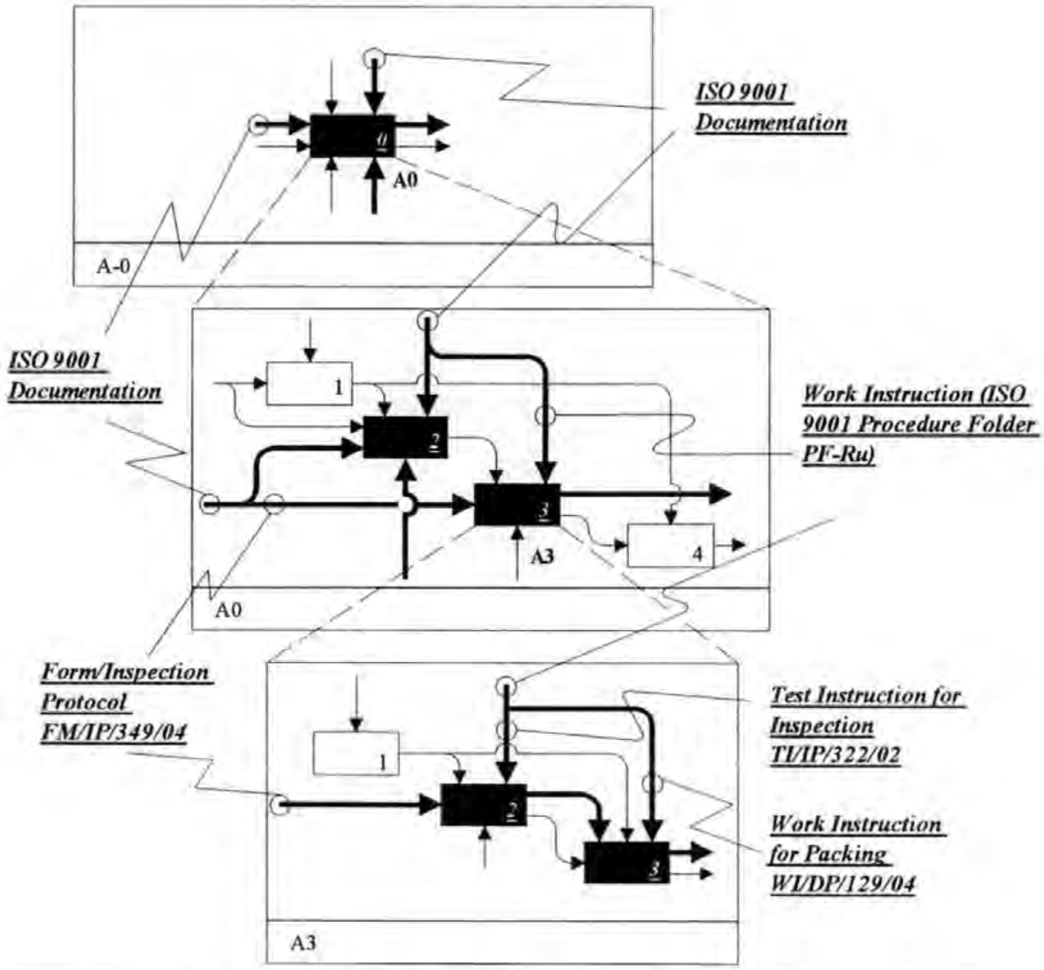


Figure 8-4: Decomposed activities and information controlled by ISO 9001

8.2.6 Identification of system boundaries of a Fulfil Order Process

Similarly to the identification of information and its flow as described in Section 8.2.3 this criterion is already a fundamental facility of the $IDEF_0$ modelling technique.

The concept of $IDEF_0$ identifies distinct system boundaries which, from a ISO 9001 viewpoint are important, as it becomes apparent what originates from the non-operating part of the quality management system or is required by it as an output from the system under study. It also shows the practitioner what a receiver might require or any feedback in terms of ISO 9001. However in the traditional $IDEF_0$ process model the source and receiver cannot be specifically identified. By labelling inputs of a source and the outputs to a receiver according to the convention as described in Section 8.2.2 the extended $IDEF_{9000}$ will support the practitioner when redesigning activities which are controlled by ISO 9001.

8.2.7 *Identification of resources controlled by ISO 9001*

All relevant elements such as inputs, outputs and resources within a quality management system need to be controlled. Identification is usually achieved by a document numbering convention and other forms of unique labelling system as seen Figure 8-4. The usually text based, conventions of identification and individual identity codes are added as text to the arrows label and formatted as described in Section 8.2.2.

8.3 Participation in the modelling approach

It is envisaged that the author of the model interviews participants who have a direct involvement in the Fulfil Order Process. Where possible a group may be formed with a team leader who will guide the group through the modelling process. The direct involvement of users will increase the chances of change and will support subsequent implementation by avoiding potential obstruction (Meyer, 1993). Prior to the interviewing and the modelling it would be advantageous for the team leader to be familiar with the proposed approach, its syntax and semantics. The guidelines discussed in this chapter will address these issues.

8.4 Application of the proposed modelling approach

The proposed approach is intended for organisations which are already ISO 9001 registered and those which intend to introduce the quality standard in the future. Depending on the organisation's situation the approach will need to be applied differently. The key issues are discussed in the following sections and should be seen as a specific set of guidelines in addition to the $IDEF_0$ methodology (National Institute of Standards and Technology, 1993).

Organisations which already have a certified quality management system should model the Fulfil Order Process and the ISO 9001 links simultaneously. This is to avoid potential rework when an already modelled Fulfil Order Process needs to be complemented with ISO 9001 links at a later stage. During the modelling process the author of the model will need to interview experts to gain a thorough knowledge of both subjects. Background information on the subject matter from an ISO 9001 viewpoint is required and all information related to ISO 9001 such as the quality manual, procedures, instructions and other controlled documents need to be available. Throughout the modelling work it should be possible to link ISO 9001 related arrows including their identification (labels) to individual activities of a Fulfil Order Process.

8.4.1 Designing the Context Diagram (A-0)

The $IDEF_0$ methodology starts by drawing a *context diagram* (A-0) which includes the context, purpose and viewpoint of the process model. In this research the subject under study is the Fulfil Order Process of an organisation for which the boundaries to the external environment need to be defined. As discussed in Chapter 5 a Fulfil Order Process contains all activities which transform product orders into products. Its key focus is to show the material and information flow essential to satisfy customer requirements. The system boundaries set by the *context diagram of* $IDEF_{9000}$ also need to identify all links relevant to ISO 9001 that are entering the operative part of the organisation.

The main purpose of $IDEF_{9000}$ is to show and identify the links between the activities of a Fulfil Order Process and the relevant criteria of the ISO 9001 quality standard. This is to enhance the understanding of practitioners when redesigning processes as the links between the standard and the activities will highlight where extra considerations are required to obtain or maintain compliance to the standard. The viewpoint to be taken for this process model therefore needs to be the Fulfil Order Process including the relevant part of the ISO 9001 quality standard.

As suggested in the guide for creating $IDEF_0$ diagrams (National Institute of Standards and Technology, 1993) some people might find it easier to develop the A-0 *context diagram* together with the next lower level A0 viewpoint diagram by going back and forth between the two diagrams until a satisfactory status has been achieved.

8.4.2 Designing the Viewpoint Diagram (A0) and subsequent diagrams

The A0 diagram decomposes A-0 into three to six functions outlining the entire system under study. This is crucial for the top level diagrams as it is important to maintain a level of abstraction throughout the entire model. It has been suggested that the designer concentrates his efforts on A0 and A1, A2, A3 etc. and carry out further decomposition from A1 into A11 or A111 at a later stage. This is to avoid extra work should there be amendments necessary at higher level diagrams.

In cases where an organisation is already registered to ISO 9001 the conventions which identify ISO 9001 links need to be applied during all stages of the modelling process. The procedure for creating a new diagram is to work down from abstract to detailed, showing the activity structure first. As modelling usually includes numerous modifications and redrawing of the diagrams it is proposed that activities controlled by ISO 9001 be identified and formatted after all decomposed diagrams have been established.

The next step is to take into account all arrows that are related to each diagram and to highlight all arrows controlled by ISO 9001 by applying the convention as discussed in Section 8.2.2. Connecting all activities to the appropriate arrows and drawing arrows between the activities follows this.

This is followed by working back up from detailed to abstract identifying activities controlled by ISO 9001 according to the convention as proposed in Section 8.2.1. There are only two reasons why an activity box needs to be formatted differently. The first rule applies to activities which are constrained by a ISO 9001 control input (entering the box from the top). Secondly, a higher level activity needs to indicate if any of its subordinate activities are controlled by ISO 9001 in order to maintain consistency when decomposing the process model. This is best achieved by working upwards from a detailed level to a general level considering only two levels at a time.

Organisations that intend to introduce ISO 9001 at a later stage should map their current situation and review the initial model for ISO 9001 relevance by referring to Section 8.4.3.

8.4.3 Reviewing conformity to ISO 9001

The proposed modelling approach relies a great extent on the practitioner's knowledge and understanding of the ISO 9001 quality standard. With the research concentrating on the operating part of an organisation not all parts of the standard need to be considered. The relevant links between ISO 9001 and a Fulfil Order Process have been discussed in detail in Chapter 6 and are shown in Appendix 3. They will assist the practitioners during the reviewing process. Each section of the ISO 9001 standard is described as *directly relevant*, *indirectly relevant* or *not relevant* to the Fulfil Order Process together with an indication what type of requirement is needed. This guide can be applied by organisations regardless of them being ISO 9001 registered or not.

For the reviewing process it is proposed that each section of ISO 9001 be assessed separately. This is to maintain transparency as individual sections of ISO 9001 can have multiple links to different activities within the process model.

A suitable starting point is to refer to Appendix 3 which indicates for each section of ISO 9001 which type of arrow and/or extra activities need to be addressed by the process model. The first check is to determine if all ISO 9001 requirements are present. This could lead to the following scenarios:

- All ISO 9001 requirements have already been addressed;
- Arrows controlled by ISO 9001 are missing and must be introduced;
- Activities controlled by ISO 9001 are missing and must be introduced.

In the first scenario where all ISO 9001 requirements have already been addressed the practitioner subsequently needs to ensure that the proposed syntax of the modelling technique has been applied completely. For arrows and activities controlled by ISO 9001 it is important that they are consistently identified throughout the various levels of the process model as discussed in Section 8.2.1 and Section 8.2.2.

The second scenario in which extra arrows controlled by ISO 9001 are introduced can lead to either linking these new arrows to already existing activities or to the requirement for additional activities. Either way the newly introduced arrows controlled by ISO 9001 must be identified in the same manner as discussed for the first scenario. The affected activities need to be checked to the rules set in Section 8.2.1 and may need to be changed to the new syntax if the ISO 9001 constraint is a *control input*. In a concluding step the practitioner must check that the consistency of activities and any subsequent activities controlled by ISO 9001 is maintained.

In the final scenario the current process model does not include all the activities required by ISO 9001. Extra activities must be introduced to comply with the standard. Similarly to the second scenario this could lead to either linking the newly introduced activities to existing arrows or to requiring extra arrows. The consistency checks for arrows and activities controlled by ISO 9001 as already described for the first two scenarios apply accordingly.

For all scenarios it is important to consider not overloading the diagrams with too much detail. This can be done by keeping the arrows at a general level and considering bundling and branching arrows as described in Section 8.2.5 and shown in Figure 8-4.

For organisations that are not currently ISO 9001 registered this part of the modelling process identifies the gaps and allows development of a future *to-be* Fulfil Order Process in compliance with ISO 9001. If an organisation has not established a convention for identifying and labelling documents and other relevant objects controlled by ISO 9001, a temporary system of labelling may need to be developed.

8.4.4 Redesign of an existing Fulfil Order Process

To redesign any process within an organisation, in-depth knowledge and understanding of the domain is required. A set of guidelines should support practitioners in their attempts to review the modelled Fulfil Order Process for potential improvements. The guidelines refer to some of the principles discussed by Jain *et al.* (1994) and their transformational approach to business process redesign as well as to recommendations derived from the IDEF$_0$ methodology. The three classes of transformations discussed by Jain *et al.* (1997) are *the relocation of activities, the aggregation of activities* and *the concurrency of activities.*

Many of the arrows controlled by ISO 9001 are usually developed and approved in the non-operating part of the quality management system. This includes work and testing procedures or other controlled documents such as forms or checklists. These arrows are referred to as being outside the system boundaries of a Fulfil Order Process. The modelling process therefore considers them as given, not specifying their content in greater detail. However during the redesign exercise these arrows may need to be investigated in greater depth if they constrain an activity. A quality management system representative or equivalent who can comment on specific ISO 9001 related information associated with these arrows may need to be present.

It is furthermore assumed that the rules for modelling with IDEF$_0$ have been applied thoroughly and that the model is correct. The additional rules of IDEF$_{9000}$ do not check whether, for example, each activity box has at least one control arrow or that all decomposed arrows are inherited consistently by subordinate activities.

The reviewer first needs to become familiarised with the process model. This is best achieved by analysing the node index to establish an overview of the process model. After the context, purpose and viewpoint of the process model has been reviewed all individual diagrams starting with the A0 viewpoint diagram need to be examined. Every diagram should be checked to see if activities/arrows are needed or if activities can be relocated, aggregated or performed in parallel.

8.4.4.1 Necessity of activities

The diagrams should be checked to see if each operation is necessary to fulfil the purpose of the process being studied. This may include activities which were introduced because of special circumstances and reviewing each output of an activity may identify whether these circumstances still exist. Examples of activities which either produce waste or are unnecessary may be documents that are stored for no reason or the reproduction of copies where there is no demand.

Identical activities performed at different stages should be identified and investigated further. Where an operation is controlled by ISO 9001 (control input) the constraint needs to be established before the particular activity can be removed or redesigned. The constraint may be a quality procedure or instruction of some sort. If the input, output or mechanism is controlled by ISO 9001 the activity itself can be redesigned as long as all required arrows controlled by ISO 9001 are still given due consideration.

8.4.4.2 Relocation of activities

This test applies when rearranging the sequence of activities within the process/diagram under investigation as well as when moving potential activities beyond the system boundaries. The first issue is concerned with improving flow of information and material. Potential opportunities to improve flow may be seen where objects or information go back and forth in a diagram visiting activities, feedback and mechanisms more than once rather than taking a serial path. This is shown when the same mechanism is used for several boxes that are not adjacent. Equally important is the question of whether a customer or supplier (source or receiver) can perform any of the activities when initiating or receiving an order. For example bank customers when making a phone inquiry are asked by a computer to key in their personal code before being connected to an operator. This reduces the time operators search for the account details after being connected to the customer. The relocation of activities might require the making of subsequent changes in ISO 9001 procedures, other controlled documents or objects. Conversely the relocation of activities could lead to the introduction of extra flows controlled by ISO 9001 to maintain compliance. This could have adverse effects on the intended objectives of the redesign.

8.4.4.3 Aggregation of activities

Aggregating activities is concerned with combining successive activities of the same type. The process model can be checked to see whether work items can be finished before they are passed on (combining subassembly and assembly) or if parts can be produced and inspected by the same operator. This may mean extending individual jobs to cover other specialities. The aggregation of activities might also lead to an accumulation of several ISO 9001 procedures, controlled forms or even resources. For example, where before the aggregation of activities it was necessary to ask for specific information by using separate forms it might now be better to combine them into a single form.

8.4.4.4 Parallel processing of activities

Independent and sequentially performed activities should be investigated to see whether they could be carried out in parallel. For example, printing the manual can be performed while preparing the final product for packing. Where activities are dependent they should be checked to see what degree of concurrency could be applied. In concurrent engineering the principle is to carry out activities in parallel even if previously started activities are not completed. Prototyping of some parts may begin before all components are completely designed. In terms of the quality standard, parallel processing might require the provision of certain documents or equipment controlled by ISO 9001 at more than one location.

8.4.4.5 Feedback

Some of the feedback loops may be unnecessary. Part of the redesign exercise should be to investigate activities that are constrained by information as part of feedback. Similarly, cases may be noted where there is no proper feedback to regulate activities; this may have to be introduced. During the redesign stages an organisation must consider the need for appropriate internal communication processes essential to operate an effective ISO 9001 quality management system. Organisations would also have to make arrangements to gather information about customer satisfaction.

As part of this research a book called *$IDEF_{9000}$ – A standard for modelling operating business processes with links to ISO 9001* has been produced. It includes the principles of $IDEF_{9000}$ and its intended method of use as discussed in this chapter. It is used during the validation of this research work in the next chapter. A copy of this book is included at Appendix 5.

8.5 Chapter Summary

This chapter has proposed how the extended $IDEF_{9000}$ modelling approach can be applied. It discussed the application of the modelling technique for organisations which are already registered to ISO 9001 but have not previously mapped their Fulfil Order Process and established the links to the relevant ISO 9001 requirements and to those which intend to implement the quality standard in the future.

To support the use of $IDEF_{9000}$, organisations without an expert knowledge in ISO 9001 are provided with a list of links that allows them to review the Fulfil Order Process in terms of ISO 9001 relevant criteria. Furthermore a set of guidelines for a redesign exercise has been discussed supporting practitioners in their pursuit to improve the Fulfil Order Process with the focus on considering the relevant links to ISO 9001 to obtain or maintain compliance to the quality standard.

The following chapters will test and validate the proposed modelling technique $IDEF_{9000}$ to see whether it can be used to meet the needs of practitioners and the criteria set out in Chapter 6.

9 Validation of the Proposed Modelling Approach

This chapter follows on from the Explanation Phase of this research and will describe the next phase of the research cycle. The objective of the Testing Phase is to determine whether the criteria set for this research work have been met. Validation is split into two stages in order to evaluate the modelling technique's usefulness and its use separately. The validation approach will also be described together with a discussion of the findings from each stage.

9.1 Objective of the validation

The objective of this research was to support practitioners in modelling a Fulfil Order Process showing the links to the ISO 9001 quality standard. The modelling approach was developed to highlight where the relevant requirements of ISO 9001 interrelate with activities of the Fulfil Order Process to draw the attention to the potential impact of changes in the process or in the standard.

The objective for this phase of the research was to establish the validity of the proposed modelling approach by focusing on an assessment by practitioners. This was carried out in two main parts with the first stage concentrating on the *validation by review* and the second stage *validating its use*. In order to assess the use of the modelling technique in a fair manner, reviewers assessed the modelling approach for its usefulness and how easy the approach is to understand during stage one of the validation process. Academics involved in the field of POM along with managers and practitioners from industry acted as reviewers. During stage two the usefulness of this approach was assessed by practitioners applying the modelling technique and the method of use in a manufacturing company. The validation criteria for both stages are described in the subsequent section.

9.2 Validation criteria

In Section 2.2 it was proposed to use the reference framework of Thomas and Tymon (1982) to assess this research project in terms of "the needs of practitioners". The five key needs are

- descriptive relevance;
- goal relevance;
- operational validity;
- non-obviousness;
- timeliness.

Together with the specific set of criteria defined for the modelling technique, the key needs form the frame for validating this research. The specific criteria as defined in Chapter 6 are as follows:

- To show activities and clearly identify the ones which are controlled by the ISO 9001:2000 quality standard;
- To identify and distinguish information and objects that are linked to a requirement of ISO 9001:2000 from those that are not;
- To show information and the flow of information;

- To show information as different types of input (control inputs, object inputs and resource inputs) to an activity;
- To decompose activities and information and to describe a process hierarchy;
- To set system boundaries in order to identify any source or receiver within the quality management system or with external stakeholders related to ISO 9001:2000 inputs or outputs;
- To show resources that are required by the activity and to identify the ones that are linked to the standard;
- To identify all relevant elements within a Fulfil Order Process using a document numbering convention or other form of unique labelling system.

The objective for the review during stage one of this validation was to determine whether the modelling approach supports linking ISO 9001 requirements to a Fulfil Order Process and whether it can be understood. The first four criteria of the Thomas and Tymon (1982) framework were therefore focused upon. *Descriptive relevance* was validated with regard to how well the proposed modelling approach addressed linking ISO 9001 requirements to activities of a Fulfil Order Process. With *goal relevance* the validation by review evaluated whether the modelling technique would be used and supported the work of practitioners. *Operational validity* was concerned with whether the model was easy to understand. This also incorporated the quality of the manual explaining the method of use. *Non-obviousness* dealt with whether the proposed modelling approach was more than simple common sense already used by the practitioner. *Timeliness* was of less priority during this first stage, as the validation was not concerned with whether the modelling technique was available to the reviewers to be used. This key need was however included to some extent to gather information on whether the modelling technique would have been available for the organisation had the reviewers expressed a current concern.

Apart from addressing the key needs of practitioners this modelling technique was developed according to a specific set of criteria derived from the requirements of ISO 9001 in a fulfil order environment. In order to establish how well the proposed modelling technique complies with the set criteria, the reviewers assessed them during the first stage of this validation.

Stage two of the validation focused on the application of the modelling technique by practitioners when developing a part of the quality management system in local manufacturing organisations. The objective of this stage was to establish the links of ISO 9001 requirements to activities of the company's Fulfil Order Process and to determine whether the proposed modelling technique could be used in this situation. This validation by use addressed all five key needs of practitioners. To fulfil the key need *descriptive relevance* the modelling technique was assessed against whether the links of ISO 9001 to a Fulfil Order Process are apparent. With the second key need, *goal relevance,* it was validated against whether the use of the modelling technique allowing the organisation to achieve its objectives. *Operational validity* evaluated how easy it was for the organisation to use the modelling technique in its particular circumstances. *Non-obviousness* addressed the question of whether the use of this approach was an improvement on the method that may otherwise have been used to understand the existing situation of the company. From the viewpoint of *timeliness* the validation concentrated on whether the modelling approach was available at the right time. Finally, all of the specific criteria for the modelling approach were assessed again. With the modelling technique used by two organisations to achieve a real objective the practitioners evaluated how well the approach addressed the specific criteria.

9.3 Validation by review (stage one)

The objective for this stage was to have the modelling approach reviewed by practitioners. As the assessment of the modelling approach requires the practitioner to spend some time reviewing, the researcher did not consider taking a statistical sample across manufacturing organisations but provided it to practitioners who were interested in reviewing the approach.

Each reviewer was presented with a draft version of the manual *$IDEF_{9000}$ – A standard for modelling operating business processes with links to ISO 9001* (Appendix 5) which contained the following:

- Principles of business processes with focus on a Fulfil Order Process;
- Modelling a Fulfil Order Process with $IDEF_0$; explaining the syntax and semantics of $IDEF_0$;
- The requirements and role of ISO 9001 in a Fulfil Order environment;
- Application of the proposed modelling approach; explaining an enhanced version of $IDEF_0$ named $IDEF_{9000}$;
- A matrix correlating the requirements of ISO 9001 to a Fulfil Order Process;
- Description of typical arrows controlled by ISO 9001;
- Feedback sheet.

9.3.1 Validation approach for stage one

The validation in stage one was carried out using a feedback sheet (Appendix 6) after the practitioners reviewed the manual. Statements in the feedback sheet were formulated to address the key needs defined by Thomas and Tymon (1982) as well as the specific criteria defined for this modelling technique. In order to express the reviewers strength of agreement or disagreement to each of the statements given, the Likert scale (Emory, 1985) was applied in the feedback sheet.

An *ordinal scale* was used as it provides extra information by rank-ordering variables (most used, second most used and so on) rather than a *nominal scale* which classifies objects or data into exclusive groups only (red, orange, yellow, green, blue, violet). Such attitude scales as used in this questionnaire are often referred to in social sciences as *interval scales* (Wright, 1997). An *interval scale*, in addition to the ranking, provides information on the magnitude of the difference in the variable and allows arithmetical calculations such as arithmetic means and standard deviations. Emory (1985) states that a Likert scale will only report that the reviewer might be more or less favourable to the subject but will not reveal to what degree. Furthermore it cannot be assumed that each reviewer interprets each degree of agreement in this questionnaire in exactly the same way. The data, which reflects the perception of the reviewers about the usefulness of the modelling technique, is therefore regarded as ordinal.

The statements are based on 31 closed questions and two open-ended questions which allow the reviewer to add extra comments. Closed questions have been chosen as they can be quickly answered and analysed. As this strength can be undermined by its potential weakness where collected data may become superficial (Easterby-Smith *et al.* 1991), the reviewers were also asked to make additional comments on each question where felt applicable or necessary.

9.3.2 Distribution to practitioners

Initially the modelling technique was presented during various stages of its development to academic colleagues and practitioners for review. With the feedback and comments from this phase the modelling technique was developed further and made available to practitioners who were interested in reviewing the modelling approach.

The final version of the modelling technique was then, together with the manual that includes the proposed method of use, distributed to academics involved in the field of POM as well as to managers and practitioners from industry.

9.3.3 Summary of the findings

The reviewers came from manufacturing companies within Europe (some of them outside the UK), consultancy and academia. Their comments about the manual and the modelling technique were encouraging and provided useful information by pointing out areas for improvement. In Appendix 7 a summary feedback sheet gives an overview of the answers given by the reviewers including their comments. The number recorded in a field reflects the number of reviewers agreeing with the corresponding statement. Additional comments are included below some of the statements in italics. A total number of 11 copies were sent to practitioners who expressed an interest in reviewing the model. Comments were received from 9 reviewers.

The following sections discuss the suggestions and issues raised by the reviewers in greater detail.

9.3.3.1 Key needs of practitioners

9.3.3.1.1 Descriptive relevance (question 6)

Reviewers stated that in general it was important to see ISO 9001 links when carrying out redesign. Eight out of the nine practitioners however stressed that this may only be true to those who have or intend to have ISO 9001. One of these nine practitioners pointed out that

> *"...it is especially important to the designer(s) of ISO 9001 Fulfil Order Processes but also to the owners of ISO 9001 related activities."*

As a majority of the procedures and other documents of existing ISO 9001 quality management systems do not reflect the current business, this proposed process-based approach was regarded as promising. Organisations that operate such quality management systems might otherwise not consider ISO 9001 links when carrying out redesign.

9.3.3.1.2 Goal relevance (questions 7 to 10)

Reviewers stated that this approach would support the practitioners' objective in designing a process-based quality management system. It supports the understanding of the ISO 9001 requirements in a process context but would require a basic knowledge of the quality standard when actually modelling with it. Two practitioners agreed and seven strongly agreed that this modelling approach can be used during the design of an ISO 9001 quality management system and as part of a redesign exercise of a Fulfil Order Process. Following on, all reviewers gave only positive feedback on whether it is useful to see the ISO 9001 links during the redesign phase of a Fulfil Order Process. It was however seen as most beneficial to the designers of the business process and particularly to those who have or intend to implement ISO 9001 while carrying out the redesign.

9.3.3.1.3 Operational validity (questions 11 to 14)

All of the reviewers were familiar to various degrees with the $IDEF_0$ methodology. Overall most reviewers pointed out that the use of the modelling approach would require a basic knowledge in $IDEF_0$ and ISO 9001. By taking this into account the description of the modelling approach was considered by the majority of the reviewers as being easy to follow and the guidelines were regarded as comprehensive. One reviewer regarded $IDEF_0$ in general as *not very user-friendly* proposing to model with flowcharts instead. This perception was reflected by the reviewer's other answers on the ease of use of the modelling approach and the ease of understanding the manual.

Some of the questions associated with this key need referred to the actual application of the modelling technique or its parts. Several participants responded to these questions with *non-applicable* as they did not use the modelling technique. These answers are included in the summary feedback sheet as *neither*.

The suggestions for alterations referred primarily to the manual. Instructions that appeared to be ambiguous were rephrased before carrying out stage two of the validation.

Overall, the comments from the reviewers on both the proposed modelling technique and the manual ranged widely. As no particular point was mentioned consistently it indicates that there does not seem to be a major flaw in either the modelling technique or the manual. The modelling technique therefore seems to be a valuable approach for establishing the links between ISO 9001 and a Fulfil Order Process.

9.3.3.1.4 Non-obviousness (question 15)

The reviewers who are experts in designing business processes and/or quality management systems regarded this approach as an improvement on the current methods used. Prior to the questionnaire a presentation to industrialists during a seminar provided a further indication that the current version of the ISO 9001 standard does not give enough answers to many of the problems organisations face with their current quality management systems. Feedback given by one Managing Director and *ISO 9001 Lead Auditor* referred to the need to more closely relate ISO 9001 requirements to business processes.

Meetings with managers from several local manufacturing companies also provided encouraging feedback on the proposed modelling approach. One Managing Director was interested in applying the modelling technique as a self assessment exercise to evaluate the effectiveness of their current ISO 9001 quality management system and to generate ideas for improvements. A visit to another local manufacturing company that considered extending its current quality management system and getting ISO 9001 certified replied with the following comment:

> *"Thanks very much for coming up to see us and discussing the quality management system. I think your method could prove very useful and we will attempt to follow it through". (General Manager)*

Seven out of the nine reviewers responded with not being aware of other ways to link ISO 9001 to Fulfil Order Process models. One however pointed out that the original $IDEF_0$ could be used instead of using the proposed approach. However by using basic $IDEF_0$ only, the specific criteria set for modelling ISO 9001 in a Fulfil Order Process would not be addressed. The specific criteria are derived from the research question for this work and address the need to highlight the links of ISO 9000 to the activities of a Fulfil Order Process when doing redesign. Only the proposed version $IDEF_{9000}$ with its extended syntax and semantics addresses these criteria fully.

Another reviewer reported knowing another way to address the links between activities and ISO 9001 and referred to the use of a matrix correlating top level business activities to the 20 sections of the 1994 version of ISO 9001. The top level business activities which presented the organisation however did not follow the characteristics of a business process as defined in this research work. At the next level of detail these business activities were decomposed and mapped using simple ANSI-flowcharts. Unfortunately the approach at this stage did not include decomposing the ISO 9001 sections into individual requirements nor did the flowcharts refer back to the ISO standard anymore. To find out which section of ISO 9001 is relevant for an activity, the practitioner needed to follow a flowcharted activity back to its top level activity in the matrix which highlighted which section(s) of the standard is relevant. The reviewer commented that

> *"...$IDEF_{9000}$ addresses the problem of highlighting the links between ISO 9001 and a business process at any level of detail! It is a big advantage to use only one method of modelling - in this case the "box and arrow approach", rather than changing between matrix and flowcharts."*

9.3.3.1.5 Timeliness (questions 16 and 17)

This key need is of minor priority during the validation by review, as this stage was not concerned with whether the modelling technique was available to the reviewer to be used. Some of the practitioners answered these questions as non-applicable which are referred in the summary feedback sheet as *neither*. Others commented that with the new version of ISO 9001:2000, their existing ISO quality management system has become a current concern again with the priority being to carry out a redesign to comply with the ISO's latest update.

9.3.3.2 Review of the specific criteria set for the modelling technique (questions 18 to 31)

The review of the specific criteria for this modelling technique during stage one of this validation did not follow the actual use of the approach. Feedback from the reviewers therefore reflected only their perception about the subject based on their background knowledge and their interpretation of the proposed method of use. All questions about how well the proposed modelling technique addressed the specific criteria were either answered in favour or strongly in favour.

The questions 18, 19, 23, 29 in the summary feedback sheet which refer either to the identification of ISO 9001 controlled activities, information, resources or to show them at the desired level of detail were answered by the majority of the reviewers as strongly in favour. The proposed style for labelling ISO 9001 controlled information, objects, resources (questions 24, 25, 30) and the application of company specific description on the arrows (question 31) was perceived and agreed by the reviewers as not being too restrictive.

9.3.3.3 General comments (questions 32 and 33)

The ISO 9001 correlation matrix (Appendix 3) which is also part of the manual (Appendix 5) was regarded by the reviewers as a useful/very useful starting point to understand ISO 9001 requirements in a Fulfil Order environment. Some of the reviewers commented that a copy of the ISO 9001:2000 standard needed to be provided with the manual. This however would raise copyright issues with the International Organization for Standardization (ISO). It may be assumed that organisations that intend to design an ISO 9001 quality management system will be in possession of a current version of the standard.

A further comment was raised by one of the reviewers regarding potential links to requirements of other standards such as the environmental standard ISO 14001 or the BS 8800/OHSAS 18001 for occupational health and safety. This statement supports the validation of this research as it supports the practitioner's key need for *descriptive relevance* and opens up opportunities for discussions and future research. This matter is discussed in greater detail in Chapter 10.

One reviewer replied that

> *"...I would be happy to use $IDEF_{9000}$ had I a current concern in my organisation".*

9.4 Validation by use (stage two)

9.4.1 Validation approach for stage two

The objective of this validation stage was to establish whether the proposed modelling technique could be used as part of designing an ISO 9001 quality management system in a manufacturing organisation. *Validation by use* was carried out in two manufacturing companies (Cases C and D) that were on the point of implementing the ISO 9001 quality standard. Meredith (1998) suggests that the case study approach is highly appropriate where a small number of studies are being carried out.

In order to test whether the practitioner can successfully use the modelling technique and not the usefulness or experience of the researcher, direct involvement during the case study phase was minimised. The Quality Improvement Manager of Case C applied the modelling approach as part of their substantial efforts to establish the needs for an ISO 9001 quality management system and to subsequently introduce the standard. Apart from the initial introduction of the project that included a presentation of the modelling technique and the method of use, no further meetings were arranged until the Quality Improvement Manager had decided that the modelling was near to completion. This should ensure that all knowledge was derived from the use of the modelling technique and not from the researcher directly. During the final meetings the Quality Improvement Manager described how the modelling approach was used in the organisation.

The same arrangements were agreed with the Management team of Case D. An unforeseeable change in the Business Improvement Manager's role for six months did not allow him to carry on with the project as originally planned. It was therefore decided to present the conducted work and carry on doing the interview to capture his experience and comments on using the modelling technique before the project hand-over.

The main sources of evidence for collecting data for both case studies were documentation and interviews. Documentation, where available was used to support the comments made by the people involved in the case study. Yin (1994) refers to documentation as likely to be relevant in any case study topic. For this case study the process model of an ISO 9001 related Fulfil Order Process was significant and played a vital part in reviewing the usefulness of the modelling technique. During the final meetings semi-structured interviews were carried out. Easterby *et al.* (1991) classify this form of interviewing as an appropriate method in cases where it is useful to know about the background situation when studying the interviewee's opinion and perception about a subject. By asking open-ended questions it usually encourages the interviewees to elaborate on the questions asked and in doing so provides the researcher with additional information about the subject (Flick, 1998). The interviews were recorded to keep an accurate and complete version of the investigation.

To strengthen the validation of Case C the transcript of the interviews and associated findings were submitted to the Quality Improvement Manager, the Technical Director and the Managing Director. Their final approval can be described as a form of triangulation using different perspectives on the same phenomenon. In a similar manner the process model was approved within Case C. Each stage of modelling was facilitated by the Quality Improvement Manager and included the consensus of all parties involved. The Technical Director also approved the final version of the process model before the interviews were conducted.

For the same purpose as explained in the previous paragraph the transcript and findings from Case D were submitted to the team responsible for the design of the quality management system. The team consists of the General Manager, the Business Improvement Manager and a senior project engineer.

As the emphasis of the Testing Phase is to validate the proposed modelling technique a *within-case analysis* approach has been chosen followed by comparing the important findings of the two cases. According to Eisenhardt (1989) the *within-case analysis* allows a thorough understanding of the details studied giving the investigator a rich picture and contributing to the uniqueness of a case. Through the final comparison that discusses important similarities and differences in the findings of the two case studies the validation will be strengthened to avoid premature or false conclusions.

9.4.2 Case C

9.4.2.1 General background

The organisation, based in the UK, employs 140 people and manufactures a large number of products for a variety of customers. Its current situation is dictated by several issues and mainly affected by a slow down in the US market, the high exchange rate of the British currency to the Euro and increasing national competition. Competitors import partly manufactured goods of competitive quality from Asia and undercut current price structures. This forced Case C to implement improvements to compete in terms of quality and price of their products. A recent management decision launched a project to implement a process-oriented ISO 9001 quality management system to build a sound foundation to support product quality and to enable their manufacturing function to contribute in the long-term competitiveness and performance of the business.

Previous attempts to gain ISO 9001 within the organisation had been abandoned mainly due to limited allocated resources. As the majority of the working instructions and quality procedures were not always kept up to date the latest effort to implement ISO 9001 effectively meant starting all over again.

9.4.2.2 Use of the modelling technique

The Quality Improvement Manager was the main contact person responsible for designing and co-ordinating the work of developing the ISO 9001 quality management system. She acted as a facilitator for the quality improvement workshops and was appointed as the project leader for this detailed case study. In a three-hour meeting the objectives for this exhaustive project were finalised and a copy of the manual was presented to the Quality Improvement Manager. The manual *$IDEF_{9000}$ – A standard for modelling operating* *business processes with links to ISO 9001* included the improved and corrected version of the proposed modelling approach.

The Quality Improvement Manager organised and facilitated all workshops for mapping the Fulfil Order Process and interviewed the key personnel. An interdisciplinary team was formed and included personnel from the departments of engineering, sales, finance and stores, from operator up to senior management level. The approach adopted by Case C applied all aspects of the proposed modelling technique with regard to the design/redesign of a Fulfil Order Process as well as a detailed investigation of the company's activities to establish the links to ISO 9001. The project lasted over five months during which the team spent a considerable amount time modelling the Fulfil Order Process and studying each possible link to ISO 9001 in great detail. This comprehensive project can be split into the following three phases:

- Model the *as-is* Fulfil Order Process using $IDEF_0$ (Appendix 8);
- Complete the *as-is* process model with ISO 9001 showing relevant flows and activities by using the proposed $IDEF_{9000}$;
- Design an improved *to-be* Fulfil Order Process including the ISO 9001 links by using $IDEF_{9000}$ (Appendix 9).

Because of Case C's current situation only parts of its Fulfil Order Process were modelled in detail. However a complete A0 diagram of Case C's Fulfil Order Process ensured that neither the process itself nor any of its subsequent activities was seen in isolation. During the first phase the *as-is* process model was established which included all approved ISO 9001 related documents such as the quality procedures and work instructions that were already in use (Appendix 8). The result was a consensus between the Quality Improvement Manager and the interviewees about the activities and the flows of the process model.

The *as-is* process model was than complemented with links relevant to ISO 9001 that the team felt were required to comply with the current quality standard. Some of those links either had not been approved by senior management at the time of modelling or were not previously considered to be relevant. In these instances the ISO 9001 related flows were labelled in anticipation of the process model as no actual document number was available.

Finally Case C carried out a comprehensive redesign exercise of the detailed parts of the existing Fulfil Order Process applying all aspects of the proposed modelling approach where possible. This thorough redesign was based on the *as-is* process model that highlighted all ISO 9001 controlled flows and activities which the team needed to consider and evaluate before introducing changes. The *to-be* process model can be seen in Appendix 9.

9.4.2.3 Descriptive relevance

According to Case C the modelling approach enabled them to establish and show the links of ISO 9001 requirements on the activities of its Fulfil Order Process. It was regarded as important to see these links when redesigning this process. Furthermore the Quality Improvement Manager commented that using the modelling technique was useful as it made them aware of current gaps and shortcomings in the *as-is* version of its Fulfil Order Process with respect to the requirements of the quality standard.

Some of the shortcomings included missing quality procedures for controlling quality records, nonconformity or corrective actions. During the modelling process it also came to light that there were instances during which the manufacturing department was working to different versions of engineering drawings due to uncontrolled documentation. Furthermore Case C experienced problems during manufacturing with the quality of incoming goods. This could vary from incorrect specifications to wrongly delivered material as Case C did not have an inspection at goods inwards per se.

The team also realised that there were instances where pre-manufactured parts could be supplied to the main manufacturing process without an inspection being carried out. A defect in one of the pre-manufactured parts would only be noticed during the final machining operations on the product. This might lead to major implications for Case C by adding extra cost and lengthening operations and jeopardising on-time delivery to its customers. According to the Quality Improvement Manager, the problem became apparent during the detailed modelling, as one input could not originally be formatted according to the convention defined in $IDEF_{9000}$.

9.4.2.4 Goal relevance

The in-depth use of the modelling approach by Case C indicates that it can be used successfully to meet the goal of the practitioner supporting them in the design of a process-based quality management system. The Quality Improvement Manager pointed out that the *process approach* proposed by ISO 9001:2000 was not sufficient to explain a process model of a Fulfil Order Process. However the proposed modelling approach did help Case C to better understand ISO 9001 in a process context. Comments by the Quality Improvement Manager refer to the ISO 9001 correlation matrix as it explained which activities and flows of a Fulfil Order Process need to be considered to address the relevant ISO 9001 requirements. Another benefit that was reported as a result of using this modelling technique was the graphical presentation of the Fulfil Order Process and the distinction of ISO 9001 and non-ISO 9001 flows.

By using the modelling technique in the various aspects of business process re-engineering, ISO 9001 and the design of a quality management system, it also stimulated discussions about whether this approach could be applied to other business processes within the organisation.

The proposed modelling approach seemed to make a difference during the meticulous redesign phase. Activity A32 (Appendix 8) originally consisted of five subsequent activities and was reduced to only four by aggregating activities A323 and A324. During the stage where the *as-is* process model was extended with the relevant ISO 9001 links activity A323 was set as an activity controlled by ISO 9001.

The two activities were originally treated as separate due to the existing personnel not having faith in the new computer system and the preference for duplicated paper records. However this was perceived by Case C that this did not add value and the records were rarely consulted after the fact. It was therefore necessary to check whether the concerned activities and flows would still address the requirements of ISO 9001 after the aggregation using the actions as proposed in the manual. The *as-is* activity A323 (Appendix 8) turns into the *to-be* activity A313 (Appendix 9).

Several activities such as activity A31 and A32 (Appendix 8) in the *as-is* process model were relocated in the *to-be* process model to address the problem with supplying incorrect/non-inspected pre-manufactured material to the manufacturing department. The proposed redesigned activities were formatted according to $IDEF_{9000}$ conventions and the process model reflected visually that only material which has been inspected to a defined testing procedure would be passed on. According to Case C this will provide the following benefits:

- *Production paperwork* will remain in department PS where manufacturing dates can be constantly reviewed;
- Department PS has a better knowledge than the Engineering department about the condition of pre-manufactured material and if modification or new material is required;
- The ability to formalise and control an inspection of pre-manufactured material before issuing it to the manufacturing department as well as upgrading the responsibilities of department PS.

9.4.2.5 Operational validity

The Quality Improvement Manager was familiar with the $IDEF_0$ syntax and the requirements of ISO 9001 and experienced no difficulties in understanding the manual. She regarded background knowledge in both topics to be important for using the modelling approach.

Case C did not have an existing model of its Fulfil Order Process and therefore decided to invest some time to model the current situation in the first instance. This included incorporating the ISO 9001 relevant documents with which Case C already operated. In the next step this *as-is* process model was then extended with all other ISO 9001 links regarded as relevant. Even though this might have required them to work through the initial process model again and re-format activities and flows to the new $IDEF_{9000}$ convention, it was regarded as the easier and more purposeful option in Case C's situation.

Some difficulties in modelling the Fulfil Order Process were reported by the Quality Improvement Manager. One problem reported was due to the nature of Case C's manufacturing environment as they produce the majority of their products only once. This initially caused some confusion when mapping the activities and its flows. Furthermore the lack of discipline in complying with working procedures resulted in difficulties mapping a valid process model. Many of the manufacturing activities are labour-intensive and require a highly skilled workforce with years of hands-on experience and knowledge in this particular field. The workforce often does not follow a common approach and it was reported to be difficult at times to document the methods of *best practice*. Where activities of the Fulfil Order Process were satisfactory no difficulties were reported to extend it with the required ISO 9001 links.

9.4.2.6 Non-obviousness

Case C recently carried out a market research exercise evaluating software packages for supporting the design and documentation of its future ISO 9001 quality management system. According to the findings reported the majority of software packages focused on the documentation of the quality management system based on database solutions. Even though the more sophisticated versions supported a process-based approach the focus was on generating procedures and other documents and to provide facilities that automatically update all relevant quality documentation. The Quality Improvement Manager did report that none of the evaluated software solutions showed ISO 9001 related links to a Fulfil Order Process or used a systemic based approach such as $IDEF_0$ or similar. At the time of writing Case C had not decided on a software package for documenting its ISO 9001 quality management system.

The company would not have used this technique if it had not been presented by the researcher. Case C was pleased with the outcome of applying the modelling technique on parts of their Fulfil Order Process.

9.4.2.7 Timeliness

The modelling approach was developed during the period in which the International Organization for Standardization (ISO) updated its quality standard ISO 9000 to the latest release in 2000 (Chapter 3 and Chapter 6). Organisations have been given a three years transition period to update their quality management systems to this latest version. The modelling approach was available for Case C at the right time, as their current situation required them to implement a quality management system that enabled them to compete successfully and sustain position in the market in the coming years.

9.4.2.8 Specific criteria set for the modelling technique

9.4.2.8.1 Identification and distinction of ISO 9001 controlled activities and flows

General comments from the Quality Improvement Manager about $IDEF_{9000}$ and its enhanced syntax and semantics suggest that this modelling technique can be used as proposed. The conventions defined for $IDEF_{9000}$ are in line with the specific criteria set for this modelling technique. It can therefore be argued that the specific criteria were successfully addressed.

The Quality Improvement Manager regarded the extended syntax of $IDEF_{9000}$ as

> *"simple ... and the graphical distinction of arrows controlled by ISO 9001 useful when reviewing the process model."*

Especially during the thorough redesign phase Case C benefited from the visual distinction between ISO 9001 controlled and uncontrolled activities and flows. Here, the graphical identification of what should be highlighted as ISO 9001 relevant made the Quality Improvement Manager aware that numerous flows and activities had to be considered for special attention. Examples included where input arrows such as *raw material* were changed to *inspected material* or *record sheets* formalised and identified with a unique document number. Apart from changing the appearance to the $IDEF_{9000}$ convention it also made Case C more conscious to make arrangements about testing procedures, how to identify material and other goods and to label an inspection status.

By taking a systemic viewpoint for the Fulfil Order Process the Quality Improvement Manager commented that the system's boundaries clarified which parts of the ISO 9001 needed considerations within the operating part of the business. The systems view taken to address the ISO 9001 requirements within a Fulfil Order Process allowed the team to focus on one part of the business and by being systemic it also allowed them to address links referring to ISO 9001 relevant parts outside the Fulfil Order Process boundaries.

9.4.2.8.2 Use of individual labelling and document numbering convention

At the time of using the modelling approach Case C had some of its ISO 9001 documents only in draft form. These forms and procedures did not have an approved document status and were included in the process model in anticipation of a new proposed numbering system. This however did not hinder the mapping of the *to-be* process model. Feedback about $IDEF_{9000}$ was not found as restrictive for labelling activities and flows controlled by ISO 9001.

9.4.2.8.3 Decomposition and branching of ISO 9001 related activities and information

The Quality Improvement Manager did not report any problems with decomposing activities and identifying the ones which were controlled by ISO 9001. In fact it was regarded as a worthwhile exercise to check activities and their subsequent activities for consistency in ISO 9001 terms. During the interviews it was also mentioned that *the number of black boxes* might be seen as an indicator to what extent the activities of a Fulfil Order Process are controlled or constrained by the quality standard.

In order to keep the diagrams of the process model simple and to avoid potential clutter Case C bundled and branched flows where possible. The process model also shows a version of $IDEF_0$'s *to all* and *from all* conventions on flows which apply identically to every activity on a diagram or is obtained identically from every activity respectively. It was considered by the Quality Improvement Manager as imperative to make use of such a rule as otherwise the number of arrows could cause confusion.

9.4.2.9 General comments

Overall Case C found the use of this modelling technique as part of designing a quality management system to be beneficial. This also included the redesign exercise on parts of the Fulfil Order Process. The Quality Improvement Manager commented that

> *"I will continue using the modelling approach $IDEF_{9000}$ within Case C. Should I move on to another organisation I will recommend the modelling approach where appropriate."*

The Quality Improvement Manager suggested that, from a project management point of view and from her personal experience in the field, this type of project needs to be a team exercise and requires a great deal of team effort. Case C's current situation and the limited allocation of resources for the project might have prevented them gaining even more from modelling with $IDEF_{9000}$.

A good knowledge of the ISO 9001 quality standard was also perceived by the Quality Improvement Manager as important when modelling with $IDEF_{9000}$. There were occasions during the detailed project work where some expert advice and different perceptions of the quality standard would have been of value.

9.4.3 Case D

9.4.3.1 General background

The 1986 founded company is based in the UK and offers their services of design, manufacture and installation of systems and products in stainless steel to a mainly national clientele. Their customers are among the major blue-chip companies in the pharmaceutical, electronic, food and brewing industries. With the focus on professionalism and delivering high quality solutions Case D only employs full time staff with a 12 months training plan in place for every new employee.

Case D did not feel any pressure from their customers to be registered to the ISO 9001 quality standard but had decided to implement the quality standard to show their full commitment to quality to their customers. In order to provide the highest quality Case D complies already with numerous industry standards, welder codings and health and safety regulations. The Business Improvement Manager described the existing approach for assuring quality as very good but uncontrolled in terms of generating written confirmation or other documentation in terms of traceability. A recent incident however was not detected by the existing procedures and resulted in shipping a non-conforming product to a customer with very strict safety specifications. The following customer complaint led to a prompt containment action and accelerated Case D's intention to implement an ISO 9001 quality management system.

9.4.3.2 Use of the modelling technique

A team of three senior members of staff including the General Manager accepted responsibility for the design of the ISO 9001 quality management system within Case D. The Business Improvement Manager was appointed with the role of the facilitator for the business process modelling and its documentation. Similar to the first validation case study an initial three-hour meeting was arranged between the team and the researcher during which the objectives and expectations of both parties were discussed and finalised. A copy of the manual *$IDEF_{9000}$ – A standard for modelling operating business processes with links to ISO 9001* was passed on to Case D at the end of this meeting.

During a period of 3 months the Business Improvement Manager organised and facilitated all workshops for mapping the Fulfil Order Process. The approach adopted by Case D applied all aspects of the proposed modelling technique regarding the design of a Fulfil Order Process together with a detailed assessment of the company's business activities to establish the links to ISO 9001. With the change of responsibility of the Business Improvement Manager's role as explained in Section 9.4.1. Case D has not completed the full *as-is* process model and therefore did not use the approach during a redesign stage. However the dedicated team used a thorough approach which is split into the following two phases:

- Model the *as-is* Fulfil Order Process using $IDEF_0$;

- Complete the *as-is* process model with ISO 9001 showing relevant flows and activities by using the proposed $IDEF_{9000}$ (Appendix 10).

Case D had experimented with modelling activities using the $IDEF_0$ methodology before the actual start of the project. They reported some difficulties with arranging the activities and defining an overall structure of a process model during the initial meeting. It led to the recommendation to consider the CIM-OSA standard as described in the manual *$IDEF_{9000}$ – A standard for modelling operating business processes with links to ISO 9001* and focus initially on modelling a Fulfil Order Process.

The *as-is* model of the basic Fulfil Order Process was modelled first taking a systemic perspective to avoid a reductionist view of individual parts of the business. This was followed by highlighting all activities and flows which are related to ISO 9001. The approach taken by the Business Improvement Manager was to study each section of the standard and to relate each requirement to the diagrams of the process model. Where required the new, and those considered to be relevant, links in terms of an ISO 9001 requirement were introduced to the process model. All existing forms and procedures to assure quality within Case D were updated as they were not numbered nor did they include the status of controlled documents. The *as-is* process model can be seen in Appendix 10.

9.4.3.3 Descriptive relevance

Prior to this project Case D attempted to use ANSI-flowcharts to map activities as well as company procedures and instructions leading to the conviction that this particular method did not allow them to display enough information. The use of $IDEF_{9000}$ made them realise that a proper modelling technique for mapping activities and highlighting the ISO 9001 links was required. This comment was made on the recognition that it is important to see links controlled by ISO 9001 during the design of a business process.

Furthermore the use of $IDEF_{9000}$ addressed issues of Case D by understanding the requirements of ISO 9001 and *translating/correlating* them to the activities of the business. With very little experience of the ISO 9001 standard prior to this project the Business Improvement Manager responded that from just reading through the standard it was not obvious to him which areas in the business the standard refers to. The use of $IDEF_{9000}$ addressed these issues by taking an *activity view* of the business, together with the identification of activities and flows controlled by ISO 9001 which enabled Case D to *translate* and *correlate* the ISO 9001 requirements to their case.

9.4.3.4 Goal relevance

In the previous section the proposed modelling technique $IDEF_{9000}$ was assessed against its ability to address problems encountered by Case D during the design of a process-based quality management system. The difficulties Case D experienced with interpreting and applying the requirements of the standard also refers to this section as Case D regarded the ISO 9001 standard as being of little help when trying to understand the ISO requirements from a process viewpoint with relevance to a Fulfil Order Process. The Business Improvement Manager commented that

> *"... by reading through ISO 9001 the standard did not seem to flow naturally through a business system such as ours. Together with the use of* $IDEF_{9000}$ *however it did all come together! When using* $IDEF_{9000}$ *it was, for example, easy to identify the checks which need to be introduced throughout the different stages of the Fulfil Order Process to comply with the standard."*

Another benefit reported by Case D is the amount of information as well as its clarity which can be displayed on the process diagrams when modelling with $IDEF_{9000}$. This benefit relates in one respect to the original $IDEF_0$ technique and its use of arrows as *inputs, controls, outputs* and *mechanisms*. It also relates to the proposed $IDEF_{9000}$ version with its graphical differentiation between those activities and flows that are controlled by ISO 9001 and those that are uncontrolled.

Case D also reported that the use of $IDEF_{9000}$ generated new ideas to improve the current approach for identifying and fully understanding all customer requirements before submitting a tender. The changes resulted in improved control mechanisms and the documentation of critical information which supported the company policy of fully accomplishing the agreed contract without adding extra costs for services required but not included in the contract or which they might be forced to provide free of charge. Furthermore the modelling with $IDEF_{9000}$ made the team realise there was a lack of control and authority when approving the final product inspection and led to the introduction of *sign off sheets* for documenting the dimensions and specifications to ensure the orders are built to drawing.

Case D's major endeavour is to design an ISO 9001 quality management system which does not put any extra burden on the existing business or obstructs the flexibility to meet orders in ways that fully satisfy all customer requirements. They are striving to design and fully integrate the ISO 9001 requirements in the activities of the existing business. The General Manager who will take over the leading role in this project replied that

> *"The instruction manual which we developed with $IDEF_{9000}$ is a very good idea for the business and gives us 100% support to what we want to achieve."*

9.4.3.5 Operational validity

Even though the Business Improvement Manager had only limited knowledge about ISO 9001 prior to the start of this project he did not report difficulties in using the proposed modelling technique. After studying the requirements of ISO 9001 for some time it did not take him long to become familiar with the $IDEF_{9000}$ manual, which was reported as being easy to understand and a useful resource to the team throughout the entire modelling process. The proposed modelling technique $IDEF_{9000}$ offered, according to the Business Improvement Manager, a *fairly simple* syntax and semantics and provided a straightforward way to identify activities and arrows which are controlled by ISO 9001. The team started by modelling their basic Fulfil Order Process and followed this by extending the diagrams with what they thought of being the relevant ISO 9001 links for their business. They then reformatted it to the conventions of $IDEF_{9000}$. According to the Business Improvement Manager they experienced no difficulties in applying $IDEF_{9000}$.

However during the initial stages of modelling with standard $IDEF_0$ some problems were reported particularly with the identification of flows and their definition. For example, during several meetings a discussion arose whether *management* should be displayed in the process diagrams as a *control* or a *mechanism* arrow. This however was recognised by the team as being due to its own inexperience in the domain of functional modelling which was resolved by spending more time on mapping business processes. The team also decided to reduce confusion with the number of arrows displayed in the $IDEF_0$ diagrams through the use of different colours for the flows to make the links easier to follow. From the researcher's viewpoint however the "obvious" solution of using colours to simplify the diagrams only complicates the syntax and semantics of both $IDEF_0$ and $IDEF_{9000}$. In the process diagram A0 in Appendix 10 Case D used different colours to identify *output* arrows which leave A0 (green arrow) compared to the pink *output* arrows which turn into *inputs* and *controls* at one of the subsequent activities on the same diagram. The green *output* arrows however turn into pale blue *input* arrows in the following diagrams. In terms of consistency for the modelling technique it would require an extra rule that specifies when the colour of the arrows needs to be changed. To add further complexity the different coloured arrows could be either thin (not related to ISO 9001) or thick (related to ISO 9001).

A final reason for not using different colours has already been discussed in Chapter 8 for reasons of monochrome reproduction. It proved valid when the Business Improvement Manager sent the latest version of the $IDEF_{9000}$ process model by fax to the researcher for evaluation purposes before the actual interviews. The different shades of grey on the black and white faxed copy did not allow clear identification of differences and made it very difficult to read. The researcher fully acknowledges Case D's way of simplifying the process models but decided, based on the reasons above, not to adopt and amend the proposed $IDEF_{9000}$ rules. Case D ultimately agreed with the black and white notation.

9.4.3.6 Non-obviousness

According to the General Manager Case D originally considered hiring a quality consultant at an early stage of the project to support their objective of fully integrating the ISO 9001 quality standard into their business. After modelling with $IDEF_{9000}$ over the three months period the team felt confident that they can also model business processes other than the Fulfil Order Process and are committed to model their entire business with $IDEF_{9000}$. While Case D experimented with $IDEF_0$ in the preliminary stages of designing a process-based ISO 9001 quality management system they never considered the inclusion of the requirements of the ISO 9001 standard in the process model. According to the General Manager and the Business Improvement Manager, the use of $IDEF_{9000}$ made a difference in the way the quality management system will now be designed and the impact it will have on the business.

The company's view on hiring external help is now limited to consulting an expert at the end of this project to carry out a final audit. This should give Case D peace of mind when preparing for the certification.

9.4.3.7 Timeliness

$IDEF_{9000}$ was readily available to Case D at the time when they decided to implement a process-based ISO 9001 quality management system. The need to improve the current mechanisms of quality control and quality assurance in their business came after a quality failure during their manufacturing that led to the delivery of a non-conforming product to a customer.

9.4.3.8 Specific criteria set for the modelling technique

As described in Section 9.4.3.5 which discussed *operational validity,* Case D responded that $IDEF_{9000}$ offers a fairly simple syntax and semantics for identifying the links controlled by ISO 9001 in a process model with ease of use. Using $IDEF_{9000}$

> *"helped very much and ensured to improve consistency in our actions of quality control and quality assurance. Modelling with $IDEF_{9000}$ was beneficial to see where ISO 9001 takes effect on our business." (Business Improvement Manager, Case D)*

The comments of Case C in Section 9.4.2.8, in relation to $IDEF_{9000}$ offering a simple convention, were echoed in this case. It can be argued that the specific criteria set for

$IDEF_{9000}$ in this case study were also successfully addressed which strengthen the overall validation of the modelling approach and give confidence that it can be used as proposed.

Case D did not use a document numbering system for their existing procedures or forms. The introduction of a new way for identifying controlled documents and using individual labels were not restrained by modelling with $IDEF_{9000}$ and the modelling technique was therefore regarded as generally applicable and compatible to their company specific conventions.

9.4.3.9 General comments

The team realised that a process model cannot be created without knowing the entire business well. A lack of knowledge in some areas delayed the modelling process and required postponing some of the workshops until a thorough understanding of the particular field could be gained. This however has been seen in hindsight as a worthwhile learning experience for the individuals and has been reported as beneficial to the design of the ISO 9001 quality management system. In summary Case D considered the application of the proposed modelling technique as being very useful especially considering their limited knowledge of ISO 9001 at the beginning of the project. This has been confirmed in writing in a letter approving the transcript of the interview that included the following quote:

> *"It has been a very worthwhile exercise using your ideas on our business practices and we can see great benefits for the future use of your techniques for modelling procedures for ISO 9000". (General Manager, Case D)*

The General Manager of Case D raised the question whether a "light" (abbreviated) version of $IDEF_{9000}$ could address the company's objective of producing a user-friendly *instruction manual* in pocket form. It is the intention of Case D to provide every new employee who joins the organisation with such a manual and support her/him to quickly gather a good understanding about the organisation and recognise her/his individual role within the business. Current concerns discussed within Case D are whether every member of the company should be familiar with $IDEF_0$ or $IDEF_{9000}$ as the process model might be too comprehensive for employees with little exposure to that kind of thinking.

To support the design of a process-based ISO 9001 quality management system however,

> *"...$IDEF_{9000}$ is a very good tool for our business." (General Manager, Case D)*

9.5 Important similarities and differences between the findings of Cases C and D

Both cases set off with a similar objective for the implementation of an ISO 9001 quality management system. This was to design a process-based quality management system which allows to the requirements of ISO 9001 to be fully integrated in order to support and strengthen their efforts to continuously improve the quality of their processes, products and services.

9.5.1 Background knowledge in ISO 9001 and $IDEF_0$

In terms of experience with ISO 9001 the two cases were very different. The Quality Improvement Manager of Case C went on various courses in the domain of quality management/quality assurance and regarded herself familiar with the requirements of ISO 9001 having composed procedures and drafted quality documentation in the past. Case D however can be seen at the other end of the continuum with the Business Improvement Manager having little experience with ISO 9001 prior to the start of this project. While Case C would have appreciated some expert advice on ISO 9001 topics Case D felt confident with the standard after spending some time studying its requirements and applying it by using $IDEF_{9000}$.

Both case companies were familiar with the $IDEF_0$ methodology. Case C reported some difficulties with modelling the basic Fulfil Order Process due to the manufacturing environment and the lack of discipline necessary to acknowledge procedures and instructions. After completing the modelling of the Fulfil Order Process Case C stated that using the $IDEF_{9000}$ convention was easy. Similarly Case D commented that the lack of knowledge in some areas of the business prolonged the modelling process and that initial problems with $IDEF_0$ led to the uncertainty when identifying the correct type of arrows. However they resolved the problem by getting more experience with the modelling technique.

With the benefits reported by both cases when modelling with $IDEF_{9000}$, it can be argued that the recommendation given in the manual *$IDEF_{9000}$ – A standard for modelling operating business processes with links to ISO 9001* that some knowledge of ISO 9001 and $IDEF_0$ is required is sufficient.

9.5.2 Use of the modelling technique

Both case companies modelled their basic Fulfil Order Process before extending the activities and flows with the relevant ISO 9001 requirements. Neither of the two case companies had a formally modelled version of their Fulfil Order Process. Both regarded it to be easier to begin the modelling with an *as-is* version of the business. Case C has already progressed with the next phase and redesigned an improved *to-be* Fulfil Order Process which includes the links to ISO 9001 while Case D is currently completing their *as-is* process with the identification of flows and activities controlled by ISO 9001.

In summary, both cases benefited from realising what extra requirements are needed in terms of ISO 9001 when modelling with $IDEF_{9000}$. This was seen as being very important as the ISO 9001 standard was regarded as not very helpful when trying to understand the requirements from a process context. Also it did not give the case companies helpful advice on how to model a business process and establish the ISO 9001 links. With a process model developed by $IDEF_{9000}$ Case D reported that it was good to see where ISO 9001 has effects on the business and Case C added that the visual distinction between ISO 9001 controlled and uncontrolled items was beneficial during their redesign exercise.

For both cases, documenting the process models used software packages (Microsoft Visio, Autodesk AutoCAD) readily available in their organisations. Case C applied the convention of $IDEF_0$ and $IDEF_{9000}$ very thoroughly and made extensive use of a version of $IDEF_0$'s *to all* and *from all* conventions in order to cut down the number of arrows in the process model. Case D also used the convention of $IDEF_{9000}$ and introduced different colours to more easily trace individual flows. Both cases found the proposed convention appropriate and not restrictive to their own company specific circumstances.

9.6 Conclusion

The modelling technique and its use have been validated using the five key needs of practitioners. The feedback during the validation suggests that these key needs have been addressed and hence the objectives of the research work have been achieved.

During stage one the reviewers responded that this modelling technique could be used as part of the design of an ISO 9001 quality management system. The modelling technique and its method of use were regarded as meaningful and easy to understand. Both manufacturing companies Cases C and D in stage two found the modelling technique easy to use and beneficial to their objectives of achieving a better understanding of ISO 9001 in a process context. The modelling approach was also seen as useful in identifying and highlighting the links between ISO 9001 requirements and the activities of a business process. Following this approach the links become apparent during redesign pointing out potential constraints. The two case companies found this approach to be non-obvious and available to them at the right time.

Valuable comments regarding project management issues were given by Case C at the end of stage two. These need to be addressed by those who decide to carry out improvement projects of a similar kind applying the proposed $IDEF_{9000}$ modelling technique. The issues reported namely working with a good interdisciplinary team is however beyond the scope of this research work.

The validation results do suggest that the findings can be generalised to all those practitioners in a similar situation to the case companies. The results from both cases show that the modelling approach and its extended application were useful to them and may therefore be useful to other companies. This however would only include companies that regard it to be important to identify the links of ISO 9001 to their business processes and are concerned about these links, their meanings and potential constraints during redesign. To those who do not share this understanding the application of this modelling approach might not be useful and might not address their key needs.

9.7 Overall summary

This chapter has described the validation approach that was split into *validation by review* (stage one) and *validation by use* (stage two). During stage one the concept and method of use of the modelling technique has been reviewed and validated by practitioners. Both the modelling technique and its intended method of use were found useful and easy to understand meeting the five key needs of practitioners. Comments and suggestions from the reviewers were incorporated in an improved version of the modelling technique called $IDEF_{9000}$.

During stage two $IDEF_{9000}$ has been used successfully in two manufacturing companies. In a detailed first case study at Case C the modelling technique was used extensively during the design and redesign stage of a Fulfil Order Process. The use of the modelling technique allowed Case C to model its Fulfil Order Process and to identify the links of ISO 9001 within its fulfil order environment. The established links resulted in an improved understanding of ISO 9001 in a process context according to the Quality Improvement Manager and highlighted potential constraints that needed to be addressed with caution during a redesign in order to maintain compliance with the quality standard. A second manufacturing company used the $IDEF_{9000}$ approach during the design of their ISO 9001 quality management system and regarded $IDEF_{9000}$ as beneficial in identifying where ISO 9001 takes effect on their business. It was perceived as a useful tool to improve the consistency in Case D's actions in terms of quality control and quality assurance. They decided to model the entire business using $IDEF_{9000}$.

10 Conclusions

This work has identified a set of criteria for a modelling technique to highlight the links of ISO 9001 to an organisation's Fulfil Order Process and to design parts of a process-based ISO 9001 quality management system. A process-based modelling technique was developed together with a set of guidelines as to how it could be used. The concept of the proposed approach and its method of use have been validated by practitioners by review and by use. Both stages of the validation addressed the five key needs of practitioners described in Section 2.2 and the specific set of criteria described in Section 6.3.

This chapter summarises the work carried out, verifies the validity of the modelling technique and describes the research work's contribution to knowledge.

10.1 Research methodology

A three-phase research cycle starting with Description followed by Explanation and Testing was used during this research work which led to many iterations between all the phases of this research. The research methodology provided a suitable structure and guidance throughout this research to meet the key needs of practitioners and lead to the contribution of new knowledge.

The Description Phase of the research cycle presented in Chapter 3 stated a problem definition of the phenomenon under study. It included a summary of the researcher's pre-understanding of the subject including his working experience. This preliminary descriptive research incorporated a literature survey from the viewpoint of quality management and the use of case study research.

During the first part of the Explanation Phase a second literature survey concentrated on the domain of business processes. It incorporated a critical evaluation of current approaches and solutions, identifying gaps when designing an ISO 9001 quality management system. The use of Action Research at this stage allowed the researcher to be closely involved with a project to design an activity-based ISO 9001 quality management system. This phase continued with the identification of two sets of criteria based on the information obtained during both phases. It was followed by an investigation as to how the criteria could be met. The outcome of the Explanation Phase was a modelling technique for modelling business processes together with a proposed method of use.

The Testing Phase of this research approach presented in Chapter 9 explained the two-stage validation of the modelling technique and a proposal for how it could be used. Stage one included the *validation by review* and was concerned with reviewing the concept and the method of use of the proposed modelling technique by practitioners. The *validation by use,* during stage two, tested the proposed modelling technique in two manufacturing companies. During the case study the researcher remained separate to ensure that the interference from knowledge derived during the validation phase was minimised. This two-stage approach allowed the modelling approach to be reviewed and, where required, to be improved, before proceeding with stage two.

10.2 Research problem

The research problem developed from personal knowledge and practical experience in the field of quality management that revealed the difficulties organisations face when designing quality management systems and implementing the quality standard ISO 9001. A first conclusion from the quality management system's literature revealed that simply documenting what an organisation does in response to ISO 9001 is still one of the most common approaches adopted. This is the result of limited guidance on how to integrate the requirements of the standard into the business processes of the organisation. Such systems often lead to extra bureaucracy in the business and their design often achieves a process-oriented character only at the documentation stage. The usefulness of a process-oriented business is often recognised but the approaches available to achieve it fail to take a systemic view of the business and the quality management system. These initial stages of the research highlighted that business processes can improve through the integration of ISO 9001 requirements to establish a responsive quality management system. The knowledge and understanding gained during this part of the research led to the following conclusion

That during the design/redesign of business processes approaches do not provide for a systemic consideration of process-based quality management systems and do not establish the links to the requirements of ISO 9001.

This conclusion stimulated further research work which sought to investigate business processes taking into account the requirements of ISO 9001. It led to the following research question:

How can a process model be best drawn to establish links between business processes and ISO 9001?

To address concerns about managing production activities and in particular fulfilling orders, this research work concentrated on the development of an improved process modelling approach. To support the research question the following was needed:

- to define a business process, in particular a Fulfil Order Process, and to describe it from a systems viewpoint;
- to identify and characterise the requirements of the quality standard ISO 9001:2000;

- to develop a set of criteria which need to be addressed by an appropriate modelling technique to model a business process to show the links to ISO 9001:2000.

The primary knowledge domains which addressed the three issues were discussed in Chapters 4, 5, and 6. These chapters build the foundation knowledge of the domains of business processes, the fundamentals of systems theory and the Fulfil Order Process in general with a particular focus on the requirements of ISO 9001.

10.2.1 Fundamental knowledge

Chapter 4 introduced the most common elements and characteristics of a business process within an organisation. They can be summarised as a set of activities which will transform inputs into outputs by using the necessary resources to fulfil a specific customer requirement. A business process flows horizontally across departmental boundaries and starts and finishes with the customer. This was followed by an introduction to systems theory, explaining the different classification of systems together with some important systems ideas and various views of a system. The concept of systems thinking has been adopted to explain a business process. As a business process is about performing activities to achieve defined goals this research describes a business process as a Human Activity System.

Chapter 5 discussed the Fulfil Order Process in detail from a systemic view and explained it by using the systems parameters *source, input, process, transformation, output, receiver* and *feedback*. It shows that a Fulfil Order Process is concerned with transforming inputs to desired outputs by performing a set of events or activities which can be altered to achieve the transformation of inputs. An overview of the principles of business process re-engineering for modelling a Fulfil Order Process was also discussed. This formed the foundation for identifying a set of criteria for a modelling technique which need to be addressed to draw a process model of a Fulfil Order Process. An appropriate modelling technique would need to address the systems parameters of a Fulfil Order Process as described and show the business process from a function or activity view. The full description of these criteria is given in Chapter 5.

Chapter 6 developed an understanding of the relevance and applicability of ISO 9001 requirements within a Fulfil Order Process. Each requirement of the standard was classified as *directly relevant, relevant,* or *not relevant* for a Fulfil Order Process and was also described by using the systems parameters. The work in this chapter showed that the relevant requirements of ISO 9001 need to be modelled as activities, information and its flow, similarly to the needs defined for a basic Fulfil Order Process. In order to address the research question, a second set of criteria for an appropriate modelling technique was developed and was discussed in Chapter 6. This extended the first set of criteria by incorporating the identification of ISO 9001 controlled activities, information and flows.

10.2.2 Evaluation of current process modelling techniques

The evaluation of the most common process modelling techniques in Chapter 7 was based on the two sets of criteria as identified in Chapter 5 and 6. The first part of the review assessed the approaches as to how well they address the criteria for modelling a basic Fulfil Order Process. This was followed by a second review of the selected modelling techniques to evaluate their ability to fulfil the criteria defined as being necessary to identify ISO 9001 controls in a fulfil order environment.

The first review revealed that the majority of the modelling techniques address the criteria for ease of use and a common language for communication fairly well. All of them were considered to require some degree of experience and basic knowledge to produce a useful model of a business process. These diagrammatic techniques often adopt a simple syntax and semantics based on a semiformal language using graphical symbols and specific rules. What becomes apparent though is that a simple or inconsistent set of rules, as identified in some of the approaches evaluated, might permit the designer of a model to develop a personalised syntax. This can make communication difficult due to different interpretations of the model. Furthermore a number of approaches do not have the means to show all the required systems parameters. The systems parameters are a key element in the evaluation process as the Fulfil Order Process was discussed from a systems viewpoint. All those modelling approaches where syntactical limitations did not support the systems parameters were excluded from further assessment.

The three modelling techniques which satisfied the first set of criteria well and were considered for the second evaluation were HIPO Charts, the Use Case approach and $IDEF_0$. None of the three approaches however fully supported, in their original form, the need to show the links to ISO 9001. The selection at the end of this evaluation was based on how easily and straightforwardly the syntax and semantics of each approach could be adapted. Based on this comparison and the assessment of the techniques given in Chapter 7, $IDEF_0$ was chosen as the most promising approach for enhancing its syntax and semantics to address the required criteria.

10.2.3 A modelling approach for modelling a Fulfil Order Process and highlighting the links to ISO 9001

Chapter 8 described the principles of an enhanced version of the modelling technique $IDEF_0$ together with its method of use. This enhanced version, called $IDEF_{9000}$, reflects in its name the emphasis on identifying ISO 9000 constraints in the design of a business process model. With the extended syntax and semantics of $IDEF_{9000}$ the modeller can graphically identify all activities and flows (inputs, controls, outputs and mechanisms) which are controlled by ISO 9001 at all levels of detail in a process model. $IDEF_{9000}$ benefits from the $IDEF_0$ facility to take a systemic view of a business process. The enhancements in $IDEF_{9000}$ and its method of use should be seen as an addition to the existing $IDEF_0$ methodology.

The application of $IDEF_{9000}$ is intended for both types of organisations, those which are already ISO 9001 registered and those which intend to introduce this quality standard in the future. ISO 9001 registered organisations that have not previously mapped their business processes should develop both their Fulfil Order Process and the links to ISO 9001 at the same time to avoid potential rework. Organisations with the intention of using this modelling technique when originally implementing this quality standard should start to model their Fulfil Order Process first. In a second step they would, where required, reformat existing flows according to the convention of $IDEF_{9000}$ and identify them as flows controlled by ISO 9001 or complement the process model with the newly identified ISO 9001 links.

To support the use of $IDEF_{9000}$, organisations (especially those without expert knowledge of ISO 9001) can consult a list of common flows controlled by ISO 9001 in a fulfil order environment as shown in Figure 8.3. Furthermore a set of guidelines for redesigning a Fulfil Order Process was discussed which placed the emphasis on assessing existing or amended activities and flows controlled by ISO 9001 for compliance to the quality standard. During a redesign the process model should be checked as to whether activities and flows are needed, and whether activities can be relocated, aggregated or performed in parallel with the focus being on maintaining compliance to ISO 9001.

Chapter 9 described the Testing Phase of this research approach. Feedback, given at the end of this stage suggested that the five key needs of practitioners were met together with the additional criteria developed for modelling a Fulfil Order Process and identifying the links to ISO 9001. Both $IDEF_{9000}$ and its intended method of use were found useful and easy to understand with the response of reviewers being that $IDEF_{9000}$ could be used as part of the design of an ISO 9001 quality management system.

During the *validation by use* (stage two), the use of the modelling approach was validated in two manufacturing companies. $IDEF_{9000}$ was found to be easy to use and beneficial in achieving the case companies' objective of a better understanding of ISO 9001 in a process context. The modelling approach was used in Case C to design a current version of the company's Fulfil Order Process that included some of the links to ISO 9001. During the next phases of this case study the *as-is* process model was complemented with all activities and flows required by ISO 9001 and formatted according to the conventions of $IDEF_{9000}$. The modelling approach was seen as useful in identifying and highlighting the links between ISO 9001 requirements and the activities of the business process especially during the redesign stage of the *as-is* process model. It highlighted potential constraints that required special attention and which needed to be addressed with caution to gain/maintain compliance to the quality standard.

Case D started with little knowledge of ISO 9001 and established a model of its Fulfil Order Process. After spending some time to familiarise themselves with the requirements of ISO 9001 Case D introduced activities and flows which they thought of as being relevant to comply to ISO 9001 and identified them according to the convention of $IDEF_{9000}$. Case D regarded the use of $IDEF_{9000}$ as very useful as it was beneficial to see where ISO 9001 takes effect on the business and helped to improve Case D's efforts in quality assurance and quality control.

The use of $IDEF_{9000}$ during the detailed case studies has proved successful in two companies. Based on the two-stage validation approach it can be concluded that the modelling approach $IDEF_{9000}$ can be applied as proposed. It can be used as part of the design of a quality management system as it enables the practitioners to establish the links of ISO 9001 in a Fulfil Order Process and highlights ISO 9001 constraints during the stages of redesign.

10.3 Contribution to knowledge

The contribution to knowledge of this research derived from literature and practical experience in the domains of business process design, systems theory and ISO 9001 quality management systems. A first contribution to knowledge has been the identification of a need to take a systemic view on business processes when designing/redesigning a process-based ISO 9001 quality management system. This led to the identification of criteria which a modelling technique needs to address when being used to model a Fulfil Order Process. These criteria were discussed in detail in Chapter 5 and are summarised here:

- Easy to use, common language for communication;
- Simple syntax and semantics;
- The identification of a systems hierarchy for activities and information;
- A means to define the whole system including its boundaries and the overall goals;
- The description of a process in terms of systems parameters.

The second contribution to knowledge has been the identification of links between ISO 9001 requirements and a Fulfil Order Process from a systems viewpoint as discussed in

Chapter 6 and shown in Appendix 3. This led to the development of criteria which a modelling technique needs to address when being used to model a Fulfil Order Process showing the links to ISO 9001. These criteria were discussed in detail in Chapter 6 and summarised here:

- To show activities and clearly identify the ones which are controlled by the ISO 9001:2000 quality standard;
- To identify and distinguish information and objects that are linked to a requirement of ISO 9001:2000 from those that are not;
- To show information and the flow of information;
- To show information as different types of input (control inputs, object inputs and resource inputs) to an activity;
- To decompose activities and information and to describe a process hierarchy;
- To set system boundaries in order to identify any source or receiver within the quality management system or with external stakeholders related to ISO 9001:2000 inputs or outputs;
- To show resources that are required by the activity and to identify the ones that are linked to the standard;
- To identify all relevant elements within a Fulfil Order Process using a document numbering convention or other form of unique labelling system.

The proposed modelling technique $IDEF_{9000}$ presented in Chapter 8 fulfils both sets of the previously identified criteria. This modelling approach and its method of use have been validated through practitioner review and a case study approach. It currently stands as the only modelling approach that fulfils the identified criteria and permits the design or redesign of a Fulfil Order Process systemically while establishing the links to the ISO 9001 quality standard.

$IDEF_{9000}$ takes a systems view of a Fulfil Order Process and allows the modelling of functions (activities, operations and processes), their functional relationships and data (information or objects). Developed from the original $IDEF_0$ modelling technique, $IDEF_{9000}$ uses an extended syntax and semantics to graphically identify the links to the ISO 9001 quality standard and visually highlights them for redesign. $IDEF_{9000}$ also includes a method of use, common links between ISO 9001 requirements and a Fulfil Order Process and a set of guidelines to follow during a redesign to maintain compliance to the standard.

Before this work, companies could not design a process model of a Fulfil Order Process systemically and identify the activities and flows that were controlled by ISO 9001. Existing ways of the process modelling did not support companies or make them aware which part of the business process might require special attention during the redesign because of ISO 9001 constraints.

This work has given the new knowledge needed about how to model a Fulfil Order Process from a systemic perspective and to identify the activities and flows which are controlled by ISO 9001. The identification of activities and flows controlled by ISO 9001 indicates where to take special consideration during the design of an ISO 9001 quality management system or a redesign exercise of a Fulfil Order Process. This work has developed and tested a modelling technique which brings this knowledge into action.

10.4 Future work

Some practitioners indicated that despite the benefits and usefulness of the modelling technique, the use of $IDEF_{9000}$ would require some expert knowledge in the domains of ISO 9001 and business process modelling. The comments received from the validation primarily suggest that it may be possible to generalise the links between activities and flows from the Fulfil Order Process and individual requirements to ISO 9001. The author suggests that due to the individuality of each organisation this might only be beneficial when using this modelling technique in conjunction with a generic model of a Fulfil Order Process as developed by Weaver (1995). For future research it is suggested that once more practical experience with using $IDEF_{9000}$ has been gained an investigation into whether it is possible to establish a set of generic ISO 9001 requirements which can be linked to Weaver's generic model.

The modelling approach has been developed to design/redesign a Fulfil Order Process and to establish and identify its links to ISO 9001 requirements. Future research could be undertaken to investigate the applicability of this modelling technique in a wider domain than purely Fulfil Order Processes. To establish the links of ISO 9001 to other business processes would be valuable and would support the development of $IDEF_{9000}$ to be used as part of designing a complete ISO 9001 quality management system.

Another area for future research would be as investigation into whether the modelling technique could be used to model any other industry standard such as the environmental standard ISO 14001 or BS 8800/OHSAS 18001 for occupational health and safety. With the ever-increasing pressure for companies to comply with numerous standards simultaneously, future work would have to investigate how a modelling technique such as $IDEF_{9000}$ could be applied. Potential conflicts between the integrated standards would need to be addressed despite the International Organization for Standardization (ISO) constant efforts to harmonise the requirements of their standards to avoid extra work and duplication.

Process models developed with $IDEF_{9000}$ can be documented with any graphics software package or preferably by using one of the specialised $IDEF_0$ process modelling suites. They generally follow the $IDEF_0$ standard (FIPS) but also allow individual formatting of the diagrams. A default facility could be integrated in the software to avoid changing the appearance of the process model manually to conform to the proposed convention of $IDEF_{9000}$. Such a facility would also have to consistently identify any ISO 9001 controls at each level which interrelate with subsequent levels in the process model. This proposition should be seen as a project work for software developers rather than a research project.

10.5 Overall conclusion

As argued in Chapter 3 the domain of business process modelling does not regard identifying links to the ISO 9001 quality standard as a priority even though they recognise the need for process-oriented quality management systems. Furthermore the usefulness of business process-oriented structures has been widely recognised in the field of quality management but approaches focus on the design of a certifiable quality management system, not taking an overall systemic view of the entire business. Current approaches for modelling business processes and designing ISO 9001 quality management systems were evaluated and found unable to establish the links between the requirements of ISO 9001 and a Fulfil Order

Process and take a systemic perspective of the integration of ISO 9001 in a business process environment. Moreover they do not support the identification of ISO 9001 controls in a Fulfil Order Process and do not highlight potential constraints of ISO 9001 during a redesign exercise in order to maintain compliance to the standard.

This modelling technique, $IDEF_{9000}$, has been developed to address these criteria and has been constantly refined during the Explanation Phase of this research. It has been validated *by review* by practitioners and applied *by use* in two manufacturing companies that were not involved in the development of the modelling approach.

Prior to this work, companies could not model a Fulfil Order Process from a systemic perspective and identify the links of this business process to the requirements of ISO 9001 to highlight areas which might be constrained by the standard during a redesign project.

This work has contributed new knowledge about how to take a holistic view of a Fulfil Order Process and how to identify the activities and flows which are controlled by ISO 9001 in order to be aware of potential constraints imposed by the standard when designing or redesigning a business process. This work has developed and tested a modelling technique called $IDEF_{9000}$ which brings this knowledge into action.

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Appendix 1 - Case A

1. Case A

This case study was carried out by the researcher over a period of seven months from May to November 1999. During that time the researcher was working on a three days per week basis for Case A studying the quality system which complied with the quality standard QS-9000.

The researcher's role could be best described as being an *observer as participant* as he was fully integrated within the company and could record information when it occurred. The main focus of this research was to understand how the quality system was designed and implemented within Case A's organisational structure and to observe its implications. In order to better understand the current design of the quality system this case also reviewed the development of the system from its earliest stages.

1.1. Structure of the case study

The following case study describes how the quality system developed from Ford's quality standard Q-101 in 1991 to the current standard of QS-9000. Sections 1.2 to 1.4 of the case study outline the research methods used. A general background of Case A and its parent organisation is explained in 1.5, while Section 1.6 focuses on an overview of the development of the quality system. A discussion of the current structure of the quality system follows in Section 1.7 concluding with the company's experience with the system in Section 1.8.

1.2. Participants

During the case study the following personnel were involved: quality manager, document controller, quality engineers, product manager, senior engineers and team leaders.

1.3. Source of data

All information gathered for this case study was based on the documented quality system and other relevant internal and external company documents. Observations were made of how the system operated and were supported by the use of unstructured interviews which were conducted with the participants (see Section 1.2).

1.4. Validation

A copy of this case study was submitted for validation to the quality manager, a quality engineer and the operations manager.

1.5. General background

Case A is part of an UK registered organisation that was originally incorporated in 1931. In 1972 the privately owned company became a wholly owned subsidiary of a U.S. organisation which is a global producer of highly engineered polymer-based products with 38 plants in nine countries. The U.S. parent organisation is one of the world's leading suppliers of sealing, trim and vibration-control systems for the worldwide automotive original equipment industry which accounts for approximately 70% of the company's' total 1998 revenues of $1.1 billion. Subsidiary companies produce rubber and plastic components for the refrigeration industry in North America as well as tread rubber and equipment for the truck retreading industry. The company employs over 10,000 people worldwide. In addition to its 100%-owned production facilities, the parent company maintains a number of joint venture and open-exchange technology agreements with companies in Japan, Mexico and Korea.

Two-thirds of the parent organisation's automotive sales were in the U.S. and Canada, with 27% coming from Europe and 6% from Latin America. The company became a major supplier for six of the 15 best-selling automotive platforms in North America during the 1990's and increased its share in the European auto market at an even faster rate. They provide expertise in body sealing and weatherstrips, vehicle powertrain isolation and dampening, exterior decorative trim, modular glass and moulded body panels.

The organisation was more recently acquired by another U.S. rubber manufacturer and signed the merger agreement in July 1999. Its acquirer was, with 10,700 employees, the world's seventh largest tyre manufacturer and a recognised leader in the replacement tire market as a low- cost, high-quality producer. This made the combined company North America's largest manufacturer of automotive sealing systems, as well as one of the leading manufacturers in Europe. On this basis the new company expected to generate $3.2 billion in revenues in its first full year of operation. According to officials this acquisition would make them a stronger competitor in the automotive arena where scale, size and technical depth are increasingly critical to success.

Prior to the merger the company was already undertaking a large restructuring programme with its business in Europe. It resulted in the closure of one of its four UK manufacturing divisions early in 1999.

Case A is a first and second tier supplier to the automobile industry and started manufacturing in 1991 with its entire output dedicated to a single U.S. customer. At that time the company was supplying 22 different parts for two car models with a total of 240,000 car sets per annum. With the continuously evolving and increasingly demanding automotive supply industry Case A was also forced to produce for its customer's European plants. By 1999 case A supplied 10 major automotive manufacturers with 126 different parts and employed 420 permanent staff. Its sales figures rose from £18 million in 1991 to £28 million in 1999.

Case A is a manufacturing site that can be split into the two main areas i. e. *extrusion* and *secondary operations*. Five extrusion lines produced over 50 different profiles that were processed in *secondary operations*. Its major secondary operations included sawing, bending, injection and transfer moulding, spraying and packing.

Case A was run in a decentralised manner by a management team incorporating the top three levels of the organisation including the general manager, departmental/programme managers and product managers. Operations Management which was one of seven departments, formed, together with three business units, the manufacturing team of the division. Each business unit was run by a product manager and set up as a cost centre with overall financial control being in the hands of the company's financial controller and its general manager. The product manager ensured that the production process met targets and quality requirements. He was also responsible for training and the prevention of product and process non-conformities and the implementation of corrective actions. Each business unit employed its own engineers, shift co-ordinators, technicians and team leaders. A matrix management structure was used to co-ordinate activities with certain managers and engineers having dual roles. With this "functional-by-product" matrix and the use of cross-functional teams for decision making Case A managed its working activities.

1.6. Development of Case A's quality system

In 1991 Case A was only supplying Ford and was operating according to the guidelines of Ford's Q-101 quality standard. In 1994 the parent organisation decided to amend the system and comply with the requirements of the international quality standard ISO 9000. As Case A was not involved in any design activities at that time it aimed for an ISO 9002 certificate but transferred to the ISO 9001 in 1997. This step was mainly carried out to finally adapt the quality system to conform with the requirements of the, ISO 9000 based, QS-9000 standard.

The QS-9000 standard is a specification for a quality management system for suppliers to the automotive industry and was developed by the Chrysler/Ford/General Motors Supplier Quality Requirements Task Force and was first published in August 1994. Chrysler, Ford, General Motors, various truck manufacturers and other subscribing companies require their suppliers to comply with QS-9000, and some of them require third party registration to QS-9000. The 'Big Three' automotive manufacturers developed QS-9000 by adding further requirements to ISO 9000. QS-9000 consists of the entire text of the ISO 9001:1994 standard supplemented with customer-specific requirements for each of the 'Big Three' that are added to appropriate sections of ISO 9001.

1.6.1. Ford's Q-101 quality system standard

Ford's quality system standard Q-101 for manufacturing operations and outside suppliers of production and service products provided assistance to both internal and external suppliers in meeting Ford's quality expectations. Case A was responsible for developing and implementing effective operating systems to control and improve the quality of their technical processes and products. To enable Ford personnel to evaluate quality products and systems, case A was required to have available evidence of quality at certain points during the life cycle of the products or the service. The quality requirements for all producers were presented in five major sections:

- Planning for quality
  Quality planning was required during the development of new processes and products as well as prior to any changes.

- Achieving process and product quality
  The producer was responsible for implementing effective systems to control and improve process and product quality.

- Documenting quality
  Two types of quality-related documentation were required for reference and customer review. *Quality systems records* described how the quality system operated and included general procedures or detailed process monitoring instructions. *Quality performance records* such as inspections and test results, control charts or quality concerns showed the results of quality-related functions.

- Special requirement for control item products
  Control item parts were selected products identified by Ford product engineering as having critical characteristics which may affect safe vehicle operation and/or compliance with regulations.

- System and sample approval
  A quality system survey carried out by Ford reviewed the use of statistical methods, examined the quality system and performance records and verified the quality of outgoing products.

Superior product quality resulted in Case A becoming a "preferred supplier", winning Ford's Q1 quality award in 1992 and becoming a "Full Service Supplier" in 1995. Q1 producers were exempt from routine surveys by Ford Quality engineers.

1.6.2. Updating the quality system to comply with QS-9000/ISO 9000

Due to a customer requirement at one of the other divisions the case A's head office decided in 1994 to register all four UK sites to the ISO 9000 standard. The project was run centrally by the organisation's headquarters designing the quality system for all sites. There was no organisational restructuring during the implementation of the ISO 9001 system and Case A kept its functional structure. The project simply created some new roles in quality system management.

The organisation and Case A oriented their quality system around the standard. In this standard-oriented system procedures followed closely the outline of the appropriate ISO 9000 standard. This made it relatively easy to ensure that all parts of the standard were addressed but did not reflect the organisation's business flow.

During the ISO 9000 implementation Case A was still supplying a single customer. Since then the business expanded in terms of customers and product variety. When in 1997 Case A adopted the QS-9000 standard the original structure of the quality system remained and additional requirements were either incorporated in existing procedures and instructions or new ones added. Case A had to consider three major sections of the QS-9000:

- Section I: ISO 9000 based requirements
  This built on the foundations established in ISO 9001 and included the same 20 elements. Each of these started with an exact quote from the relevant element in ISO 9001.

- Section II: Sector-specific requirements
  This specified additional requirements that were beyond the scope of the ISO 9001 and covered quality management systems like continuous improvement, manufacturing capabilities, and production part approval process.

- Section III: Customer-specific requirements
  This section included quality systems requirements that were unique to any one of the "Big Three" automakers.

1.7. Structure of the quality system

1.7.1. Documentation structure of the quality system

The quality system which was fully documented and developed to meet Case A's requirements, the specified standards of their customers and the ISO 9001 quality system standards and documentation, was structured in four levels (see Figure 1-1):

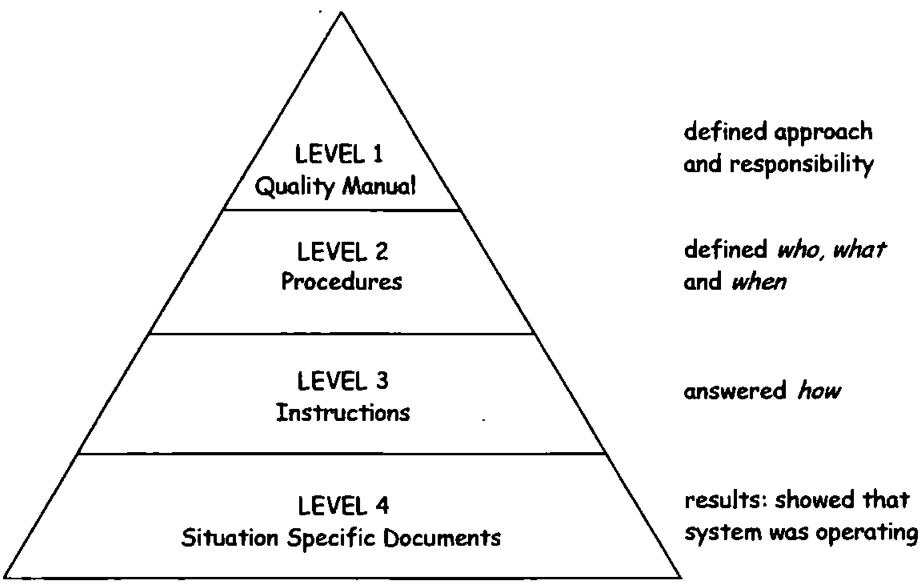

Figure 1-1: Case company's quality system documentation structure

At level 1 the quality manual contained the quality policy, described the quality system and the responsibilities of the management throughout the entire organisation. The purpose of this quality manual which applied to all sites, was to document the quality system used to guarantee the requirements of their customers were met and also to maintain approval to the ISO 9000 series of quality system standards. It followed precisely the 20 sections of the ISO 9001 standard to explain the approach undertaken by Case A to comply with its requirements. At this level the explanation was not very detailed, as it needed to be valid on four different sites. Each section of the quality manual contained specific references to procedures at level 2 that were used to implement the system.

At level 2 Case A operated using procedures that defined broadly what had to be done. The procedures were split into three different categories dealing with quality (C1), tooling (C2) and health&safety/environmental issues (C3). To comply to all the quality-related requirements Case A produced thirty procedures for C1 and five for C2. At the time of writing the sixteen C3 procedures were kept separately from the quality manual as Case A was in the progress of implementing the environmental standard ISO 14001.

Over 65 *office instructions* at level 3 defined in detail how tasks in the quality system documentation had to be carried out and they were categorised as W1 to W3 to match the categories of the procedures.

All level 2 and 3 documents included a short explanation of their objectives and scope. The objective answered the need for a procedure and how it might be achieved while the scope dealt with the *where and when* a procedure had to be applied. A basic "block flow diagram" showed the logical sequence of activities to fulfil the objective and also identified responsibility for individual activities. However much detail was missing from these over simplistic diagrams and some were even used as checklists and included questions rather than phrases describing the activities being performed. A reference mark at each box referred to a legend giving additional information.

Another type of instruction which Case A used as a level 3 document was the standard operating instruction (SOI). Case A operated with over 1,600 standard operating instructions for manufacturing, machine setting, inspection and testing. Their purpose was to define in detail how tasks had to be carried out. While work instructions mainly referred to tasks which only needed descriptive instructions the SOI could also incorporate visual instructions (quality points) such as sketches, photographs etc.

Control plans that were a customer-specific requirement as stated in section III of QS-9000 existed for all Case A's manufactured products. They acted as a summary document and included product characteristics, the operations which were carried out, and the tooling which was used. Moreover they referred to relevant inspection and test methods including quality points and forms that had to be completed.

Forms such as tally sheets, reports or other log sheets were used as level 4 documents. These were either used as a standard means of communication or for providing a means of recording information that resulted in documented evidence that procedures, instructions and processes were being executed to fulfil stated requirements. Their use was generally identified in higher level procedures or instructions.

1.7.2. Document control

All procedures were originally proposed and written by *Central Quality* at the organisation's headquarters. Case A approved or made suggestions to amend the draft version before *Central Quality* finally released them. While the approval of C1 procedures remained the responsibility of the organisation's *Central Quality,* the general manager of Case A could approve C2, W1, and W2 documents. All C3 and W3 documents including the standard operating instructions remained entirely under control of Case A.

The documents that formed part of the quality and environmental system, were subject to document control. A document controller at each site was appointed to create and maintain a master index and the distribution list for each document group (see Table 1-1). A formal system defined how procedures and work instructions had to be numbered in order to be identified by their code. However for standard operating instructions Case A only used a consecutive numbering system starting from zero. The system did not allow for the grouping of related standard operating instructions. The document controller only kept a distribution list that showed the department to which the standard operating instructions were sent.

In terms of referencing to relevant documents the system failed on occasions only showing the interrelationships between higher to lower level documents. This made manual searches particularly difficult and time consuming when amendments were necessary. While standard operating instructions did refer to a certain *quality point* there was no interrelationship diagram or matrix that pointed out if this particular *quality point* was used by another document and whether its alteration might cause a conflict.

Document group	Location	Responsibility
Quality and environmental manuals	Central quality	Control and distribution
Procedures C1, C2, C3	Central quality	Control and distribution
Office instructions W1, W2, W3	Central quality	Control and distribution
Specifications and standards	Central quality	Control and distribution
Quality manual	Divisional	Distribution only
Procedures C1, C2, C3	Divisional	Distribution only
Office instructions W1, W2, W3	Divisional	Distribution only
Standard operating instruction	Divisional	Control and distribution
Control plans	Divisional	Control and distribution

Table 1-1: Document control of the quality system – excerpt

1.7.3. Relationship between the quality system and the organisational structure

The headquarters designed the organisation's quality documentation system around the QS-9000/ISO 9000 standard. A difficulty with this approach was relating it to Case A's normal business flow. While the tasks for operators on the shopfloor were clearly specified and documented in over 1,600 standard operating instructions it was more difficult for staff to relate to the quality system. Their understanding of *which* part of the quality system needed to be used and when relied mainly on three factors:

- Training of new employees
- Training after job transfer
- Own authority to consult the quality system

Case A provided over 60 job specifications to ensure consistent assessment of the nature of jobs in the organisation. Some of them stated a requirement to "contribute and comply with the quality systems procedures" but did not go into any greater detail. In only a few cases, for example the job of the *training co-ordinator,* clearly stated what needed to be performed in accordance with a quality procedure.

Job descriptions for the personnel in the quality department naturally related more closely to the quality system and referred to procedures and other documents. However none of the job descriptions was intended to be exhaustive. As a copy of the quality manual was available in each of the departments it was everyones responsibility to consult its index and to ensure that a particular task was carried out according to the requirements stated in the quality system.

1.8. Experience with the quality system

Case A has been operating a continuously evolving documented quality system for many years and, at the time of writing, the quality department operated with eleven staff. Its document controller worked full-time on keeping the system documentation up to date while the quality engineers who were located in the business units each spent between 25 and 30 hours a week maintaining the system. They estimated that about 80% of Case A's operations were carried out in accordance with the procedures in the quality system. The main reason for not working to the quality system were stated as inadequate training of those new employees who were likely to become involved in the design of procedures and instructions.

To rectify this situation training could be carried out using "real cases" of how to write instructions and procedures while work instructions could be generated in a more approachable format such as ANSI (American National Standards Institute) flowcharts. The documentation of the system is produced using only word-processing and spreadsheets. So far Case A does not make use of database applications which could avoid a great deal of extra bureaucracy while searching for related documents when alterations are required.

From an integration point of view it can be argued that the business activities did not closely link to the quality system. This disadvantage could only be partially compensated for by additional training in the application of the quality system. Unfortunately the quality of training which would usually be carried out to enable new employees to work with the quality system deteriorated over recent years. This resulted in extra work having to be carried out after alterations such as *product and engineering changes* were introduced without considering the impact on other parts of the quality system.

Business for Case A is expected to increase over the next year or two due to the concentration of work in the remaining two manufacturing sites in the UK. This will result in even more documentation putting extra strain on the system and the people who operate it.

Appendix 2 - Case B

1. Case B

This case study was carried out using an Action Research approach by the researcher over a period of eight months from July 1998 to February 1999. The researcher was one of two consultants who implemented an ISO 9001 quality management system at Case B. Their contract was to consult to and support the company as it progressed towards ISO 9001 registration. During the design and implementation stage of this project the two consultants assisted Case B by facilitating workshops to design the overall quality management system with its quality manual and the necessary documentation. It also included supporting Case B in implementing the ISO 9001 requirements as well as in conducting training and documenting the quality management system.

The following case study describes an activity-based approach for the implementation of the ISO 9001 quality standard in a functionally designed organisation. As the company kept its functional structure its documented "business activities" were referred to as "activities" throughout this case study rather than to "processes". The "business activities" showed some similarities to business processes as discussed in literature as they include *inputs* or *outputs* etc. but lack to be cross-functional and customer facing.

The main interests of this case study focus on the design of the quality management system and its impact and implementation related to the organisational structure of Case B. This case study is however not concerned with the process of achieving certification nor its audit or feedback systems.

1.1. Structure of the case study

The case study describes an activity-based approach to the implementation of the requirements of the ISO 9001 quality standard in a manufacturing company. In Sections 1.1 to 1.4 the case study outlined the research methods used. An overview and background information on Case B and its parent organisation was discussed in Section 1.5. The activity-based approach implemented at Case B has been explained in Section 1.6.

1.2. Participants

The employee orientated approach which will be explained in Section 1.6 included the entire senior management team, other members of staff as well as operators which were involved in the ISO 9001 project.

1.3. Source of data

All information gathered from the ISO 9001 projects' formal and informal meetings as well as from the workshops were available as case study material. This also included internal audits, carried out in the form of structured interviews, prior to the final certification audit and the draft version of the processed quality manual. An average of two days a week were spent at Case B by the consultants during the project. Further interviews were conducted with the management representative of Case B as well as with the leading consultant six months after the successful ISO 9001 certification.

1.4. Validation

During the project transcripts of all meetings and workshops were sent to the process owner or the internal project co-ordinator for approval and validation. A copy of this case study also was submitted for validation to the general manager and the leading consultant.

1.5. General background

Case B is part of a group incorporating 5 other autonomous manufacturing divisions all based in West Germany employing just over 600 people. The parent company has been family owned since 1836 and starting in 1951, further specialist paper factories, rich in tradition, were acquired. With the incorporation in 1972 of the parent company as a holding company, today's organisational structure was established. 1988 saw the conversion to a joint-stock company and in September 1991 the company went public. The group achieved an annual turnover of 239.1 million DM in 1997/1998 and manufactures a wide range of high quality paper for various applications with an output of 120.4 thousand tonnes.

Case B is a paper mill operating with a computer controlled paper making machine which employs front edge technology to produce label paper, art and matt coated and coloured paper. All products are produced to customer requirements including to specific sheet/reel sizes and finishing specifications. Its products are used for matt or glossy labels for all kinds of food or consumer products, lamination and wrapping paper. For the office stationery market the product range covers offset, ink jet, xerography for laser and riesography in either typewriter quality or for high output xerography machines.

Its share of the German market for single coated paper was 25% and 10-20% in the segment of coloured paper in 1997/1998. Their products are exported worldwide and available in five continents. Case B's international competitors have their manufacturing sites either in Europe or in South Africa. All of the competitors' countries have adopted the ISO 9000 as their national quality standard.

Case B's turnover in 1997/1998 reached 125 million DM compared to the 1996/1997 figure of 127 million DM employing 246 people. A decline in the consumption of beverages due to poor weather conditions influenced the sales of their products used for labels and therefore the annual turnover.

According to Case B's marketing and sales professionals there was no immediate pressure in the paper industry to be registered to the ISO 9000 quality standard. The company's decision to go ahead with a certified quality management system derived from their need to guarantee their customers a superior quality product. In order to achieve a high level of reproducibility in their operations they wanted to standardise their procedures and technical processes. The ISO 9001 quality management system was to act as the basis for a systematic improvement of the company's operations.

Another division in the group tried to establish a section-based ISO 9001 approach where the documentation of the quality manual was structured and written along the 20 sections of the ISO 9001 standard. 12 months prior to Case B' initial moves towards a certified management system a "dummy" certification audit failed. The division's inability to relate its organisational structure to the section-based structure of quality manual resulted in the project being halted. To avoid similar problems Case B decided to adopt an activity-based approach and took the role of a trailblazer. With this approach the documentation of the quality system showed the organisation's activities linked with the ISO 9001 standard.

1.5.1. Organisational structure of Case B

Case B was divided into three directorates consisting of technology, finance/human resources and sales. The directorates were functionally orientated with five hierarchical layers. Its hierarchy seen in Figure 1-1 was arranged as follows: managing director, functional directors, managers, team leaders, and operators.

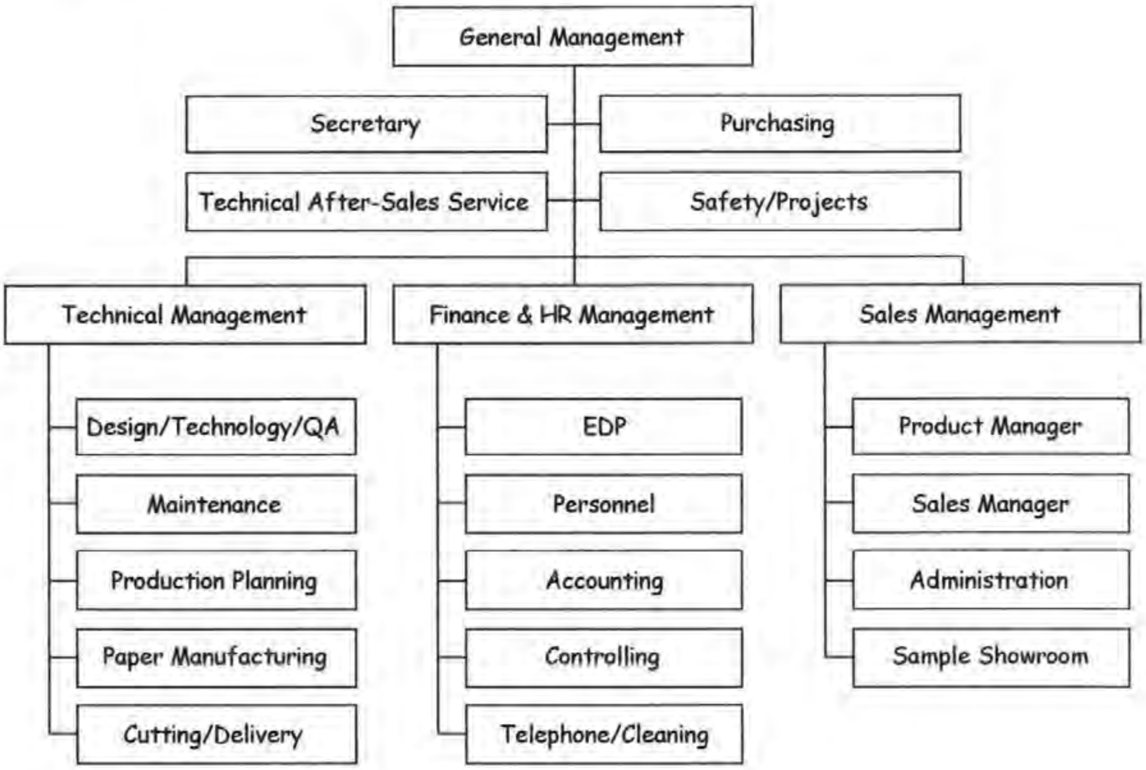

Figure 1-1: Case B, Organisation Chart

1.6. ISO 9001 implementation at Case B

The project at Case B was conducted by a consultancy. Their profession was to consult and support companies in their pursuit of the ISO 9001 registration. Two consultants assisted Case B during the design and implementation stage of the quality management system.

An internal project co-ordinator was nominated by the senior management team to organise and run the project. His only responsibility was to achieve the ISO 9001 registration for Case B and he was released from all other work duties. Formerly a general manager at one of Case B's affiliated divisions he had in-depth knowledge on all areas of its activities. This was of great advantage throughout the entire project and especially during the crucial start-up period where the consultants inquired in-depth background knowledge about the organisation and its structure.

The project can be divided into stages of design and implementation. Both stages involved a great deal of staff involvement from senior management to individual operators.

1.6.1. The Principal ideas on the design of the quality management system

The international standards in the ISO 9000 family describe what elements quality systems should encompass, but not how a specific organisation should implement these elements. The consultants' approach to the design of the ISO 9001 quality management system for Case B was an activity-based framework using employee ownership (see Figure 1-2). Part 1 of the ISO 9004 which consists of a set guidelines of how to establish quality management systems was used internally by the organisation. The quality management system was to be designed around the organisation's activities, which were mapped by employees involved in the activity. Overall business objectives set the basis for the company's quality policy from which the quality objectives were finally derived. A set of individual objectives for each activity was defined and reflected the relevant quality objectives. All activities were clustered into meaningful categories of "key sections" by using the affinity diagram technique. Some of the key sections were named after organisational departments as Case B kept its functional structure. Prior to the discussed mapping exercise a draft activity model was proposed by the consultants after they assessed the plant. The activity-based approach used a correlation matrix to establish the relationship between the defined organisation's activities and the ISO 9001 requirements as discussed in Section 1.6.2.2. The correlation matrix was a central document to identify where changes in either the ISO requirements or the organisational activities could have an impact. It also served as a guide or overview document for external auditors.

This universal approach had been developed and refined by the consultancy ever since 1993. Typically the consultancy' first ISO 9000 implementation projects were closely related to the structure of the standard and they implemented the quality management system as a section-based approach at their clients. The consultancy, however, soon realised that this section-based layout did not reflect any organisational structure and involved unnecessary work for the client. This was the main reason for the consultancy investigating in alternative approaches and focusing on the company and its people rather than simply on the ISO 9000 standard.

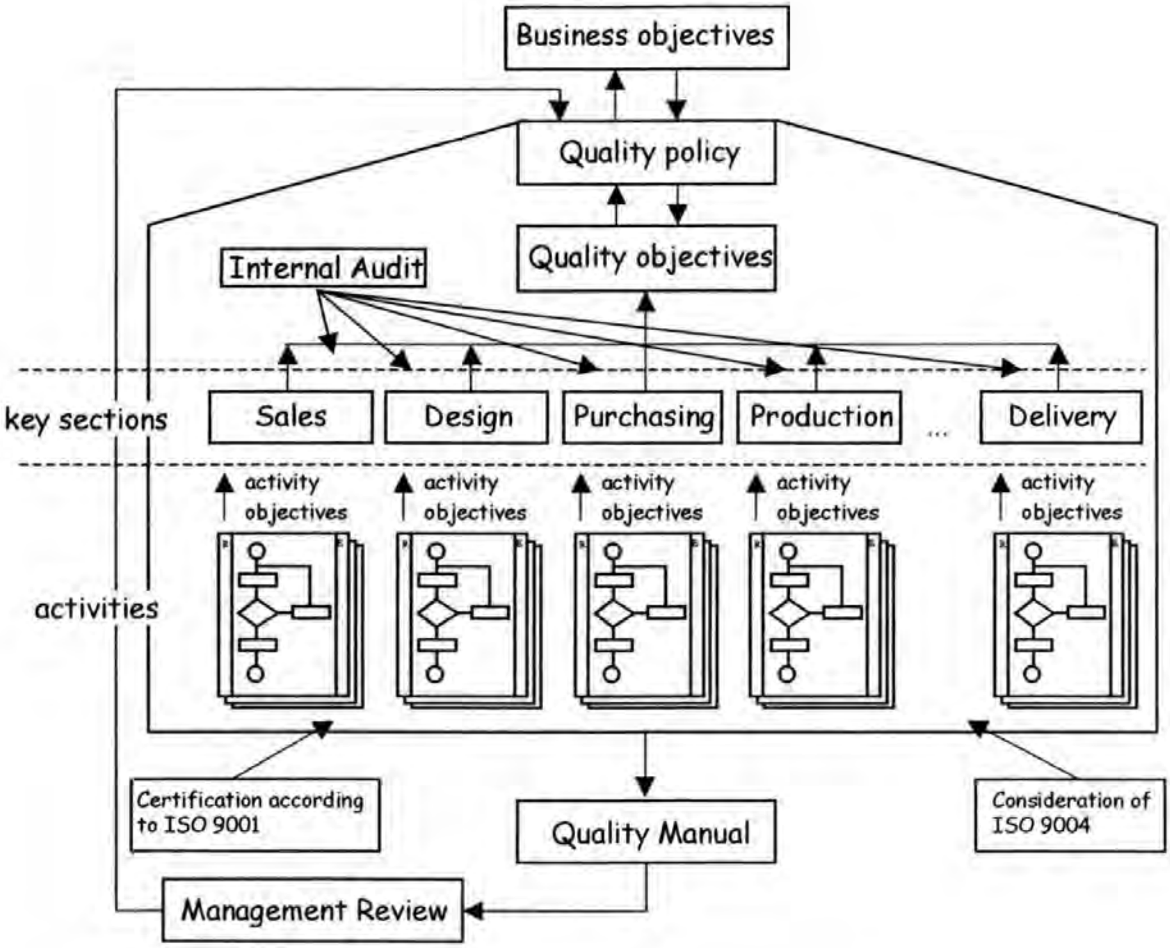

Figure 1-2: Activity-based ISO 9001 quality management system approach

1.6.2. General structure of the quality management system

The documentation structure used in this approach was based on the quality system documentation pyramid (see Figure 1-3). This generic approach was used independently of ISO standards by many companies. At the top of the pyramid were the business objectives together with the quality policy. The quality manual was supported by two main layers of documentation and reflected the structure of the quality management system. It acted as a reference document for the implementation and maintenance of the quality system and all other quality related documents. It also provided an overview about the organisational structure, interfaces and links between activities as well as the responsibilities of its owners.

Figure 1-3 : Documentation pyramid

1.6.2.1. Business objectives and the top management's commitment to quality

While the consultant's general approach distinguished between business objectives and quality objectives Case B's situation was different. Only a volume related target of output per annum had been formulated by the senior management in previous years. The primary objective of Case B was the economic success which represented the basis to secure its future. One set of general objectives was defined to establish a basis for the ISO 9001 project. The two overall business objectives therefore were:

- To achieve sustainable company profit
- To guarantee and increase the value of the organisation

With the following eight additional business objectives which also were established during the workshops Case B presented their overall commitment to quality:

- We want enthusiastic customers;
- We want to expand the company's market share;
- We want to play an active role in the market;
- We want flexible and competent suppliers;

- We want flexible and effective structures within the organisation;
- We want flexible and effective structures within production;
- We want committed and responsibly-minded employees;
- We want relationships based on partnership with all involved, relevant, direct and indirect stakeholders.

During various workshops both the company's policy and the business objectives were developed and formulated as draft. All members of senior management were involved and took part in the decision-making. Each business objective was formulated as a statement followed by short explanations of how to approach and finally reach the individual target. Senior management decided to review all business objectives on a monthly basis throughout the duration of the ISO 9001 before their final approval. In the quality manual each business objective was explained in greater detail describing how the company wanted to pursue and finally achieve this aim.

An existing policy statement prepared by Case B was rewritten to include all relevant quality issues. This general code of practice was extended partly with the defined business objectives and showed Case B's business intentions and its commitment to quality and its employees. It was written to comply with the ISO 9001 requirements but also to inform its staff and other interested parties about Case B's commitment to quality. The company's policy was to protect their market position in all of their product segments against worldwide competition as well as to expand the market share of one of its three product ranges. They acknowledged the need for an outstanding quality level and a hands-on quality management to achieve this. Therefore it was the company's decision to continuously improve the quality management system by implementing the ISO 9001.

It was the company's understanding that they would only get the most out of the system if all employees were actively involved in "quality work". The people were therefore the main focus in Case B's quality management.

1.6.2.2. Correlation of the business activities to the ISO 9001 requirements

This activity-based approach considered all significant company activities and how they related to the requirements of the ISO 9001. The following correlation matrix (see Table 1-1) linked all 40 activities (second column) of Case B with the 20 sections of the ISO 9001. A cross indicates where requirements of a particular section of the ISO 9001 needed to be considered for mapping an activity. The quality manual included the documentation of all activities and formed the second level of the document pyramid.

ISO 9001:1994

Key sections of the quality manual	Activities involved	Management responsibility	Quality system	Contract review	Design control	Document and data control	Purchasing	Control of customer-supplied products	Product identification and traceability	Process control	Inspection and testing	Control of inspection, measuring and test equipment	Inspection and test status	Control of nonconforming product	Corrective and preventive action	Handling, storage, packaging, preservation and delivery	Control of quality records	Internal quality audits	Training	Servicing	Statistical techniques
Introduction		X	X			X															X
Company policy		X		X																	
Design	New products, product optimisation,				X																
	Process optimisation				X										X						
Purchasing	Fibre raw material						X														
	Additional goods						X														
	Periodic supplier assessment						X														
	New suppliers						X														
	Services						X														
	Investments						X														
Personnel	Recruitment of new employees																		X		
	Training of new employees																		X		
	Training																		X		
Sales	Marketing																				
	Special inquiry			X																	
	Specimens			X																	
	Contract commission			X																	
	After-sales service																			X	
Production planning										X											
Goods inwards									X		X					X					
Pulp preparation	Paper manufacturing									X											
	Coating									X											
Production	Set-up/start up									X											
	Manufacturing								X	X	X		X	X		X					X
	Maintenance, repair									X					X						
	Cleaning									X											
Water preparation	Steam generation									X											
Cutting/Packaging									X	X	X		X	X		X					X
Stockkeeping, delivery	Disposition of delivery															X					
	Packaging material								X		X										

	ISO 9001:1994	Management responsibility	Quality system	Contract review	Design control	Document and data control	Purchasing	Control of customer-supplied products	Product identification and traceability	Process control	Inspection and testing	Control of inspection, measuring and test equipment	Inspection and test status	Control of nonconforming product	Corrective and preventive action	Handling, storage, packaging, preservation and delivery	Control of quality records	Internal quality audits	Training	Servicing	Statistical techniques
Laboratory	Inspection, testing										X										
	Control of inspect. measure, test equipment											X									
Administration	Annual business planning																				
	Business controlling	X																			
	Data security					X															
	Invoice outwards																				
	Invoice inwards																				
Management	Internal audits																	X			
	Documents																X				
	Corrective actions														X						

Not relevant

Table 1-1: Correlation matrix ISO 9000 – business activities

At the next lower level of the document pyramid Case B included all department specific documents such as standard operating procedures and other relevant standards. Specific documents related to individual contracts, products or workplaces formed the base of the document pyramid. Here Case B had to distinguish between regulations, manuals, instructions for testing and inspection, work instructions and other relevant specifications. Only the top 40 business activities were documented in the manual and notes referred to other relevant documents that were kept separately.

All activities were documented in the form of flowcharts for ease of understanding. The quality manual was written using Microsoft's Office 97 and professional software for documenting flow-charts was used.

Part of the consultants' contract was the documentation of the quality management system. It will be the responsibility of the management representative to provide an up-to-date documentation and distribute the latest revision of the quality manual at the end of the project. A brief introduction of how to use the flowcharting software was part of the training which the management representative received. Every activity owner was provided with a hardcopy of the manual, Case B not considering a "paperless" on-line quality manual to be an option at that time.

1.6.2.3. Documentation of the business activities and the correlation matrix

During a 2-day introduction the consultants generated a draft activity model of Case B by following the workflow for a particular product order. For the draft design of the activity model the consultants compared it with a set of generic quality related activities from previous ISO 9001 projects and established a matrix correlating these with the 20 sections of the ISO 9001 (see Table 1-1).

The actual mapping exercise for the activities was carried out in individual workshops after senior management approved the draft activity overview and appointed all activity owners. During these workshops the consultants pointed out the relevant ISO 9001 requirements that the team needed to consider at that time. Appropriate training about the relevant parts of the ISO 9001 was introduced at a later stage. The mapping of activities mainly included the documentation of existing business activities. During the documentation Case B did not take the opportunity to rethink the flow of their activities or to combine the ISO 9001 project with a redesign exercise. A first step, however, was to establish for each activity a set of objectives including criteria to measure performance was set. All activity objectives derived from the overall business objectives. Each chapter of the quality manual included a summary sheet with the relevant quality objectives, criteria for measurements as well as additional rules and documents.

None of the existing activities needed to be altered to comply with the requirements of the ISO 9001 requirements. Only the following four activities were newly designed:

- Internal audit;
- Documents;
- Training;
- Periodic supplier assessment.

All activities were mapped according to the flow of material and the defined key activities mainly reflected Case B's departments. As the organisation's layout was not modified due to the ISO 9001 project its functional structure remained and the horizontal flow of the defined activities did not go across any departmental borders. Therefore the present layout of the quality manual would be seen as a forecast of how the company may evolve and be organised in the future.

The type of flowcharts used was based on the ANSI (American National Standards Institute) standard flowchart. For simplicity Case B adopted a standard set of symbols published by ANSI which were explained in a glossary page as part of the quality manual. Two columns at the right hand side of each flowchart gave further information to individual activities including responsibilities.

All flowcharts showed activities to denote tasks of any kind. A short description of the individual activity outlined only a general statement of an action and none of them were broken down in greater detail and documented in the quality manual. Links from one activity to another were marked. A reference mark in the flowchart referred to relevant procedures which were kept separate from the manual. The quality manual however was still a comprehensive 100 A4 pages long.

1.6.2.4. Standard operating procedures and work instructions

These documents were kept separate from the quality manual. Many of them were intermediate work instructions and kept at the shopfloor. Case B's manufacturing process depends on strictly controlled on-line production control. It therefore had already an excellent system in place to ensure the quality of incoming raw material, to monitor its manufacturing process as well as to test over 25 product characteristics during a final inspection. This also included a procedure to control inspection, measuring and test equipment. In terms of ISO 9001 compliance there were no changes necessary. About 50 documents were kept in two separate folders in production. Most of them were in written as opposed to the easier flowchart format.

1.6.3. Development of the quality management system

An activity team documented the activities during various workshop sessions. Such a team consisted of the activity owner, various users, project co-ordinator and if required a facilitator. The facilitator co-ordinated and led the workshop. The aims of all individual teams were to develop the activity objectives and appropriate performance measurements as well as to map the activities themselves. This also included to structure flow charts, define preventative and operative control circuits, determine the critical interfaces and specify the most important documents. For all activities relevant business objectives, the organisation's present situation and any known or planned improvements or changes needed to be incorporated.

1.6.3.1. The new roles for employees within the quality management system

This activity-based approach produced new responsibilities and required employees who were involved in the project to take one or more of the following roles:

- Owner of an activity;
- User of an activity;
- Internal customer;
- Management representative;
- Project co-ordinator.

The task of each owner was to review his owned activity. This included updating all relevant documents based on the relevant business and activity objectives. Any additional documents necessary to describe the quality management system such as operating or working procedures had to be designed or approved by the activity owner. This individual was responsible for providing a functional activity to all users and customers, which included monitoring and assessing any improvements carried out on the activity. Informing and training all users and customers on the activity content was also part of this task as was to act as a contact person for all concerns.

Users assisted the activity team in the mapping of the activity. They were involved in the implementation of the activity as well as identifying potential improvements for this particular activity. During the implementation of improvements they played a crucial part.

A management representative was made responsible for raising commitment and consciousness for quality within the organisation. This task also included keeping the quality manual up to date, guaranteeing its implementation and ensuring the management systems' compliance to the ISO 9001 standard. Moreover this role involved the development and implementation of an audit plan and establishing the effectiveness and efficiency of the quality management system.

The project co-ordinator was responsible for leading and monitoring the project and supporting each individual activity owner. This task also included the provision of information for every one interested in the project. This very labour intense management system approach involved more than 30 employees during the implementation phase. The release of these people and the provision of extra resources was only possible due to a strong management commitment.

1.6.3.2. Activity mapping workshops

Before the actual activity mapping was carried out the activity owner prepared the workshop by identifying the basic and special characteristics of the relevant activity. A checklist was used which included the following issues (see Table 1-2):

Initiators	events or decisions which trigger off a process
Description of an activity	relevant tasks, decisions and operative control circuits. Documents which needed to be initiated during the activity
Standards and guidelines	all documents, standards, guidelines or instructions the activity needed to consider
Output	information, documents, products or any other outcome of the activity
Suppliers	information, if any, provided by the supplier
Users	identified all involved users
Customer	all internal and external activity customers. It included expectations customers had about the particular activity as well as information on how customers defined the quality of the activity

Table 1-2: Activity checklist

All results of the workshop were documented and the activities finally mapped by the facilitator. The activity owner and the project co-ordinator reviewed the first draft before it was made available company-wide for comments and changes. For a limited period staff who were not involved in the workshops could submit proposals for changes. Finally the management representative approved the activity. The activity owner then provided training related to the activity to all users.

1.6.3.3. Training in the quality management system

During the project several training programmes were carried out. This included introducing staff to the basics of the ISO 9001 standard and the characteristics of the quality management system to be implemented. A comprehensive training programme especially designed for the different types of audits such as system audits, process audits, product audits and supplier audits was introduced. All activity owners and other members of staff received a special auditor training provided by the consultancy. The activities were co-ordinated and looked after by twelve owners of which eight were also trained as internal auditors. In total Case B operated with 14 internal quality auditors.

1.6.4. Statements and experiences about the ISO 9001 project

After a successful certification audit in April 1999 the group management board decided to have the other divisions registered to the ISO 9001 by using the consultants' activity-based approach again. Satisfied with the outcome in Case B and the work carried out by the consultants the directors appointed them once more. The internal project co-ordinator was also appointed and joined the consultant. At time of writing two of the four divisions have already completed the documentation of their business activities and have a draft quality manual in place, whereas the remaining two are in their early stages of the project.

Case B and its people involved gave a positive feedback about the consultants approach especially about the ownership of activities. It spread the workload as well as the responsibility across several employees and ensured that the management system would be maintained and improved on a continuous basis. The employees felt confident within their new roles and could identify themselves with the management system as it reflected their areas of responsibility.

Six months after the successful certification the workload for the management representative maintaining the management system is expected not to exceed five hours a week. On top of that all process owners have to carry out ongoing internal audits and an audit program was scheduled for one year. At this moment it is difficult to estimate how much of their time will be required.

Appendix 3 - ISO 9001 Correlation Matrix

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
4. Quality management system		
4.1 General requirements a), b), c), d), e), f)	indirectly relevant	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, resources)
4.2 Documentation requirements		
4.2.1 General		
4.2.1 General a) b)	not relevant	
4.2.1 General c)	indirectly relevant	*Procedure documents* (documents) established in the non-operating part of the quality management system which control operating type activities
4.2.1 General d)	indirectly relevant	*Procedure documents* (documents) established in the non-operating part of the quality management system and other kind of *documents* (input, output, and control)
4.2.1 General e)	indirectly relevant	*Record documents* (controls and outputs)
4.2.2 Quality Manual		
4.2.2 Quality manual a)	not relevant	

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
4.2.2 Quality manual b)	indirectly relevant	Procedure documents (documents) established in the non-operating part of the quality management system which control operating type activities
4.2.2 Quality manual c)	not relevant	
4.2.3 Control of documents a), b), c), d), e), f), g)	indirectly relevant	Procedure documents (documents) established in the non-operating part of the quality management system which control documents which are used by operating type activities in the form of inputs, outputs, and controls
4.2.4 Control of records	indirectly relevant	Procedure documents (documents) established in the non-operating part of the quality management system which control record documents (records) which are used by operating type activities in the form of inputs, outputs, and controls
5. Management responsibility		
5.1 Management commitment a), b), c), d), e)	not relevant	
5.2 Customer focus	not relevant	
5.3 Quality policy a), b), c), d), e)	not relevant	
5.4 Planning		
5.4.1 Quality objectives	indirectly relevant	Quality objectives will be incorporated in the relevant procedure documents (documents) or other form of documents established in the non-operating part of the quality management system

Section of ISO 9001:2000	**Strength of linkage between the standard and the Fulfil Order Process** **Type of requirement/comments**	
5.4.2 Quality management system planning a), b)	indirectly relevant	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, resources)
5.5 Responsibility, authority and communication		
5.5.1 Responsibility and authority	indirectly relevant	Responsibility and authority will be incorporated in the relevant procedure documents (documents) established in the non-operating part of the quality management system Responsibility and authority might also to be shown as a resource (human resource)
5.5.2 Management representative a), b), c)	not relevant	
5.5.3 Internal communication	indirectly relevant	Information and the flow of information
5.6 Management review		
5.6.1 General	indirectly relevant	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, resources)

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
5.6.2 Review input a), b), c), d), e), f), g)	indirectly relevant	Data and information in the form of record documents (records) and other kind of documents which are used by operating type activities in the form of inputs, outputs, and controls
5.6.3 Review output a), b), c)	indirectly relevant	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, resources)
6. Resource management		
6.1 Provision of resources a), b)	indirectly relevant	Physical requirements for the activities and human resources of the participants shown as a resource
6.2 Human resources		
6.2.1 General	not relevant	
6.2.2 Competence, awareness and training a), c)	indirectly relevant	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, resources)
6.2.2 Competence, awareness and training b), d), e)	not relevant	

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
6.3 Infrastructure a), b), c)	not relevant	
6.4 Work environment	not relevant	
7. Product realisation		
7.1 Planning of product realisation a)	indirectly relevant	Process characteristics
7.1 Planning of product realisation b)	indirectly relevant	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information in the form of record documents, other kind of documents and resources in the form of people or equipment)
7.1 Planning of product realisation c)	directly relevant	Activities (validating, verifying, monitoring, testing and inspection)
7.1 Planning of product realisation d)	directly relevant	Activities (recording, filing) Data and information in the form of record documents and other kind of documents which are used by operating type activities in the form of inputs, outputs, and controls
7.2 Customer-related processes		

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
7.2.1 Determination of requirements related to the product a), b), c), d)	not relevant	
7.2.2 Review of requirements to the product a), b), c)	not relevant	
7.2.3 Customer communication a), b), c)	not relevant	
7.3 Design and development		
7.3.1 Design and development planning a), b), c)	not relevant	
7.3.2 Design and development inputs a), b), c), d)	not relevant	
7.3.3 Design and development outputs a), b), c), d)	not relevant	
7.3.4 Design and development review a), b)	not relevant	

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
7.3.5 Design and development verification	not relevant	
7.3.6 Design and development validation	not relevant	
7.3.7 Control of design and development changes	not relevant	
7.4 Purchasing		
7.4.1 Purchasing process	directly relevant	Activities (evaluating and controlling) Process characteristics (data and information in the form of record documents and other kind of documents, products in the form of inputs/outputs and resources in the form of people or equipment) Procedure documents (documents) established in the non-operating part of the quality management system which control the operating type activities Note: supplier control processes (evaluation and selection) are not to be considered as an operating type activity
7.4.2 Purchasing information a), b), c)	directly relevant	Process characteristics (data and information in the form of documents and procedure documents)
7.4.3 Verification of purchased product	directly relevant	Activities (inspecting, verifying) Process characteristics (data and information in the form of record documents and other kind of documents, products in the form of inputs/outputs and resources in the form of people or equipment) Procedure documents (documents) established in the non-operating part of the quality management system which control the operating type activities

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
7.5 Production and service provision		
7.5.1 Control of production and service provision a), b)	indirectly relevant	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information in the form of documents, procedure documents, and resources in the form of people and equipment)
7.5.1 Control of production and service provision c), d), e), f)	directly relevant	Activities (monitoring, measuring) Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information in the form of documents, procedure documents, and resources in the form of people and equipment)
7.5.2 Validation of processes for production and service provision a), b), d), e)	indirectly relevant	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information in the form of documents, procedure documents, record documents, and resources in the form of people and equipment)

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
7.5.2 Validation of processes for production and service provision c)	directly relevant	Activities (applying) Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information in the form of documents, procedure documents, record documents, and resources in the form of people and equipment)
7.5.3 Identification and traceability	directly relevant	Activities (identifying, recording) Process characteristics (data and information in the form of documents, procedure documents, record documents, and resources in the form of people and equipment)
7.5.4 Customer property	directly relevant	Activities (identifying, verifying, protecting, safeguarding, reporting, and recording) Process characteristics (data and information in the form of documents, procedure documents, record documents, products in the form of inputs/outputs, and resources in the form of people and equipment)
7.5.5 Preservation of product	directly relevant	Activities (identifying, handling, packing, storing, and protecting) Process characteristics (data and information in the form of documents, procedure documents, record documents, products in the form of inputs/outputs, and resources in the form of people and equipment)
7.6 Control of monitoring and measuring devices a), b), c), d), e)	indirectly relevant	Activities (monitoring, measuring) Process characteristics (data and information in the form of documents, procedure documents, record documents, products in the form of inputs/outputs, and resources in the form of people and identifiable equipment)

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
8. Measurement, analysis and improvement		
8.1 General a), b), c)	indirectly relevant	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, input and outputs, resources and controls)
8.2 Monitoring and measurement		
8.2.1 Customer satisfaction	not relevant	
8.2.2 Internal audit a), b)	indirectly relevant	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, input and outputs, resources and controls)
8.2.3 Monitoring and measurement of processes	indirectly relevant	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, input and outputs, resources and controls)

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
8.2.4 Monitoring and measurement of product	directly relevant	Activities (monitoring, measuring, verifying, recording, releasing, filing) Process characteristics (data and information in the form of documents, procedure documents, record documents, products in the form of inputs/outputs, and resources in the form of people and equipment)
8.3 Control of nonconforming product a), b), c)	directly relevant	Activities (identifying, controlling, preventing, reworking, authorising, releasing, recording, filing) Process characteristics (data and information in the form of documents, procedure documents, record documents, products in the form of inputs/outputs, and resources in the form of people and equipment)
8.4 Analysis of data a), d)	not relevant	
8.4 Analysis of data b), c)	indirectly relevant	Process characteristics (data and information in the form of documents and record documents)
8.5 Improvement		
8.5.1 Continual improvement	indirectly relevant	Data and information in the form of record documents and other kind of documents which are used by operating type activities in the form of inputs, outputs, and controls
8.5.2 Corrective action a), b), c), d), e), f)	indirectly relevant	Data and information in the form of record documents and other kind of documents which are used by operating type activities in the form of inputs, outputs, and controls
8.5.3 Preventive action a), b), c), d), e)	indirectly relevant	Data and information in the form of record documents and other kind of documents which are used by operating type activities in the form of inputs, outputs, and controls

Appendix 4 - Quality Management Systems – Requirements ISO 9001:2000

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 9001

December 2000

ICS 00.012.10

Supersedes EN ISO 9001:1994, EN ISO 9002:1994 and EN ISO 9003:1994

English version

Quality management systems - Requirements (ISO 9001:2000)

Systèmes de management de la qualité - Exigences (ISO 9001:2000)

Qualitätsmanagementsysteme - Forderungen (ISO 9001:2000)

This European Standard was approved by CEN on 15 December 2000.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN ISO 9001:2000 E

Foreword

The text of the International Standard ISO 9001:2000 has been prepared by Technical Committee ISO/TC 176 "Quality management and quality assurance", Subcommittee 2 "Quality systems". The transposition into a European Standard has been managed by the CEN Management Centre (CMC) with the assistance of CEN/BT WG 107.

This European Standard supersedes EN ISO 9001:1994, EN ISO 9002:1994 and EN ISO 9003:1994.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2001, and conflicting national standards shall be withdrawn at the latest by June 2001.

NOTE The following is specifically intended for organizations that need to comply with "New Approach" European Directives in order to affix CE marking on their products and to the other parties involved in that process.

The publication of EN ISO 9001:2000 has implications for Council Decision 93/465/EEC of 22 July 1993 concerning the modules for the various phases of the conformity assessment procedures and the rules for affixing and use of the CE conformity marking, which are intended to be used in the technical harmonization directives. It is important to note that the modules used in individual technical harmonization directives may vary in some respects compared to those described in Council Decision 93/465/EEC. In all cases, it is the annex of the applicable directive(s) which is legally binding. The principles set out in this foreword remain valid regardless of these variations.

Three of the modules cited in Council Decision, i.e. modules E, D and H, require that "*the manufacturer must operate an approved quality system*". The scope of the quality systems required by these modules addresses:
- Final product inspection and testing (module E)
- Production, final inspection and testing (module D),
- Design manufacture and final product inspection and testing (module H).

Council decision 93/465/EEC specifies that conformity to the harmonized standards EN 29001, EN 29002 or EN 29003 provides a presumption of conformity to the relevant requirements of modules H, D and E.

EN 29001, EN 29002 and EN 29003 were superseded by EN ISO 9001:1994, EN ISO 9002:1994 and EN ISO 9003:1994 respectively, which in turn are now superseded by EN ISO 9001:2000.

Where organizations wish to implement quality management systems in conformance with modules E, D or H, they may use EN ISO 9001:2000. In seeking compliance with modules D, E or H organizations may exclude specific requirements.

Only those requirements in clause 7 of EN ISO 9001:2000 pertaining to the difference between modules E, D and H may be excluded whilst retaining the presumption of conformity.

Module E Permissible exclusions	Module D Permissible exclusions	Module H Permissible exclusions
Sub-clause 7.1: planning of product realization Sub-clause 7.2.3: customer communication Sub-clause 7.3: design and development Sub-clause 7.4 purchasing Sub-clause 7.5.1: control of production and service provision Sub-clause 7.5.2: validation of processes for production and service provision Sub-clause 7.5.3: Identification and traceability	Sub-clause 7.3: design and development	NO exclusions permitted
It should be noted that no explicit requirements in modules H, D and E relate to the concepts of "customer satisfaction" and "continual improvement". As a consequence, non compliance with requirements of EN ISO 9001:2000 explicitly related to these concepts does not infringe upon the presumption of conformity to the appropriate module		

It should be noted that where the exclusions described in sub-clause 1.2 of EN ISO 9001:2000 are exceeded, conformity to EN ISO 9001:2000 shall not be claimed.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of the International Standard ISO 9001:2000 has been approved by CEN as a European Standard without any modifications.

NOTE: Normative references to International Standards are listed in annex ZA (normative).

(ISO) (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electronical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 9001 was prepared by Technical Committee ISO/TC 176, *Quality management and quality assurance*, Subcommittee SC 2, *Quality systems*.

This third edition of ISO 9001 cancels and replaces the second edition (ISO 9001:1994) together with ISO 9002:1994 and ISO 9003:1994. It constitutes a technical revision of these documents. Those organizations which have used ISO 9002:1994 and ISO 9003:1994 in the past may use this International Standard by excluding certain requirements in accordance with 1.2.

The title of ISO 9001 has been revised in this edition and no longer includes the term "Quality assurance". This reflects the fact that the quality management system requirements specified in this edition of ISO 9001, in addition to quality assurance of product, also aim to enhance customer satisfaction.

Annexes A and B of this International Standard are for information only.

EN ISO 9001:2000

INTERNATIONAL STANDARD

ISO 9001

Third edition
2000-12-15

Quality management systems — Requirements

Systèmes de management de la qualité — Exigences

Reference number
ISO 9001:2000(E)

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reword

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Introduction

0.1 General

The adoption of a quality management system should be a strategic decision of an organization. The design and implementation of an organization's quality management system is influenced by varying needs, particular objectives, the products provided, the processes employed and the size and structure of the organization. It is not the intent of this International Standard to imply uniformity in the structure of quality management systems or uniformity of documentation.

The quality management system requirements specified in this International Standard are complementary to requirements for products. Information marked "NOTE" is for guidance in understanding or clarifying the associated requirement.

This International Standard can be used by internal and external parties, including certification bodies, to assess the organization's ability to meet customer, regulatory and the organization's own requirements.

The quality management principles stated in ISO 9000 and ISO 9004 have been taken into consideration during the development of this International Standard.

0.2 Process approach

This International Standard promotes the adoption of a process approach when developing, implementing and improving the effectiveness of a quality management system, to enhance customer satisfaction by meeting customer requirements.

For an organization to function effectively, it has to identify and manage numerous linked activities. An activity using resources, and managed in order to enable the transformation of inputs into outputs, can be considered as a process. Often the output from one process directly forms the input to the next.

The application of a system of processes within an organization, together with the identification and interactions of these processes, and their management, can be referred to as the "process approach".

An advantage of the process approach is the ongoing control that it provides over the linkage between the individual processes within the system of processes, as well as over their combination and interaction.

When used within a quality management system, such an approach emphasizes the importance of

a) understanding and meeting requirements,

b) the need to consider processes in terms of added value,

c) obtaining results of process performance and effectiveness, and

d) continual improvement of processes based on objective measurement.

The model of a process-based quality management system shown in Figure 1 illustrates the process linkages presented in clauses 4 to 8. This illustration shows that customers play a significant role in defining requirements as inputs. Monitoring of customer satisfaction requires the evaluation of information relating to customer perception as to whether the organization has met the customer requirements. The model shown in Figure 1 covers all the requirements of this International Standard, but does not show processes at a detailed level.

TE In addition, the methodology known as "Plan-Do-Check-Act" (PDCA) can be applied to all processes. PDCA can be briefly scribed as follows.

Plan: establish the objectives and processes necessary to deliver results in accordance with customer requirements and the organization's policies.

Do: implement the processes.

Check: monitor and measure processes and product against policies, objectives and requirements for the product and report the results.

Act: take actions to continually improve process performance.

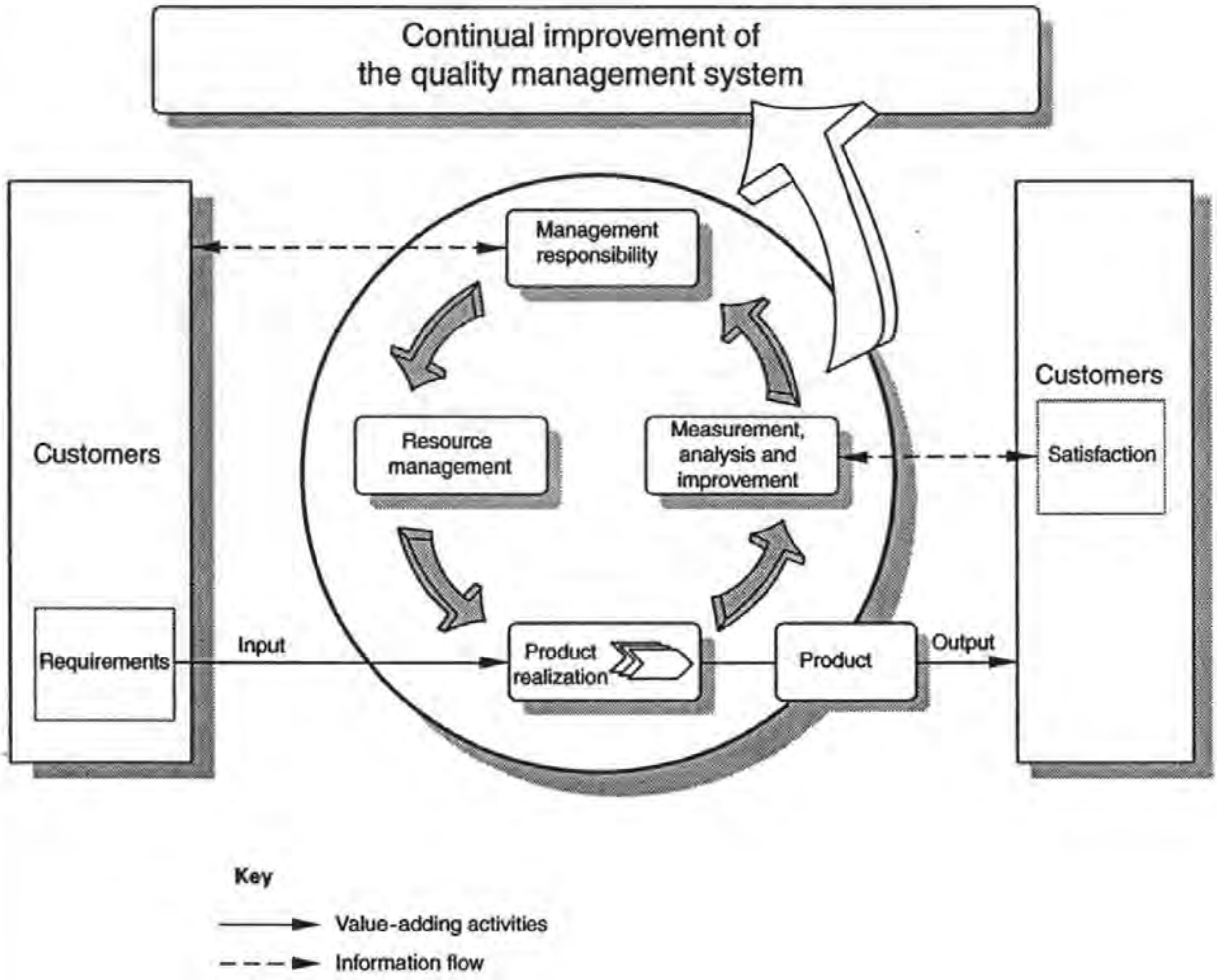

Figure 1 — Model of a process-based quality management system

3 Relationship with ISO 9004

e present editions of ISO 9001 and ISO 9004 have been developed as a consistent pair of quality management stem standards which have been designed to complement each other, but can also be used independently. hough the two International Standards have different scopes, they have similar structures in order to assist their plication as a consistent pair.

O 9001 specifies requirements for a quality management system that can be used for internal application by ganizations, or for certification, or for contractual purposes. It focuses on the effectiveness of the quality anagement system in meeting customer requirements.

ISO 9004 gives guidance on a wider range of objectives of a quality management system than does ISO 9001, particularly for the continual improvement of an organization's overall performance and efficiency, as well as its effectiveness. ISO 9004 is recommended as a guide for organizations whose top management wishes to move beyond the requirements of ISO 9001, in pursuit of continual improvement of performance. However, it is not intended for certification or for contractual purposes.

0.4 Compatibility with other management systems

This International Standard has been aligned with ISO 14001:1996 in order to enhance the compatibility of the two standards for the benefit of the user community.

This International Standard does not include requirements specific to other management systems, such as those particular to environmental management, occupational health and safety management, financial management or risk management. However, this International Standard enables an organization to align or integrate its own quality management system with related management system requirements. It is possible for an organization to adapt its existing management system(s) in order to establish a quality management system that complies with the requirements of this International Standard.

Quality management systems — Requirements

1 Scope

1.1 General

This International Standard specifies requirements for a quality management system where an organization

a) needs to demonstrate its ability to consistently provide product that meets customer and applicable regulatory requirements, and

b) aims to enhance customer satisfaction through the effective application of the system, including processes for continual improvement of the system and the assurance of conformity to customer and applicable regulatory requirements.

NOTE In this International Standard, the term "product" applies only to the product intended for, or required by, a customer.

1.2 Application

All requirements of this International Standard are generic and are intended to be applicable to all organizations, egardless of type, size and product provided.

Where any requirement(s) of this International Standard cannot be applied due to the nature of an organization and ts product, this can be considered for exclusion.

Where exclusions are made, claims of conformity to this International Standard are not acceptable unless these exclusions are limited to requirements within clause 7, and such exclusions do not affect the organization's ability, or esponsibility, to provide product that meets customer and applicable regulatory requirements.

2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated eferences, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain egisters of currently valid International Standards.

ISO 9000:2000, *Quality management systems — Fundamentals and vocabulary.*

Terms and definitions

r the purposes of this International Standard, the terms and definitions given in ISO 9000 apply.

ne following terms, used in this edition of ISO 9001 to describe the supply chain, have been changed to reflect the cabulary currently used:

supplier ⟶ **organization** ⟶ **customer**

ıe term "organization" replaces the term "supplier" used in ISO 9001:1994, and refers to the unit to which this ernational Standard applies. Also, the term "supplier" now replaces the term "subcontractor".

ıroughout the text of this International Standard, wherever the term "product" occurs, it can also mean "service".

Quality management system

1 General requirements

ıe organization shall establish, document, implement and maintain a quality management system and continually ıprove its effectiveness in accordance with the requirements of this International Standard.

ıe organization shall

identify the processes needed for the quality management system and their application throughout the organization (see 1.2),

determine the sequence and interaction of these processes,

determine criteria and methods needed to ensure that both the operation and control of these processes are effective,

ensure the availability of resources and information necessary to support the operation and monitoring of these processes,

monitor, measure and analyse these processes, and

implement actions necessary to achieve planned results and continual improvement of these processes.

ıese processes shall be managed by the organization in accordance with the requirements of this International andard.

'here an organization chooses to outsource any process that affects product conformity with requirements, the ganization shall ensure control over such processes. Control of such outsourced processes shall be identified ithin the quality management system.

OTE Processes needed for the quality management system referred to above should include processes for management tivities, provision of resources, product realization and measurement.

2 Documentation requirements

2.1 General

ıe quality management system documentation shall include

documented statements of a quality policy and quality objectives,

a quality manual,

documented procedures required by this International Standard,

documents needed by the organization to ensure the effective planning, operation and control of its processes, and

records required by this International Standard (see 4.2.4).

OTE 1 Where the term "documented procedure" appears within this International Standard, this means that the procedure is tablished, documented, implemented and maintained.

NOTE 2 The extent of the quality management system documentation can differ from one organization to another due to

a) the size of organization and type of activities,

b) the complexity of processes and their interactions, and

c) the competence of personnel.

NOTE 3 The documentation can be in any form or type of medium.

4.2.2 Quality manual

The organization shall establish and maintain a quality manual that includes

a) the scope of the quality management system, including details of and justification for any exclusions (see 1.2),

b) the documented procedures established for the quality management system, or reference to them, and

c) a description of the interaction between the processes of the quality management system.

4.2.3 Control of documents

Documents required by the quality management system shall be controlled. Records are a special type of document and shall be controlled according to the requirements given in 4.2.4.

A documented procedure shall be established to define the controls needed

a) to approve documents for adequacy prior to issue,

b) to review and update as necessary and re-approve documents,

c) to ensure that changes and the current revision status of documents are identified,

d) to ensure that relevant versions of applicable documents are available at points of use,

e) to ensure that documents remain legible and readily identifiable,

f) to ensure that documents of external origin are identified and their distribution controlled, and

g) to prevent the unintended use of obsolete documents, and to apply suitable identification to them if they are retained for any purpose.

4.2.4 Control of records

Records shall be established and maintained to provide evidence of conformity to requirements and of the effective operation of the quality management system. Records shall remain legible, readily identifiable and retrievable. A documented procedure shall be established to define the controls needed for the identification, storage, protection, retrieval, retention time and disposition of records.

5 Management responsibility

5.1 Management commitment

Top management shall provide evidence of its commitment to the development and implementation of the quality management system and continually improving its effectiveness by

a) communicating to the organization the importance of meeting customer as well as statutory and regulatory requirements,

b) establishing the quality policy,

c) ensuring that quality objectives are established, conducting management reviews, and

ensuring the availability of resources.

2 Customer focus

p management shall ensure that customer requirements are determined and are met with the aim of enhancing stomer satisfaction (see 7.2.1 and 8.2.1).

3 Quality policy

p management shall ensure that the quality policy

is appropriate to the purpose of the organization,

includes a commitment to comply with requirements and continually improve the effectiveness of the quality management system,

provides a framework for establishing and reviewing quality objectives,

is communicated and understood within the organization, and

is reviewed for continuing suitability.

4 Planning

4.1 Quality objectives

p management shall ensure that quality objectives, including those needed to meet requirements for product [see 1 a)], are established at relevant functions and levels within the organization. The quality objectives shall be easurable and consistent with the quality policy.

4.2 Quality management system planning

p management shall ensure that

the planning of the quality management system is carried out in order to meet the requirements given in 4.1, as well as the quality objectives, and

the integrity of the quality management system is maintained when changes to the quality management system are planned and implemented.

5 Responsibility, authority and communication

5.1 Responsibility and authority

p management shall ensure that responsibilities and authorities are defined and communicated within the ganization.

5.2 Management representative

p management shall appoint a member of management who, irrespective of other responsibilities, shall have sponsibility and authority that includes

ensuring that processes needed for the quality management system are established, implemented and maintained,

b) reporting to top management on the performance of the quality management system and any need for improvement, and

c) ensuring the promotion of awareness of customer requirements throughout the organization.

NOTE The responsibility of a management representative can include liaison with external parties on matters relating to the quality management system.

5.5.3 Internal communication

Top management shall ensure that appropriate communication processes are established within the organization and that communication takes place regarding the effectiveness of the quality management system.

5.6 Management review

5.6.1 General

Top management shall review the organization's quality management system, at planned intervals, to ensure its continuing suitability, adequacy and effectiveness. This review shall include assessing opportunities for improvement and the need for changes to the quality management system, including the quality policy and quality objectives.

Records from management reviews shall be maintained (see 4.2.4).

5.6.2 Review input

The input to management review shall include information on

a) results of audits,

b) customer feedback,

c) process performance and product conformity,

d) status of preventive and corrective actions,

e) follow-up actions from previous management reviews,

f) changes that could affect the quality management system, and

g) recommendations for improvement.

5.6.3 Review output

The output from the management review shall include any decisions and actions related to

a) improvement of the effectiveness of the quality management system and its processes,

b) improvement of product related to customer requirements, and

c) resource needs.

6 Resource management

6.1 Provision of resources

The organization shall determine and provide the resources needed

a) to implement and maintain the quality management system and continually improve its effectiveness, and

b) to enhance customer satisfaction by meeting customer requirements.

2 Human resources

2.1 General

rsonnel performing work affecting product quality shall be competent on the basis of appropriate education, ining, skills and experience.

2.2 Competence, awareness and training

e organization shall

determine the necessary competence for personnel performing work affecting product quality,

provide training or take other actions to satisfy these needs,

evaluate the effectiveness of the actions taken,

ensure that its personnel are aware of the relevance and importance of their activities and how they contribute to the achievement of the quality objectives, and

maintain appropriate records of education, training, skills and experience (see 4.2.4).

3 Infrastructure

ie organization shall determine, provide and maintain the infrastructure needed to achieve conformity to product quirements. Infrastructure includes, as applicable

buildings, workspace and associated utilities,

process equipment (both hardware and software), and

supporting services (such as transport or communication).

4 Work environment

ie organization shall determine and manage the work environment needed to achieve conformity to product quirements.

Product realization

1 Planning of product realization

ie organization shall plan and develop the processes needed for product realization. Planning of product realization all be consistent with the requirements of the other processes of the quality management system (see 4.1).

planning product realization, the organization shall determine the following, as appropriate:

quality objectives and requirements for the product;

the need to establish processes, documents, and provide resources specific to the product;

required verification, validation, monitoring, inspection and test activities specific to the product and the criteria for product acceptance;

records needed to provide evidence that the realization processes and resulting product meet requirements (see 4.2.4).

The output of this planning shall be in a form suitable for the organization's method of operations.

NOTE 1 A document specifying the processes of the quality management system (including the product realization processes) and the resources to be applied to a specific product, project or contract, can be referred to as a quality plan.

NOTE 2 The organization may also apply the requirements given in 7.3 to the development of product realization processes.

7.2 Customer-related processes

7.2.1 Determination of requirements related to the product

The organization shall determine

a) requirements specified by the customer, including the requirements for delivery and post-delivery activities,

b) requirements not stated by the customer but necessary for specified or intended use, where known,

c) statutory and regulatory requirements related to the product, and

d) any additional requirements determined by the organization.

7.2.2 Review of requirements related to the product

The organization shall review the requirements related to the product. This review shall be conducted prior to the organization's commitment to supply a product to the customer (e.g. submission of tenders, acceptance of contracts or orders, acceptance of changes to contracts or orders) and shall ensure that

a) product requirements are defined,

b) contract or order requirements differing from those previously expressed are resolved, and

c) the organization has the ability to meet the defined requirements.

Records of the results of the review and actions arising from the review shall be maintained (see 4.2.4).

Where the customer provides no documented statement of requirement, the customer requirements shall be confirmed by the organization before acceptance.

Where product requirements are changed, the organization shall ensure that relevant documents are amended and that relevant personnel are made aware of the changed requirements.

NOTE In some situations, such as internet sales, a formal review is impractical for each order. Instead the review can cover relevant product information such as catalogues or advertising material.

7.2.3 Customer communication

The organization shall determine and implement effective arrangements for communicating with customers in relation to

a) product information,

b) enquiries, contracts or order handling, including amendments, and

c) customer feedback, including customer complaints.

Design and development

Design and development planning

ırganization shall plan and control the design and development of product.

g the design and development planning, the organization shall determine

ıe design and development stages,

ıe review, verification and validation that are appropriate to each design and development stage, and

ıe responsibilities and authorities for design and development.

ırganization shall manage the interfaces between different groups involved in design and development to ensure ive communication and clear assignment of responsibility.

ıing output shall be updated, as appropriate, as the design and development progresses.

Design and development inputs

s relating to product requirements shall be determined and records maintained (see 4.2.4). These inputs shall le

ınctional and performance requirements,

pplicable statutory and regulatory requirements,

'here applicable, information derived from previous similar designs, and

ther requirements essential for design and development.

e inputs shall be reviewed for adequacy. Requirements shall be complete, unambiguous and not in conflict with other.

Design and development outputs

outputs of design and development shall be provided in a form that enables verification against the design and lopment input and shall be approved prior to release.

gn and development outputs shall

ıeet the input requirements for design and development,

rovide appropriate information for purchasing, production and for service provision,

ontain or reference product acceptance criteria, and

pecify the characteristics of the product that are essential for its safe and proper use.

Design and development review

ıitable stages, systematic reviews of design and development shall be performed in accordance with planned gements (see 7.3.1)

o evaluate the ability of the results of design and development to meet requirements, and

o identify any problems and propose necessary actions.

cipants in such reviews shall include representatives of functions concerned with the design and development e(s) being reviewed. Records of the results of the reviews and any necessary actions shall be maintained (see).

7.3.5 Design and development verification

Verification shall be performed in accordance with planned arrangements (see 7.3.1) to ensure that the design and development outputs have met the design and development input requirements. Records of the results of the verification and any necessary actions shall be maintained (see 4.2.4).

7.3.6 Design and development validation

Design and development validation shall be performed in accordance with planned arrangements (see 7.3.1) to ensure that the resulting product is capable of meeting the requirements for the specified application or intended use, where known. Wherever practicable, validation shall be completed prior to the delivery or implementation of the product. Records of the results of validation and any necessary actions shall be maintained (see 4.2.4).

7.3.7 Control of design and development changes

Design and development changes shall be identified and records maintained. The changes shall be reviewed, verified and validated, as appropriate, and approved before implementation. The review of design and development changes shall include evaluation of the effect of the changes on constituent parts and product already delivered.

Records of the results of the review of changes and any necessary actions shall be maintained (see 4.2.4).

7.4 Purchasing

7.4.1 Purchasing process

The organization shall ensure that purchased product conforms to specified purchase requirements. The type and extent of control applied to the supplier and the purchased product shall be dependent upon the effect of the purchased product on subsequent product realization or the final product.

The organization shall evaluate and select suppliers based on their ability to supply product in accordance with the organization's requirements. Criteria for selection, evaluation and re-evaluation shall be established. Records of the results of evaluations and any necessary actions arising from the evaluation shall be maintained (see 4.2.4).

7.4.2 Purchasing information

Purchasing information shall describe the product to be purchased, including where appropriate

a) requirements for approval of product, procedures, processes and equipment,

b) requirements for qualification of personnel, and

c) quality management system requirements.

The organization shall ensure the adequacy of specified purchase requirements prior to their communication to the supplier.

7.4.3 Verification of purchased product

The organization shall establish and implement the inspection or other activities necessary for ensuring that purchased product meets specified purchase requirements.

Where the organization or its customer intends to perform verification at the supplier's premises, the organization shall state the intended verification arrangements and method of product release in the purchasing information.

Production and service provision

1 Control of production and service provision

organization shall plan and carry out production and service provision under controlled conditions. Controlled ditions shall include, as applicable

the availability of information that describes the characteristics of the product,

the availability of work instructions, as necessary,

the use of suitable equipment,

the availability and use of monitoring and measuring devices,

the implementation of monitoring and measurement, and

the implementation of release, delivery and post-delivery activities.

.2 Validation of processes for production and service provision

organization shall validate any processes for production and service provision where the resulting output cannot verified by subsequent monitoring or measurement. This includes any processes where deficiencies become parent only after the product is in use or the service has been delivered.

idation shall demonstrate the ability of these processes to achieve planned results.

e organization shall establish arrangements for these processes including, as applicable

defined criteria for review and approval of the processes,

approval of equipment and qualification of personnel,

use of specific methods and procedures,

requirements for records (see 4.2.4), and

revalidation.

.3 Identification and traceability

ere appropriate, the organization shall identify the product by suitable means throughout product realization.

e organization shall identify the product status with respect to monitoring and measurement requirements.

ere traceability is a requirement, the organization shall control and record the unique identification of the product e 4.2.4).

TE In some industry sectors, configuration management is a means by which identification and traceability are maintained.

.4 Customer property

e organization shall exercise care with customer property while it is under the organization's control or being used the organization. The organization shall identify, verify, protect and safeguard customer property provided for use incorporation into the product. If any customer property is lost, damaged or otherwise found to be unsuitable for e, this shall be reported to the customer and records maintained (see 4.2.4).

TE Customer property can include intellectual property.

7.5.5 Preservation of product

The organization shall preserve the conformity of product during internal processing and delivery to the intended destination. This preservation shall include identification, handling, packaging, storage and protection. Preservation shall also apply to the constituent parts of a product.

7.6 Control of monitoring and measuring devices

The organization shall determine the monitoring and measurement to be undertaken and the monitoring and measuring devices needed to provide evidence of conformity of product to determined requirements (see 7.2.1).

The organization shall establish processes to ensure that monitoring and measurement can be carried out and are carried out in a manner that is consistent with the monitoring and measurement requirements.

Where necessary to ensure valid results, measuring equipment shall

a) be calibrated or verified at specified intervals, or prior to use, against measurement standards traceable to international or national measurement standards; where no such standards exist, the basis used for calibration or verification shall be recorded;

b) be adjusted or re-adjusted as necessary;

c) be identified to enable the calibration status to be determined;

d) be safeguarded from adjustments that would invalidate the measurement result;

e) be protected from damage and deterioration during handling, maintenance and storage.

In addition, the organization shall assess and record the validity of the previous measuring results when the equipment is found not to conform to requirements. The organization shall take appropriate action on the equipment and any product affected. Records of the results of calibration and verification shall be maintained (see 4.2.4).

When used in the monitoring and measurement of specified requirements, the ability of computer software to satisfy the intended application shall be confirmed. This shall be undertaken prior to initial use and reconfirmed as necessary.

NOTE See ISO 10012-1 and ISO 10012-2 for guidance.

8 Measurement, analysis and improvement

8.1 General

The organization shall plan and implement the monitoring, measurement, analysis and improvement processes needed

a) to demonstrate conformity of the product,

b) to ensure conformity of the quality management system, and

c) to continually improve the effectiveness of the quality management system.

This shall include determination of applicable methods, including statistical techniques, and the extent of their use.

8.2 Monitoring and measurement

8.2.1 Customer satisfaction

As one of the measurements of the performance of the quality management system, the organization shall monitor information relating to customer perception as to whether the organization has met customer requirements. The methods for obtaining and using this information shall be determined.

2 Internal audit

organization shall conduct internal audits at planned intervals to determine whether the quality management tem

conforms to the planned arrangements (see 7.1), to the requirements of this International Standard and to the quality management system requirements established by the organization, and

is effectively implemented and maintained.

audit programme shall be planned, taking into consideration the status and importance of the processes and as to be audited, as well as the results of previous audits. The audit criteria, scope, frequency and methods shall defined. Selection of auditors and conduct of audits shall ensure objectivity and impartiality of the audit process. litors shall not audit their own work.

responsibilities and requirements for planning and conducting audits, and for reporting results and maintaining ords (see 4.2.4) shall be defined in a documented procedure.

management responsible for the area being audited shall ensure that actions are taken without undue delay to inate detected nonconformities and their causes. Follow-up activities shall include the verification of the actions en and the reporting of verification results (see 8.5.2).

TE See ISO 10011-1, ISO 10011-2 and ISO 10011-3 for guidance.

.3 Monitoring and measurement of processes

organization shall apply suitable methods for monitoring and, where applicable, measurement of the quality nagement system processes. These methods shall demonstrate the ability of the processes to achieve planned ults. When planned results are not achieved, correction and corrective action shall be taken, as appropriate, to ure conformity of the product.

.4 Monitoring and measurement of product

organization shall monitor and measure the characteristics of the product to verify that product requirements e been met. This shall be carried out at appropriate stages of the product realization process in accordance with planned arrangements (see 7.1).

dence of conformity with the acceptance criteria shall be maintained. Records shall indicate the person(s) horizing release of product (see 4.2.4).

duct release and service delivery shall not proceed until the planned arrangements (see 7.1) have been sfactorily completed, unless otherwise approved by a relevant authority and, where applicable, by the customer.

Control of nonconforming product

organization shall ensure that product which does not conform to product requirements is identified and trolled to prevent its unintended use or delivery. The controls and related responsibilities and authorities for ling with nonconforming product shall be defined in a documented procedure.

organization shall deal with nonconforming product by one or more of the following ways:

by taking action to eliminate the detected nonconformity;

by authorizing its use, release or acceptance under concession by a relevant authority and, where applicable, by the customer;

by taking action to preclude its original intended use or application.

cords of the nature of nonconformities and any subsequent actions taken, including concessions obtained, shall maintained (see 4.2.4).

When nonconforming product is corrected it shall be subject to re-verification to demonstrate conformity to the requirements.

When nonconforming product is detected after delivery or use has started, the organization shall take action appropriate to the effects, or potential effects, of the nonconformity.

8.4 Analysis of data

The organization shall determine, collect and analyse appropriate data to demonstrate the suitability and effectiveness of the quality management system and to evaluate where continual improvement of the effectiveness of the quality management system can be made. This shall include data generated as a result of monitoring and measurement and from other relevant sources.

The analysis of data shall provide information relating to

a) customer satisfaction (see 8.2.1),

b) conformity to product requirements (see 7.2.1),

c) characteristics and trends of processes and products including opportunities for preventive action, and

d) suppliers.

8.5 Improvement

8.5.1 Continual improvement

The organization shall continually improve the effectiveness of the quality management system through the use of the quality policy, quality objectives, audit results, analysis of data, corrective and preventive actions and management review.

8.5.2 Corrective action

The organization shall take action to eliminate the cause of nonconformities in order to prevent recurrence. Corrective actions shall be appropriate to the effects of the nonconformities encountered.

A documented procedure shall be established to define requirements for

a) reviewing nonconformities (including customer complaints),

b) determining the causes of nonconformities,

c) evaluating the need for action to ensure that nonconformities do not recur,

d) determining and implementing action needed,

e) records of the results of action taken (see 4.2.4), and

f) reviewing corrective action taken.

8.5.3 Preventive action

The organization shall determine action to eliminate the causes of potential nonconformities in order to prevent their occurrence. Preventive actions shall be appropriate to the effects of the potential problems.

ocumented procedure shall be established to define requirements for
determining potential nonconformities and their causes,
evaluating the need for action to prevent occurrence of nonconformities,
determining and implementing action needed,
records of results of action taken (see 4.2.4), and
reviewing preventive action taken.

Annex A
(informative)

Correspondence between ISO 9001:2000 and ISO 14001:1996

Table A.1 — Correspondence between ISO 9001:2000 and ISO 14001:1996

ISO 9001:2000		ISO 14001:1996	
Introduction			**Introduction**
General	0.1		
Process approach	0.2		
Relationship with ISO 9004	0.3		
Compatibility with other management systems	0.4		
Scope	1	1	Scope
General	1.1		
Application	1.2		
Normative reference	2	2	**Normative references**
Terms and definitions	3	3	**Definitions**
Quality management system	4	4	**Environmental management system requirements**
General requirements	4.1	4.1	General requirements
Documentation requirements	4.2		
General	4.2.1	4.4.4	Environmental management system documentation
Quality manual	4.2.2	4.4.4	Environmental management system documentation
Control of documents	4.2.3	4.4.5	Document control
Control of records	4.2.4	4.5.3	Records
Management responsibility	5	4.4.1	Structure and responsibility
Management commitment	5.1	4.2 4.4.1	Environmental policy Structure and responsibility
Customer focus	5.2	4.3.1 4.3.2	Environmental aspects Legal and other requirements
Quality policy	5.3	4.2	Environmental policy
Planning	5.4	4.3	Planning
Quality objectives	5.4.1	4.3.3	Objectives and targets
Quality management system planning	5.4.2	4.3.4	Environmental management programme(s)
Responsibility, authority and communication	5.5	4.1	General requirements
Responsibility and authority	5.5.1	4.4.1	Structure and responsibility
Management representative	5.5.2		
Internal communication	5.5.3	4.4.3	Communication
Management review	5.6	4.6	Management review
General	5.6.1		
Review input	5.6.2		
Review output	5.6.3		
Resource management	6	4.4.1	Structure and responsibility
Provision of resources	6.1		
Human resources	6.2		
General	6.2.1		
Competence, awareness and training	6.2.2	4.4.2	Training, awareness and competence
Infrastructure	6.3	4.4.1	Structure and responsibility
Work environment	6.4		

Table A.1 — Correspondence between ISO 9001:2000 and ISO 14001:1996 (*continued*)

ISO 9001:2000		ISO 14001:1996	
oduct realization	7	4.4 4.4.6	Implementation and operation Operational control
anning of product realization	7.1	4.4.6	Operational control
istomer-related processes	7.2		
etermination of requirements related to the oduct	7.2.1	4.3.1 4.3.2 4.4.6	Environmental aspects Legal and other requirements Operational control
eview of requirements related to the product	7.2.2	4.4.6 4.3.1	Operational control Environmental aspects
istomer communication	7.2.3	4.4.3	Communications
esign and development	7.3		
esign and development planning	7.3.1	4.4.6	Operational control
esign and development inputs	7.3.2		
esign and development outputs	7.3.3		
esign and development review	7.3.4		
esign and development verification	7.3.5		
esign and development validation	7.3.6		
ontrol of design and development changes	7.3.7		
irchasing	7.4	4.4.6	Operational control
irchasing process	7.4.1		
irchasing information	7.4.2		
rification of purchased product	7.4.3		
oduction and service provision	7.5	4.4.6	Operational control
ontrol of production and service provision	7.5.1		
lidation of processes for production and rvice provision	7.5.2		
entification and traceability	7.5.3		
istomer property	7.5.4		
eservation of product	7.5.5		
ontrol of monitoring and measuring devices	7.6	4.5.1	Monitoring and measurement
easurement, analysis and improvement	8	4.5	Checking and corrective action
eneral	8.1	4.5.1	Monitoring and measurement
onitoring and measurement	8.2		
istomer satisfaction	8.2.1		
ternal audit	8.2.2	4.5.4	Environmental management system audit
onitoring and measurement of processes	8.2.3	4.5.1	Monitoring and measurement
onitoring and measurement of product	8.2.4		
ontrol of nonconforming product	8.3	4.5.2 4.4.7	Nonconformance and corrective and preventive action Emergency preparedness and response
ialysis of data	8.4	4.5.1	Monitoring and measurement
iprovement	8.5	4.2	Environmental policy
ontinual improvement	8.5.1	4.3.4	Environmental management programme(s)
orrective action	8.5.2	4.5.2	Nonconformance and corrective and preventive action
eventive action	8.5.3		

Table A.2 — Correspondence between ISO 14001:1996 and ISO 9001:2000

ISO 14001:1996		ISO 9001:2000	
Introduction	—	0	**Introduction**
		0.1	General
		0.2	Process approach
		0.3	Relationship with ISO 9004
		0.4	Compatibility with other management systems
Scope	1	1	**Scope**
		1.1	General
		1.2	Application
Normative references	2	2	**Normative reference**
Definitions	3	3	**Terms and definitions**
Environmental management system requirements	4	4	**Quality management system**
General requirements	4.1	4.1	General requirements
		5.5	Responsibility, authority and communication
		5.5.1	Responsibility and authority
Environmental policy	4.2	5.1	Management commitment
		5.3	Quality policy
		8.5	Improvement
Planning	4.3	5.4	Planning
Environmental aspects	4.3.1	5.2	Customer focus
		7.2.1	Determination of requirements related to the product
		7.2.2	Review of requirements related to the product
Legal and other requirements	4.3.2	5.2	Customer focus
		7.2.1	Determination of requirements related to the product
Objectives and targets	4.3.3	5.4.1	Quality objectives
Environmental management programme(s)	4.3.4	5.4.2	Quality management system planning
		8.5.1	Continual improvement
Implementation and operation	4.4	7	**Product realization**
		7.1	Planning of product realization
Structure and responsibility	4.4.1	5	**Management responsibility**
		5.1	Management commitment
		5.5.1	Responsibility and authority
		5.5.2	Management representative
		6	**Resource management**
		6.1	Provision of resources
		6.2	Human resources
		6.2.1	General
		6.3	Infrastructure
		6.4	Work environment
Training, awareness and competence	4.4.2	6.2.2	Competence, awareness and training
Communication	4.4.3	5.5.3	Internal communication
		7.2.3	Customer communication
Environmental management system documentation	4.4.4	4.2	Documentation requirements
		4.2.1	General
		4.2.2	Quality manual

Table A.2 — Correspondence between ISO 14001:1996 and ISO 9001:2000 (*continued*)

ISO 14001:1996		ISO 9001:2000	
cument control	4.4.5	4.2.3	Control of documents
erational control	4.4.6	7	**Product realization**
		7.1	Planning of product realization
		7.2	Customer-related processes
		7.2.1	Determination of requirements related to the product
		7.2.2	Review of requirements related to the product
		7.3	Design and development
		7.3.1	Design and development planning
		7.3.2	Design and development inputs
		7.3.3	Design and development outputs
		7.3.4	Design and development review
		7.3.5	Design and development verification
		7.3.6	Design and development validation
		7.3.7	Control of design and development changes
		7.4	Purchasing
		7.4.1	Purchasing process
		7.4.2	Purchasing information
		7.4.3	Verification of purchased product
		7.5	Production and service provision
		7.5.1	Control of production and service provision
		7.5.3	Identification and traceability
		7.5.4	Customer property
		7.5.5	Preservation of product
		7.5.2	Validation of processes for production and service provision
nergency preparedness and response	4.4.7	8.3	Control of nonconforming product
necking and corrective action	4.5	8	**Measurement, analysis and improvement**
onitoring and measurement	4.5.1	7.6	Control of monitoring and measuring devices
		8.1	General
		8.2	Monitoring and measurement
		8.2.1	Customer satisfaction
		8.2.3	Monitoring and measurement of processes
		8.2.4	Monitoring and measurement of product
		8.4	Analysis of data
onconformance and corrective and eventive action	4.5.2	8.3	Control of nonconforming product
		8.5.2	Corrective action
		8.5.3	Preventive action
ecords	4.5.3	4.2.4	Control of records
vironmental management system audit	4.5.4	8.2.2	Internal audit
anagement review	4.6	5.6	Management review
		5.6.1	General
		5.6.2	Review input
		5.6.3	Review output

Annex B
(informative)

Correspondence between ISO 9001:2000 and ISO 9001:1994

Table B.1 — Correspondence between ISO 9001:1994 and ISO 9001:2000

ISO 9001:1994	ISO 9001:2000
1 Scope	1
2 Normative reference	2
3 Definitions	3
4 Quality system requirements [title only]	
4.1 Management responsibility [title only]	
4.1.1 Quality policy	5.1 + 5.3 + 5.4.1
4.1.2 Organization [title only]	
4.1.2.1 Responsibility and authority	5.5.1
4.1.2.2 Resources	6.1 + 6.2.1
4.1.2.3 Management representative	5.5.2
4.1.3 Management review	5.6.1 + 8.5.1
4.2 Quality system [title only]	
4.2.1 General	4.1 + 4.2.2
4.2.2 Quality system procedures	4.2.1
4.2.3 Quality planning	5.4.2 + 7.1
4.3 Contract review [title only]	
4.3.1 General	
4.3.2 Review	5.2 + 7.2.1 + 7.2.2 + 7.2.3
4.3.3 Amendment to a contract	7.2.2
4.3.4 Records	7.2.2
4.4 Design control [title only]	
4.4.1 General	
4.4.2 Design and development planning	7.3.1
4.4.3 Organizational and technical interfaces	7.3.1
4.4.4 Design input	7.2.1 + 7.3.2
4.4.5 Design output	7.3.3
4.4.6 Design review	7.3.4
4.4.7 Design verification	7.3.5
4.4.8 Design validation	7.3.6
4.4.9 Design changes	7.3.7
4.5 Document and data control [title only]	
4.5.1 General	4.2.3
4.5.2 Document and data approval and issue	4.2.3
4.5.3 Document and data changes	4.2.3
4.6 Purchasing [title only]	
4.6.1 General	
4.6.2 Evaluation of subcontractors	7.4.1
4.6.3 Purchasing data	7.4.2
4.6.4 Verification of purchased product	7.4.3

Table B.1 — Correspondence between ISO 9001:1994 and ISO 9001:2000 (*continued*)

ISO 9001:1994	ISO 9001:2000
4.7 Control of customer-supplied product	7.5.4
4.8 Product identification and traceability	7.5.3
4.9 Process control	6.3 + 6.4 + 7.5.1 + 7.5.2
4.10 Inspection and testing [title only]	
4.10.1 General	7.1 + 8.1
4.10.2 Receiving inspection and testing	7.4.3 + 8.2.4
4.10.3 In-process inspection and testing	8.2.4
4.10.4 Final inspection and testing	8.2.4
4.10.5 Inspection and test records	7.5.3 + 8.2.4
4.11 Control of inspection, measuring and test equipment [title only]	
4.11.1 General	7.6
4.11.2 Control procedure	7.6
4.12 Inspection and test status	7.5.3
4.13 Control of nonconforming product [title only]	
4.13.1 General	8.3
4.13.2 Review and disposition of nonconforming product	8.3
4.14 Corrective and preventive action [title only]	
4.14.1 General	8.5.2 + 8.5.3
4.14.2 Corrective action	8.5.2
4.14.3 Preventive action	8.5.3
4.15 Handling, storage, packaging, preservation & delivery [title only]	
4.15.1 General	
4.15.2 Handling	7.5.5
4.15.3 Storage	7.5.5
4.15.4 Packaging	7.5.5
4.15.5 Preservation	7.5.5
4.15.6 Delivery	7.5.1
4.16 Control of quality records	4.2.4
4.17 Internal quality audits	8.2.2 + 8.2.3
4.18 Training	6.2.2
4.19 Servicing	7.5.1
4.20 Statistical techniques [title only]	
4.20.1 Identification of need	8.1 + 8.2.3 + 8.2.4 + 8.4
4.20.2 Procedures	8.1 + 8.2.3 + 8.2.4 + 8.4

Table B.2 — Correspondence between ISO 9001:2000 and ISO 9001:1994

ISO 9001:2000	ISO 9001:1994
1 Scope	1
1.1 General	
1.2 Application	
2 Normative reference	2
3 Terms and definitions	3
4 Quality management system [title only]	
4.1 General requirements	4.2.1
4.2 Documentation requirements [title only]	
4.2.1 General	4.2.2
4.2.2 Quality manual	4.2.1
4.2.3 Control of documents	4.5.1 + 4.5.2 + 4.5.3
4.2.4 Control of records	4.16
5 Management responsibility [title only]	
5.1 Management commitment	4.1.1
5.2 Customer focus	4.3.2
5.3 Quality policy	4.1.1
5.4 Planning [title only]	
5.4.1 Quality objectives	4.1.1
5.4.2 Quality management system planning	4.2.3
5.5 Responsibility, authority and communication [title only]	
5.5.1 Responsibility and authority	4.1.2.1
5.5.2 Management representative	4.1.2.3
5.5.3 Internal communication	
5.6 Management review [title only]	
5.6.1 General	4.1.3
5.6.2 Review input	
5.6.3 Review output	
6 Resource management [title only]	
6.1 Provision of resources	4.1.2.2
6.2 Human resources [title only]	
6.2.1 General	4.1.2.2
6.2.2 Competence, awareness and training	4.18
6.3 Infrastructure	4.9
6.4 Work environment	4.9
7 Product realization [title only]	
7.1 Planning of product realization	4.2.3 + 4.10.1
7.2 Customer-related processes [title only]	
7.2.1 Determination of requirements related to the product	4.3.2 + 4.4.4
7.2.2 Review of requirements related to the product	4.3.2 + 4.3.3 + 4.3.4
7.2.3 Customer communication	4.3.2
7.3 Design and development [title only]	
7.3.1 Design and development planning	4.4.2 + 4.4.3
7.3.2 Design and development inputs	4.4.4

Table B.2 — Correspondence between ISO 9001:2000 and ISO 9001:1994 (*continued*)

ISO 9001:2000	ISO 9001:1994
7.3.3 Design and development outputs	4.4.5
7.3.4 Design and development review	4.4.6
7.3.5 Design and development verification	4.4.7
7.3.6 Design and development validation	4.4.8
7.3.7 Control of design and development changes	4.4.9
7.4 Purchasing [title only]	
7.4.1 Purchasing process	4.6.2
7.4.2 Purchasing information	4.6.3
7.4.3 Verification of purchased product	4.6.4 + 4.10.2
7.5 Production and service provision [title only]	
7.5.1 Control of production and service provision	4.9 + 4.15.6 + 4.19
7.5.2 Validation of processes for production and service provision	4.9
7.5.3 Identification and traceability	4.8 + 4.10.5 + 4.12
7.5.4 Customer property	4.7
7.5.5 Preservation of product	4.15.2 + 4.15.3 + 4.15.4 +.4.15.5
7.6 Control of monitoring and measuring devices	4.11.1 + 4.11.2
8 Measurement, analysis and improvement [title only]	
8.1 General	4.10.1 + 4.20.1 + 4.20.2
8.2 Monitoring and measurement [title only]	
8.2.1 Customer satisfaction	
8.2.2 Internal audit	4.17
8.2.3 Monitoring and measurement of processes	4.17 + 4.20.1 + 4.20.2
8.2.4 Monitoring and measurement of product	4.10.2 + 4.10.3 + 4.10.4 + 4.10.5 + 4.20.1 + 4.20.2
8.3 Control of nonconforming product	4.13.1 + 4.13.2
8.4 Analysis of data	4.20.1 + 4.20.2
8.5 Improvement [title only]	
8.5.1 Continual improvement	4.1.3
8.5.2 Corrective action	4.14.1 + 4.14.2
8.5.3 Preventive action	4.14.1 + 4.14.3

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[5] ISO 10007:1995, *Quality management — Guidelines for configuration management.*

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http://www.bsi.org.uk/iso-tc176-sc2

1) To be revised as ISO 19011, *Guidelines on quality and/or environmental management systems auditing.*

2) To be published. (Revision of ISO 9000-4:1993)

3) Available from website: http://www.iso.ch

4) Available from ISO Central Secretariat (sales@iso.ch).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normativereferences are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE Where an International Publication has been modified by common modifications, indicated by (mod.), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
ISO 9000	2000	Quality management systems – Fundamentals and vocabulary	EN ISO 9000	2000

Appendix 5 - IDEF$_{9000}$ – A standard for modelling operating business processes with links to ISO 9001

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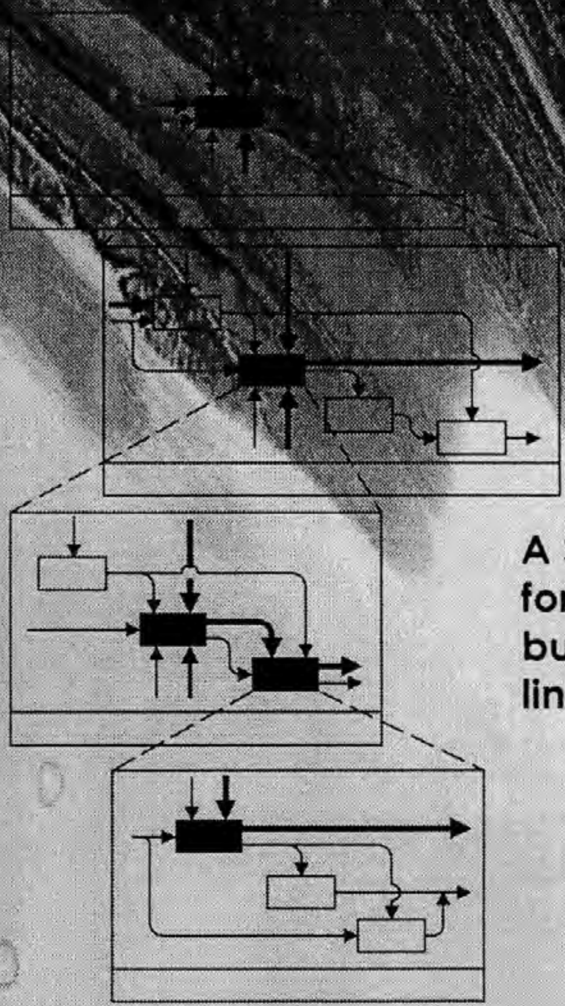
IDEF 9000 A Standard for modelling operating business processes with links to ISO 9001 J.Gingele

IDEF 9000



A Standard for modelling operating business processes with links to ISO 9001

Joachim Gingele

IDEF$_{9000}$

A Standard
for modelling operating business
processes with links to ISO 9001

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Preface

Even with its revision to ISO 9001:2000 organisations still find it difficult to apply and integrate the requirements of the quality standard effectively. Simply documenting what a company does in response to the requirements of the ISO 9001 is still one of the most common approaches adopted, which in many cases, leads to increased bureaucracy because existing organisational structures are not redesigned to suit. The usefulness of business process-oriented organisational structures has been widely recognised but quality management systems often achieve a process-oriented character only within the documentation. The focus has often been on the design of a certifiable quality management system and not on an overall systemic view of the business process.

As organisations are increasingly focusing on flexibility, innovation and processes there now appears to be a need to assess current approaches to the implementation of the ISO 9001 requirements. With the publication of a completely revised ISO 9001:2000 it is an opportune moment for management to update or restructure the company's quality management system.

With this as the main objective a modelling technique was developed that enables practitioners to create a model of a business process that allows them to establish links between the requirements of the standard and the activities of this business process.

It is based on a recognition that for any design/redesign exercise the process model needs to be able to show the practitioners which activities are linked to ISO 9001 and consequently need special attention. This guide explains the concept of the modelling technique together with its method of use with particular reference to the modelling of the Fulfil Order Process. I hope you will find it a useful resource.

Joachim Gingele

Plymouth, October 2001

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1 Introduction

The re-engineering of business processes in an environment controlled by a standard cannot simply be achieved by brainstorming and creativity since there is a danger of losing activities or procedures that provide essential quality management. Similarly the implementation or revision of a standard calls for a good understanding of the relationships between the standard, its associated documentation and the activities, inputs and outputs of the business process. $IDEF_{9000}$ provides a graphical technique to show clearly the links between an implementation of a standard and the business process concerned. It allows practitioners to:

- show links between the requirements of the ISO 9001 standard and the Fulfil Order Process of an organisation;
- take a holistic perspective of the integration of ISO 9001 in a business process environment;
- implement ISO 9001 in the Fulfil Order Process of an organisation;
- update relevant links to ISO 9001 in the Fulfil Order Process of an organisation to the latest version;
- highlight potential constraints of ISO 9001 during a redesign exercise to maintain compliance to the standard.

The aim of this guide is to introduce the $IDEF_{9000}$ modelling technique to show the links of the ISO 9000 quality standard within a Fulfil Order Process. It describes how the proposed modelling approach may be used to help understand which activities, information and flows are controlled by the standard and what controls them.

The use of the modelling technique should help practitioners to take a systemic perspective of the integration of ISO 9000 in a business process environment. It should assist them in their work when either implementing ISO 9000 in their organisation's Fulfil Order Process or when updating the operating part of their quality management systems to the latest version of the standard. Practitioners should benefit from a tool that supports the modelling of a Fulfil Order Process to fully complement ISO 9000. $IDEF_{9000}$ has been developed from the $IDEF_0$ technique to allow links to ISO 9000 to be identified and shown clearly.

The name $IDEF_{9000}$ refers to the ISO 9000 series, which is still the most widely used term for this standard. Organisations which seek registration to this standard must also address the quality management systems requirements published in ISO 9001.

$IDEF_{9000}$ is intended for all practitioners who need to redesign the business processes of their organisation. It is envisaged that the designer of the process model would interview participants who have a direct involvement in the Fulfil Order Process and, where possible, a working group will be formed with a team leader who will guide that group through the modelling process. Prior to the interviewing and the modelling it would be advantageous for the team leader to be familiar with the proposed approach, its syntax and semantics. This guide will address these issues in the following sections.

Section 1 and 2 start with an introduction to business processes, in particular the Fulfil Order Process, and a description of the process modelling language $IDEF_0$. Those who have already some knowledge of business processes, business process re-engineering (BPR) and are familiar with the basic principles of $IDEF_0$ should start from Section 3.

Section 3 gives an overview of ISO 9001's relevance within a Fulfil Order Process. Together with Appendix 1 which correlates each individual requirement of the standard to the elements of a Fulfil Order Process the practitioner should be able to understand how ISO 9001 controls the activities of a Fulfil Order Process and how to identify the different types of ISO 9001 controls.

Section 4 describes the use and application of $IDEF_{9000}$ to show the links to ISO 9001. It explains in detail how to map the links of a Fulfil Order Process to ISO 9001 and how to highlight the possible constraints dictated by the standard. A set of recommendations are presented for reviewing the process model for consistency with ISO 9001, as well as what to consider and where to focus when redesigning a Fulfil Order Process related to ISO 9001.

Note: $IDEF_{9000}$ was developed for and tested with a typical manufacturing *Fulfil Order Process* and the ISO 9000 series of standards in mind. However, the author believes it will be equally applicable to other processes in other industries regulated by other standards.

2 Principles of Business Processes

2.1 Definition of a Business Process

The business process view has concentrated attention on flows of products and information through the business. A review of some of the principal writers[1] in the field leads to the principles that a business process:

- transforms inputs into useful and effective outputs;
- starts and ends with the customer;
- focuses on goals;
- can be measured to allow feedback and process improvements;
- flows horizontally using a hierarchical structure;
- crosses organisational (functional) boundaries;
- requires resources to transform inputs into outputs.

For the purpose of this book a business process is defined as

[1] Davenport and Short (1990), Rummler and Brache (1990), Harrington (1991), Hammer and Champy (1993), Johansson *et al.* (1993), Hammer and Stanton (1995);

> *a structured, measured set of activities and flows that are independent of departmental structures and that use resources of the organisation to provide specified output for a particular customer.*

2.2 Business Process Architecture

There are many examples of organisations identifying a hierarchy of business processes. A useful structure established by the CIM-OSA Standards Committee (Computer Integrated Manufacturing Open Systems Architecture) (CIM-OSA/AMICE, 1989) groups processes into *manage, operate* and *support.*

- *manage processes* are processes that develop a set of business objectives, a business strategy and manage the overall behaviour of the organisation;
- *operate processes* are viewed as those that are directly related to satisfying the requirements of the external customer;
- *support processes* are processes that include the activities providing financial, personnel, facilities management and information systems.

Transforming inputs into products to fulfil a customer's order can be viewed as being an *operate* type process because it is directly related to satisfying an external customer's requirements. The four operate processes are defined and described by Childe *et al.* (1995) as Develop Product, Get Order, Fulfil Order and Support Product. Figure 2-1 shows typical activities in operate processes.

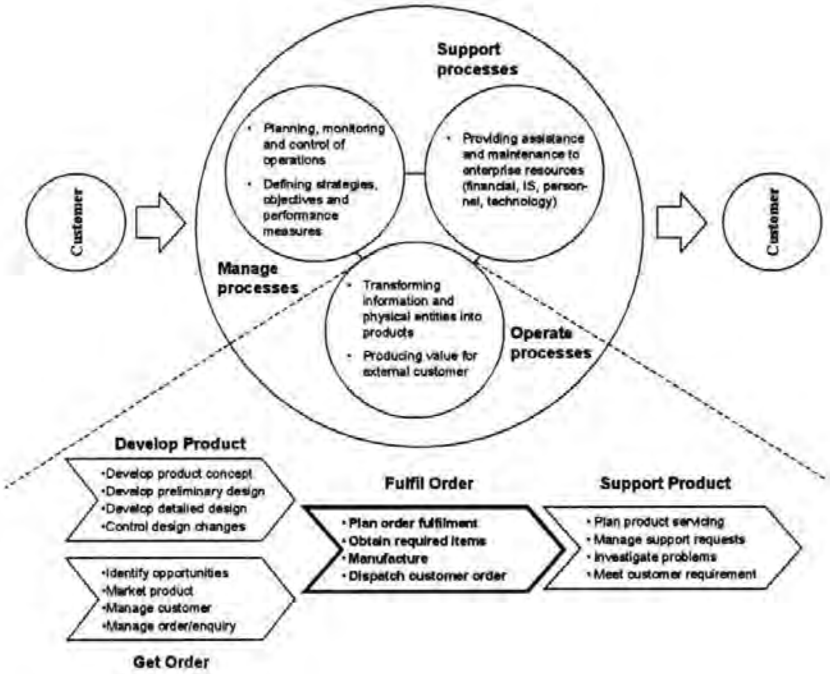

Figure 2-1: A typical operate business process in the CIM-OSA process architecture

2.3 Description of a Fulfil Order Process

The Fulfil Order Process contains activities performed by humans and machines. Its principal transformations are product orders into products and enquiries into specifications. It includes the flow of both the material and the information that results in the fulfilment of the external customer order or enquiry. The process constantly seeks to fulfil customer requirements whilst balancing stakeholder requirements (Childe *et al.* 1995).

Typical inputs, activities and outputs for a Fulfil Order Process are:

- Inputs:
  product information, preliminary design, business strategy, customer order, externally supplied items such as materials and parts;
- Activities:
  plan order fulfilment, obtain required items, manufacture, dispatch customer order;
- Output:
  enquiry feasibility i.e. information process capability, customer communication, request for product development, product/service as ordered.

2.4 Characteristics of a Fulfil Order Process from a systems perspective

Systems theory discusses various concepts that can be useful for the analysis of a business process and the definition of its environment. Churchman's (1971) considerations of a system in terms of its parameters namely: *source, input, process, transformation, output, receiver, feedback* is a useful approach. These parameters were used to outline a typical Fulfil Order Process as shown in Figure 2-2.

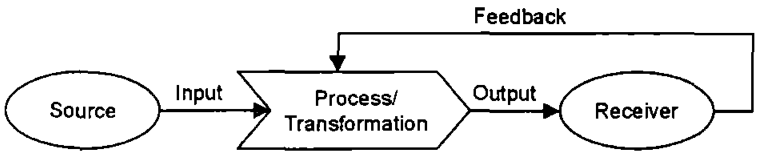

Figure 2-2: System parameters from the viewpoint of a process

- Source

A source is the origin which is outside the boundaries of a system and provides useful inputs. There are often alternative sources for each input. For a Fulfil Order Process inputs usually originate from various suppliers, customers and other stakeholders.

- Input

Inputs are those things needed by the process to fulfil its purpose and which come from outside the defined system's boundary. Typical inputs for a Fulfil Order Process are information about a product or about a business strategy, preliminary design, product order or supplied items.

- Transformation

The transformation can be thought of as the result of the operating process in transforming the inputs into outputs. In a Fulfil Order Process the transformation can be seen in the change in form or shape of incoming materials or the content or location of information leading to the satisfaction of a customer requirement.

- Processes

This parameter deals with the conversion and the adding of values to inputs in order to generate desired outputs. Processes can be explained as chains of events that are performed to achieve transformation. Processes can be altered to achieve the same transformation of inputs. This is the basis of re-engineering where the transformation is kept but the process to achieve it will be changed. Plan order fulfilment, Obtain required items, Manufacture, or Dispatch a customer order are typical activities within a Fulfil Order Process. The term *business process* describes a *system* in Checkland's (1981) terms but emphasises the aspect of it consisting of a chain of activities.

- Output

An output can be anything that will cross the system's boundary into its surrounding environment. Outputs may take the form of objects or information. An output could be a product as ordered while information might leave the system in the form of customer or supplier communication or a request for product development.

- Receiver

Any party outside the system's boundary that is interested in the output of the system is called a receiver. Outputs should be useful and of value to a particular receiver such as customers and suppliers. Waste product outputs also go to a receiver.

- Feedback

Information from earlier events will be fed back to influence future choices about sources, inputs, processes, and outputs. Generally feedback can be thought of as a kind of input that comes from a receiver. In terms of a Fulfil Order Process internal feedback might deal with process or product control while external feedback loops might deal with customer issues and concerns.

3 Modelling a Fulfil Order Process with IDEF$_0$

To support its Integrated Computer Aided Manufacturing programme (ICAM) the U.S. Air Force developed a system definition method known as the ICAM Definition (IDEF) methodology (LeClair, 1982). IDEF$_0$ is an activity based modelling technique for designing and analysing a system as a set of interrelated activities or functions. It is a process mapping technique based on combining graphics and text to gain an understanding of how process functions operate and interrelate. The following subsections have been adapted from a document published by Federal Information Processing Standards Publication (NIST - FIPS PUBS 183, 1993). The structure of an IDEF$_0$ model consists of the following main parts: *a node index, the context diagram* and a set of *activity diagrams*. Additional information can be included in *"For Exposition Only" (FEO) diagrams* and *a glossary*. *FEO diagrams* may be used to give a graphic description to highlight and explain a certain part of an IDEF$_0$ diagram. They need not conform to the general IDEF$_0$ rules. A *glossary* may provide a textual description of all parts represented by the model.

3.1 The Node Index

The node index is a listing of all activities or nodes used in an IDEF$_0$ model in a *outline* format similar to an ordinary table of contents. The list presents a hierarchical structure of the processes and any subordinate activities including diagram titles and/or activity names.

3.2 The Context Diagram

The context diagram establishes the scope and purpose of the model as well as the particular viewpoint. It defines the boundaries with the outside world. Everything in the model comes from a decomposition of the context diagram.

3.3 Activity Diagrams

The diagrams of the model define the process. The diagram is the basic unit of the model and contains boxes and arrows. The boxes represent activities in the process being modelled. Box labels are named using imperative verbs. Imperative verbs can be explained as active verbs that should describe the function.

Arrows connect boxes together and represent interfaces or interconnections between the boxes. Arrows may be split (branched) or may be joined together (bundled). This indicates that the kind of data or

object represented by the arrow may be used or produced by more than one activity.

In IDEF$_0$, there is a meaning associated with each side of the box where an arrow enters it or leaves it (see Figure 3-1). The left side is reserved for *inputs*, things transformed into outputs by the activity. The right side is reserved for *outputs*, the transformed inputs. The top is reserved for *controls*, inputs such as constraints or rules that dictate the conditions of the transformation. The bottom is reserved for *mechanisms*, tools, people and systems used during the transformation. These four types of arrows, *inputs, controls, outputs*, and *mechanisms* are sometimes referred to as ICOMs. Whereas activities are always verbs or verb phrases, arrows are always nouns.

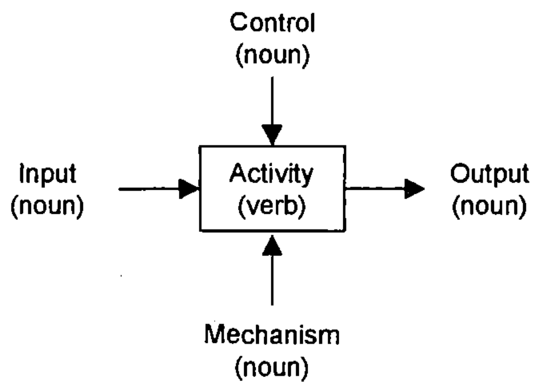

Figure 3-1: Activity box and ICOMs

3.4 Decomposition

IDEF$_0$ models show a top-down decomposition from the context diagram. The first level of decomposition breaks the context diagram A-0 (A-minus-zero) down into an A0 (A-zero) diagram containing three to six subordinate activities. These subordinate activities may then be decomposed in the same way and there is no limit to the number of levels of decomposition. The title of a decomposition diagram is taken from the box it decomposes. The result is a model whose top diagram describes a system in general terms and whose bottom diagrams describe very detailed activities of the system. Activities can be described as being a parent or a child. An example of this decomposition is shown in Figure 3-2.

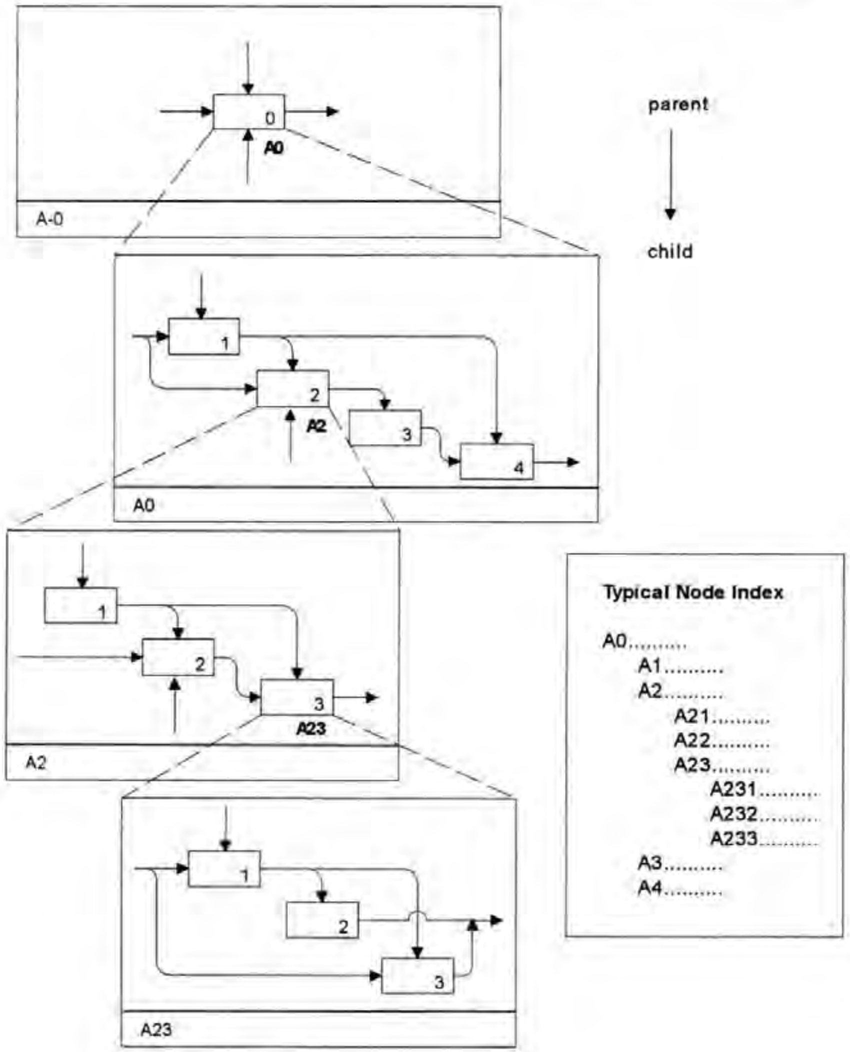

Figure 3-2: Decomposition example and Node Index

3.5 Interpretation of an $IDEF_0$ Model

- There are a number of points that should be remembered when interpreting $IDEF_0$ diagrams.
- An $IDEF_0$ model should be read top-down, by considering each diagram in the context of its parent activity.
- The node index provides a good starting point from which to understand the structure of a model and identify the high level diagrams.
- There is a general flow from top left to bottom right in most $IDEF_0$ diagrams.
- For a particular diagram:
- scan the activity boxes to gain an overall impression;
- refer back to the parent diagram to note the most important arrows on the child diagram;
- walk through the diagram top left to bottom right noting the interactions between activities, which activities may happen concurrently, identify any feedback loops etc.

- For a transformation to happen in the parent activity it need not involve all the child activities or may not mean that all the inputs are required each time the parent activity happens. Those activities and flows which are required can be determined by looking at the lower levels of decomposition.
- Arrows do not show the volume of information flowing between activities.
- $IDEF_0$ diagrams do not show time. For example, queues and waiting periods are not shown.

4 ISO 9001 in a Fulfil Order Process

The requirements of ISO 9001 that apply to a Fulfil Order Process can be identified as being *directly relevant*, *indirectly relevant*, or *not relevant* (see Appendix 1). In some areas the standard's requirements are more directly relevant to *manage* or *support* processes than to *operate* processes.

4.1 ISO 9001 requirements - directly relevant

Requirements which are considered to be directly relevant are those such as "Planning of product realisation" (ISO 9001 Section 7.1c) which require activities such as *verifying*, *validating*, *monitoring*, *inspecting* and *testing* tasks etc. that are specific to the product. An example would be "Identification and traceability" (ISO 9001 Section 7.5.3) which requires activities to *identify* the product throughout its production.

4.2 ISO 9001 requirements - indirectly relevant

Requirements of the standard that are considered to be indirectly relevant are usually dealt with in the non-operating/non fulfil-order part of the quality management system. However this part of the quality management system often requires data and information from the Fulfil Order Process. For example, an activity in the Fulfil Order Process which uses forms (documents) and data records is indirectly linked to ISO 9001 Section 4.2.3 "Control of documents" and to ISO 9001 Section 4.2.4 "Control of records" if the forms and records are required by the quality management system. ISO 9001 Section 4.2.3 controls aspects such as the *approval of documents for adequacy, ensuring the use of documents with current revision status only*, and *preventing the use of obsolete documents*. In ISO 9001 Section 4.2.4 the standard requires the user to be specific about the *identification*, *storage*, and *protection of records*. ISO 9001 Section 8.5 "Improvement" which deals with continual improvement of the quality management system is another example of being only indirectly linked to fulfil order activities. Information and data in the form of records or other documents provided by the fulfil order activities are often required by processes in the non-operating/non fulfil-order part of the quality management system to introduce improvements.

4.3 ISO 9001 requirements - not relevant

Sections of ISO 9001 considered to be not relevant to fulfil order activities are, for example, "Management commitment" (ISO 9001 Section 5.1) and "Design and development" (ISO 9001 Section 7.3). The first of these includes the establishment of a *quality policy* that is appropriate and communicated company wide. This ISO 9001 section would apply to the group *manage processes* rather than to the *operate processes* of a business process architecture. The second deals with the design and development of products, including *relevant inputs* and *outputs to the design process, design reviews,* and *the control of design changes.* This ISO 9001 section would apply to another of the four operating type processes described as *Develop Product* and is therefore not considered here.

4.4 Requirements for modelling an ISO 9001 Fulfil Order Process

In order to show the links of ISO 9001 in a Fulfil Order Process the following criteria need to be addressed:

- To show activities and to clearly identify the ones which are controlled by the ISO 9001 quality standard;
- To identify and distinguish information and objects that are linked to a requirement of ISO 9001 from those which are not;
- To show information and the flow of information;
- To show information as different types of input (control inputs, object inputs and resource inputs) to an activity;
- To decompose activities and information and describe a process hierarchy;
- To set system boundaries in order to identify any source or receiver within the quality management system or with external stakeholders related to ISO 9001 inputs or outputs;
- To show resources that are required by the activity and to identify the ones that are linked to the standard;
- To identify all relevant elements within a Fulfil Order Process using a document numbering convention or other form of unique labelling system.

4.5 Description of typical arrows controlled by ISO 9001

4.5.1 Inputs and Controls

In ISO 9001, material, equipment, personnel and information are considered to be inputs for processes and activities. Activities of a Fulfil Order Process affected by the standard are constrained by inputs in the form of *data* and *information* and *resources. Data* and *information* are either processed in electronic form by computers, or come as different types of documents. The documents, which are mostly paper based, convey data and information and can be divided into four classes: *policies, practices, derived documents* and *reference documents* (Hoyle, 1998).

Policies are documents that define the organisation's approach to achieving set objectives. For the Fulfil Order Process, policies are not relevant as they are dealt with within the non-operating part of the quality management system outside the system's boundaries.

Practices are statements that define the details of an operation such as What, When, Where, How and Who and need to be shown by the modelling technique. In ISO 9001, *practices* can be in the shape of procedures, forms, labels or notices. Control procedures control the work that is carried out within particular activities while operating procedures prescribe how specific tasks are to be performed. Documents that are required by the quality management system must be controlled and control procedures must be established. Sub-

categories of operating procedures may be inspection procedures or test procedures. The former may ensure that purchased goods conform to the purchase requirements while the latter may monitor and measure the characteristics of the product during the production process. Operating procedures must also be established for "Corrective action" or "Preventive action" to take appropriate actions for eliminating the causes of nonconformities and potential nonconformities to prevent reoccurrence or occurrence respectively. Procedures in general do not cause people to carry out work, they only specify a particular way to perform activities. They may show the sequence of uninterrupted tasks that have defined entry and exit conditions and are needed to execute a routine task. The modelling technique should therefore show that procedures constrain the performance of an activity.

Blank forms and labels can be classed as an *object input* as they are usually transformed by being filled in and completed with data and information. Forms and labels can be seen as being consumed or *used up*, a characteristic of an *object input*; while *control inputs* or *resource inputs* are usually *used*. When blank forms or labels are completed (consumed) they generally become records. Records must be established and maintained where the quality management system requires evidence of conformity.

Derived documents are the result of implementing policies and practices and can be further divided into *prescriptive* and *descriptive* documents. *Prescriptive documents* are, for example, plans (business plan, quality plan), instructions, or product specifications and need to be shown as *control inputs* by a modelling technique as they contain requirements. Instructions such as work instructions define specific tasks, when they are to commence and be completed. The organisation might issue instructions to identify, handle, pack, store and protect finished products in a certain way and complete work on a particular date. (A procedure might clarify in detail how to complete individual tasks).

Hoyle (1998) describes the fourth type of document as *reference document*. Documents of this nature often only include information without giving instructions. A list of approved suppliers including names and addresses or other data is an example. Where reference documents must be used by an activity they can also affect the way it is done. A procedure or other type of practice often refers to the reference documents necessary to complete an activity. Engineering drawings, purchase orders or government regulations may be among the requirements which belong to this category. They are usually identified documents and controlled in ISO terms. In some instances reference documents can also be classed as *resource inputs* where they give guidance and support an activity. Examples could be the use of *Yellow Pages* or the *World Wide Web* but would not become controlled documents.

Both classes of inputs are legitimate and, at this stage, it is only important that the modelling technique be able to distinguish between *control* and *resource inputs*.

4.5.2 Output

Outputs in general can be described as processed information or objects and often act as input for subsequent activities. Processed information that derives from measurements or assessments is documented as records and may be written up in reports. It can therefore be classified as being descriptive. A *descriptive document* can be defined in general as containing results and information on any kind of achievement. As described earlier, forms and labels once completed may become records and are transformed from being *inputs* to *outputs*. Depending on the type of information included, prescriptive documents might be used as inputs in the form of a specification or a procedure. The use of a check-sheet for the activity *to set up a machine* is an example of a form transforming from an *object input* to an output. As the original check-sheet might require to have certain machine parameter settings recorded or given specifications checked, it changes its status and acts as a *control input* for a subsequent activity such as *start producing parts*.

The quality management system, with its need for continual improvement, requires reliable data and information to ensure the suitability and effectiveness of the overall system. Therefore the organisation needs to determine, collect and analyse appropriate data. This requires activities in the Fulfil Order Process to *provide* data and information which can be used to achieve continual improvement. These requirements are only indirectly relevant to the Fulfil Order Process. Regardless of where the improvements and the redesign will be implemented, be it within the Fulfil Order Process system boundaries or outside, relevant data from activities within the Fulfil Order Process needs to be provided to make them happen in the first place.

4.5.3 Mechanisms

Mechanisms or *Resource inputs* in general are any kind of physical requirement, including human resources, that are utilised by activities to perform their functions. ISO 9001 states that if work affects product quality it needs to be carried out by personnel who are appropriately educated, trained or are experienced and qualified for the job. This requirement applies to any activity involving quality and should therefore not be interpreted differently for any of the tasks and jobs carried out within an organisation. The required levels of qualification within any organisation vary immensely. It ranges from being able to read work instructions and complete a job accordingly to being able to use complex computerised measuring and test equipment.

The modelling technique needs to be able to show qualified personnel as a human resource that is required for certain activities. Procedures may include information about who is entitled to carry out certain tasks or what qualifications are required. Forms also often state who is authorised to sign off or approve products or components. Furthermore the modelling technique also needs to show physical equipment that affects the quality of work. Not only is the control of monitoring and measuring devices by qualified personnel important but also the devices themselves need to be shown. As they have to be controlled in ISO terms they require some sort of identification if they are to be included in the model. Another example where the Fulfil Order Process needs to consider ISO 9001 is when controlling *customer property*. Customer property such as any type of machinery, tooling or measuring equipment that is used or facilitates the completion of an activity needs to be shown as a *resource input* and must be identified clearly as being customer property.

5 Application of the modelling approach IDEF$_{9000}$

The proposed approach is intended both for organisations that are already registered to ISO 9001 and those which intend to introduce the quality standard in the future. Depending on the organisation's situation the approach will need to be applied differently. The key issues are discussed in the following sections and should be seen as a specific set of guidelines in addition to the IDEF$_0$ methodology.

Organisations which already have a certified quality management system should model the Fulfil Order Process and the ISO 9001 links simultaneously. This is to avoid rework when an already modelled Fulfil Order Process needs to be complemented with ISO 9001 links at a later stage. During the modelling process the designer of the process model will need to interview experts to gain a thorough knowledge of the Fulfil Order Process. Background information on the subject matter from an ISO 9001 viewpoint is required and all information related to ISO 9001 such as the quality manual, procedures, instructions and other controlled documents need to be available. Throughout the modelling work it should be possible to link arrows related to ISO 9001 including their identification (labels) to individual activities of a Fulfil Order Process.

Organisations with limited ISO 9001 experience are encouraged to map the Fulfil Order Process without considering the standard in the first instance. Once familiar with the standard the existing process model can then be reviewed according to Section 5.3 and

completed with the extended IDEF$_{9000}$ convention as described in Section 5.2.1.

5.1 Designing the Context Diagram (A-0)

The IDEF$_0$ methodology starts with drawing a context (A-0) diagram which includes the context, purpose and viewpoint of the process model. A Fulfil Order Process contains all activities which transform product orders into products. Its key focus is to show the material and information flow essential to satisfy customer requirements. The system boundaries set by the context diagram also need to identify all links relevant to ISO 9001 that are entering the operative part of the organisation.

The main purpose of this process model is to show and identify the links between the activities of a Fulfil Order Process and the relevant criteria of the ISO 9001 quality standard. This is to enhance the understanding of practitioners when redesigning processes, as the links between the standard and the activities will highlight where extra considerations are required to maintain compliance with the standard.

The viewpoint to be taken for this process model therefore needs to be the Fulfil Order Process including the relevant parts of the ISO 9001 quality standard.

When creating IDEF$_0$ diagrams some designers might find it easier to develop the A-0 context diagram together with the next lower level A0 viewpoint diagram by going back and forth between the two diagrams until a satisfactory representation has been achieved.

5.2 Designing the Viewpoint Diagram (A0) and subsequent diagrams

The A0 diagram decomposes A-0 into three to six activities outlining the entire system under study. As it is important to maintain a level of abstraction throughout the entire model this is crucial for the top level diagrams. It is suggested that efforts should be concentrated on A0 and A1, A2, A3 etc. and to carry out further decomposition from A1 into A11 or A111 at a later stage. This is to avoid extra work should there be amendments necessary at higher level diagrams.

In cases where an organisation is already registered to ISO 9001 the conventions necessary to identify ISO 9001 links need to be applied during all stages of the modelling process. The procedure for creating a new diagram is to work down from an abstract to a detailed level, showing the activity structure first. As modelling usually includes numerous modifications and redrawing of the diagrams it is suggested that at this stage none of the boxes should be identified as being ISO 9001 controlled. It is suggested that ISO 9001 controlled activities are identified and formatted after all the decomposed diagrams have been established.

The next step is to summarise all arrows that are related to each diagram and to highlight all ISO 9001 controlled arrows by applying the convention as discussed in Section 5.2.1.2. Next, activities are connected by drawing in the appropriate arrows.

This is followed by working back up from the detailed level identifying activities controlled by ISO 9001 according to the convention as detailed in Section 5.2.1.1. There are only two reasons why an activity box needs to be formatted differently. The first rule is when activities are constrained by an ISO 9001 control input (entering the box from the top). The second is when a higher level activity needs to indicate if any of its subordinate activity is controlled by ISO 9001 in order to maintain consistency when decomposing the process model. This is best achieved by working upwards from a detailed level to a general level considering only two levels at a time.

Organisations that intend to introduce ISO 9001 at a later stage should map their current situation and review the initial model for ISO 9001 relevance by referring to Section 5.3.

5.2.1 *Enhanced IDEF$_{9000}$ to show the links to ISO 9000*

The IDEF$_0$ approach can be grouped into the IDEF$_0$ language itself and the IDEF$_0$ methodology which provides additional procedures for developing and interpreting process models. The existing generic IDEF$_0$ methodology is acknowledged as valid and appropriate as the basis for the proposed modelling approach described in this document.

This section will now discuss the extensions in the semantics of IDEF$_{9000}$ together with the adapted syntax for each ISO 9001 criteria.

5.2.1.1 Identification of activities controlled by ISO 9001

The adapted IDEF$_{9000}$ modelling technique needs to show activities and clearly identify these which are controlled by the ISO 9001 quality standard. In a traditional IDEF$_0$ activity diagram, boxes are used to represent activities of the process being modelled, and the box labels are named using imperative verbs.

The enhanced modelling technique for ISO 9001 links identifies and distinguishes graphically between activities that are controlled by the ISO standard and those that are not. A transparent box with a normal black font style represents ordinary activities. Using ***a black box with the font style white, italics, bold and underlined*** indicates that either this box or any subordinate box (or boxes) is controlled by

ISO 9001 (see Figure 5-2 and Figure 5-3). It is mandatory that this rule is applied when controls governed by ISO 9001 are present. Typical controls that rule and constrain how an activity needs to be performed are ISO 9001's control or operating procedures. However this extension in the syntax and semantics of IDEF$_{9000}$ does not apply to inputs (object inputs), outputs or mechanisms (resource inputs) related to ISO 9001 as shown in Figure 5-1. Such object inputs may be controlled forms, identified goods or inspected components which do not constrain the nature of the activity itself. They only need to be transformed by a particular activity by using certain mechanisms to produce a specific output. With the graphically different layout of a ISO 9001 controlled, black activity box the attention of the designer is drawn to the ISO 9001 control which constrains the activity first before starting the redesign.

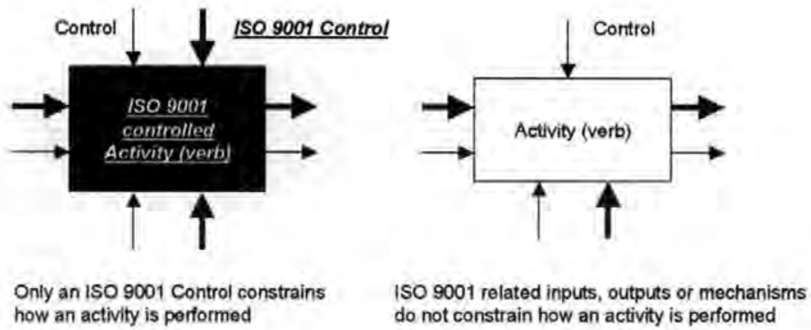

Figure 5-1: Identification of activities controlled by ISO 9001

During redesign workshops, process maps are often initially documented by hand when drawing on paper, whiteboards or even *Post-it* notes. At this stage it will not be practical to adapt the full $IDEF_{9000}$ convention as proposed when using a software tool, so activities linked to ISO 9001 can be identified by an asterisk symbol (*).

5.2.1.2 Identification of inputs, controls, outputs and mechanisms controlled by ISO 9001 (ISO 9001 arrows)

To identify and distinguish information and objects that are linked to a requirement of ISO 9001 from those that are not, the modelling technique will need to label them differently. It may also be necessary to include to refer to sources within the quality management system from where documents originate. The syntax proposed for identifying ISO 9001 links is to draw arrows using a heavier or thicker line. For the labelling of arrows controlled by ISO 9001 the font style is changed to ***<u>italics, bold and underlined</u>*** as seen in Figure 5-2. When drawing the process model by hand ISO 9001 controlled arrows and activities should be identified by an asterisk symbol (*).

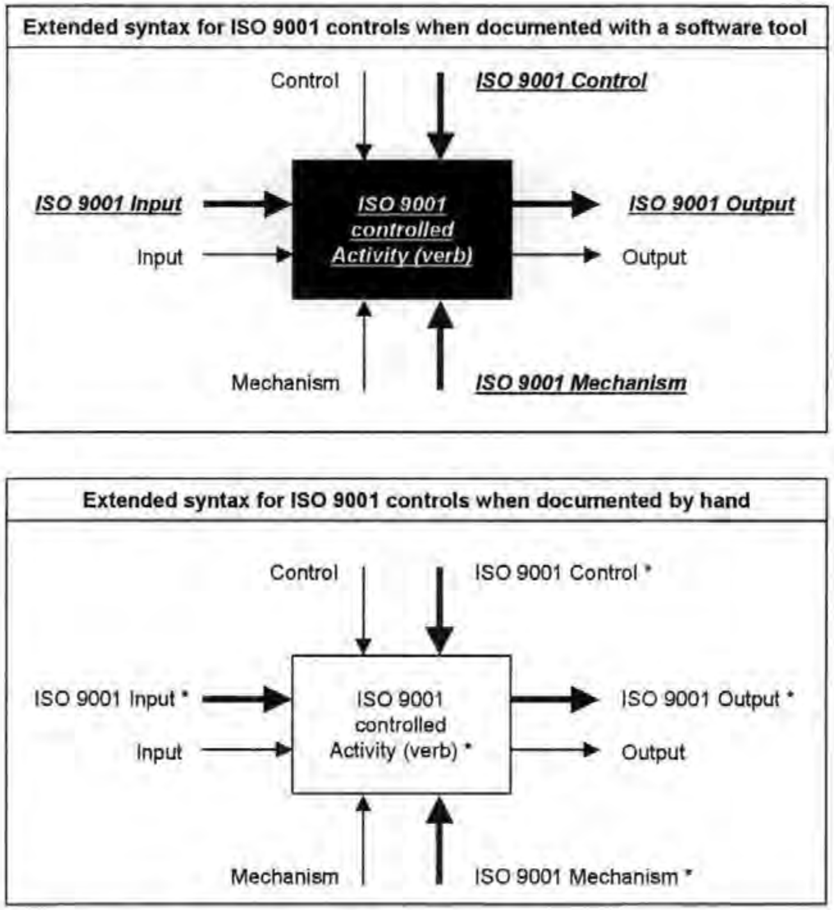

Figure 5-2: Identification of an $IDEF_{9000}$ activity controlled by ISO 9001

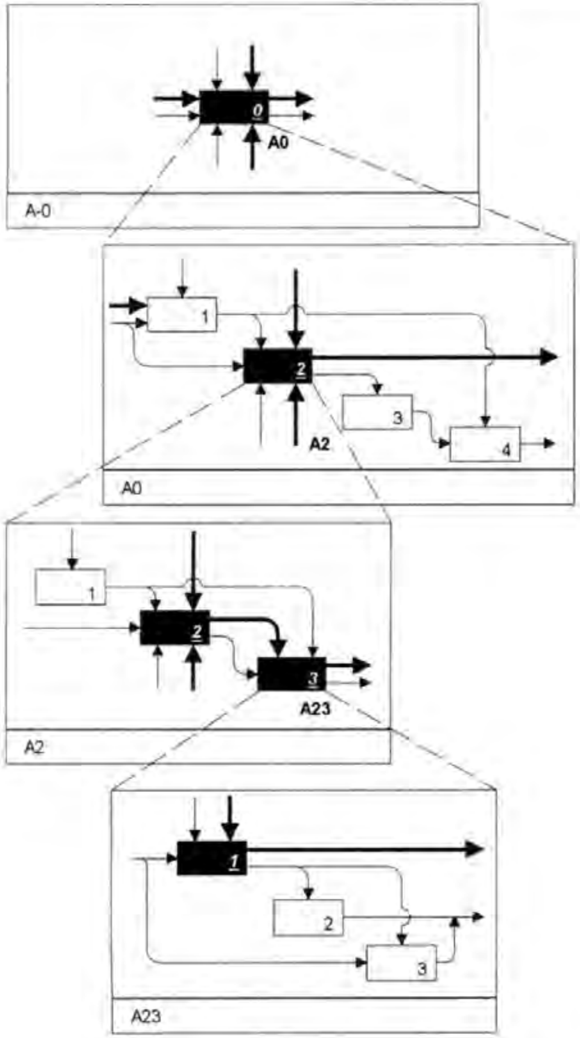

Figure 5-3: Identification of IDEF$_{9000}$ activities controlled by ISO 9001 (decomposed)

Some typical inputs, controls, outputs and mechanisms for a Fulfil Order Process from an ISO 9001 viewpoint are shown in Figure 5-4. Inputs (object inputs) can usually be classified as being either controlled documents (information and data) or objects. Similarly to the traditional IDEF$_0$ rules, inputs can also become controls where appropriate. An activity always has to have a control arrow regardless whether it is controlled by ISO 9001 or not, though it need not always have inputs. Where there is uncertainty whether an arrow should be labelled as an input or a control it should be shown as a control. Determining whether certain arrows are needed may not always be straightforward. If at a later stage, it becomes apparent that an arrow has been left out, it should be reintroduced.

Typical ISO 9001 related outputs are completed documents in the form of reports and charts or objects such as inspected and identified goods. Mechanisms that are identified with the new syntax could be for example customer owned equipment, any measuring and testing equipment or qualified personnel.

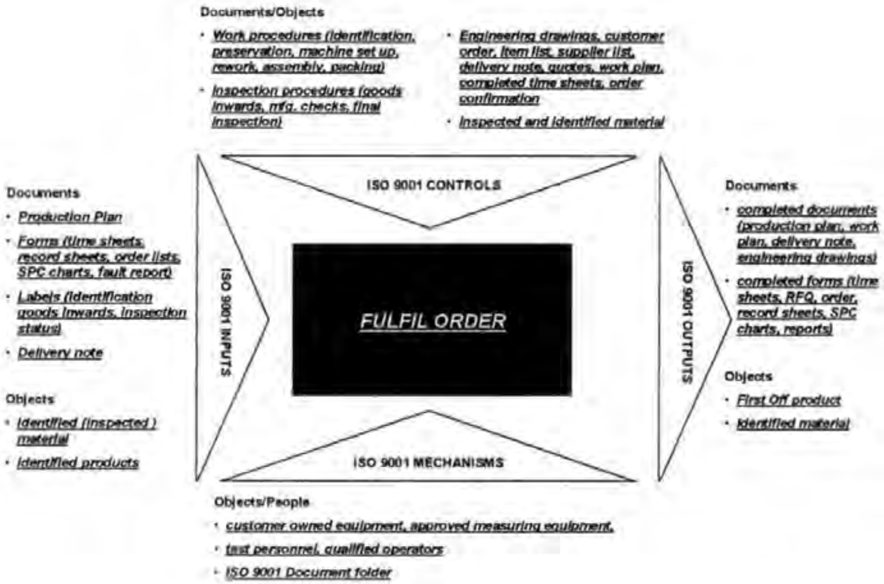

Figure 5-4: Typically ISO 9001 arrows in a Fulfil Order Process

5.2.1.3 Identification of information as different types of input to an activity

Any form of information, be it electronically or paper document based, must be shown as different types of input to an activity. The different types of inputs have been identified as *control inputs*, *object inputs* or *resource inputs*. The *control input* is $IDEF_0$'s original constraint (top of the box), the *object input* is the original input (left side of the box) and the *resource input* is the original mechanism (bottom of the box). This requirement also applies to feedback from outside the boundaries of a defined Fulfil Order Process.

Documents that are transformed from inputs to outputs and include the processed information that is required by the standard need to be identified. This, for example, applies to forms which on being filled in become quality records.

5.2.1.4 Decomposition of activities and information describing a process hierarchy

To decompose activities into sub-activities to the level of detail necessary to link them to documents or objects controlled by ISO 9001, the modelling technique will use the ability of $IDEF_0$ to describe a hierarchy that composes systems from subsystems. $IDEF_0$'s original facility for decomposing activities needs to be combined with the identification of activities controlled by ISO 9001 as described in Section 5.2.1.1.

Similarly to the hierarchy of processes, the decomposition of information down to the different levels of detail needs to consider the extended syntax to identify information controlled by ISO 9001 at all levels as described in Section 5.2.1.2. As there is always concern about overloading the diagrams the arrows should only be branched at the required level of detail. For example instead of drawing all individual *work and test instructions* (control inputs) entering the more general activity *make product* they could be bundled to one arrow labelled as "***Work instruction (ISO 9001 Procedure Folder PF-RU)"*** and decomposed at the next lower level of the more detailed diagram (see Figure 5-5). This example also shows the source or location of documents and other information on each arrow label. This is required as many ISO 9001 documents have their origin outside the boundaries of a Fulfil Order Process. They need to be shown on the context diagram entering the system at a high level (bundled) and should be identified as for example ***ISO 9001 documentation***.

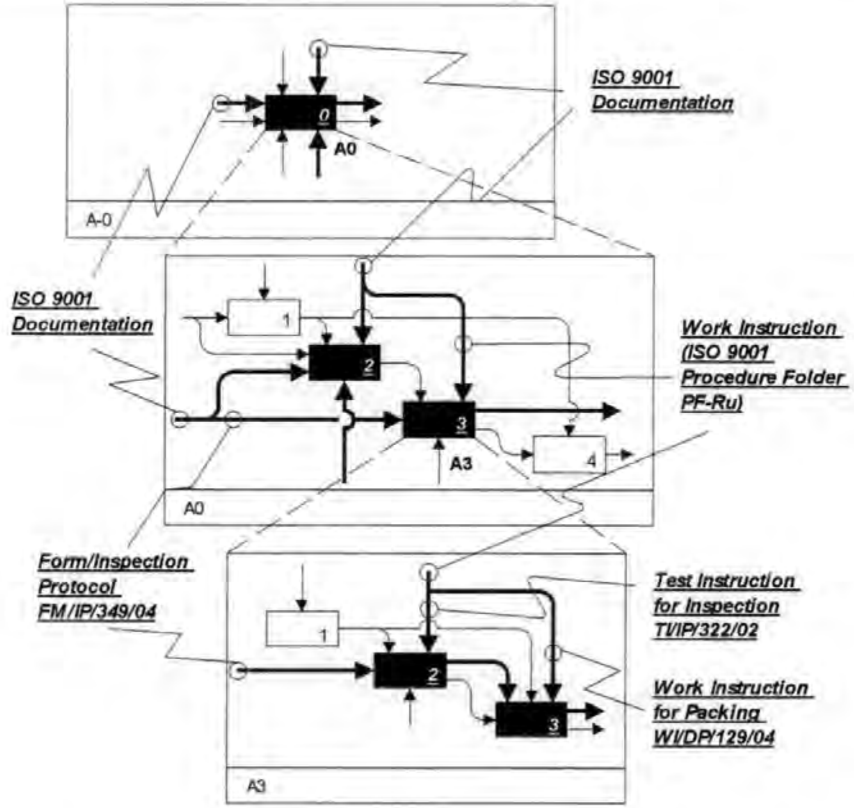

Figure 5-5: Decomposing activities and information controlled by ISO 9001

5.2.1.5 Identification of system boundaries of a Fulfil Order Process

The concept of $IDEF_{9000}$ identifies distinct system boundaries which are important as it becomes apparent what originates from the non-operating part of the quality management system or is required by it. It also shows the practitioner what feedback a receiver might require in terms of ISO 9001. In traditional $IDEF_0$ the source and receiver themselves cannot be specifically identified. However, extending the technique's syntax by labelling inputs of a source and the outputs to a receiver according to the convention as described in Section 5.2.1.2 will support the designer when redesigning activities which are controlled by ISO 9001.

5.2.1.6 Identification of resources controlled by ISO 9001

All relevant elements such as inputs, outputs and resources within a quality management system need to be controlled. Identification is usually achieved by a document numbering convention and other forms of unique labelling system as seen in Figure 5-5. The normally text based conventions of identification and individual identity codes are added to the labels of the arrows and formatted as described in Section 5.2.1.2.

5.3 Reviewing conformity of the process model to ISO 9001

The proposed modelling approach relies a great deal on the designer's knowledge and understanding of the ISO 9001 quality standard. When concentrating only on the operating part of an organisation not all parts of the standard need to be considered. The relevant links between ISO 9001 and a Fulfil Order Process are shown in Appendix 1. They will assist the practitioners during the reviewing process. Each section of the ISO 9001 standard is described as ***directly relevant, indirectly relevant*** or ***not relevant*** to the Fulfil Order Process together with an indication what type of requirement is needed. This guide can be applied by organisations regardless of their ISO 9001 registration status.

For the reviewing process it is proposed that each section of ISO 9001 be assessed separately. This is to maintain transparency as individual sections of ISO 9001 can have multiple links to different activities within the process model.

A suitable starting point is to refer to Appendix 1 which indicates for each section of ISO 9001 which type of arrow and/or extra activities need to be addressed by the process model. The first check is to determine whether all ISO 9001 requirements are present.

This could lead to the following scenarios:

- All ISO 9001 requirements have already been addressed;
- Arrows controlled by ISO 9001 are missing and must be introduced;
- Activities controlled by ISO 9001 are missing and must be introduced.

In the first scenario where all ISO 9001 requirement have already been addressed the practitioner subsequently needs to ensure that the proposed syntax of the modelling technique has been applied fully. For arrows and activities controlled by ISO 9001 it is important that they are consistently identified throughout the various levels of the process model as discussed in Section 5.2.1.1 and Section 5.2.1.2.

The second scenario in which extra arrows controlled by ISO 9001 are needed can lead to either linking these newly introduced arrows to already existing activities or to the requirement for additional activities. Either way the newly introduced arrows controlled by ISO 9001 must be identified in the same manner as discussed for the first scenario. The affected activities need to be checked in accordance with the rules set in Section 5.2.1.1 and may need to be changed to the new syntax if the ISO 9001 constraint is a *control input*.

In a concluding step the practitioner must check that the consistency of activities controlled by ISO 9001 and any subsequent activities is maintained.

In the final scenario the existing process model does not include all activities required by ISO 9001. Extra activities must be introduced to comply with the standard. Similarly to the second scenario this could lead to either linking the newly introduced activities to existing arrows or to requiring extra arrows. The consistency checks for ISO 9001 controlled arrows and activities as already described for the first two scenarios also apply.

For all scenarios it is important to consider not to overload the diagrams with too much detail keeping the arrows at a general level and to consider bundling and branching arrows as described in Section 5.2.1.4 and as shown in Figure 5-5.

For organisations that are not currently registered to ISO 9001 this part of the modelling process identifies the gaps and allows them to develop a *to-be* Fulfil Order Process in compliance with ISO 9001. If organisations at this stage have not established a convention for identifying and labelling documents and other relevant objects controlled by ISO 9001, some scheme for identifying arrows in anticipation of ISO 9001 should be used.

5.4 Redesign of an existing Fulfil Order Process

To redesign any process within an organisation, in-depth knowledge and understanding of the domain is required. A set of guidelines should support practitioners in their attempts to review the modelled Fulfil Order Process for potential improvements.

Many of the arrows controlled by ISO 9001 are developed and approved in the non-operating part of the quality management system. This includes work and testing procedures and other controlled documents such as forms or checklists. These arrows are outside the system boundaries of a Fulfil Order Process. The modelling process therefore considers them as given, not specifying their content in any further detail. However during the redesign exercise these arrows may need to be investigated in greater depth if they constrain an activity. A quality management system representative or equivalent person who can comment on specific information related to ISO 9001 may need to be consulted.

The redesign guidelines assume that the rules for modelling with IDEF$_{9000}$ have been applied thoroughly and that the model is correct. For example, each activity box has at least one control arrow and that all decomposed arrows are inherited consistently by subordinate activities.

The reviewer first needs to become familiarised with the model. This is best achieved by studying the node index to establish an overview of the process model. After the context, purpose and viewpoint of the process model have been reviewed all individual diagrams starting with the A0 viewpoint diagram should be examined. Every diagram must be checked to see whether activities or arrows are needed and whether activities can be relocated, aggregated or performed in parallel, as described in 5.4.1.

The following guidelines refer to some of the principles discussed by Jain *et al.* (1994) and their transformational approach to business process redesign as well as to the recommendations from the IDEF$_0$ methodology. The three classes of transformations discussed by Jain *et al.* (1994) comprise *the relocation of activities, the aggregation of activities* and *the concurrency of activities.*

5.4.1 Necessity of activities

The diagrams should be checked to see if each operation is necessary to fulfil the purpose and objective of the process being studied. This may include activities which were introduced because of special circumstances and reviewing each output of an activity may identify whether these circumstances still exist. Examples of activities which either produce waste or are unnecessary may be documents that are stored for no reason or the reproduction of copies where there is no demand.

Identical activities performed at different stages should be identified and investigated further. Where an operation is controlled by ISO 9001 (control input) the constraint needs to be established before the particular activity can be removed or redesigned. The constraint may be a quality procedure or instruction of some sort. If the input, output or mechanism is controlled by ISO 9001 the activity itself can be redesigned as long as all required arrows controlled by ISO 9001 are still given due consideration.

5.4.2 Relocation of activities

When rearranging the sequence of activities within the process/diagram under investigation as well as when moving potential activities beyond the system boundaries the first issue is concerned with improving flow of information and material. Potential opportunities to improve flow may be seen where objects or information go back and forth in a diagram visiting activities, feedback and mechanisms more than once rather than taking a serial path. This is shown when the same mechanism is used for several boxes that are not adjacent. Equally important is the question of whether a customer or supplier (source or receiver) can perform any of the activities when initiating or receiving an order. For example bank customers when making a phone inquiry are asked by a computer to key in their personal code before being connected to an operator. This reduces the time operators search for the account details after being connected to the customer. The relocation of activities might require making subsequent changes in ISO 9001

procedures, other controlled documents or objects. Conversely the relocation of activities could lead to the introduction of extra flows controlled by ISO 9001 to maintain compliance. This could have adverse effects on the intended objectives of the redesign and requires special attention.

5.4.3 Aggregation of activities

Aggregating activities is concerned with combining successive activities. The process model can be checked to see whether work, for example, items can be finished before they are passed on (combining subassembly and assembly) or if parts can be produced and inspected by the same operator. This may mean extending individual jobs to cover other specialities. The aggregation of activities might also lead to an accumulation of several ISO 9001 procedures, controlled forms or even resources. For example, where before the aggregation of activities it was necessary to ask for specific information by using separate forms it might now better to combine them into a single form.

5.4.4 *Parallel processing of activities*

Independent and sequentially performed activities should be investigated to see whether they could be carried out in parallel. For example printing the manual can be performed while preparing the final product for packing. Where activities are dependent they should be checked to see what degree of concurrency could be applied. In concurrent engineering the principle is to carry out activities in parallel even if previously started activities are not completed. Prototyping of some parts may begin before all components are completely designed. In terms of the quality standard parallel processing might require the provision of certain documents or equipment controlled by ISO 9001 at more than one location.

5.4.5 *Feedback*

Some of the feedback loops may be unnecessary. Part of the redesign exercise should be to investigate activities that are constrained by information as part of feedback. Similarly, cases may be noted where there is no proper feedback to regulate activities; this may have to be introduced. From the ISO 9001 viewpoint an organisation needs to consider the provision of appropriate internal communication processes to operate an effective quality management system. Organisations may also have to make arrangements to gather information about customer satisfaction and the methods for obtaining those.

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Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
4. Quality management system		
4.1 General requirements a), b), c), d), e), f)	Indirectly	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, resources)
4.2 Documentation requirements		
4.2.1 General		
4.2.1 General a) b)	Not relevant	
4.2.1 General c)	Indirectly	*Procedure documents* (documents) established in the non-operating part of the quality management system which control operating type activities
4.2.1 General d)	Indirectly	*Procedure documents* (documents) established in the non-operating part of the quality management system and other kind of *documents* (input, output, and control)
4.2.1 General e)	Indirectly	*Record documents* (controls and outputs)

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
4.2.2 Quality Manual		
4.2.2 Quality Manual a)	Not relevant	
4.2.2 Quality Manual b)	Indirectly	*Procedure documents* (documents) established in the non-operating part of the quality management system which control operating type activities
4.2.2 Quality Manual c)	Not relevant	
4.2.3 Control of documents a), b), c), d), e), f), g)	Indirectly	*Procedure documents* (documents) established in the non-operating part of the quality management system which control *documents* which are used by operating type activities in the form of inputs, outputs, and controls
4.2.4 Control of records	Indirectly	*Procedure documents* (documents) established in the non-operating part of the quality management system which control *record documents* (records) which are used by operating type activities in the form of inputs, outputs, and controls
5. Management responsibility		
5.1 Management commitment a), b), c), d), e)	Not relevant	
5.2 Customer focus	Not relevant	
5.3 Quality policy a), b), c), d), e)	Not relevant	

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
5.4 Planning		
5.4.1 Quality objectives	Indirectly	Quality objectives will be incorporated in the relevant *procedure documents* (documents) or other form of *documents* established in the non-operating part of the quality management system
5.4.2 Quality management system planning a), b)	Indirectly	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, resources)
5.5 Responsibility, authority and communication		
5.5.1 Responsibility and authority	Indirectly	Responsibility and authority will be incorporated in the relevant *procedure documents* (documents) established in the non-operating part of the quality management system Responsibility and authority might also to be shown as a resource (human resource)
5.5.2 Management representative a), b), c)	Not relevant	
5.5.3 Internal communication	Indirectly	Information and the flow of information

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
5.6 Management review		
5.6.1 General	Indirectly	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, resources)
5.6.2 Review input a), b), c), d), e), f), g)	Indirectly	Data and information in the form of *record documents* (records) and other kind of *documents* which are used by operating type activities in the form of inputs, outputs, and controls
5.6.3 Review output a), b), c)	Indirectly	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, resources)
6. Resource management		
6.1 Provision of resources a), b)	Indirectly	Physical requirements for the activities and human resources of the participants shown as a resource

Section of ISO 9001:2000	**Strength of linkage between the standard and the Fulfil Order Process** **Type of requirement/comments**	
6.2 Human resources		
6.2.1 General	Not relevant	
6.2.2 Competence, awareness and training a), c)	Indirectly	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, resources)
6.2.2 Competence, awareness and training b), d), e)	Not relevant	
6.3 Infrastructure a), b), c)	Not relevant	
6.4 Work environment	Not relevant	
7. Product realisation		
7.1 Planning of product realisation a)	Indirectly	Process characteristics

Section of ISO 9001:2000	**Strength of linkage between the standard and the Fulfil Order Process** **Type of requirement/comments**	
7.1 Planning of product realisation b)	Indirectly	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information in the form of *record documents*, other kind of *documents* and resources in the form of people or equipment)
7.1 Planning of product realisation c)	Directly	Activities (validating, verifying, monitoring, testing and inspection)
7.1 Planning of product realisation d)	Directly	Activities (recording, filing) Data and information in the form of *record documents* and other kind of *documents* which are used by operating type activities in the form of inputs, outputs, and controls
7.2 Customer-related processes		
7.2.1 Determination of requirements related to the product a), b), c), d)	Not relevant	
7.2.2 Review of requirements to the product a), b), c)	Not relevant	

APPENDIX 1 ISO 9001 CORRELATION MATRIX

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
7.2.3 Customer communication a), b), c)	Not relevant	
7.3 Design and development		
7.3.1 Design and development planning a), b), c)	Not relevant	
7.3.2 Design and development inputs a), b), c), d)	Not relevant	
7.3.3 Design and development outputs a), b), c), d)	Not relevant	
7.3.4 Design and development review a), b)	Not relevant	
7.3.5 Design and development verification	Not relevant	
7.3.6 Design and development validation	Not relevant	
7.3.7 Control of design and development changes	Not relevant	

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
7.4 Purchasing		
7.4.1 Purchasing process	Directly	Activities (evaluating and controlling) Process characteristics (data and information in the form of *record documents* and other kind of *documents*, products in the form of inputs/outputs and resources in the form of people or equipment) *Procedure documents* (documents) established in the non-operating part of the quality management system which control the operating type activities Note: supplier control processes (evaluation and selection) are not to be considered as an operating type activity
7.4.2 Purchasing information a), b), c)	Directly	Process characteristics (data and information in the form of *documents* and *procedure documents*)
7.4.3 Verification of purchased product	Directly	Activities (inspecting, verifying) Process characteristics (data and information in the form of *record documents* and other kind of *documents*, products in the form of inputs/outputs and resources in the form of people or equipment) *Procedure documents* (documents) established in the non-operating part of the quality management system which control the operating type activities

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
7.5 Production and service provision		
7.5.1 Control of production and service provision a), b)	Indirectly	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information in the form of *documents, procedure documents*, and resources in the form of people and equipment)
7.5.1 Control of production and service provision c), d), e), f)	Directly	Activities (monitoring, measuring) Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information in the form of *documents, procedure documents*, and resources in the form of people and equipment)
7.5.2 Validation of processes for production and service provision a), b), d), e)	Indirectly	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information in the form of *documents, procedure documents, record documents*, and resources in the form of people and equipment)

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
7.5.2 Validation of processes for production and service provision c)	Directly	Activities (applying) Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information in the form of *documents, procedure documents, record documents*, and resources in the form of people and equipment)
7.5.3 Identification and traceability	Directly	Activities (identifying, recording) Process characteristics (data and information in the form of *documents, procedure documents, record documents*, and resources in the form of people and equipment)
7.5.4 Customer property	Directly	Activities (identifying, verifying, protecting, safeguarding, reporting, and recording) Process characteristics (data and information in the form of *documents, procedure documents, record documents*, products in the form of inputs/outputs, and resources in the form of people and equipment)
7.5.5 Preservation of product	Directly	Activities (identifying, handling, packing, storing, and protecting) Process characteristics (data and information in the form of *documents, procedure documents, record documents*, products in the form of inputs/outputs, and resources in the form of people and equipment)

Section of ISO 9001:2000	**Strength of linkage between the standard and the Fulfil Order Process** **Type of requirement/comments**	
7.6 Control of monitoring and measuring devices a), b), c), d), e)	Indirectly	Activities (monitoring, measuring) Process characteristics (data and information in the form of *documents*, *procedure documents*, *record documents*, products in the form of inputs/outputs, and resources in the form of people and identifiable equipment)
8. Measurement, analysis and improvement		
8.1 General a), b), c)	Indirectly	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, input and outputs, resources and controls)
8.2 Monitoring and measurement		
8.2.1 Customer satisfaction	Not relevant	
8.2.2 Internal audit a), b)	Indirectly	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, input and outputs, resources and controls)

Section of ISO 9001:2000	**Strength of linkage between the standard and the Fulfil Order Process** **Type of requirement/comments**	
8.2.3 Monitoring and measurement of processes	Indirectly	Process identification (labelling of the components of the modelling technique) Process sequence (structure of the modelling technique) Dependence of processes and activities Process characteristics (data and information, input and outputs, resources and controls)
8.2.4 Monitoring and measurement of product	Directly	Activities (monitoring, measuring, verifying, recording, releasing, filing) Process characteristics (data and information in the form of *documents*, *procedure documents*, *record documents*, products in the form of inputs/outputs, and resources in the form of people and equipment)
8.3 Control of nonconforming product a), b), c)	Directly	Activities (identifying, controlling, preventing, reworking, authorising, releasing, recording, filing) Process characteristics (data and information in the form of *documents*, *procedure documents*, *record documents*, products in the form of inputs/outputs, and resources in the form of people and equipment)
8.4 Analysis of data a), d)	Not relevant	
8.4 Analysis of data b), c)	Indirectly	Process characteristics (data and information in the form of *documents* and *record documents)*

Section of ISO 9001:2000	Strength of linkage between the standard and the Fulfil Order Process Type of requirement/comments	
8.5 Improvement		
8.5.1 Continual improvement	Indirectly	Data and information in the form of *record documents* and other kind of *documents* which are used by operating type activities in the form of inputs, outputs, and controls
8.5.2 Corrective action a), b), c), d), e), f)	Indirectly	Data and information in the form of *record documents* and other kind of *documents* which are used by operating type activities in the form of inputs, outputs, and controls
8.5.3 Preventive action a), b), c), d), e)	Indirectly	Data and information in the form of *record documents* and other kind of *documents* which are used by operating type activities in the form of inputs, outputs, and controls

Appendix 6 - Feedback Sheet

School of Computing

University of Plymouth
Drake Circus
Plymouth
Devon PL4 8AA
United Kingdom

Tel 01752 232541
Fax 01752 232540

Professor Patricia D Pearce
BSc, MSc, PhD, MBCS
Head of School

Dear All 02/06/01

This manual is designed for practitioners to use the proposed modelling approach to model their Fulfil Order Process establishing the links to ISO 9001. As part of the validation process of my research this pilot study is designed to address the "validation by review". As you are all experts in the field of Production and Operations Management I would like to ask you to work through the manual and complete the questionnaire. The information you provide will help me to better understand the quality of this approach and to improve both the approach and the manual.

The questionnaire is intended to provide feedback from the practitioners who have actually applied the modelling approach. Although you might find some of the questions as being not applicable in your case please review them from a validation point of view. The response, names and questionnaire will not be made available to anyone other than the research team. A summary of the results will be mailed to you after the pilot study is analysed.

I will also be available to support you in any work related to this approach.

Thank you very much for your time and cooperation. I greatly appreciate your help.

Regards,

Joachim Gingele

Joachim Gingele

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Manufacturing and Business Systems Research Group (MABS)
University of Plymouth
Drake Circus
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United Kingdom
Phone: ++44.1752.232615 Fax:++44.1752.232617
Email: j.gingele@plymouth.ac.uk

Please add any comments where necessary.

		0	1-3	>3
1	In how many Business Process Design/Reengineering projects have you been involved in the past			
2	In how many ISO 9001 implementation/design projects have you involved in the past			

		Strongly disagree	Disagree	Neither	Agree	Strongly agree
3	I was very familiar with $IDEF_0$ as a modelling technique before conducting this project					
4	I was very familiar with ISO 9001 before conducting this project					
5	My organisation is very well advanced in implementing ISO 9001					
6	It is important to see the links of ISO 9001 when redesigning a Fulfil Order Process					
7	This modelling technique could be applied in other organisations to support a Business Process Reengineering project					
8	This modelling technique helps to understand the influences of ISO 9001 on a Fulfil Order Process					
9	It is useful to see ISO 9001 links during the redesign phase of a Fulfil Order Process					
10	This modelling technique helps understanding ISO 9001 in a process context					

		Strongly disagree	Disagree	Neither	Agree	Strongly agree
11	This manual is easy to understand (Please add any comments)					
12	This modelling technique is easy to use					
13	This modelling technique was easy to apply in my case					
14	I had no difficulties in applying the technique					
15	I know of other ways to link ISO 9001 to Fulfil Order Process models (Please list)					
16	ISO 9001 and Business Process Reengineering are current concerns in our organisation					
17	This modelling approach addresses a current concern in our organisation					
18	This modelling technique allows ISO 9001 controlled activities to be easily identified					
19	This modelling technique shows links to ISO 9001 controlled activities at the desired level of detail					
20	This modelling technique allows activities to be combined and decomposed at various levels of detail					
21	This modelling technique allows information flows to be shown					

		Strongly disagree	Disagree	Neither	Agree	Strongly agree
22	This modelling technique allows information to be shown at any level of detail					
23	The proposed modelling approach identifies information that is controlled by ISO 9001					
24	The way of identifying ISO 9001 controlled information is too restrictive					
25	The way of identifying ISO 9001 controlled objects is too restrictive					
26	The proposed modelling approach allows me to refer to other parts of the *quality management system* outside the Fulfil Order Process					
27	This modelling technique allows clear reference to be made to any sources outside the Fulfil Order Process					
28	This modelling technique allows clear reference to be made to receivers outside the Fulfil Order Process					
29	The modelling technique allows ISO 9001 controlled resources to be identified					
30	The way of identifying ISO 9001 controlled resources is too restrictive					
31	The modelling technique is too restrictive when applying your own company specific description on the flows to identify ISO 9001 controlled items					

32	The questions may not have allowed you to report some things you may want to say about the modelling approach. (Please comment)
33	How would you like to see the proposed modelling approach improved? (Please explain)

Appendix 7 - Summary Feedback Sheet

Please add any comments where necessary.

		0	1-3	>3
1	In how many Business Process Design/Reengineering projects have you been involved in the past		4	5
2	In how many ISO 9001 implementation/design projects have you involved in the past	3	5	1

		Strongly disagree	Disagree	Neither	Agree	Strongly agree
3	I was very familiar with $IDEF_0$ as a modelling technique before conducting this project		1		5	3
4	I was very familiar with ISO 9001 before conducting this project		3		4	2
5	My organisation is very well advanced in implementing ISO 9001		3	3	2	1
6	It is important to see the links of ISO 9001 when redesigning a Fulfil Order Process • *Only if you already have/intend to have ISO 9001* • *Especially important to the designer(s) of ISO 9001 Fulfil Order Processes but also to the owners of ISO 9001 related activities*			1	5	3
7	This modelling technique could be applied in other organisations to support a Business Process Reengineering project				2	7
8	This modelling technique helps to understand the influences of ISO 9001 on a Fulfil Order Process				4	5

9	It is useful to see ISO 9001 links during the redesign phase of a Fulfil Order Process • *Only if you already have/intend to have ISO 9001* • *It is beneficial to the designers*				6	3
10	This modelling technique helps understanding ISO 9001 in a process context				4	5
11	The manual is easy to understand (please discuss) • *Occasionally heavy going*		1		6	2
12	The modelling technique is easy to use • *Reasonably – if you have an understanding about $IDEF_0$ and ISO 9001 it becomes fairly easy*		1	1	7	
13	The modelling technique was easy to apply in my case			7	1	1
14	I had no difficulties in applying the technique • *Not very confident with ISO 9001*			6	2	1
15	I know of other ways to link ISO 9001 to Fulfil Order Process models (please name) • *Plain $IDEF_0$* • *I used a matrix to correlate high level business activities (not business processes as defined in this guide) to the main 20 sections of the ISO 9001. The next level down activity flows were mapped with simple ANSI-flowcharts. Unfortunately this approach did not allow making links between the business activity/ISO 9001 matrix and the flowcharts. This proposed approach addresses the problem! A big advantage is the "box and arrow approach" all the way, not like the mentioned method which changes from matrix to flowcharts!*	5	2		2	
16	ISO 9001 and Business Process Reengineering are current concerns in our organisation • *After evaluating new ISO 9001 it will now be implemented*		1	3	4	1

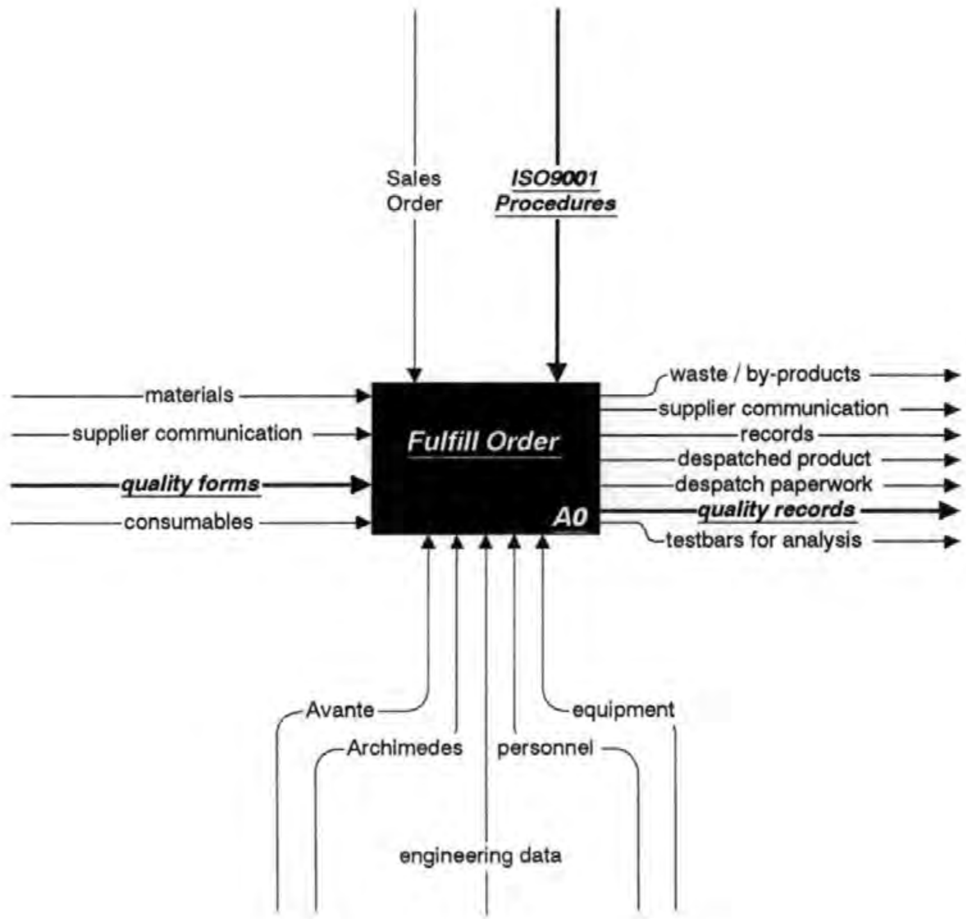
17	The modelling approach addresses a current concern in our organisation		2	5	1	1
18	The modelling technique allows ISO 9001 controlled activities to be easily identified				3	6
19	The modelling technique shows links to ISO 9001 controlled activities at the desired level of detail				4	5
20	The modelling technique allows activities to be combined and decomposed at various levels of detail				5	4
21	The modelling technique allows information flows to be shown				4	5
22	The modelling technique allows information to be shown at any level of detail				3	6
23	The proposed modelling approach identifies information that is controlled by ISO 9001				2	7
24	The way of labelling ISO 9001 controlled information is too restrictive	2	7			
25	The way of labelling ISO 9001 controlled objects is too restrictive	2	7			
26	The proposed modelling approach allows me to refer to other parts of the quality system outside the Fulfil Order Process				6	3
27	The modelling technique allows clear reference to be made to sources outside the Fulfil Order Process				7	2
28	The modelling technique allows clear reference to be made to receivers outside the Fulfil Order Process				5	4
29	The modelling technique allows ISO 9001 controlled resources to be identified				2	7
30	The way of labelling ISO 9001 controlled resources is too restrictive	3	6			

31	The modelling technique is too restrictive on applying your own company specific description on the flows to identify ISO 9001 controlled items	4	5				
32	The questions may not have allowed you to report some things you may want to say about the modelling approach. (please comment) • *Some knowledge about $IDEF_0$ and ISO 9001 required* • *It uses a lot of toner* • *Complicated at times, would have been easier if I'd done it* • *ISO 9001 correlation matrix was very useful* • *How do I know which activities and ICOMs should be ISO 9001 controlled?* • *I would use this modelling technique if I would have a current concern*						
33	How would you like to see the proposed modelling approach improved? (please explain) • *Links to other management system standards* • *I can't think of any*						

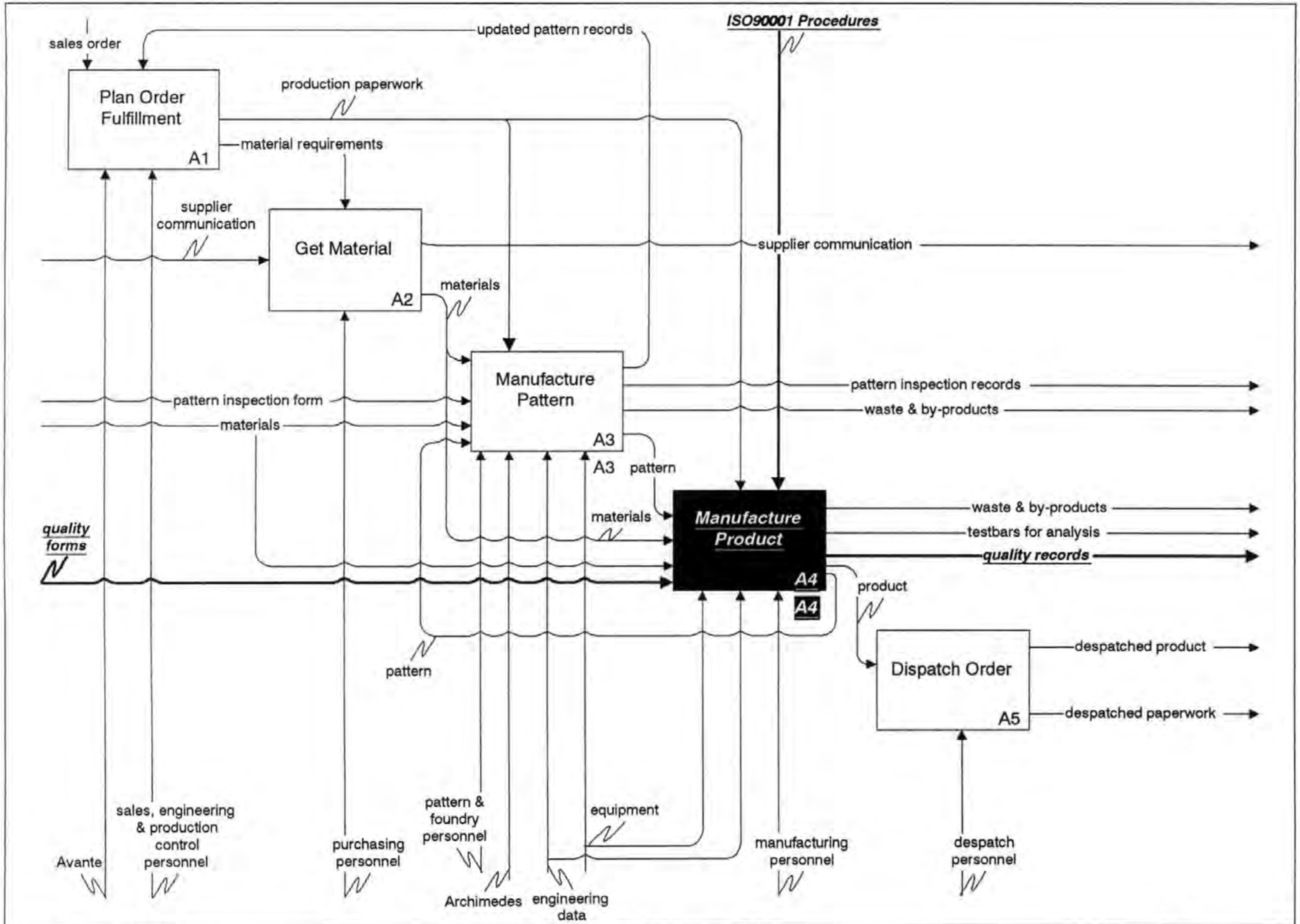
Appendix 8 - As-is process model Case C

Note

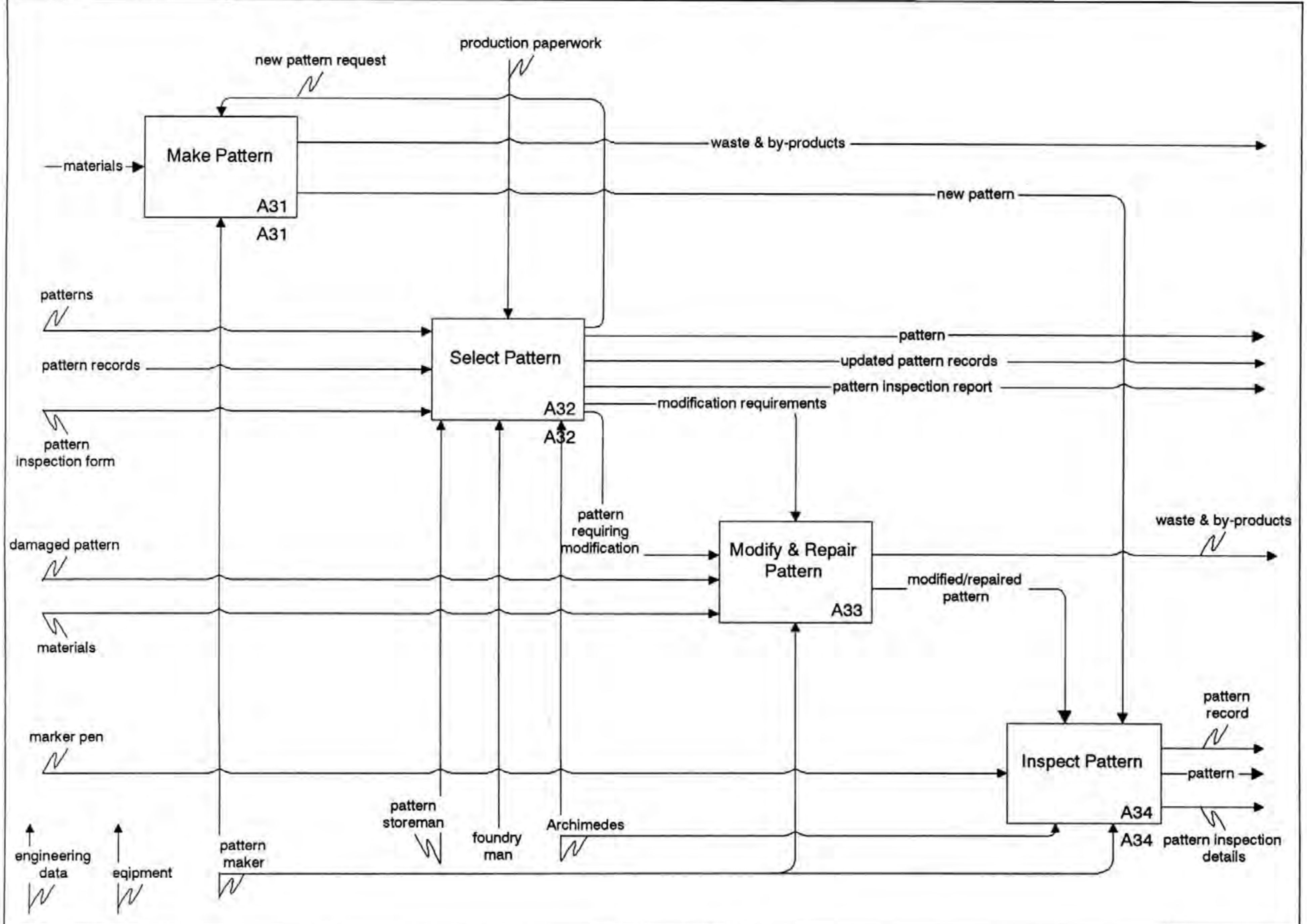
Case C personnel had no formal training in the $IDEF_0$ methodology. The following process model is therefore based on the case company's understanding of process modelling and does not strictly adhere to the rules of $IDEF_0$ as stated in the standard FIPS 183.



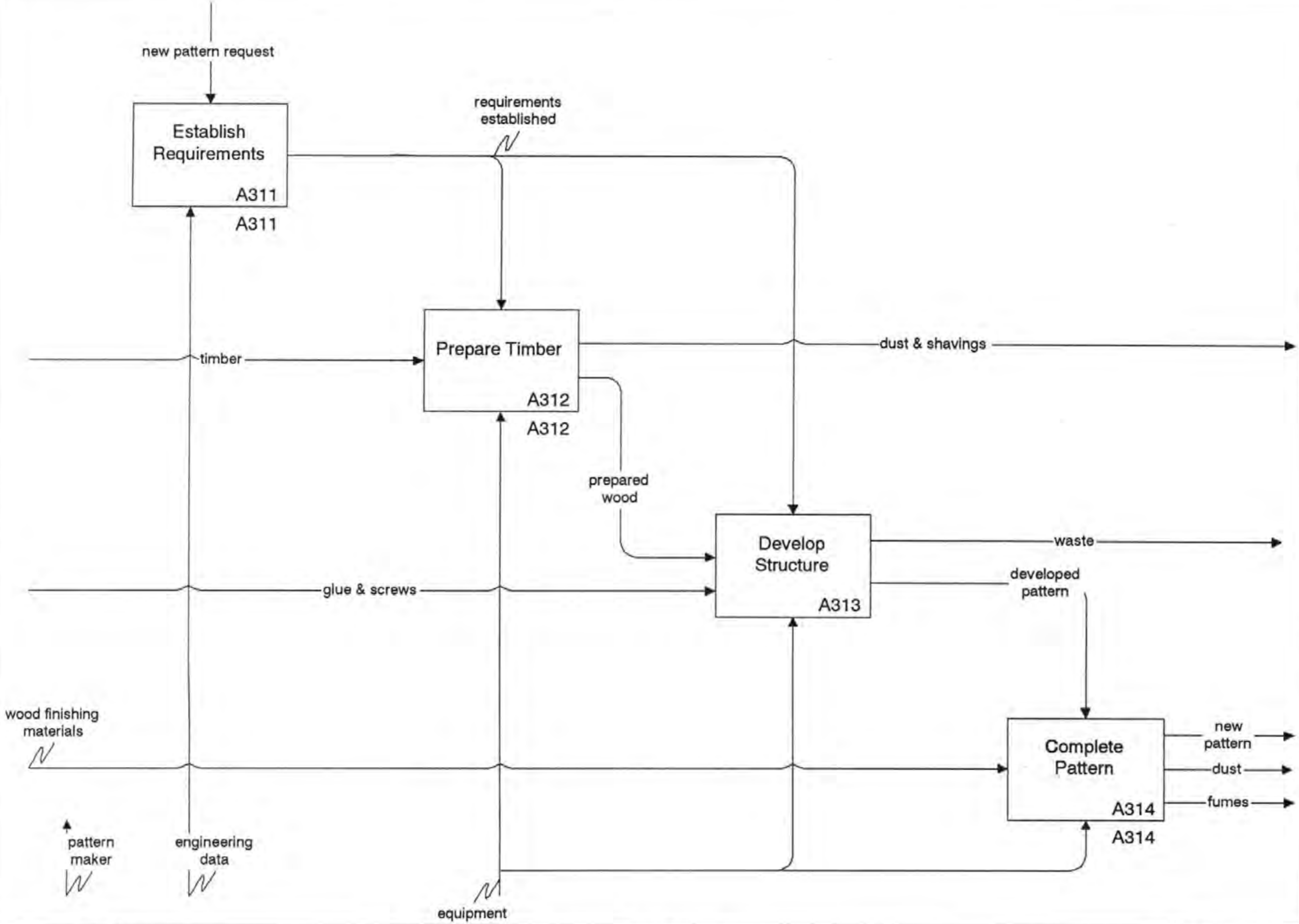
NODE: A-0	TITLE: Fulfill Order	NO.: A0



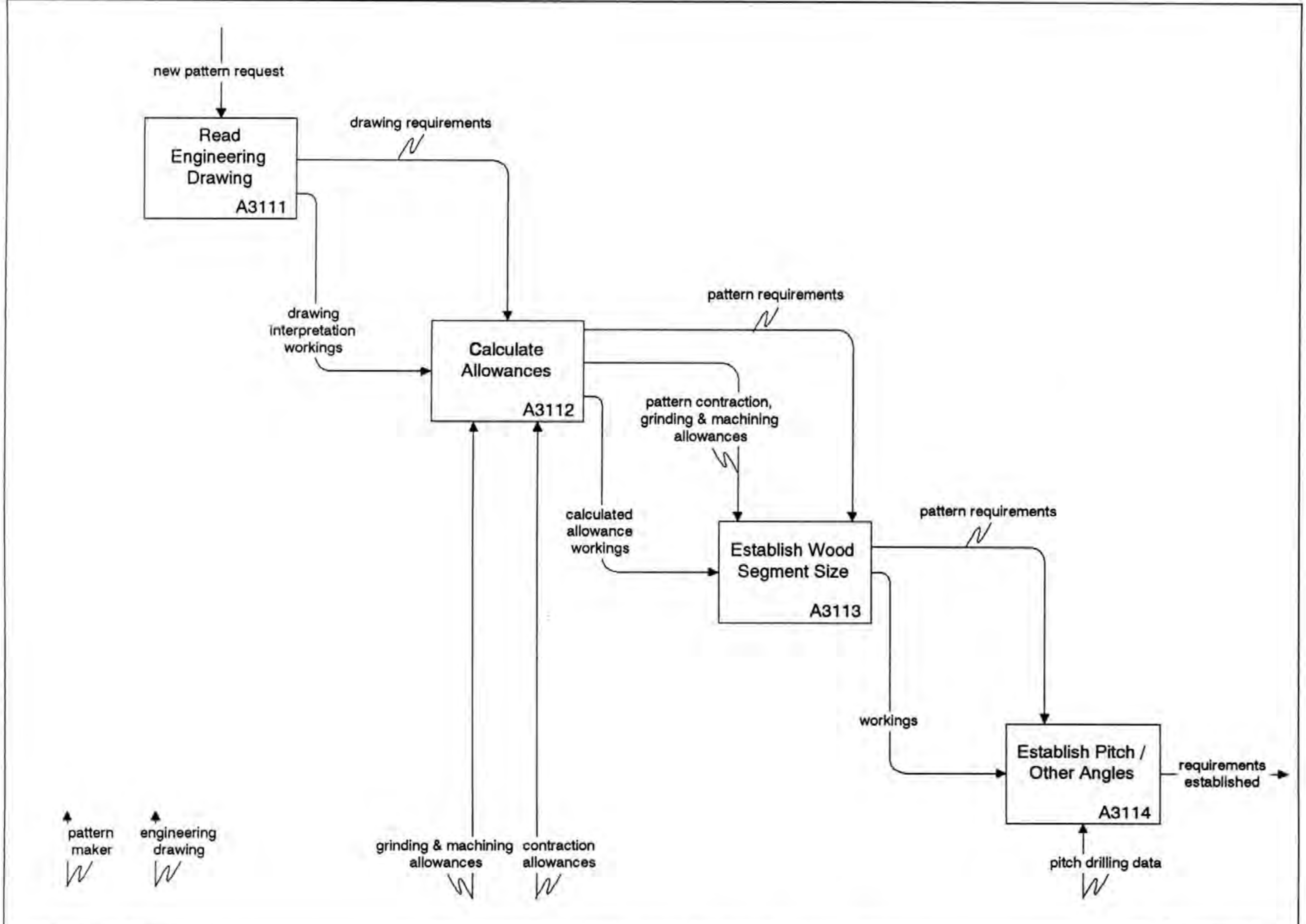
NODE: A0	TITLE: Fulfill Order Process	NO.: 1



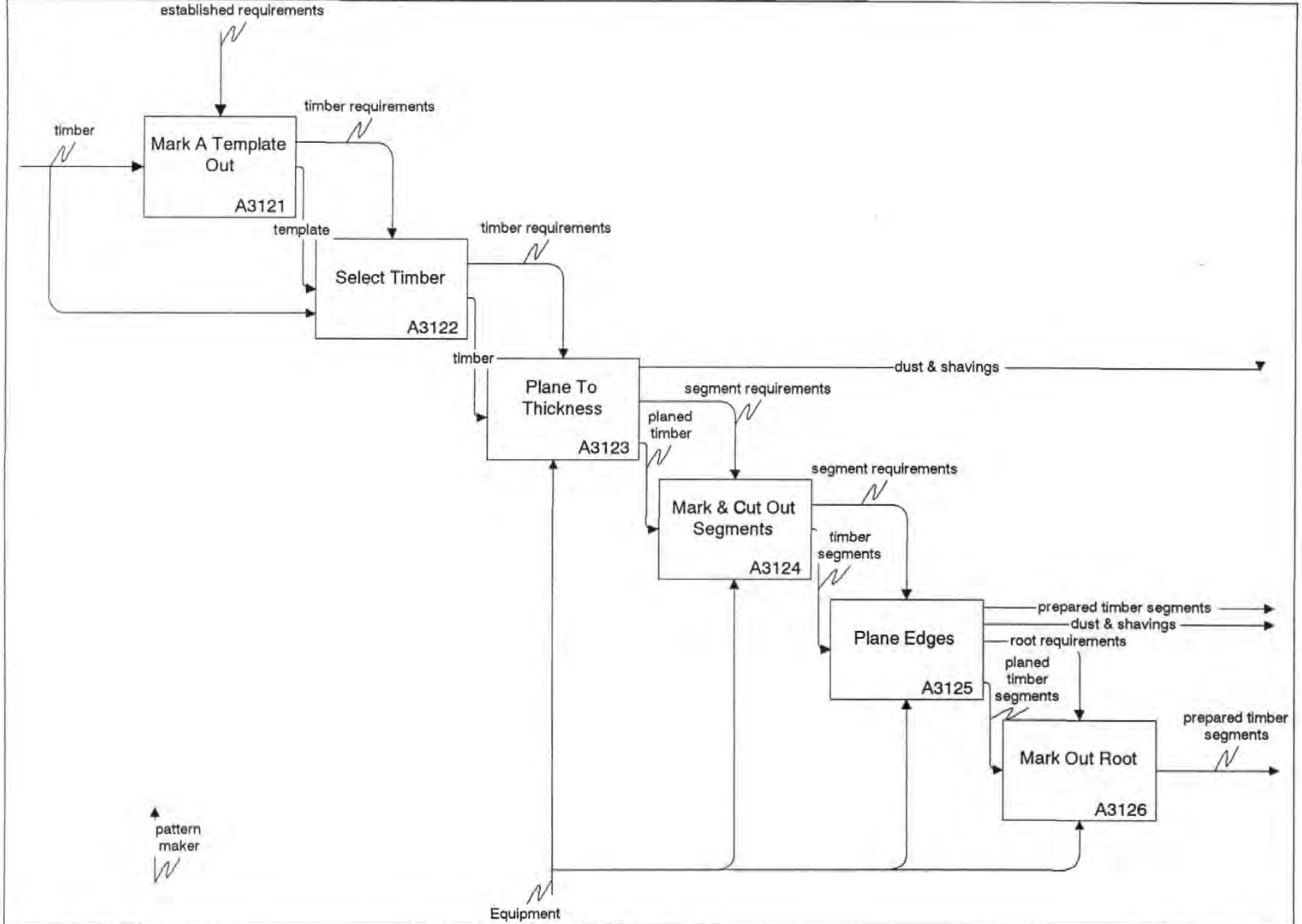
NODE: A3	TITLE: Manufacture A Pattern	NO.: 2



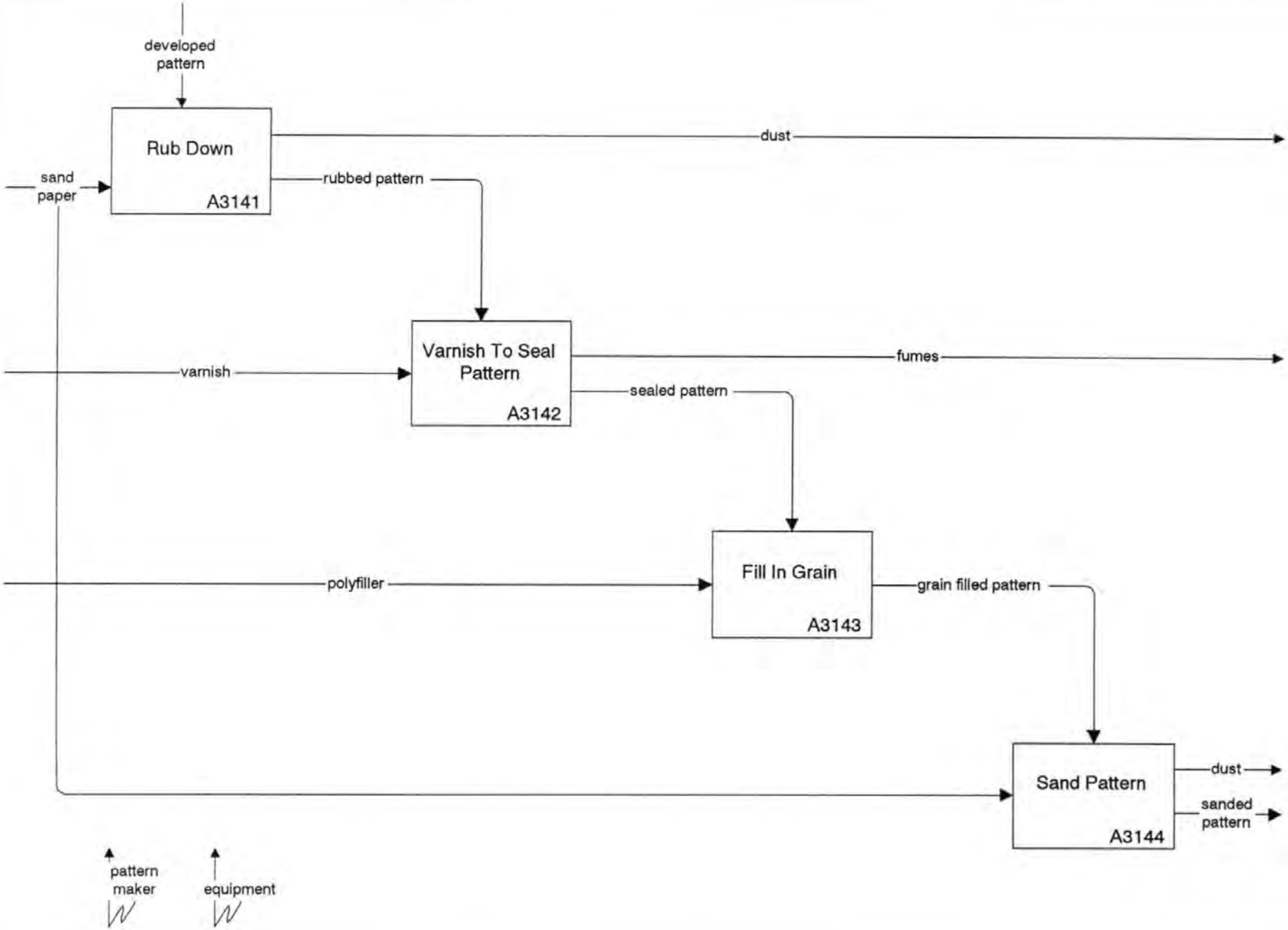
NODE:	A31	TITLE:	Make Pattern	NO.:	3



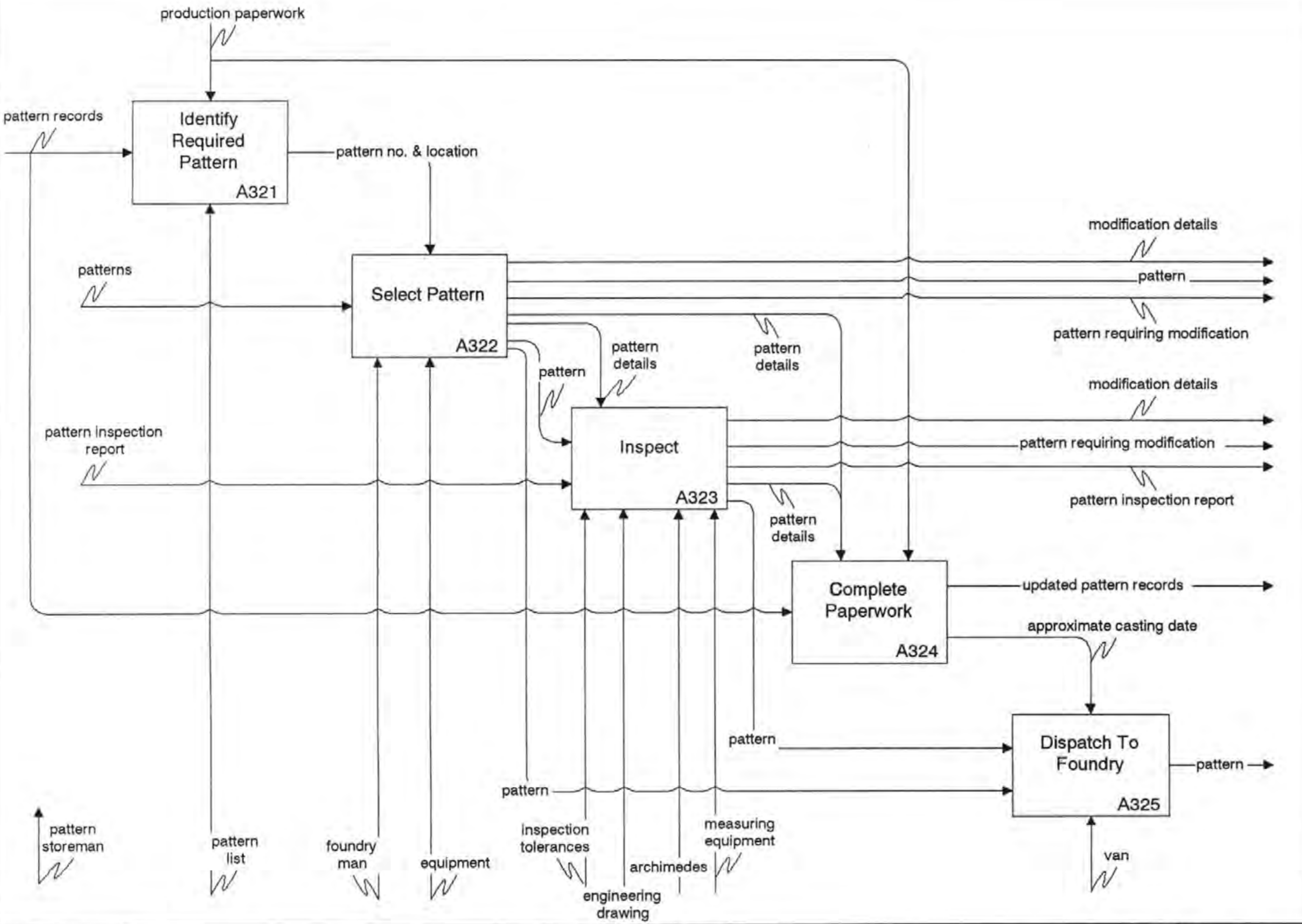
NODE: A311	TITLE: Establish Pattern Requirements	NO.: 4



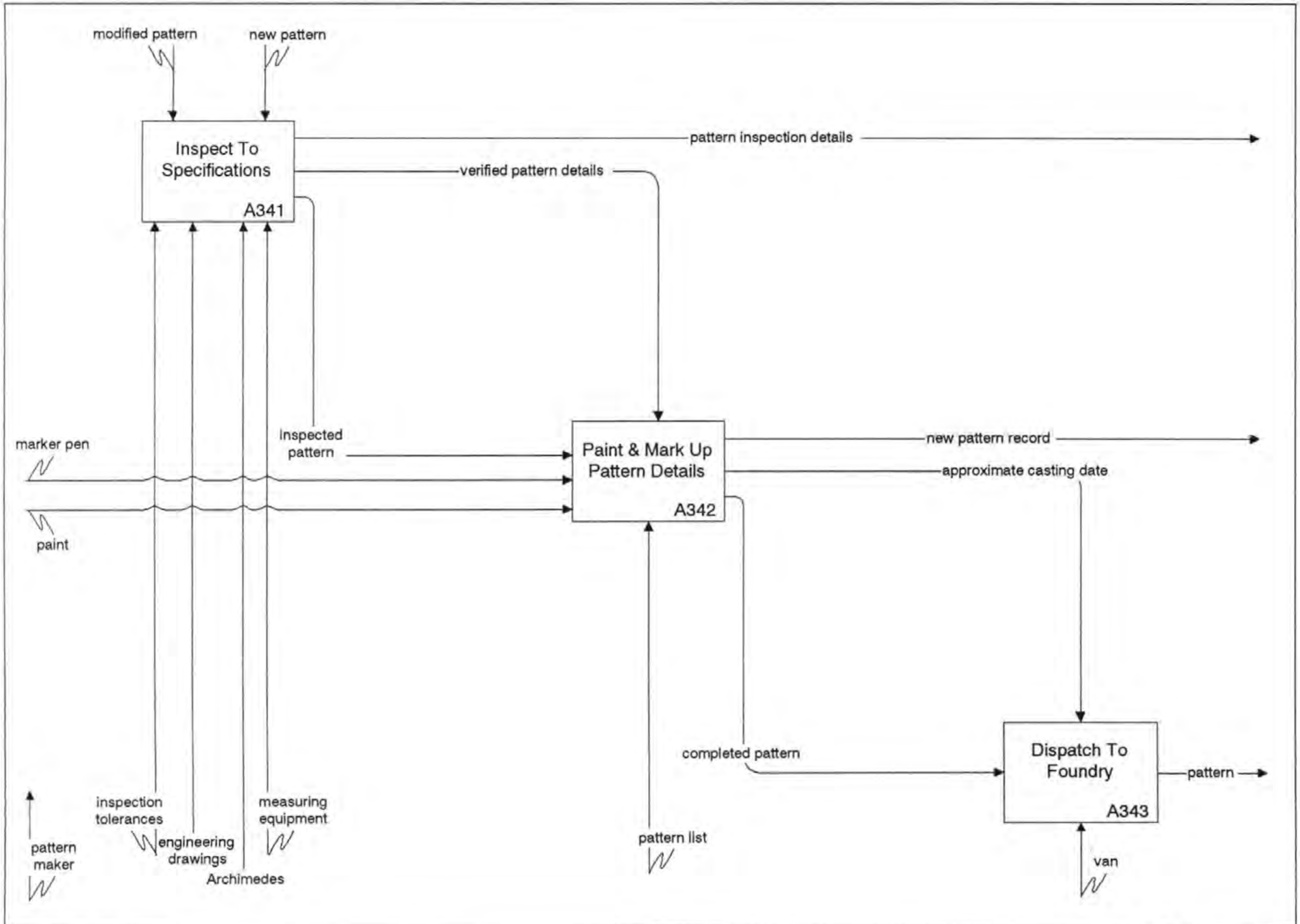
NODE: A312 TITLE: Prepare Timber NO.: 5



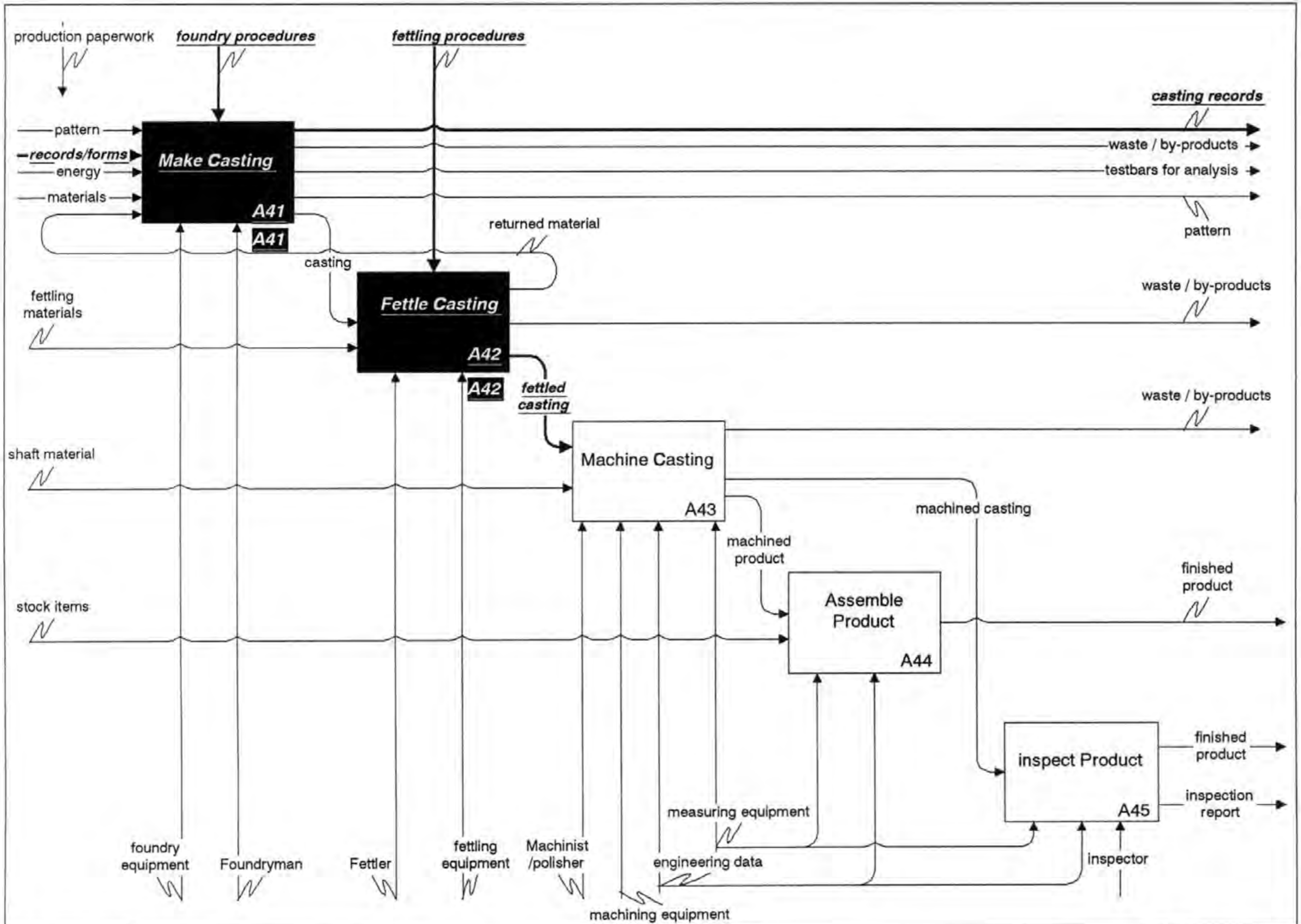
NODE: A314	TITLE: Complete Pattern	NO.: 6



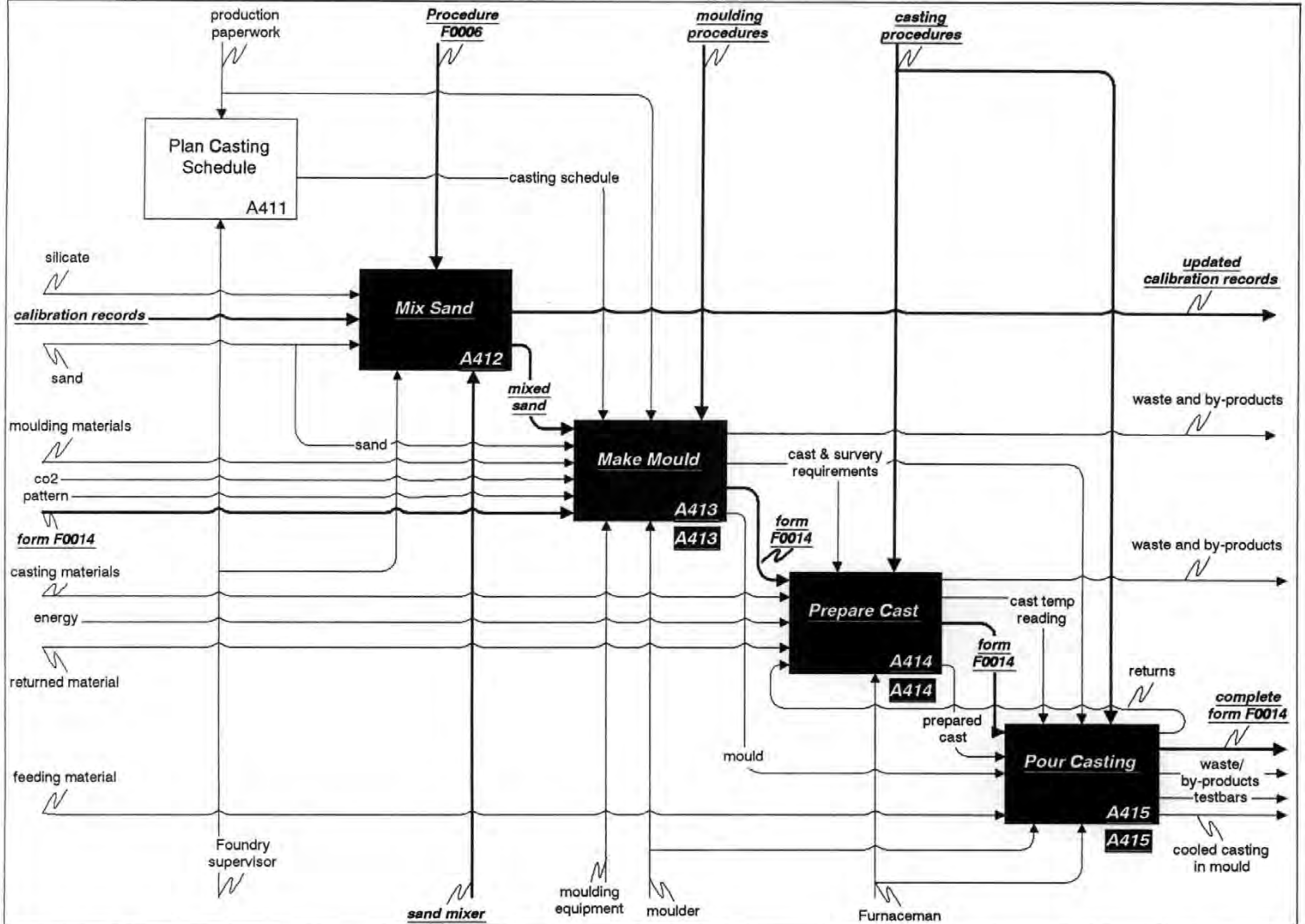
NODE: A32 TITLE: Select Pattern NO.: 7



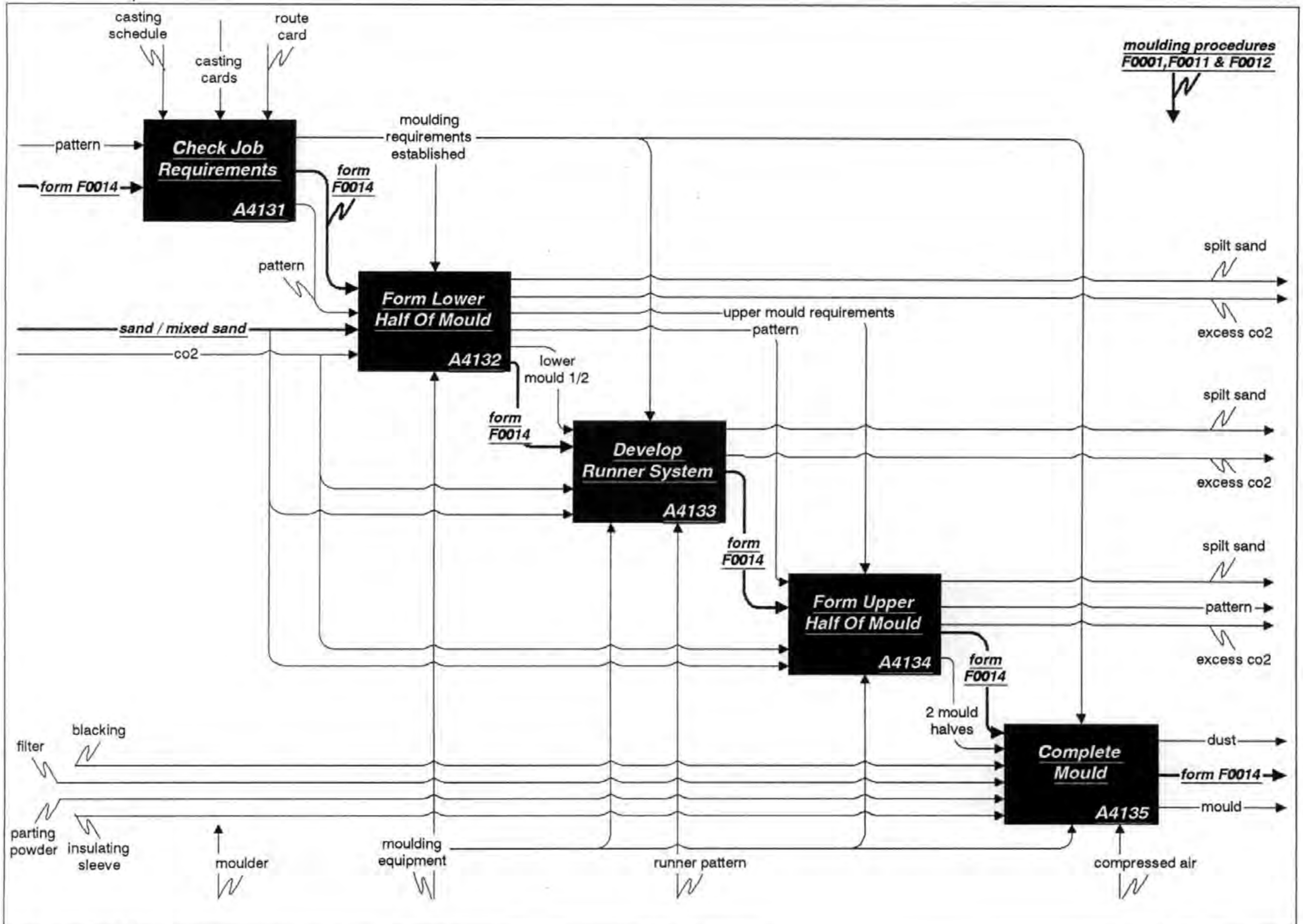
NODE: A34	TITLE: Inspection	NO.: 8



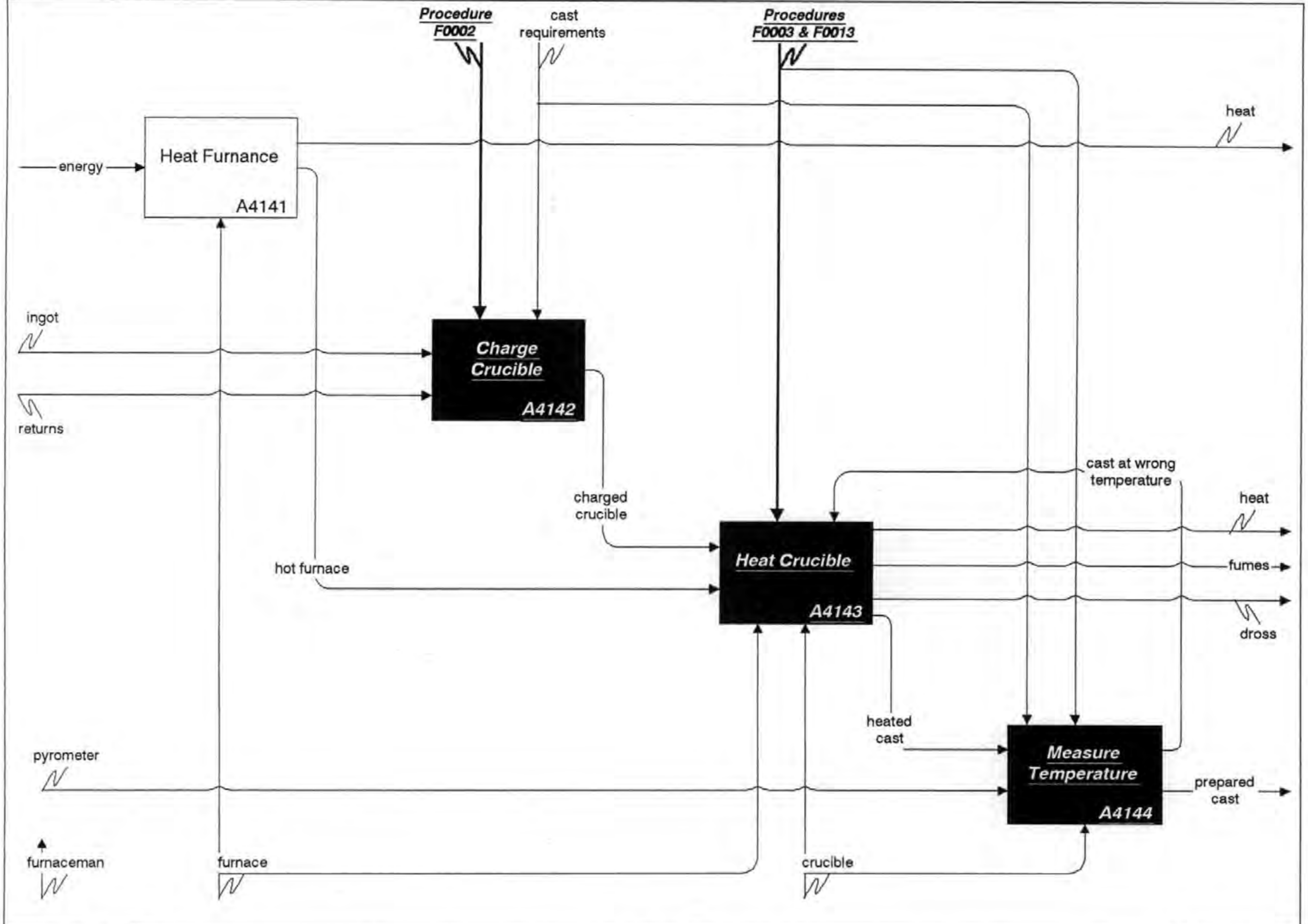
NODE: A4 TITLE: Manufacture Product NO.: 9



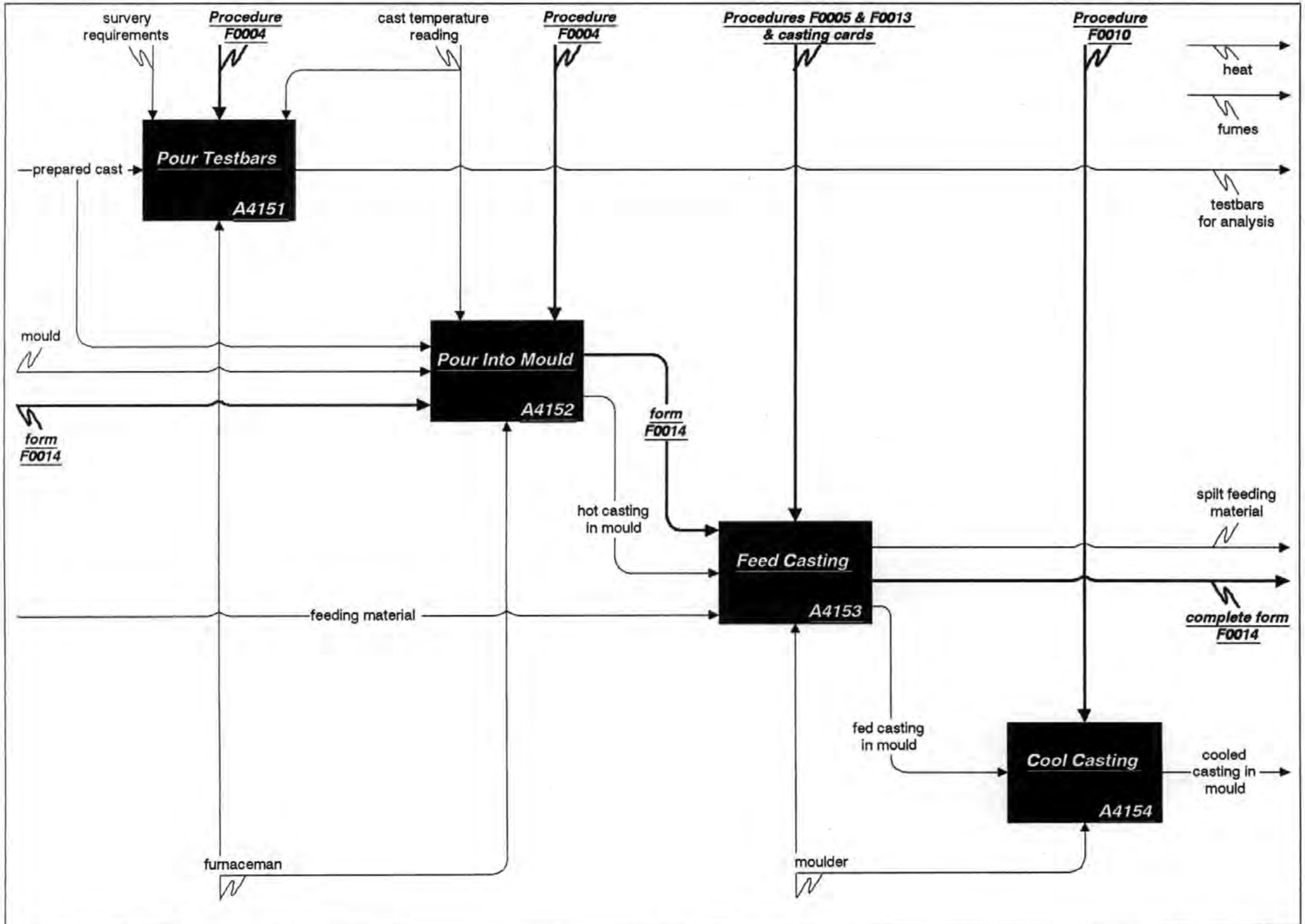
NODE: A41	TITLE: Make Casting	NO.: 10



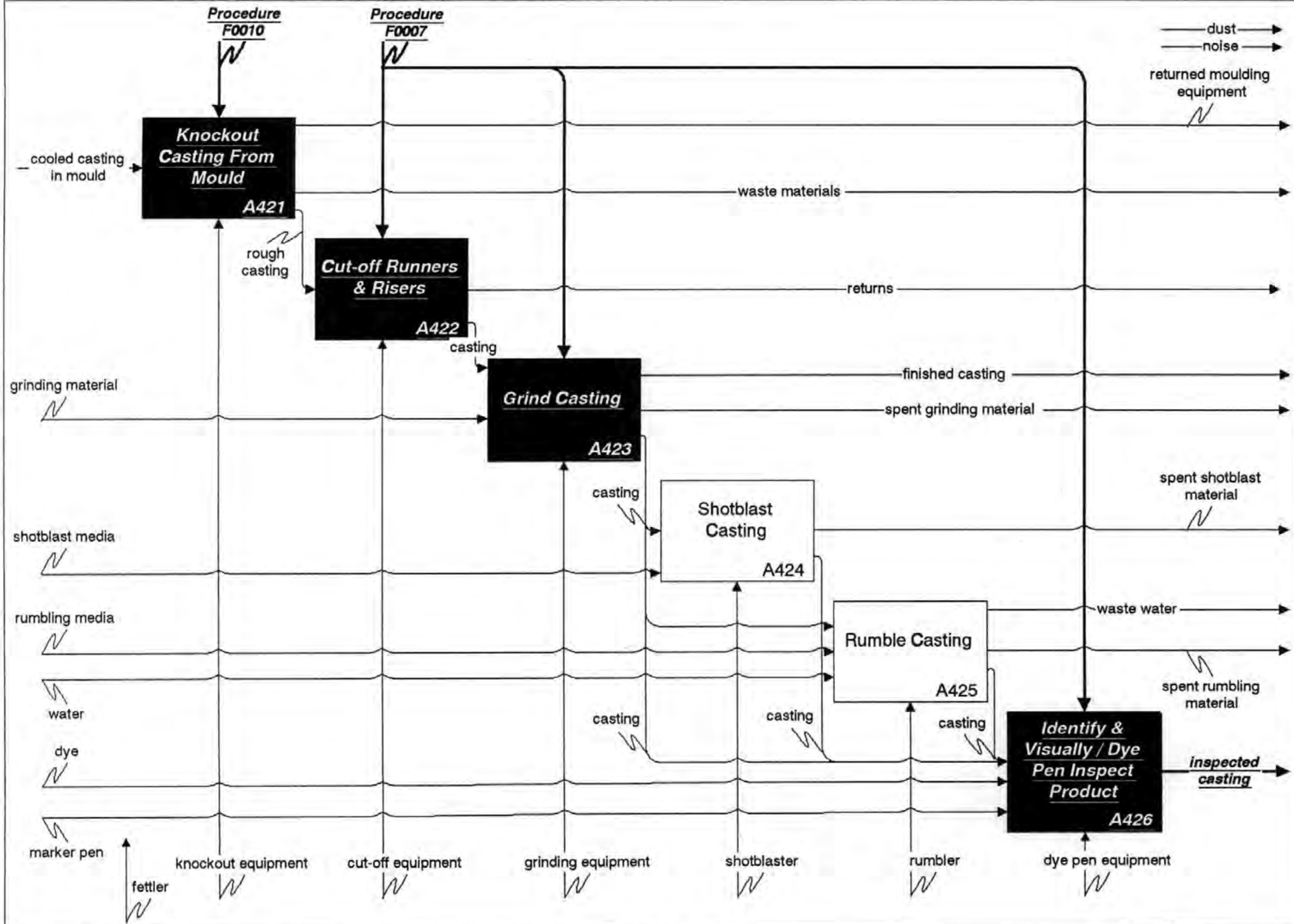
NODE: A413	TITLE: Make Mould	NO.: 11



NODE: A414	TITLE: Prepare Cast	NO.: 12



NODE: A415	TITLE: Pour Cast	NO.: 13

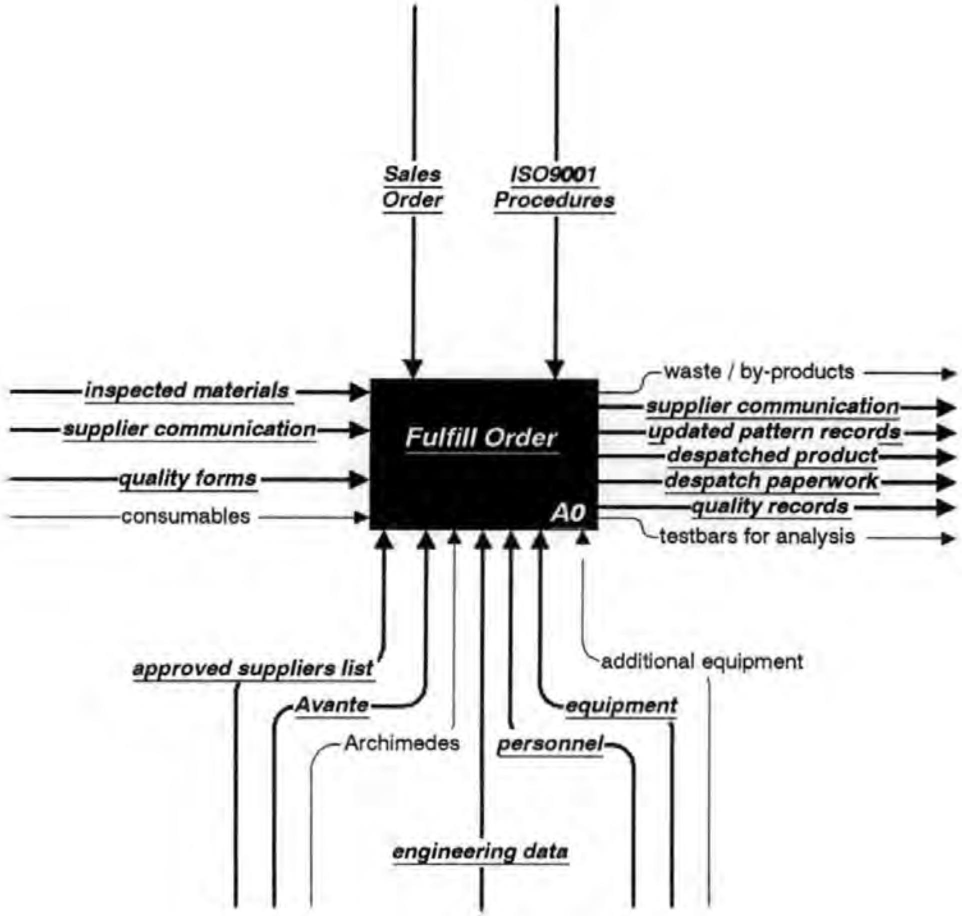


NODE: A42	TITLE: Fettle Casting	NO.: 14

Appendix 9 - To-be process model Case C

Note

Case C personnel had no formal training in the $IDEF_0$ methodology. The following process model is therefore based on the case company's understanding of process modelling and does not strictly adhere to the rules of $IDEF_0$ as stated in the standard FIPS 183.



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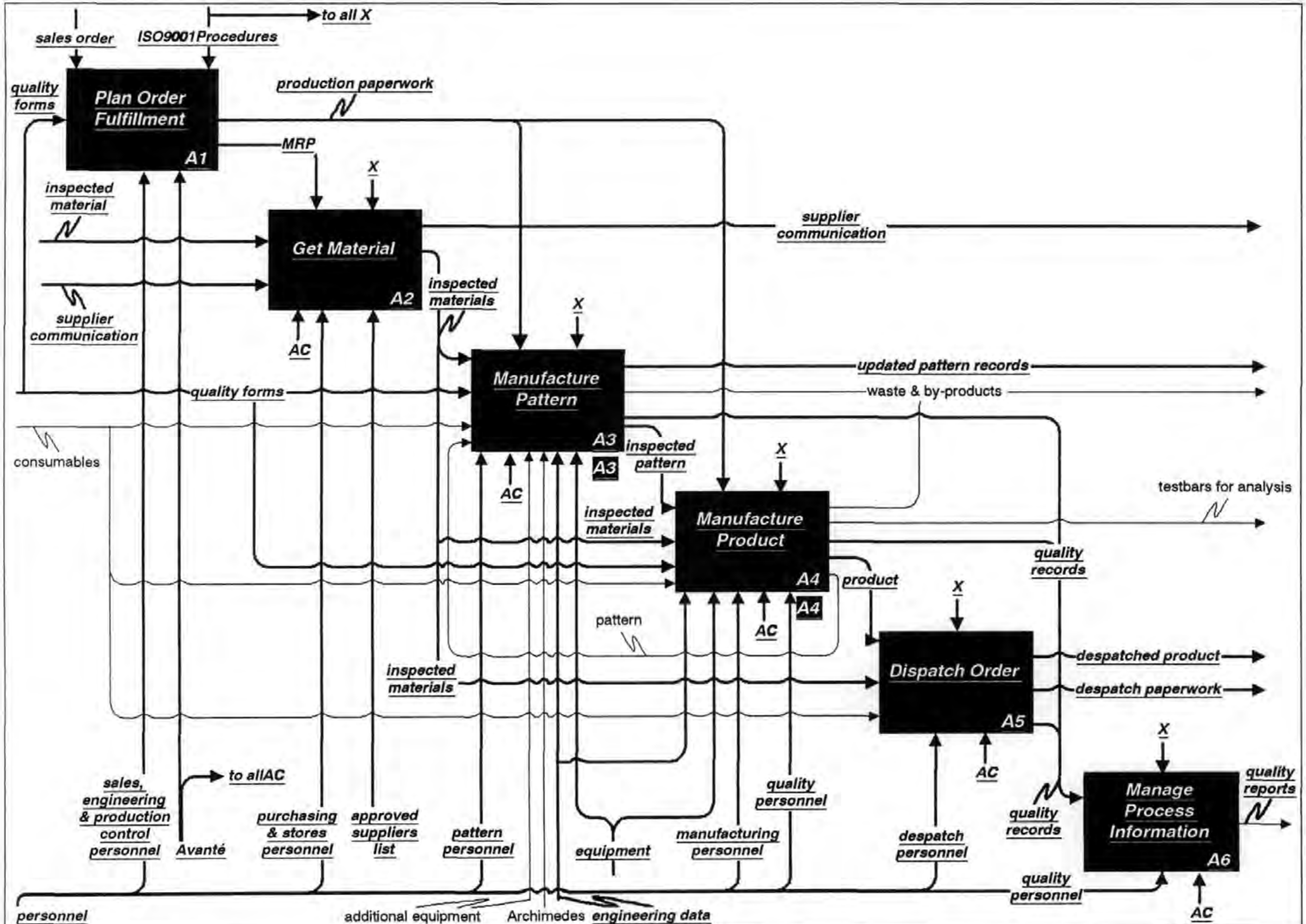
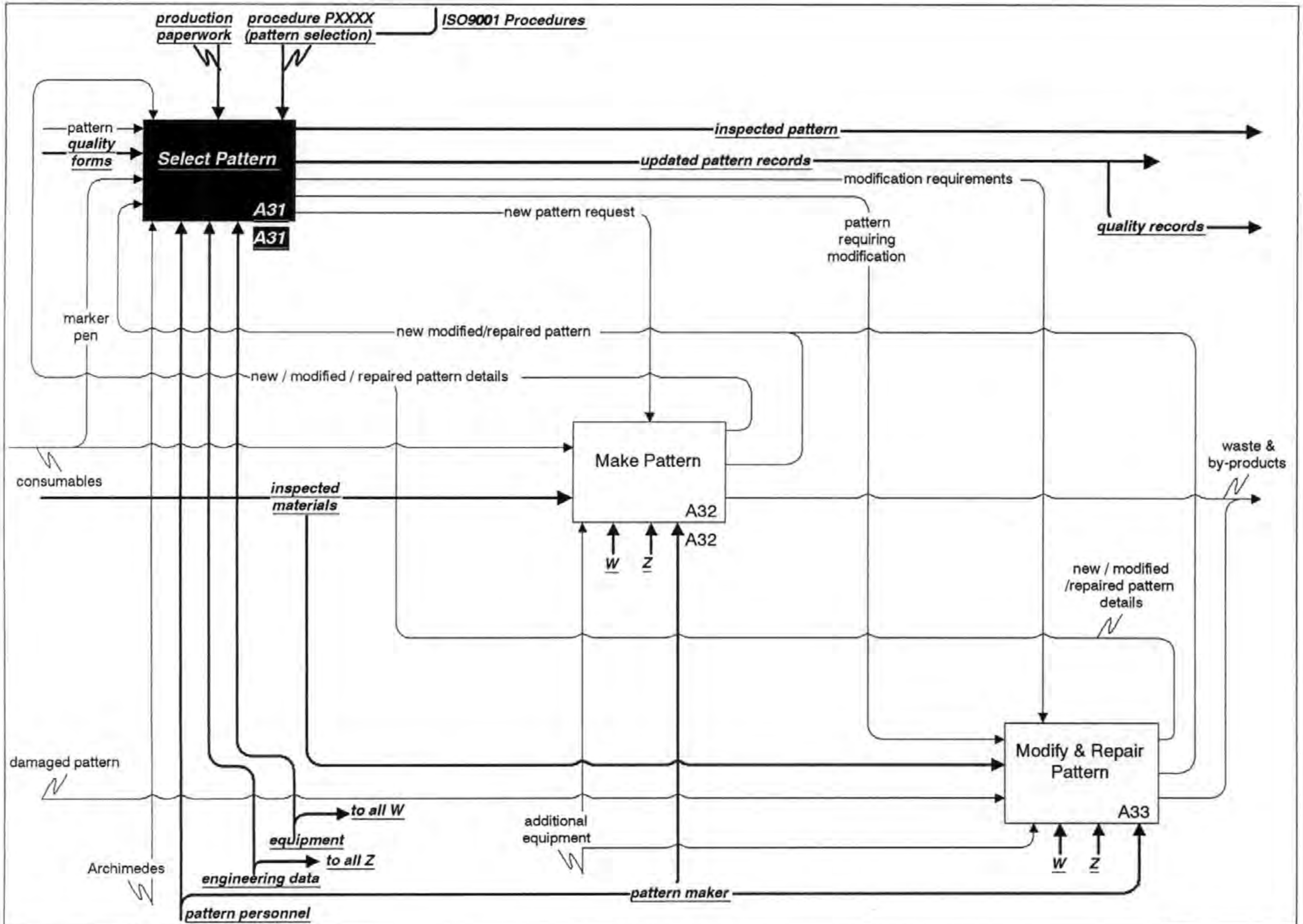
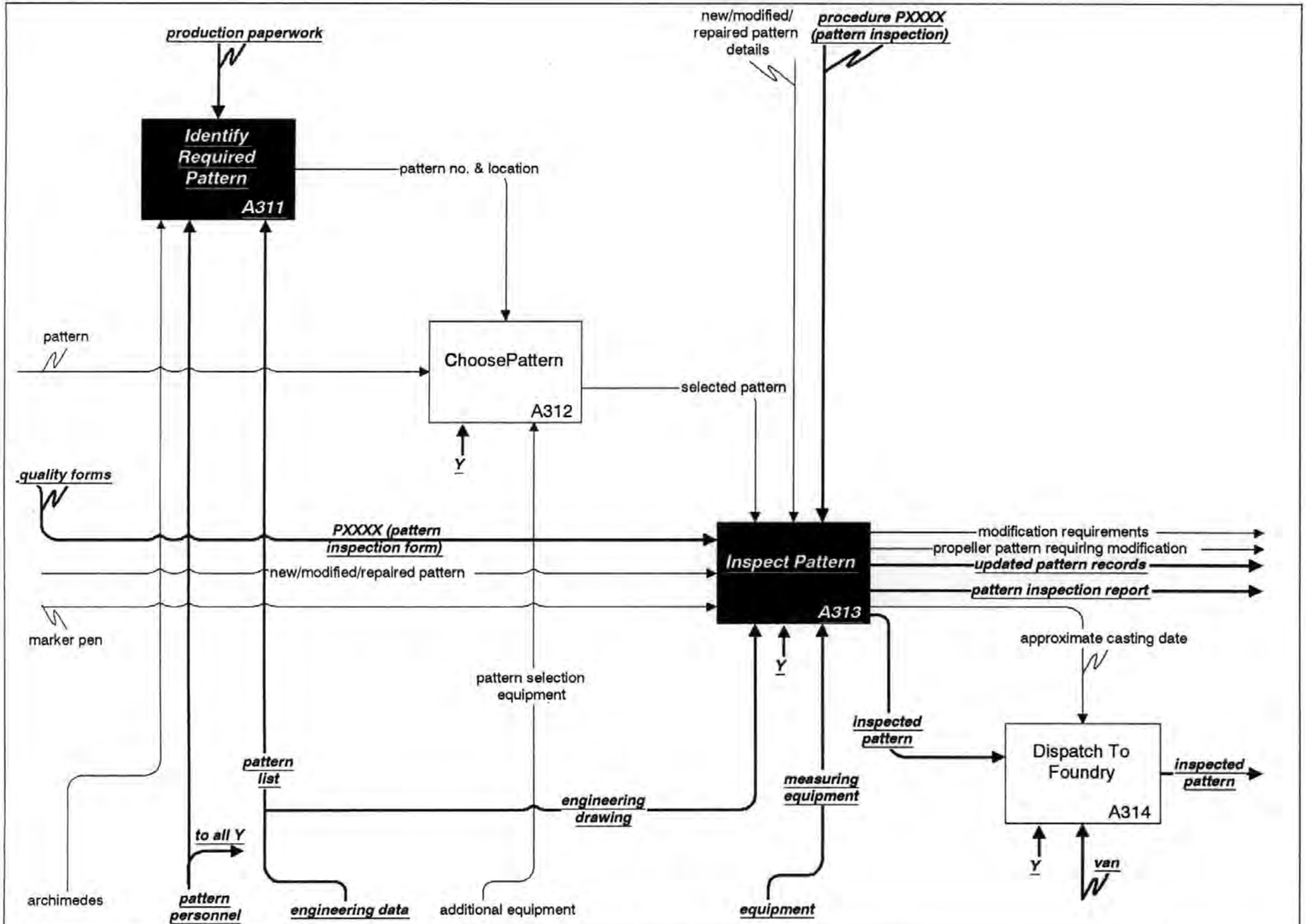


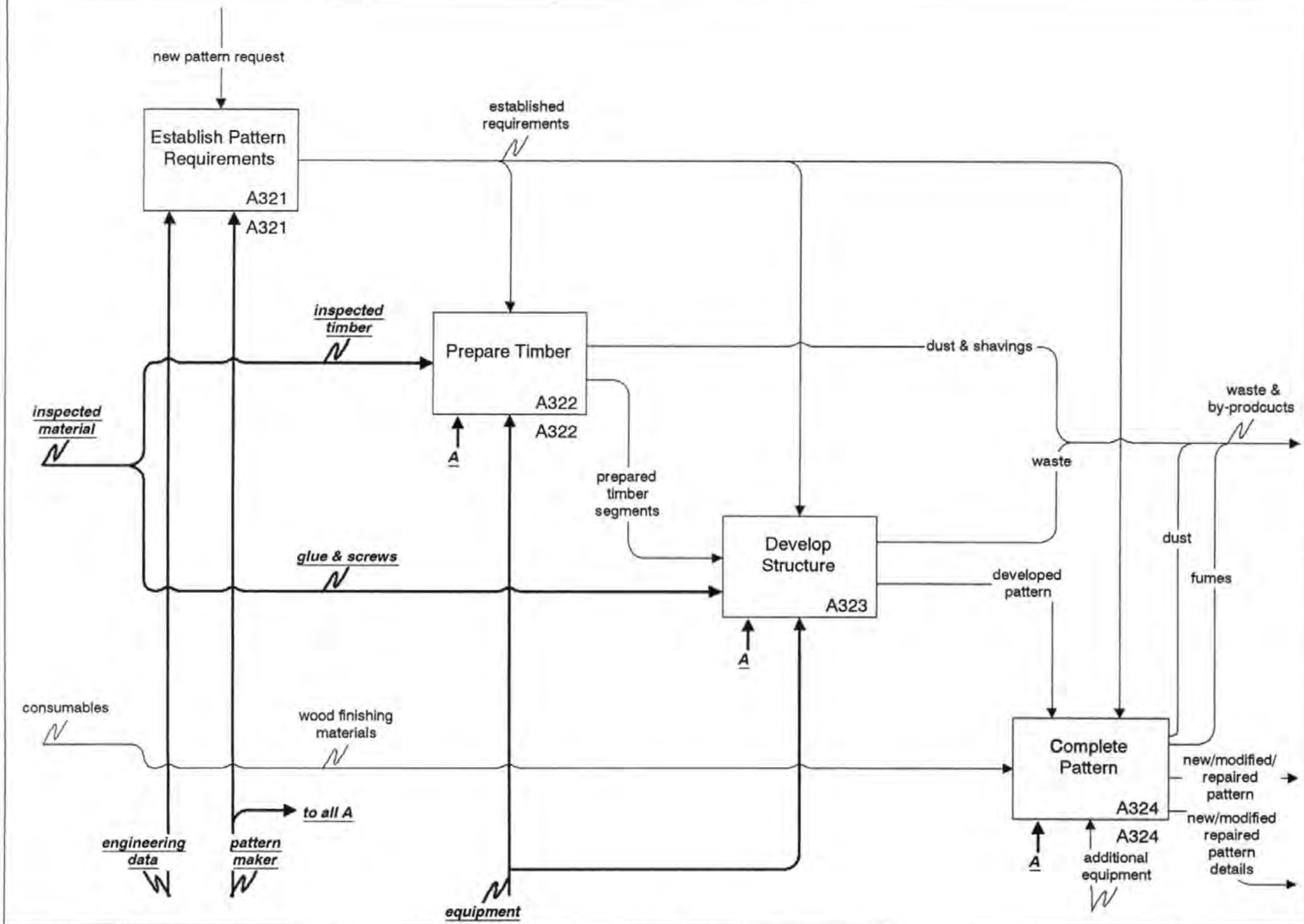
NODE: A0 | TITLE: Fulfill Order | NO.: 1



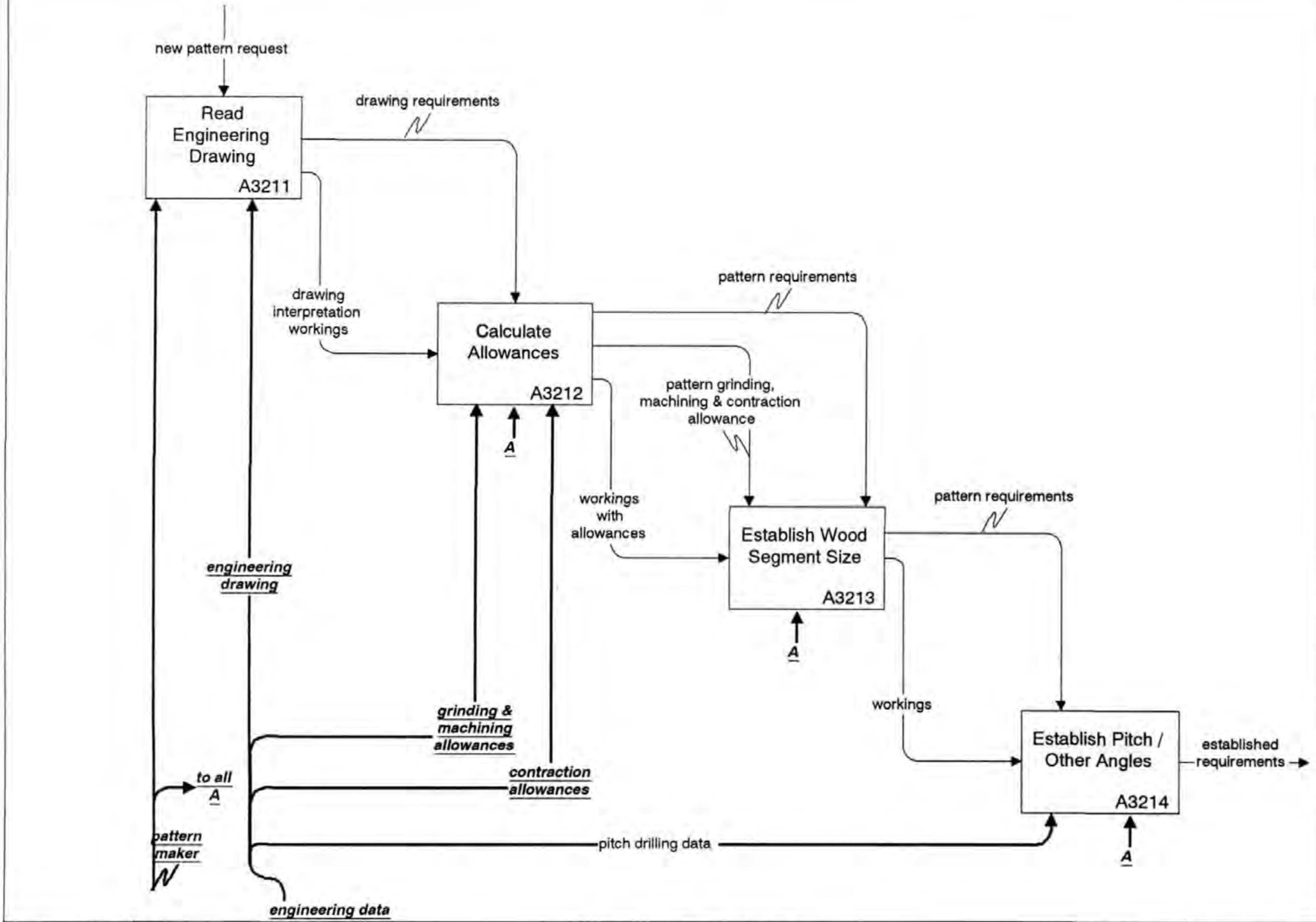
NODE: A3	TITLE: Manufacture Pattern	NO.: 2



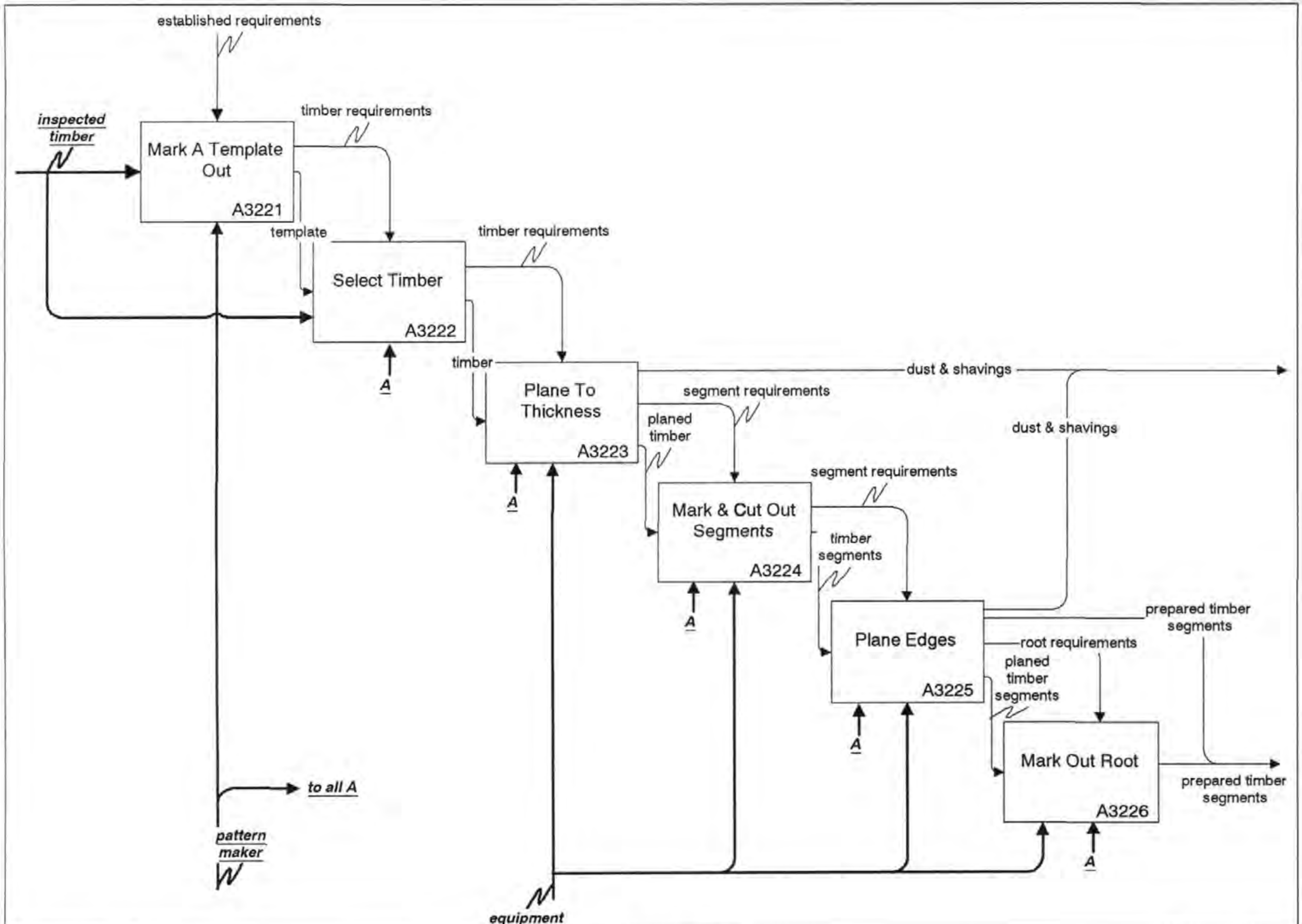
NODE: A31	TITLE: Select Pattern	NO.: 3



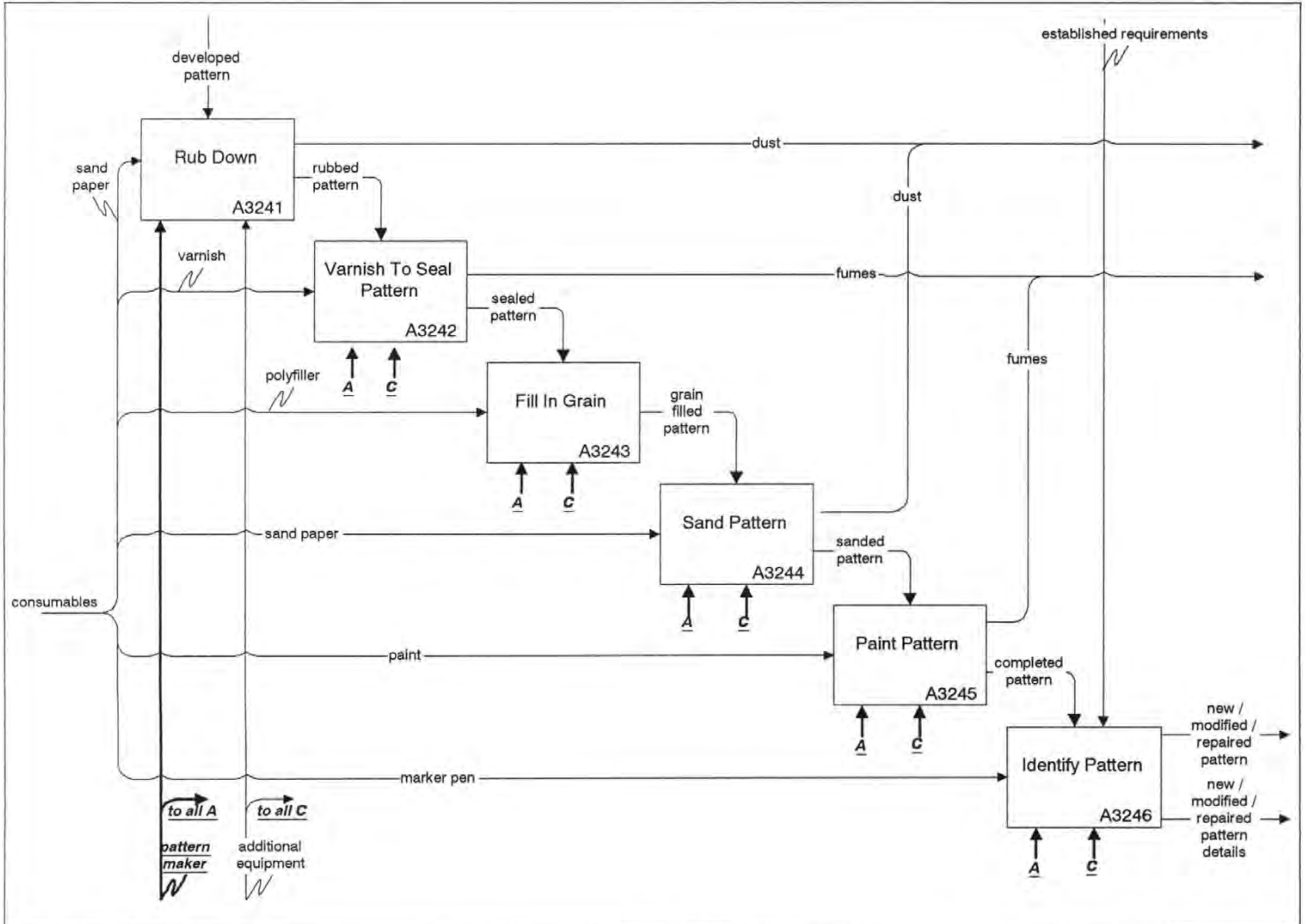
NODE: A32	TITLE: Make Pattern	NO.: 4



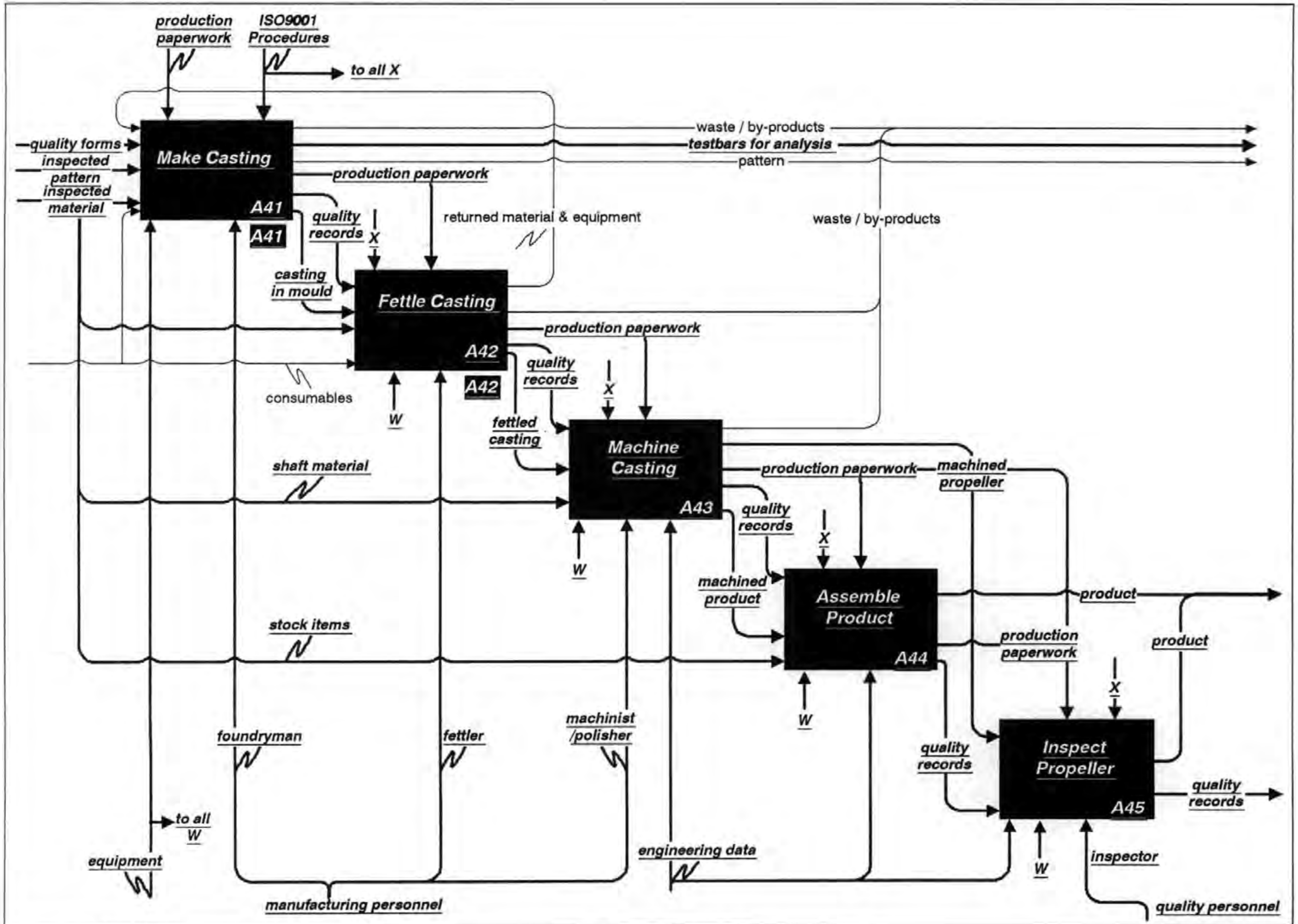
NODE: A321	TITLE: Establish Pattern Requirements	NO.: 5



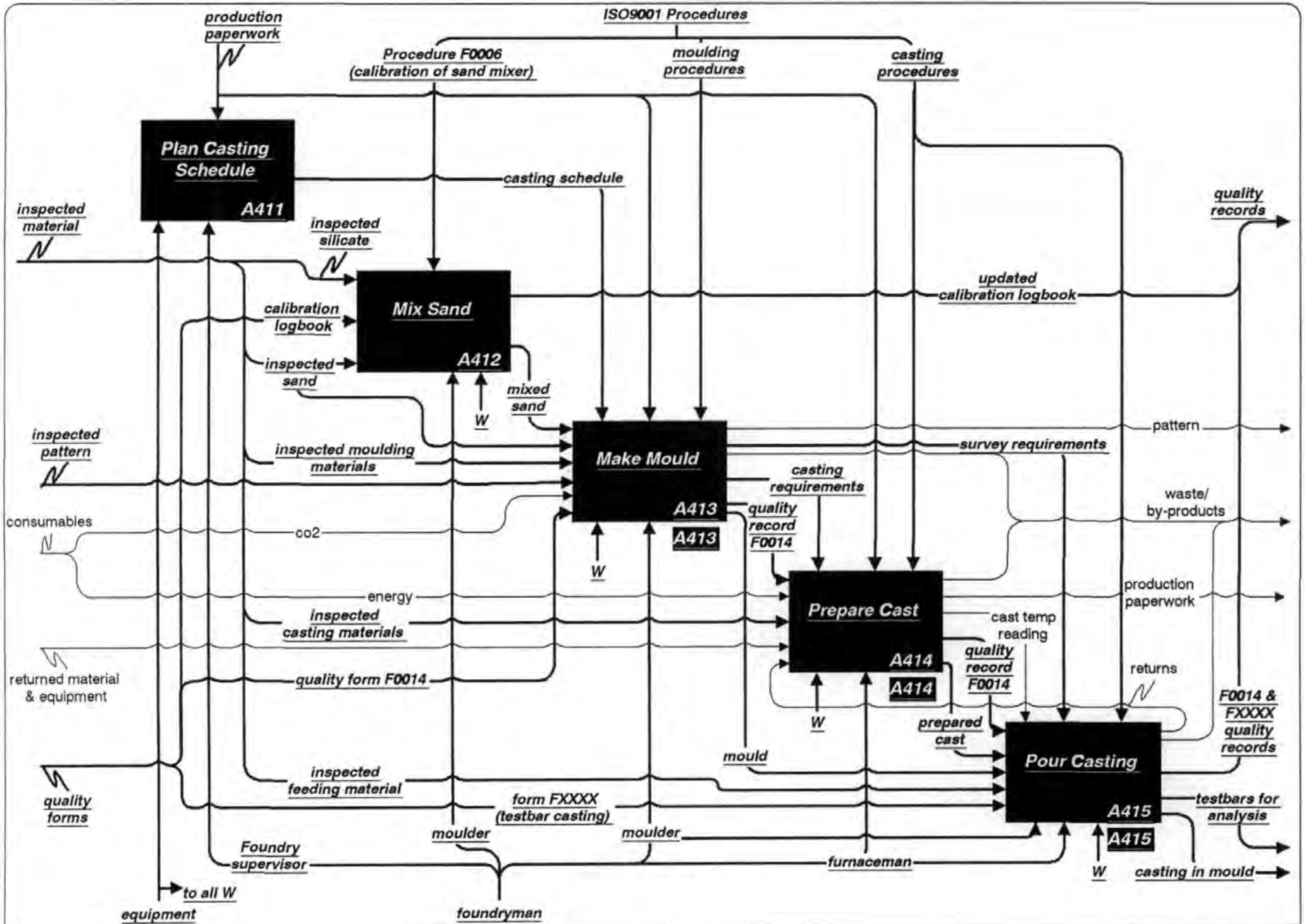
NODE: A322	TITLE: Prepare Timber	NO.: 6



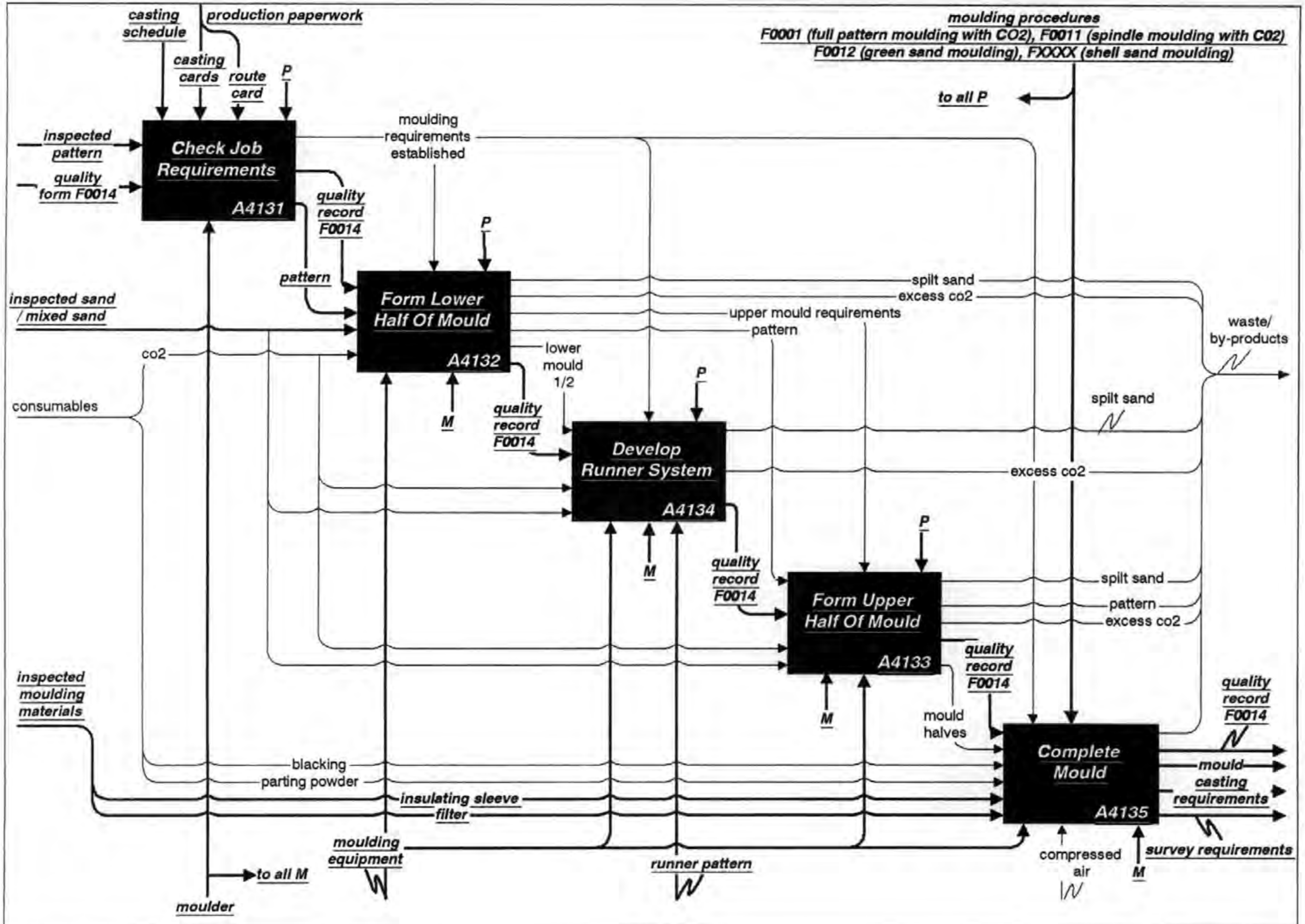
NODE: A324	TITLE: Complete Pattern	NO.: 7



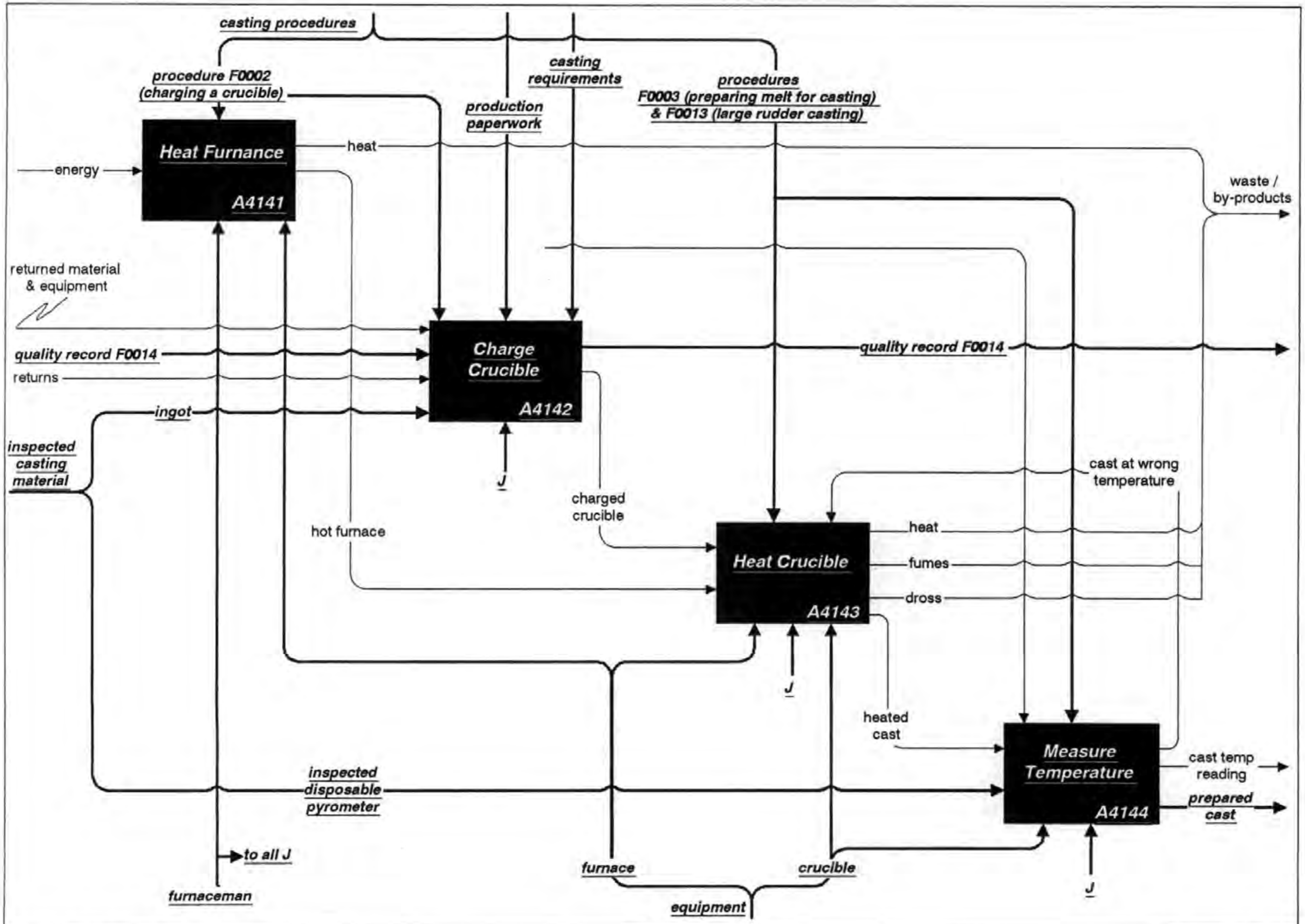
NODE: A4	TITLE: Manufacture Product	NO.: 8



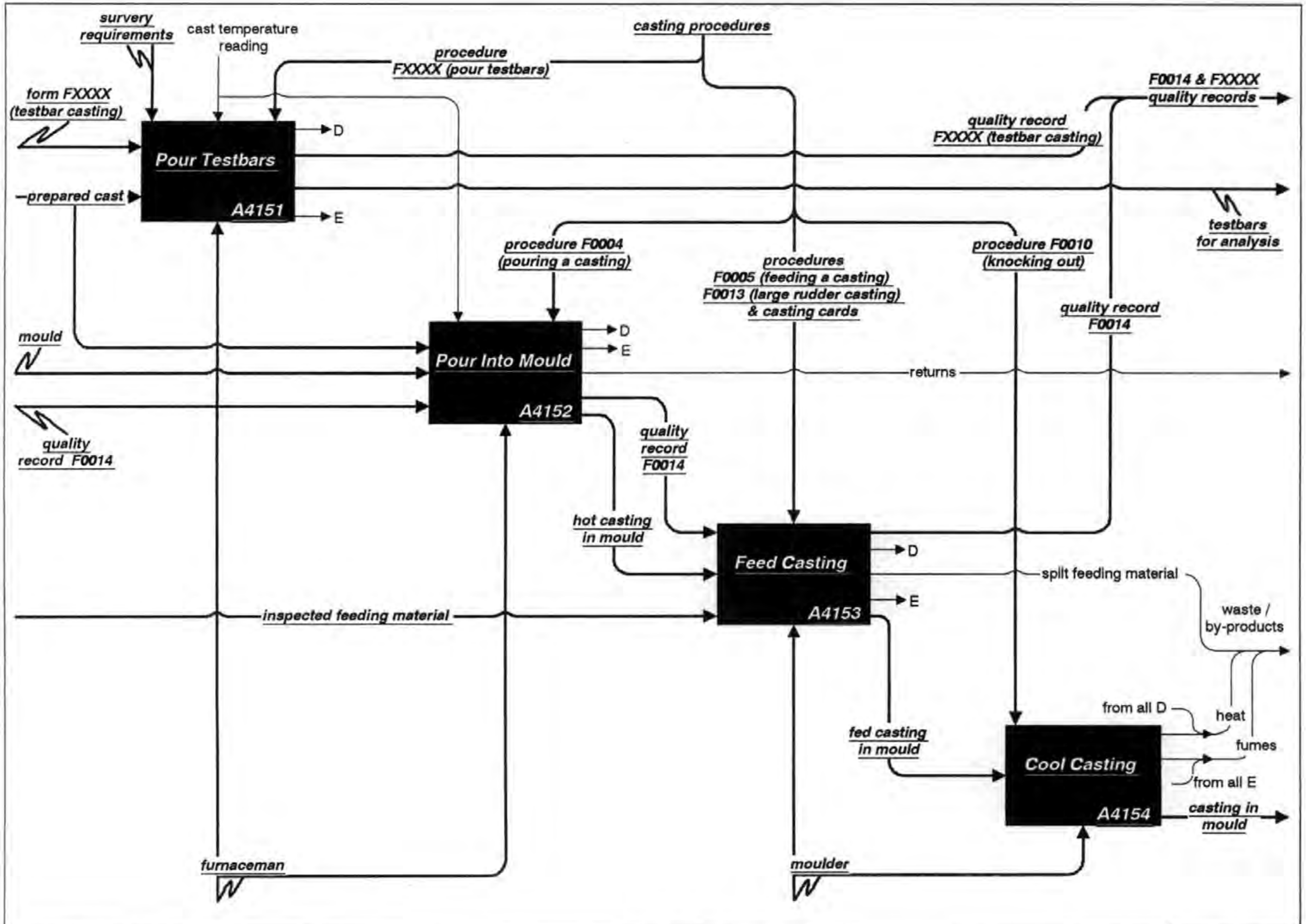
NODE: A41	TITLE: Make Casting	NO.: 9



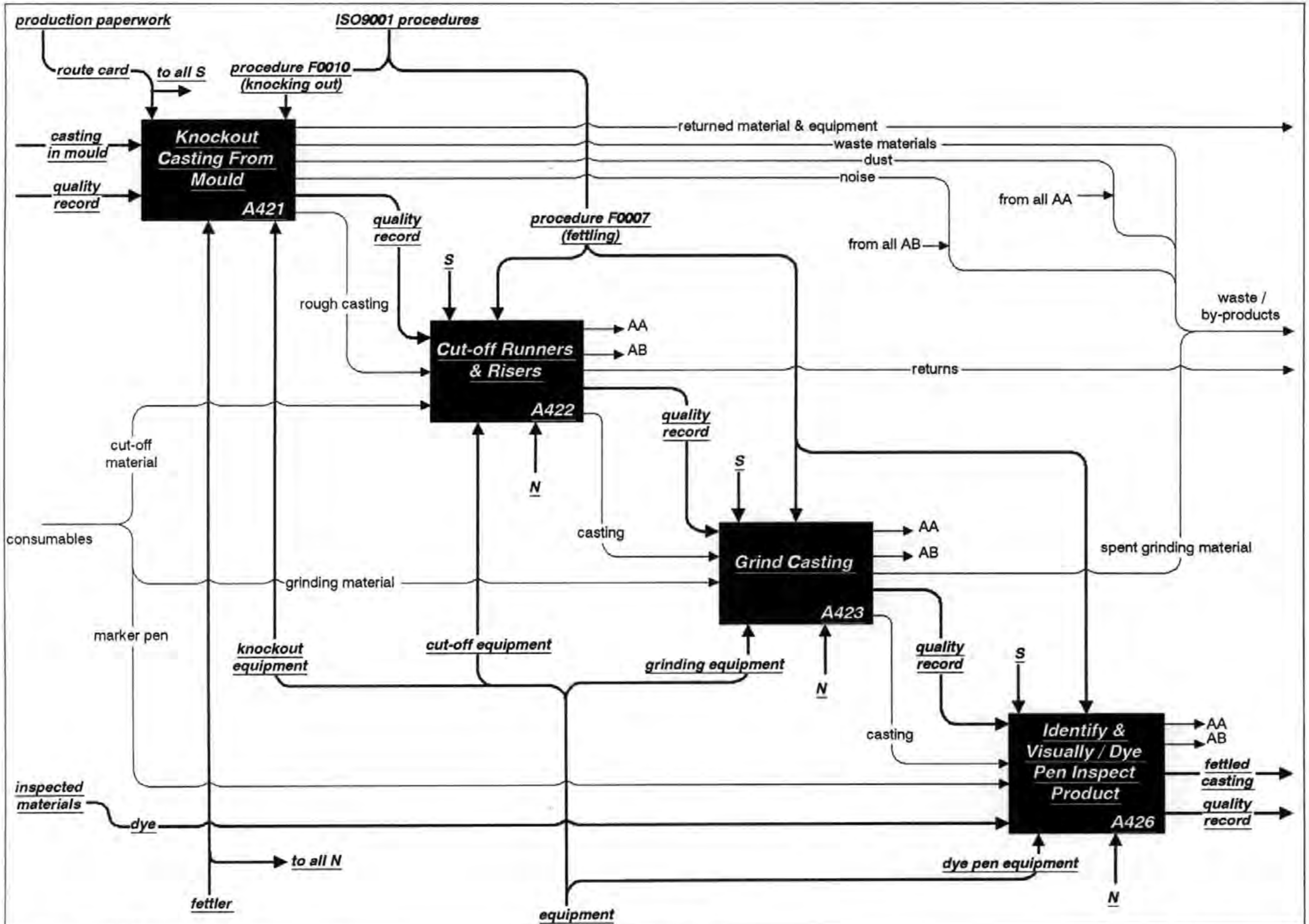
NODE: A413	TITLE: Make Mould	NO.: 10



NODE: A414	TITLE: Prepare Cast	NO.: 11

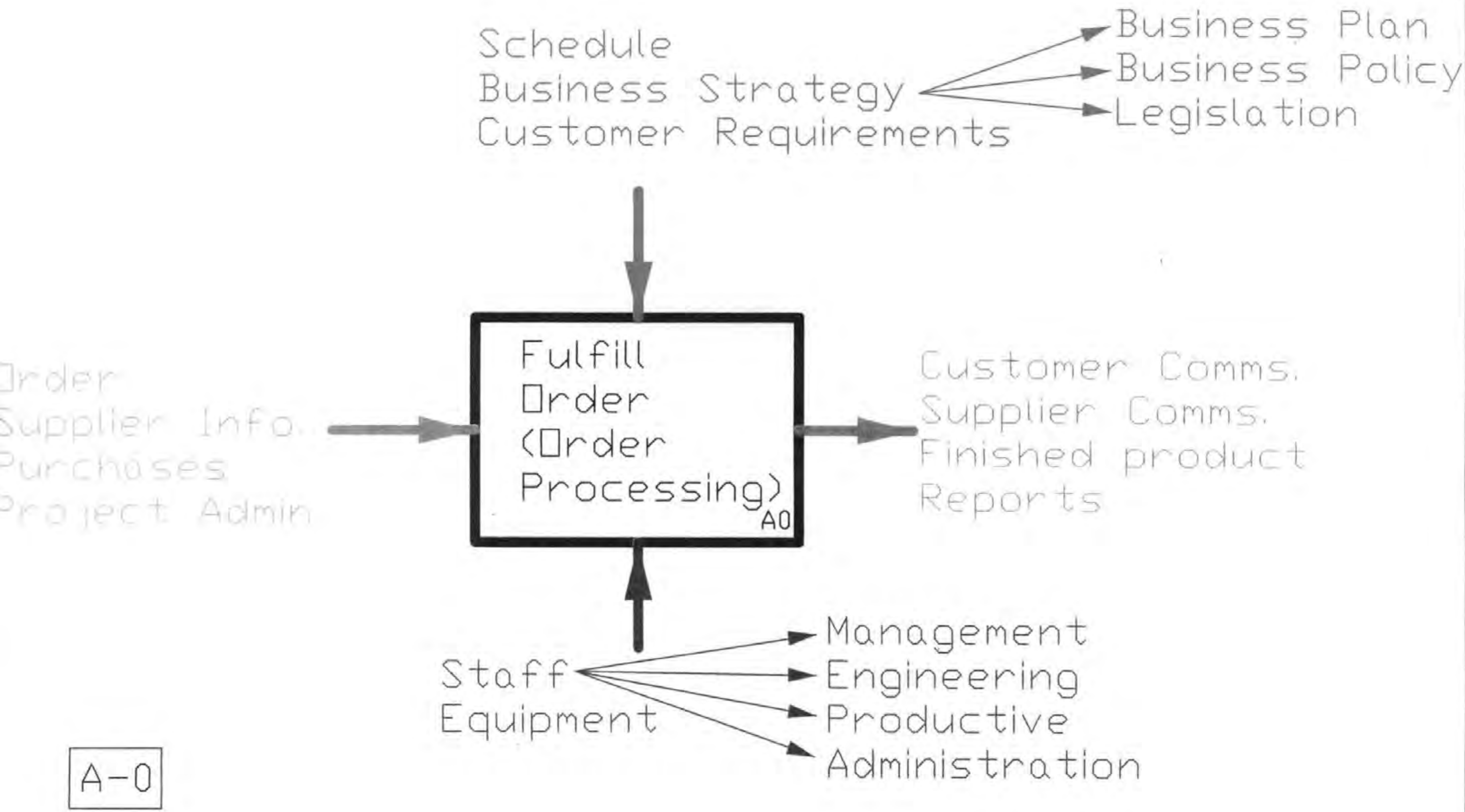


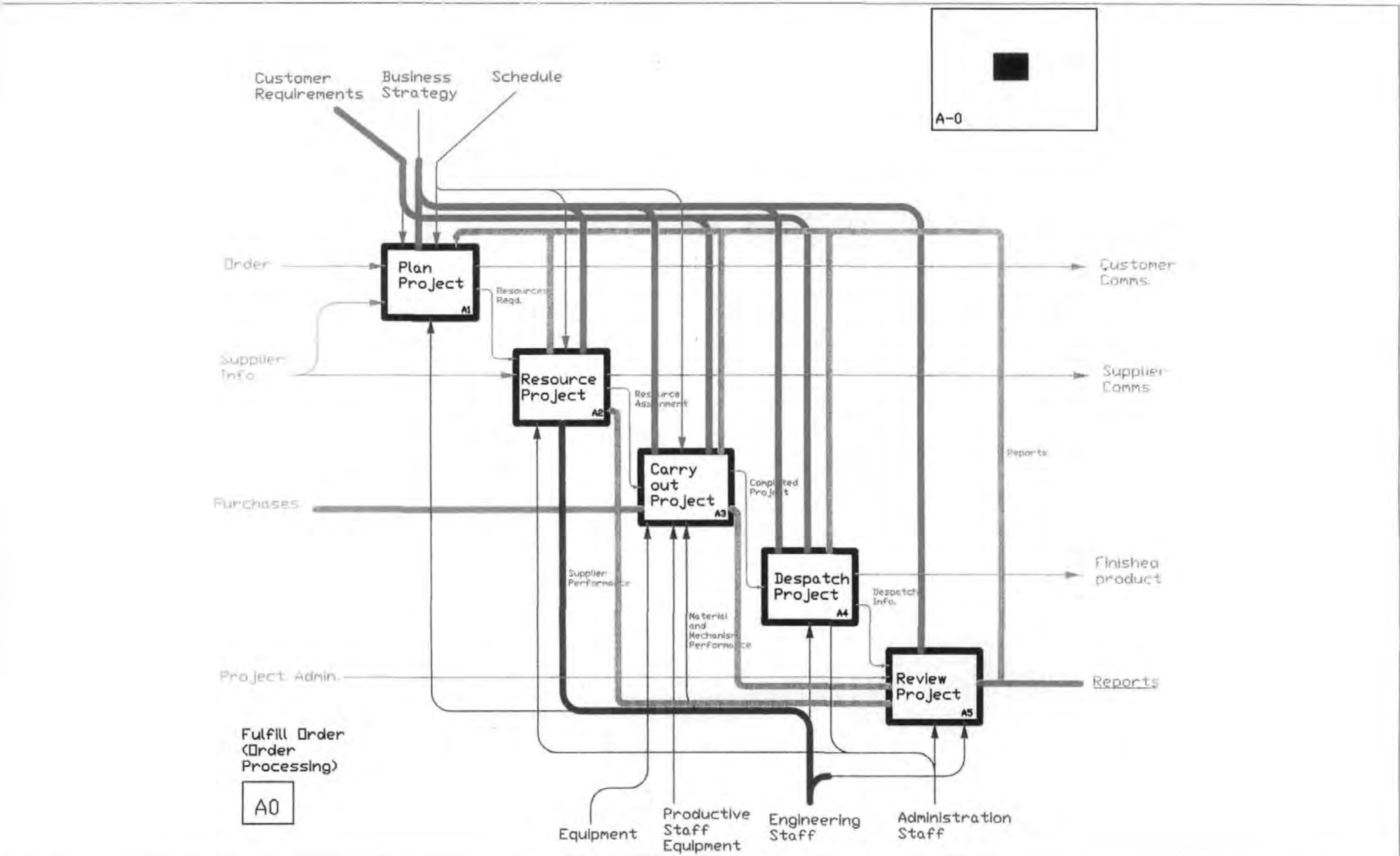
NODE: A415	TITLE: Pour Casting	NO.: 12

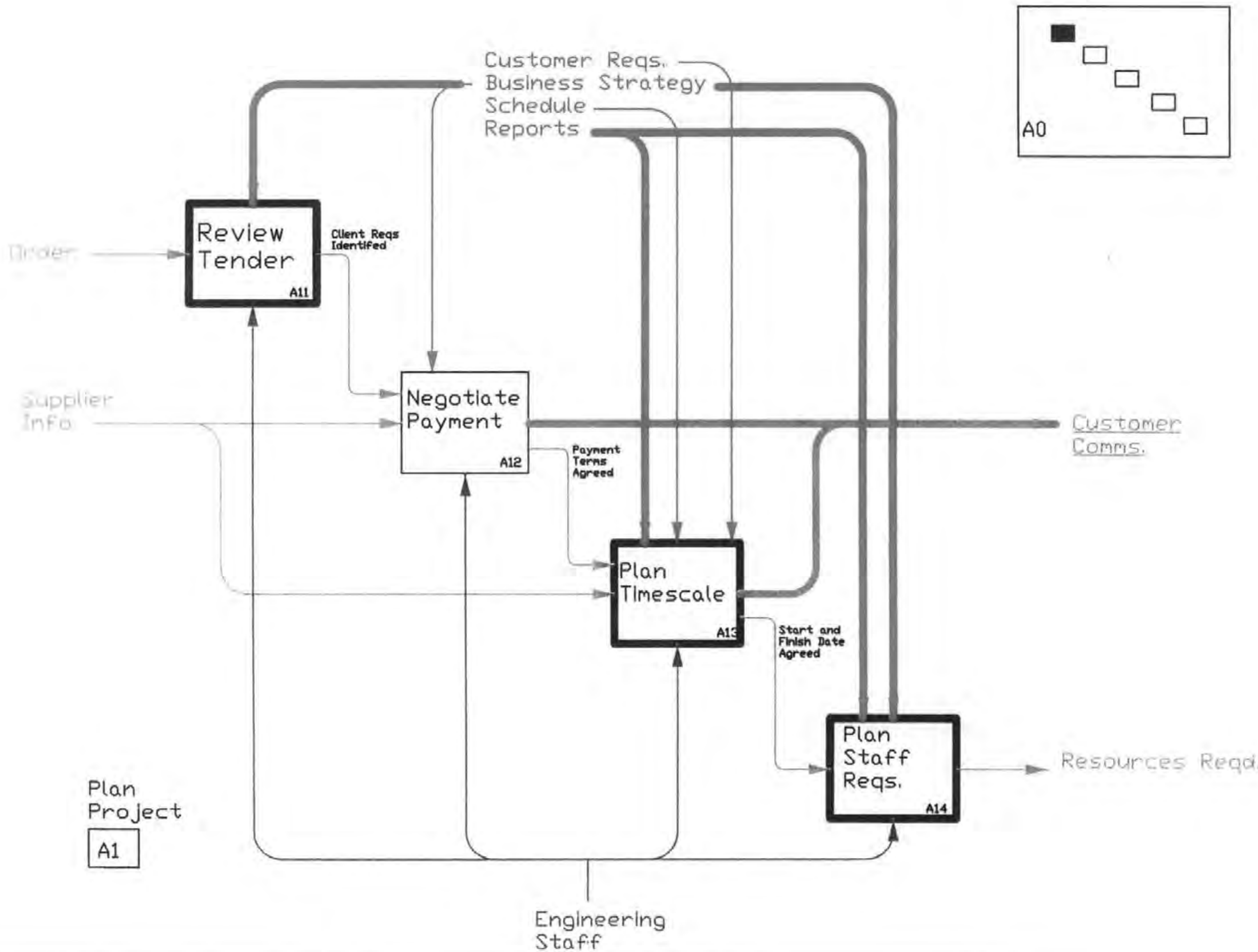


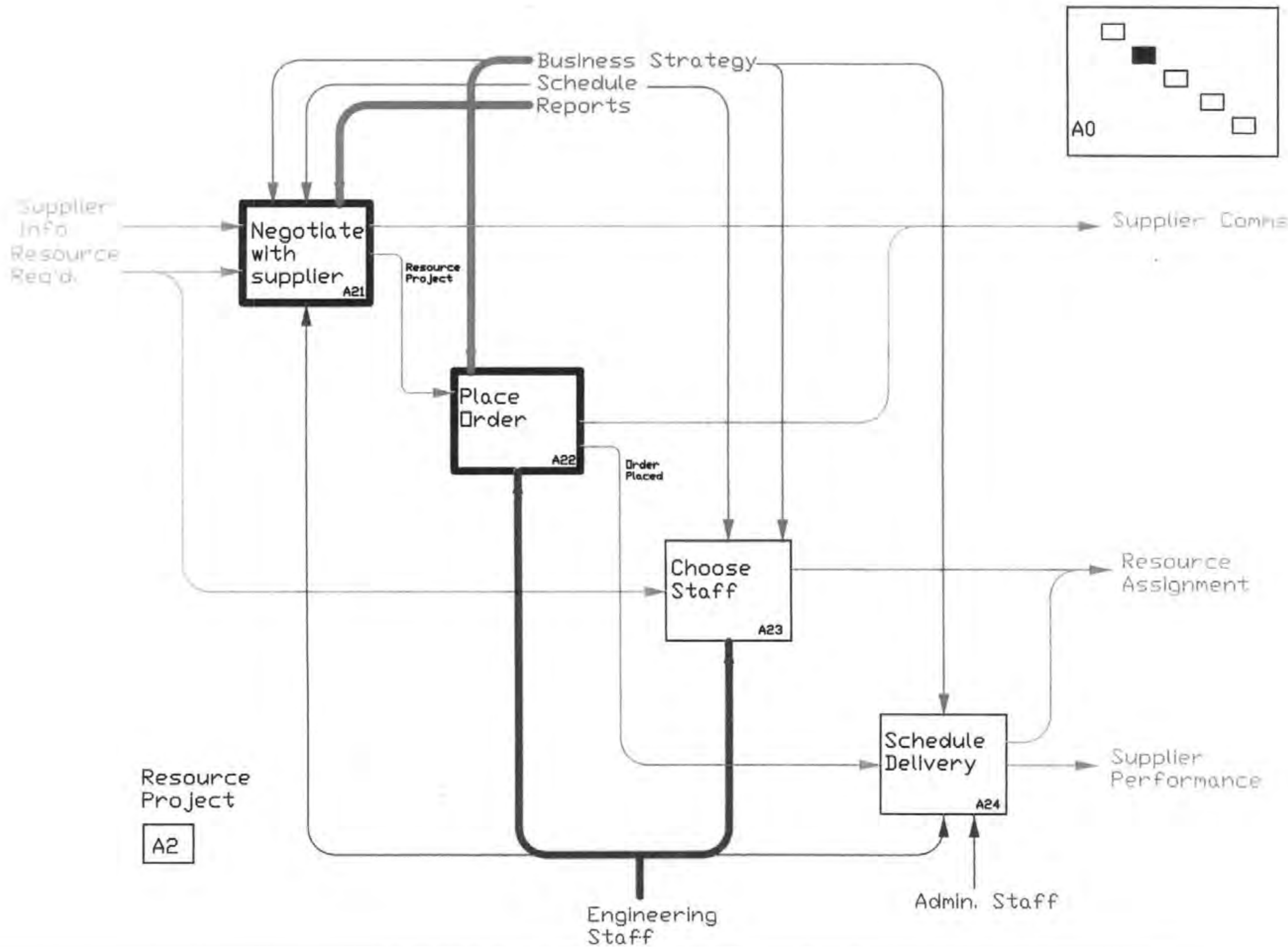
NODE: A42	TITLE: Fettle Casting	NO.: 13

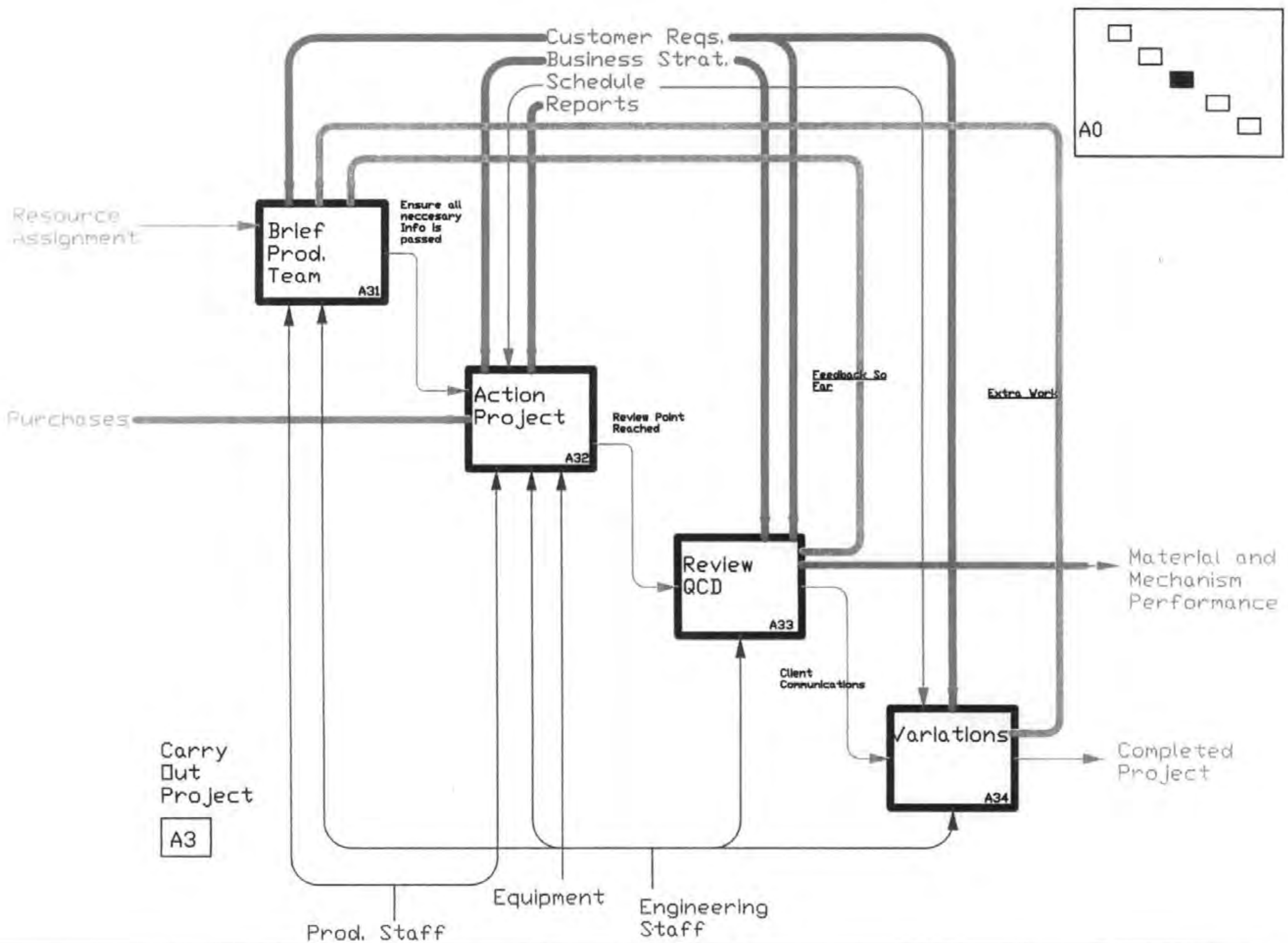
Appendix 10 - As-is process model Case D


Schedule
Business Strategy
Customer Requirements
Business Plan
Business Policy
Legislation
Order
Supplier Info.
Purchases
Project Admin
Fulfill Order (Order Processing)
A0
Customer Comms.
Supplier Comms.
Finished product
Reports
Staff
Equipment
Management
Engineering
Productive
Administration
A-0

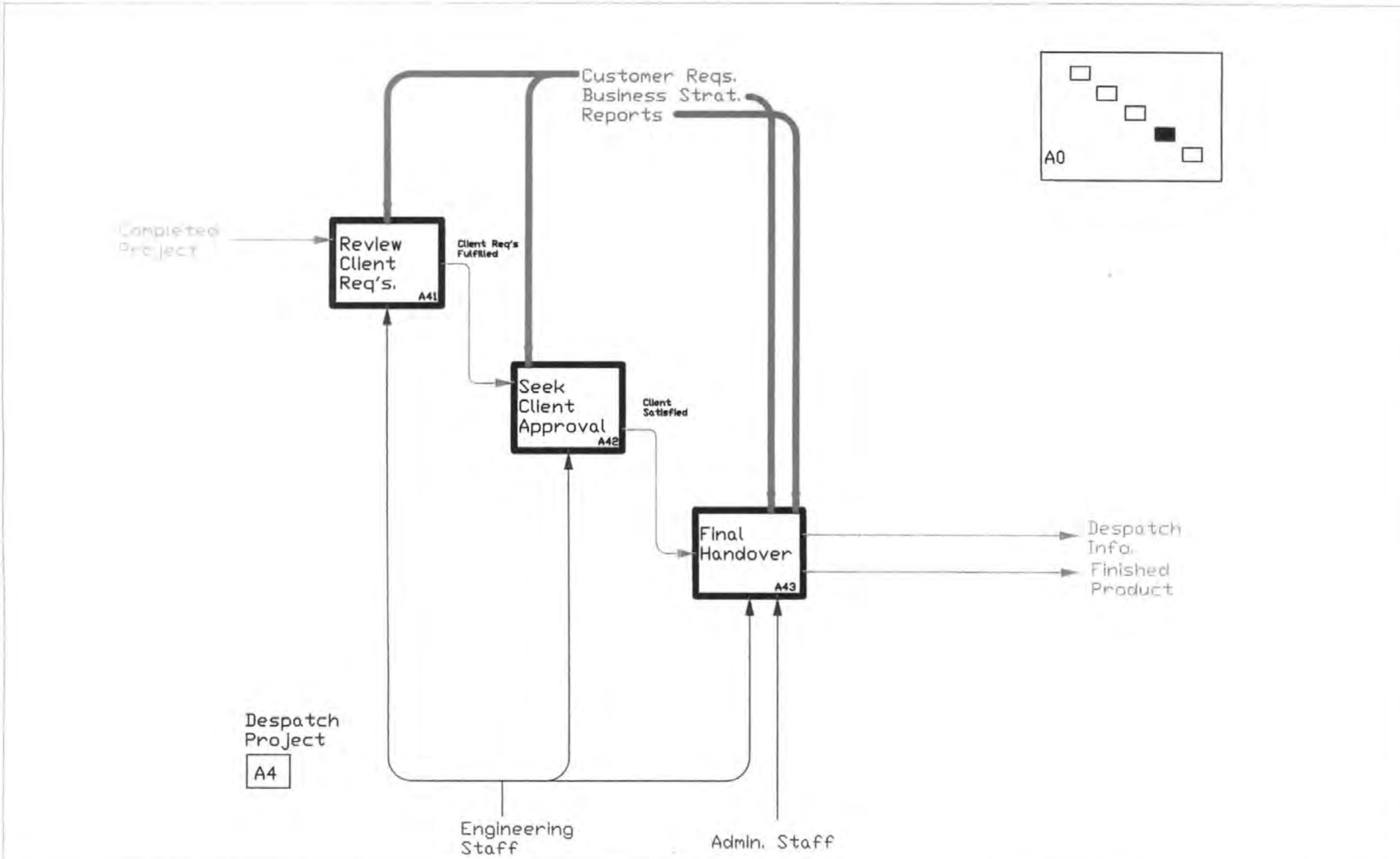

A-0
Customer Requirements
Business Strategy
Schedule
Order
Supplier Info
Purchases
Project Admin.
Plan Project
A1
Resources Reqd.
Resource Project
A2
Carry out Project
A3
Despatch Project
A4
Despatch Info.
Review Project
A5
Reports
Customer Comms.
Supplier Comms.
Finished product
Reports
Equipment
Productive Staff Equipment
Engineering Staff
Administration Staff
Fulfill Order (Order Processing)
A0


Customer Reqs.
Business Strategy
Schedule
Reports
A0
Order
Review Tender
A11
Client Reqs Identifed
Supplier Info
Negotiate Payment
A12
Customer Comms.
Payment Terms Agreed
Plan Timescale
A13
Start and Finish Date Agreed
Plan Staff Reqs.
A14
Resources Reqd.
Plan Project
A1
Engineering Staff

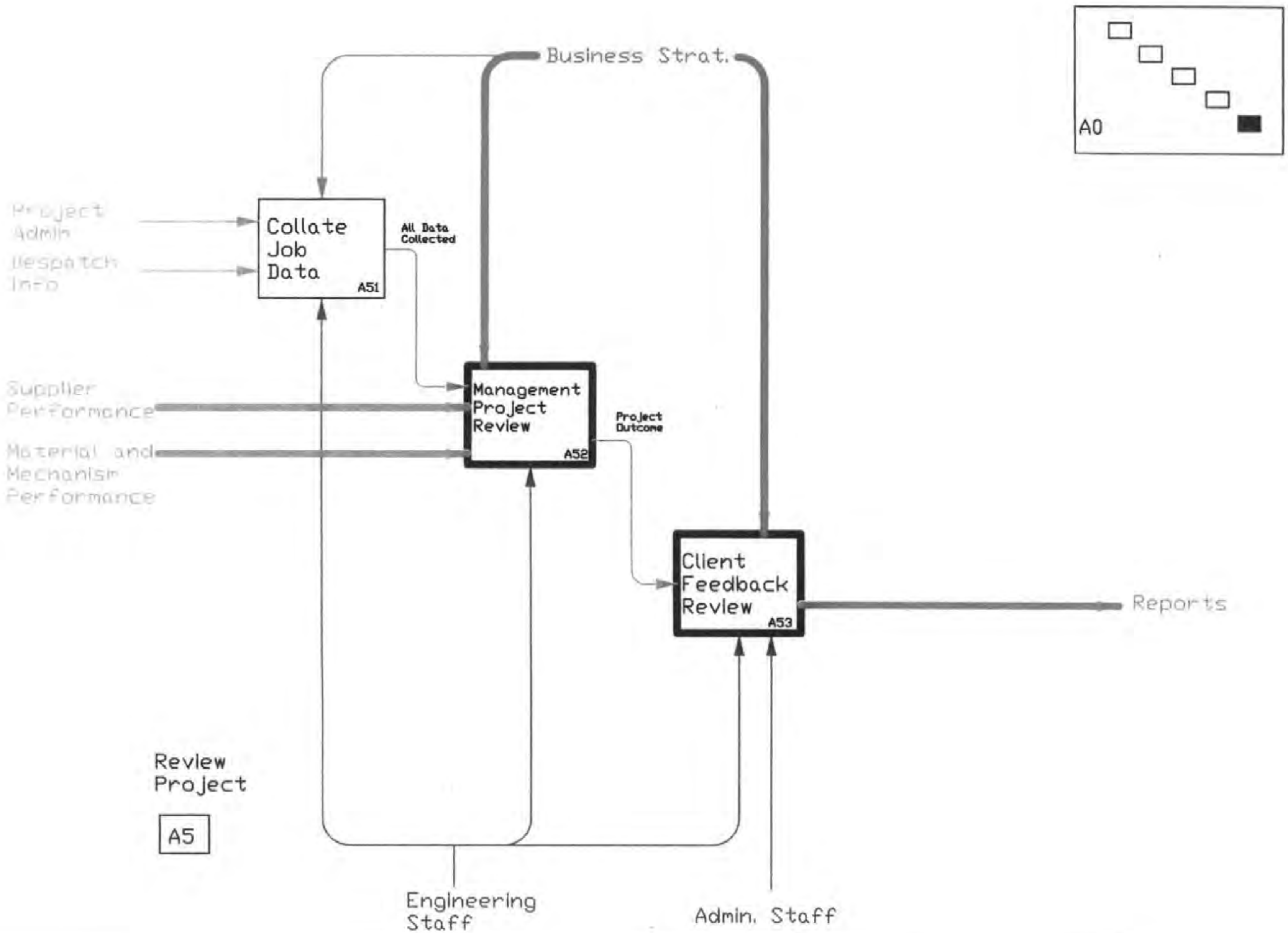

Business Strategy
Schedule
Reports
A0
Supplier Info
Resource Req'd
Negotiate with supplier
A21
Resource Project
Supplier Comms
Place Order
A22
Order Placed
Choose Staff
A23
Resource Assignment
Schedule Delivery
A24
Supplier Performance
Resource Project
A2
Engineering Staff
Admin. Staff



Customer Reqs.
Business Strat.
Schedule
Reports
Resource Assignment
Brief Prod. Team
A31
Ensure all neccesary info is passed
Action Project
A32
Purchases
Review Point Reached
Feedback So Far
Extra Work
Review QCD
A33
Material and Mechanism Performance
Client Communications
Variations
A34
Completed Project
Carry Out Project
A3
A0
Equipment
Prod. Staff
Engineering Staff



Customer Reqs.
Business Strat.
Reports
Completed Project
Review Client Req's.
A41
Client Req's Fulfilled
Seek Client Approval
A42
Client Satisfied
Final Handover
A43
Despatch Info.
Finished Product
A0
Despatch Project
A4
Engineering Staff
Admin. Staff


A0
Business Strat.
Project Admin
Despatch Info
Collate Job Data
A51
All Data Collected
Supplier Performance
Material and Mechanism Performance
Management Project Review
A52
Project Outcome
Client Feedback Review
A53
Reports
Engineering Staff
Admin. Staff
Review Project
A5

Appendix 11 - Refereed Publications

Gingele, J., Integriertes Management erschließt Potentiale. *Proceedings of the 12th International Trade Fair for Quality Assurance* 12-15/5/98 Sinsheim, Germany

Gingele, J., Childe, S.J., A business process view of the design of quality systems – specification of a tool. *43rd Annual Conference OR43 Operational Research Society, 4-6 September 2001 Bath*

A business process view of the design of quality systems – specification of a tool

J. Gingele, S.J. Childe

University of Plymouth, Manufacturing and Business Research Group (MABS)

Abstract

Despite the updated version of ISO 9001:2000 organisations still face the difficulty of how to apply and integrate the requirements of the quality standard effectively. Documenting what a company does in response to the requirements of the ISO 9001 is still one of the most common approaches adopted which in many cases can lead to increased bureaucracy due to minimal impact on existing organisational structures. The usefulness of business process-oriented organisational structures has been widely recognised but the design of quality systems often achieves a process-oriented character only at the documentation stage. The focus has been on the design of a certifiable quality system, not taking an overall systemic view of the entire business.

This paper discusses a case study which used an activity-based approach to the design of an ISO 9001 quality system and specifies a technique needed to deal with the relationship between ISO and business processes.

Keywords

Quality system, ISO 9001:1994, ISO 9001:2000, business process design, business process modelling

Introduction

As organisations are increasingly focusing on flexibility, innovation and processes there now appears to be a need to assess current approaches to the implementation of the ISO 9000 requirements. With over 340,000 certificates granted by the end of December 1999 (ISO 9th cycle) [1] even its keenest supporters were surprised how quickly this standard model achieved world-wide acceptance. However ISO 9000 has had some very bad press. Much of the work undertaken in the area of ISO 9000 quality systems has focused on complying with ISO 9000 requirements to get or maintain a certified quality system which could lead to very high levels of record-keeping and form-filling. Critics such as Seddon [2] reported it as being an expensive and in many cases, an irrelevant and inappropriate system for many businesses. The commonest criticism is excessive bureaucracy and the inflexibility it generates [3]. Jonker *et al.* [4] argue that due to the lack of proper methodology, the integration of such models remains difficult and that a "methodological body of knowledge" to facilitate integration should be developed.

With the publication of a completely revised ISO 9000/1:2000 it is an opportune moment for management to update or restructure the company's quality system. The new 2000 version of ISO 9001 is a major structural and strategic revision of the standards. With the replacement of the familiar 20 sections that formed current ISO 9001:1994, the new structure incorporates the so called "Process Model" based on the following four main sections:

- Management responsibility
- Resource management
- Product and/or service realisation
- Measurement, analysis and improvement

The above describe the four phases referred to as the "Process Model" and are intended to function similar to the Plan-Do-Check-Act Cycle (PDCA) for a continual improvement process by Deming [5]. The model recognises the customers and other relevant stakeholders in playing a significant role during the process of defining the input requirements. It also considers satisfaction measurements of all relevant interested parties that are used as feedback to evaluate and validate whether customer requirements have been achieved. ISO 9001:2000, encourages organisations in the adoption of a process-based approach for a quality system. The "Process Model" is however not intended to reflect processes at the detailed level [6] and pays no attention to an architecture model for enterprise modelling or more importantly to process modelling.

The implementor of a quality system needs to decide how to design a ISO system according to the objectives and aims for the project. Hoyle [7] summarises the various approaches to ISO 9001 implementation in the following four ways.

- **Simply following what the standard dictates.**
  This method documents the activities and documentation that are required by the standard. From there it usually generates a quality manual that addresses each of the 20 sections of the ISO 9001:1994 in the sequence in which the standard is presented, regardless of the relevance to the business. The quality manual becomes a "carbon copy" of the original standard document not reflecting the unique structure of the business.

- **Documenting what you do in response to the requirements of ISO 9001.**
  The usual approach to documenting quality systems is to write procedures. In many cases procedures are in text form but more recently flowcharts have been used to map what happens in an organisation. Documenting what an organisation does will however not necessarily create a system but may only describe its components [7,8]. Aberer *et al.* [9] suggest that many companies demonstrate the first signs of being process-based by presenting their procedures in the form of flowcharts. Many of them do this without changing any of the existing functional organisational structure.

- **Limited documentation of the business processes to meet the requirements of ISO 9001.**
  This method focuses on the processes that convert customer input into customer output and maps the requirements of the standard onto the process model [7]. Tranmer [10] and Renfrew [11] both argue that a good starting point to design a process-oriented quality system is to split the processes into the following three distinct types: *core processes* which reflect the sequences of events that cause customers to value the product or services; *supporting processes* which are tasks ensuring the core processes work effectively; *assurance processes* which ensure that an organisation is meeting its operational objectives.

- **Creating an integrated management system that covers all processes and where relevant, addresses the requirements of ISO 9001.**
  There is some confusion in the literature as to what precisely constitutes an "integrated management system". To some it is a combination or linkage of various standards such as ISO 9000, the environmental standard ISO 14000 and OHAS 18001 (occupational health and safety management systems) into one single management system such as the QUENSH approach (Quality, Environment, Safety and Health) [11]. Others [12-16] present integrated management concepts that are not designed around standards and argue that the discussion needs a holistic approach in which quality or any other requirement can or must be embedded.

The following summarises the results of a literature review on the experiences of existing approaches and their key weaknesses:

- Documenting what a company does in response to the requirements of the ISO 9001 is still one of the most common approaches adopted. It is seen as an easy option as it requires little or no changes in the organisational structure [17]. Such an approach can however lead to increased bureaucracy due to minimal impact of the quality system on the existing organisational structure which results in additional work [18-20].

- The design of quality systems often achieves the process-oriented character at the documentation stage but fails to create the corresponding organisational structure [9]. As a universal standard for all kind of businesses ISO 9000 does not specify how to develop quality processes but simply mandates that an organisation must define appropriate processes, document them and show evidence that it implements them [21]. In many cases documentation is still seen as much more important than the processes described in it [8] and being process-based at the documentation stage might make current business activities more transparent but does not resolve problems caused by functional and departmental boundaries [22].

- The usefulness of business process-oriented organisational structures has been widely recognised. The approaches in the field of quality, however, often keep the focus on the design of a certifiable quality system, not taking an overall systemic view of the entire business. Karapetrovic [8] argues that the future of ISO 9000 lies in systems thinking and while the realm of systems thinking goes beyond the systems understanding of ISO 9000 it could be used to assure effectiveness. Similarly Carlsson *et al.* [23] concluded in their study that several scientific issues about the ISO 9000 will need to be studied further of which one is to develop a greater knowledge of the system on all levels.

With the business process approach recognised as a way to successfully run an organisation in order to achieve business excellence [24], companies are beginning to design their quality systems in a process-oriented manner. Authors such as Harrington [25], Hoyle [7], and Mertins *et al.* [26], suggest that quality systems should be aligned with business processes. This paper discusses the findings of a case study and its approach to designing a quality system using ISO 9001:1994 with reference to a process-oriented structure.

The case study organisation

The case organisation employed 246 people at the time of study and is one of five subsidiaries of a German paper company. Its manufacturing capability consists of a computer controlled paper making machine which employs front edge technology to produce label paper, art and matt coated and coloured paper for all kinds of food or consumer products and the office stationery market. According to the case company's marketing and sales professionals there was no immediate pressure in the paper industry to be registered to the ISO 9000 quality standard. The company's decision to go ahead with a certified quality system derived from their need to guarantee its customers a superior quality product. In order to achieve a high level of reproducibility in their operations they wanted to standardise their procedures and technical processes. The ISO 9001 quality system was to act as the basis for a systematic improvement of the company's operations.

Activity-based approach for a ISO 9001 quality system

As the case company's objective was to implement an effective quality system they used a process-focused and team-oriented textbook approach based on the ideas of Harrington [25] and Hoyle [7]. The case company designed its quality system using some of the ideas discussed in the business process literature. As the company kept its functional structure the authors referred to the defined processes as "business activities". Even if these business activities had a horizontal flow they were not defined at start and finish with a customer nor did they cross any departmental borders. (These are key characteristics of a business process as described at a later stage of this paper). The functional departments of Sales, Design, Purchasing etc. incorporated all top-level activities (see Figure 1) which were modified in such a way so they formed the procedures for the quality system. The activities/procedures could therefore be described as fractions of complete business processes that were never properly defined nor mapped.

The project started off with various strategy workshops that were carried out together with senior management to develop and document the company's overall business objectives. These business objectives set the basis for the company's quality policy from which the quality objectives finally derived. Objectives which reflected the relevant quality objectives were defined for each activity. This set together with simple performance measures for each individual activity the basis for the mapping workshops. Teams using ANSI flowcharts mapped all business activities and a draft version of each business activity was made available company-wide for comments and changes. For a limited period of time members of the workforce who were not involved in the workshops could submit proposals for changes. The flowcharts used to document the quality system showed links to other business activities and gave the impression of a business process oriented organisation. The current format of the quality manual may be an indication of how the company may evolve and be organised in the future.

This team-oriented approach empowered twelve members of the workforce who were assigned to take on ownership of a business activity. The owners' task included the reviewing (process audit) of their activity/(ies) on a regular basis to provide an effective *activity diagram* to everyone involved. This involvement could be as either a user concerned about an easy flow of the activity or a customer who is interested in the final outcome of the activity. The improvement aspect of this approach included regular improvement meetings with the people involved in the activity. Each owner was responsible to update all relevant documentation, inform and train everyone involved and generally act as a contact person for all concerns regarding the activity.

The ISO 9001 project team had the unique opportunity to work together with a former general director from one of the case company's affiliated divisions. Appointed as internal project co-ordinator and released from any other work duty he provided the team with in-depth knowledge on all areas of its activities.

General documentation structure of the quality system

The documentation structure used in this approach was based on the traditional model of the quality system documentation pyramid referenced in ISO 10013 (Guidelines for developing quality manuals) [27] which acts as a guidance in preparing a quality manual. The version adopted by the case company shown in Figure 2 contained the policies, quality objectives and all top-level activities which described the interdepartmental activities relevant to ISO 9001. Its foundation was built of instructions, technical manuals and other standard documents which supported the overall structure. The quality manual acted as a reference document for the implementation and maintenance of the quality system and all other quality related documents. It also provided an overview of the organisational structure, interfaces and links between activities and the responsibilities of the people involved in the business activities.

Correlation of the business activities to the ISO 9001 requirements

This activity-based approach considered all mapped activities and determined their relationship to the requirements of ISO 9001. 40 business activities were clustered in 16 top-level groups called "key sections" mainly though reflecting departmental functions of the organisation. Each activity was cross-referenced with the relevant sections of the standard using an activity/ISO 9001 correlation matrix as shown in Table 1 to reveal the relationship to the organisation. The correlation matrix is part of the quality manual and required expert knowledge to be established. The version presented in this paper does however not show the links between activities, its owners and the relevant ISO sections due to reasons of confidentiality. This team-based approach shows what special knowledge and understanding about the ISO standard each owner has to have depending on the activity owned. The extra training came on top of the basic introduction to ISO 9001 which was given to every employee.

Discussion

Findings from the case study research

The case study findings revealed that the approach is somewhere between Hoyle's [17] method of "document what you do" and the "business process" method. With the literature proposing that a process-oriented approach to design a ISO 9001 quality system is a good idea the case study findings reported a responsive and more effective system.

Another major advantage seen by the company was the team-based approach during which the business activities were modelled. The assigned owner of each business activity facilitated the modelling workshops. This activity-based approach produced new responsibilities and required employees who were involved in the project to take on new roles such as activity owner, activity user, and internal customer. Activity owners were appointed for all activities and took ownership to keep up the commitment for a high level of continuous improvement. The teams were cross-departmental and incorporated employees with different interest and views in the activity. In the company's policy senior management encouraged the continuous improvement idea by allowing its workforce to call meetings with the original team members about a specific business activity at any time. This very labour intense quality system approach involved more than fifteen percent of the workforce during the design phase and proved to be successful in several aspects. Satisfied with the outcome, the directors appointed the project co-ordinator again to apply the same approach in another division. The people of the case company gave positive feedback especially on the ownership of activities. This spread the workload as well as the responsibilities across several employees and ensured that the quality system would be maintained and improved on a continuous basis. The employees felt confident within their new roles and could identify themselves with the quality system as it reflected their areas of responsibility. Only a strong management commitment throughout the project that required releasing the people and providing extra resources made this project possible.

In their original figure Childe *et al.* [28] point out that in functionally organised companies the horizontal flow of a business process is interrupted due to the crossing of boundaries between departments (silos). This may lead to all sort of problems such as break-up of communication, poor material or information flow etc. From a business process viewpoint Figure 3 highlights where the case company did not get far enough and only modelled its business activities within the departments. They kept its functional structure and the idea of being process-oriented only materialised at the stage of documenting the modelled business activities. Nevertheless the case company gained some improvement in terms of transparency by showing the flow of activities. Mapping was regarded as the biggest benefit of the project as it made activities more understandable and reflected the organisation's current business.

However when stopping at departmental borders the idea of being systemic cannot be maintained and the interdependencies of activities may become unclear. Making changes to one part of a business activity could result in problems in other parts of the organisation. The mapping of activities mainly included the documentation of existing business activities and its change to comply with the ISO standard. The case company did not take the opportunity to rethink the flow of activities or to reorganise its organisational structure to become truly process-focused. A functionally based organisation that starts documenting in a process-orientated manner what it does in terms of ISO 9000 but does not change its organisational structure is more likely to create such a "describing" quality system than an organisation which is already business process-focused. For a functionally based organisation, departmental or functional boundaries can easily result in loss of a logical flow of processes and products and set the focus again on the standard and not on processes and activities.

The case company experienced difficulties with the decomposition and links of its activities within the quality system. While complete business processes in terms of being customer oriented or independent of functions and departments were never defined in this project the mapped activities were all documented to describe the same level of detail. To overcome the problem the case company cross-referenced related activities within the ANSI flowcharts. The matrix however was too general and only related entire sections of the standard to business activities.

Understanding business processes

It is been agreed that in the design of a process-based quality system the focus must be on the business processes of an organisation. Harrington [25] and Hoyle [17] suggest that a business process approach cannot start with the standard or by documenting what to do. It needs to start with a model of the business – indicating business processes and their interrelationships. Generally however process-oriented quality system approaches limit their defined business processes only to the relevant activities needed for complying with ISO 9000. The defined system boundaries delimit the system and might result in what we see as an unresponsive quality system. Such a design does not provide the quality system with a mechanism to acknowledge if there is change in the business structure of the organisation. This might result in a system documentation that is outdated and the discrepancy between the documentation and the way the organisation operates might jeopardise the certification. What seems to be important is to develop a way of understanding business processes better in relation to ISO 9000.

Before doing so a brief overview summarises the main characteristics of a business process. A business process may be seen as a set of activities which:

- transforms inputs into useful and effective outputs [29-31]
- starts and ends with the customer [32,33].
- focuses on goals [32,33].
- can be measured to allow feedback and process improvements [29,32,33].
- flows horizontally using a hierarchical structure [29,32].
- crosses organisational (functional) boundaries [29,30,32].
- uses resources to transform inputs into outputs [34-36].

While this list may not be complete it incorporates the fundamental issues discussed in business process literature. In this paper a business process is defined as: *"A structured, measured set of activities and flows which are independent of departmental structures and that use necessary resources of the organisation to provide specified output for a particular customer."*

Approaches proposed by Harrington [25] or Hoyle [17] decompose the quality system and define a hierarchical structure from the top level down to specific tasks. As any kind of system in an organisation can be very complex it becomes apparent that models should be used that are capable to deal with multiple views and address all aspects such as events, conditions and users of each element of a process. From the authors' viewpoint further research should establish all necessary views of business processes and what view(s) best reflect the requirements of the ISO 9000 standard. To deal with the complexity of systems, models are often divided into individual views that represent different aspects and can be handled independently [37]. The following four views are widely discussed in the literature and also used within process models such as CIM-OSA (Computer Integrated Manufacturing Open Systems Architecture) [38] or ARIS (Architecture of Integrated Information Systems) [39].

The logical structure of data to be used and produced by the functions (activities) is described by a *data view*. Events such as "order received" are information and are represented by data. The *function view* contains the description of the function (activity) itself, the relationship between functions and sub-functions and the system's boundaries. The *organisation view* represents the organisational structure of the company and the interrelationship between users and the organisational units they are assigned to. In the *resource view* resources such as information technology, materials, tooling and other equipment are shown which might be both consumed and/or produced by activities.

The need for a more advanced modelling technique

To document different views of a business process the design team can choose between many modelling tools specially developed to represent a particular view. Modelling techniques are usually based on combining graphics and text to present the context of a process and its interrelationship with others in an organised and systematic graphic presentation. They are used to provide reference architecture for business processes. ANSI standard flowcharts and block diagrams were used in the discussed approach to document activities. Interrelationship matrices highlighted the interdependencies between activities. While block diagrams or ANSI-flowcharts are widely used, Maull *et al.* [40] report that they often permit users to interpret the individual flowcharts differently due to inconsistent set of rules defining the design of models. The mapping of subsequent activities as well as decomposition can be achieved but requires the strict application of procedures to ensure consistency. Due to the lack of formal rules this is rarely achieved [40,41]. Considering alternative process techniques, the design of ISO 9000 quality systems could benefit from representing an improved overview of relevant activities, the interrelationship of activities and the links to relevant sections of ISO 9001.

Modelling techniques such as the ICAM model (Integrated Computer Aided Manufacturing) use an ordered collection of diagrams to achieve top down decomposition of complex processes. The ICAM model is supported by the IDEF (ICAM Definition) methodology [42,43] and consists of several different modelling approaches. $IDEF_0$ is used to build functional models and allows the construction of process hierarchies decomposing activities and information flows. Role activity diagrams (RAD) based on Petri-Nets and Object Oriented Enterprise Modelling (OOEM) [24] are just a few other techniques used by business process designers and could also be considered when choosing a modelling tool for the design of a process-based quality system.

Conclusion

After over a decade of experience with ISO 9000 based quality systems, the textbook approaches as well as the latest version of ISO 9000 have become more and more process-oriented. Despite all this positive development the current approaches are not enough to help practitioners to design an effective quality system. The objective is to build on the discussed development and to provide practitioners and quality systems designers with an approach that will help them to take a more systemic perspective of the integration of ISO 9000. The findings also lead to the conclusion that the current approaches do not sufficiently address the following: 1) the definition of a business process; 2) the viewpoint of a business process for addressing the ISO 9001 requirements; 3) the design of business process using appropriate modelling techniques.

An improved approach would have to concentrate on modelling the organisation's business processes and establish the relevant links to the requirements of ISO 9000. The model needs to be able to take a function viewpoint of the business process but must also allow information and resources to be shown. It must address the construction of process hierarchies where business processes can be decomposed down to activities and tasks to reduce the complexity of the system. Such an approach would therefore need to be able to allow process modelling which goes beyond simple flowcharts. An outline specification of such a technique derived from studying the requirements of ISO 9001:2000 taking a business process viewpoint and would include the following key points:

- To show activities and clearly identify the ones that are controlled by the ISO 9001 quality standard. A *function view* of a business process is required which will allow it to show activities, an activity's dependence on other activities and its flow. The modelling technique needs to identify and distinguish between activities that are constrained by the standard and those that are not.

- To decompose activities into sub-activities to the level of detail necessary to link them to individual requirements of ISO 9001. The modelling technique needs to describe a hierarchy that composes systems of subsystems.

- To show information and the flow of information. Similarly to the hierarchy of processes the modelling technique needs also to decompose information down to the different levels of detail. To redesign activities, information or data structures need not be altered. Information will only need to be shown as graphical labels and not include the content and structure of information. Therefore the modelling technique does not need to show a separate *information view*.

- To identify and distinguish information that is linked to a requirement of ISO 9001 from that which is not. Where data and information are classed as different types of documents such as practices, derived documents, or reference documents the modelling technique needs to be able to label them accordingly. This may also include referring to sources within the quality management system from where documents originate.

- Any form of information, be it electronically or paper document based, must be shown as different types of input to an activity. The different types of inputs have been identified as "control inputs", "object inputs" or "resource inputs". This requirement also applies to feedback.

- To show resources that are required by the activity and to identify the ones that are linked to the standard. The different types of resources required to be shown by the modelling technique have been defined as human resources and equipment.

- All relevant elements such as inputs, outputs and resources within a quality system need to be controlled and identification is usually achieved by a document numbering conventions and other forms of unique labelling system. The modelling technique needs to refer to the various conventions of identification and show individual identity codes.

The fulfillment of these requirements will lead to the development of a tool that will allow business process improvement and quality management to be fully integrated. The design and testing of one such tool is the subject of ongoing work at the University of Plymouth.

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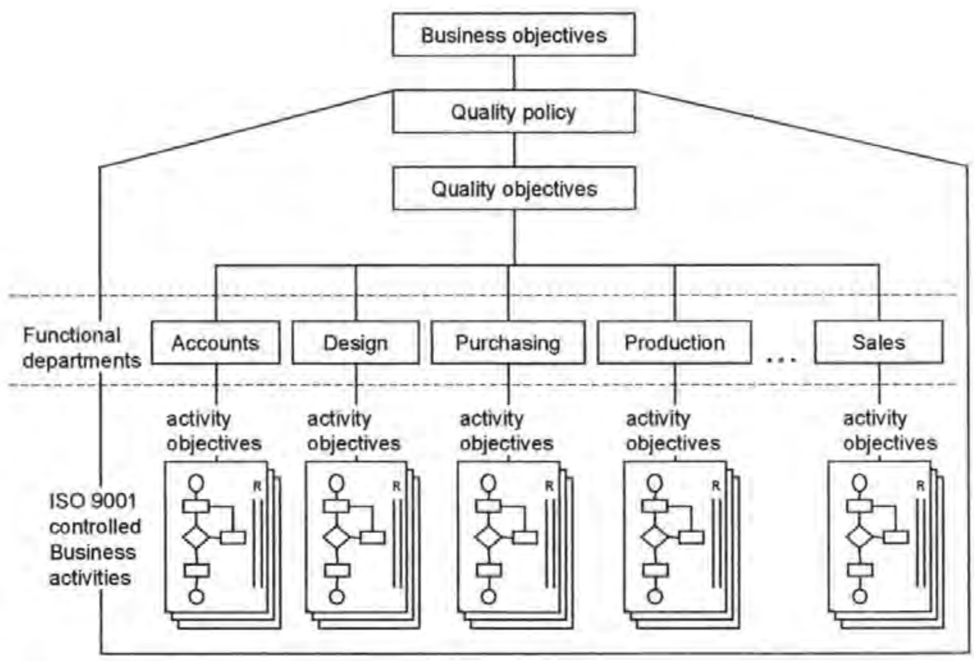

Figure 1: Activity-based ISO 9001 quality systems approach

Figure 2: Documentation pyramid

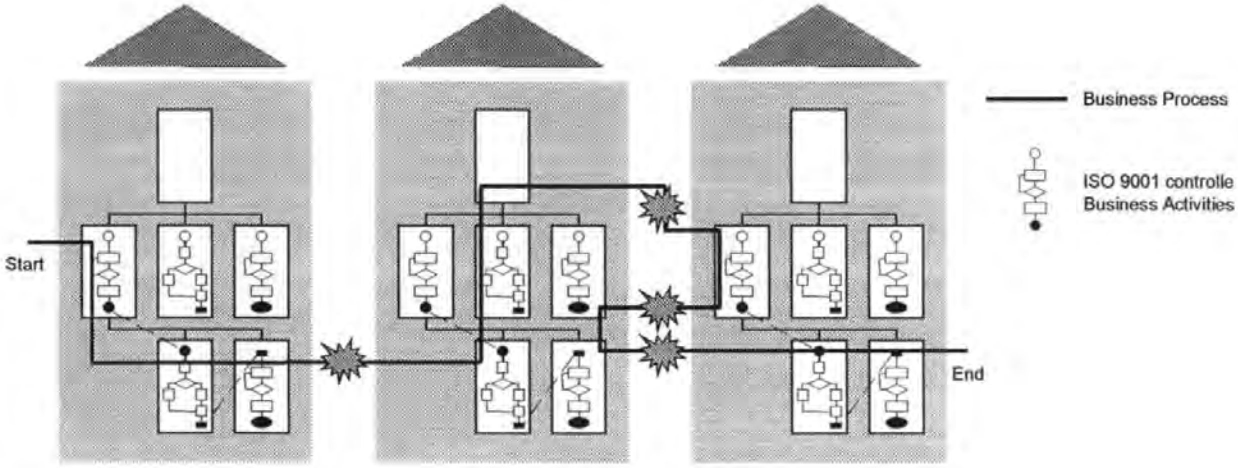

Figure 3: Flow of business processes (adapted from Childe *et al.* 1994)

ISO 9001:1994		Management responsibility	Quality system	Contract review	Design control	Document and data control	Purchasing	Control of customer-supplied products	Product identification and traceability	Process control	Inspection and testing	Control of inspection, measuring and test equipment	Inspection and test status	Control of nonconforming product	Corrective and preventive action	Handling, storage, packaging, preservation and	Control of quality records	Internal quality audits	Training	Servicing	Statistical techniques
Key sections of the quality manual	**Business activities involved**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Introduction		X	X			X															X
Company policy		X		X																	
Design	New products, product optimisation,				X																
	Process optimisation				X										X						
Purchasing	Fibre raw material						X														
	Additional goods						X														
	Periodic supplier assessment						X														
	New suppliers						X														
	Services						X														
	Investments						X														
Personnel	Recruitment of new employees																		X		
	Training of new employees																		X		
	Training																		X		
Sales	Marketing																				
	Special inquiry			X																	
	Specimens			X																	
	Contract commission			X																	
	After-sales service																			X	
Production planning										X											

Table 1: Correlation matrix ISO 9000 – business activities

ISO 9001:1994

Key sections of the quality manual	Business activities involved	1 Management responsibility	2 Quality system	3 Contract review	4 Design control	5 Document and data control	6 Purchasing	7 Control of customer-supplied products	8 Product identification and traceability	9 Process control	10 Inspection and testing	11 Control of inspection, measuring and test equipment	12 Inspection and test status	13 Control of nonconforming product	14 Corrective and preventive action	15 Handling, storage, packaging, preservation and	16 Control of quality records	17 Internal quality audits	18 Training	19 Servicing	20 Statistical techniques
Goods inwards									x		x					x					
Pulp preparation	Paper manufacturing									x											
	Coating									x											
Production	Set-up/start up									x											
	Manufacturing								x	x	x		x	x		x					x
	Maintenance, repair									x					x						
	Cleaning									x											
Water preparation	Steam generation									x											
Cutting/Packaging									x	x	x		x	x		x					x
Stock-keeping, delivery	Disposition of delivery															x					
	Packaging material								x		x										
Laboratory	Inspection, testing										x										
	Control of inspection, measure, test equipment											x									
Administration	Annual business planning																				
	Business controlling	x																			
	Data security					x															
	Invoicing (sales)																				
	Invoicing (purchasing)																				
Management	Internal audits																	x			
	Documents																x				
	Corrective actions														x						

Not relevant

Table 1: Correlation matrix ISO 9000 – business activities (continued)

Integriertes Management erschließt Potentiale

Joachim Gingele

12. Control

Internationale Fachmesse für Qualitätssicherung

12. – 15. Mai 1998 Messe Sinsheim

Einleitung

Die Forderung nach flexiblen Strukturen zwingt Unternehmen ihre Managementsysteme zu verändern. Modelle für Managementsysteme haben Hochkonjunktur. Jedes verspricht Erfolg. Wie soll sich der Unternehmer entscheiden und wonach soll er sich richten?

Dazu sind die vielschichtigen und sich ständig ändernden Einflußfaktoren, denen die Unternehmen im Wettbewerb ausgesetzt sind, näher zu spezifizieren. In fast jedem Artikel oder neu erschienenen Buch zu Unternehmens- und Organisationsentwicklung ist die zunehmende Internationalisierung, die Globalisierung der Märkte oder der Aufbruch ins Informationszeitalter Diskussionspunkt und werden diese als die entscheidenden Faktoren für die Zukunftssicherung der Unternehmen genannt. Glaubt man James McCalman (1992), einem britischen Dozenten und Managementberater, so haben sich die Anforderungen denen Unternehmen heutzutage ausgesetzt sind in den letzten 20 Jahren nur wenig verändert. Er vergleicht die Aussagen von Richard Beckhard aus dem Jahre 1969 mit denen von Charles Handy (1989). Beide Autoren sprechen in ihren Arbeiten von einer verstärkten Internationaliserung der Märkte, kürzeren Produktlebenszeiten, dem zunehmenden Einfluß von Marketing, neuen Organisationsformen oder der Veränderung unseres Arbeitsverhaltens. Eigentlich treffen alle von Beckhard gemachten Aussagen auch heute noch nach 20 Jahren zu, und McCalman macht uns darauf aufmerksam, daß sich zwar einiges verändert hat, aber nicht wirklich alles neu ist. Was sich tatsächlich verändert hat ist die Bedeutung einzelner Kriterien, ihr Zusammenwirken und die Geschwindigkeit mit der sie sich weiterentwickeln.

STEP-Faktoren

Das äußere Umfeld in dem Unternehmen operieren wird klassisch durch 4 Kategorien aus der Soziologie, Technik, Wirtschaft und Politik bestimmt. Die Managementlehre beschreibt diese auch als die 4 STEP-Faktoren, gleichbedeutend für sociological, technical, economic und political (Kermally, 1997). Hauptwirkungen oder mögliche Interpedenzen mehrerer Faktoren, deren Einwirken auf unsere Unternehmen, Institutionen sowie deren Umfelder gilt es stärker zu durchleuchten, um Strukturen zu schaffen, die es uns erlaubt schneller und effektiver auf Veränderungen reagieren zu können. Um die Wichtigkeit und das Zusammenwirken dieser Faktoren besser verstehen zu können, werden die Kategorien nachfolgend näher beschrieben.

Soziologische Faktoren

Soziale Faktoren werden den Veränderungen in unserer Gesellschaft zugeordnet. Diese Veränderungen beeinflussen unser Verhalten, Wertvorstellungen, unseren Lebenswandel, das Bildungssystem und viele andere Aspekte in unserem Leben. Aber auch industrielle und organisatorische Strukturen sind davon betroffen. Weiterhin sind demographische Entwicklungen wie Geburtenrate, Bevölkerungsdichte, Altersstruktur der Weltbevölkerung oder Mobilität für die Marketingstrategien und den "Human Resources" der Unternehmen bedeutsam.

Organisationen werden durch demographische Faktoren in zwei Bereichen stark beeinflußt: einerseits durch die sich ständig ändernde Marktsituation aufgrund von Trends oder Lebenswandel bei der Bevölkerung wie auch durch die sich wandelnde Alterstruktur der Arbeitnehmer. Bei näherer Betrachtung erkennen wir eine zunehmend älter werdende Weltbevölkerung, deren Auswirkungen sich mehr und mehr zur globalen Herausforderung entwickeln, deutlich sichtbar bereits für unser Gesundheits- und Rentenwesen. Während 1990 bereits über 500 Millionen Menschen das 60. Lebensjahr erreicht oder überschritten haben, das entspricht 9% der Weltbevölkerung, schätzt die Weltbank den Anstieg auf 1.4 Milliarden Menschen für das Jahr 2030. Mabey et. al. (1993) sieht vorallem die Veränderungen bei der Flexibilität und Mobilität der älter werdenen Arbeitnehmer als besonders drastisch. Im Jahre 2000 werden 75% der Beschäftigten, die bereits 1993 in einem Arbeitsverhältnis standen, noch einer Arbeit nachgehen.

Von einer "grünen Revolution" sind wir vielleicht noch weit entfernt, trotzdem hat sich in den letzten Jahren das Umweltbewußtsein der Menschen gewandelt. Die Gesellschaft erkennt ihren Einfluß und ihre Belastung auf die Umwelt und so sind nicht nur private Haushalte aktiv mit Mülltrennung oder -vermeidung beschäftigt, sondern haben sich auch die europäischen Industrienationen mit der EU-Öko-Audit-Verordnung einem freiwilligen Standard untergeordnet, und mit der internationalen Umweltnorm ISO 14000 wurde ein weiterer Schritt zur Berücksichtigung umweltrelevanter Aspekte in den Organisationen verabschiedet. Somit wird auch die Umwelt ein immer wichtigerer Gesichtspunkt bei der Ausrichtung der Unternehmen.

Technische Faktoren

Technologische Innovationen finden mit einem scheinbar unaufhaltsamen Tempo statt, wie am Beispiel der Telekommunikation deutlich gemacht werden soll. Viele der sogenannten "neuen Technologien" in den 50er und 70er Jahren umgesetzt, wurden bereits in den 30er Jahren entwickelt. Peter F. Drucker stellt heraus, daß die wirklich herausragenden Entwicklungen der Industrie in den 8oer Jahren nur in der Computer- und Pharmabranche zu finden sind (1980; 1995). Die Neuentwicklungen der Glasfasertechnologie und der Satellitentechnik kombiniert mit Computern führen uns zu dem vielversprechenden "globalen Superhighway". Das Internet, ein internationales Netzwerk, in der Zwischenzeit allen ein Begriff, war nur der Start ins digitale Zeitalter. Man sagt, daß der Microchip möglicherweise die größte Erfindung seit dem Rad sei und daß das Zeitalter der Informationstechnologie mit seinen Erfindungen die Menschheit mit am stärksten beeinflussen wird (Jackson, 1997).

Somit bleibt die Technologie bedeutsamer Faktor der unsere Unternehmen noch stärker beeinflussen wird als bisher. Verantwortlich dafür ist der Transfer technischer Innovationen der sowohl von Industrie zu Industrie als auch über nationale Grenzen hinweg ständig zunimmt (Mayon-White et. al.1993), und die globale Marktsituation unterstützt durch fallende Handelbeschränkungen, die den Erhalt oder das Zurückhalten von Innovationen schier unmöglich zu machen scheint. Zudem ermöglichen solche globalen Netzwerke vor allem im Bereich der Dienstleistung den einfachen Eintritt in neue Märkte zu minimalen Investitionen. Die Unternehmen werden zunehmend zu "Global Players" und Ländergrenzen spielen immer weniger eine Rolle. Um hier erfolgreich bestehen zu können, ist es Voraussetzung flexibel auf den Markt und den Wettbewerb reagieren zu können.

Wirtschaftliche Faktoren

Globalisierung und wachsende Komplexität sind beliebte Formulierungen für das Ende der 90er. Es ist allerdings nicht abzustreiten, daß durch Zusammenschluß der globalen Märkte diese eigentlich nicht größer werden, sondern durch den gleichzeitig verstärkten internationalen Wettbewerb eher kleiner zu werden scheinen. Eine solche Situation zwingt die Unternehmen die ständig zunehmenden und relevanten Aspekte für Unternehmensentscheidungen hinsichtlich Wachstum, Rücklagen, Inflation, Arbeitslosigkeit oder Investitionen zu berücksichtigen. Globalisierung ist bereits Realität und 70 bis 85% der US-Unternehmen spüren bereits verstärkt einen internationalen Wettbewerb (Mayon-White et. al.1993). In dieser Situation scheint der Zusammenschluß zu Großkonzernen die sinnvollste Lösung zu sein um langfristig auf internationalem Parkett bestehen zu können, auch wenn niemand mit Bestimmtheit sagen kann, ob das Zusammenschließen oder das Auseinanderbrechen solcher Strukturen den langfristigen Erfolg bringen wird (Peters, 1988). Während die amerikanische Flugzeugindustrie fusioniert, Autokonzerne durch spektakuläre Fusionen und Übernahmen von sich Reden machen, ob deutsche Unternehmen in der Stahlindustrie sich zusammenschließen und ähnliches für die Bereiche Versicherung, Banken, Chemie oder Pharma gilt, so gehen Großkonzerne wie AT&T seit Jahren den umgekehrten Weg. Bereits 1995 hat der amerikanische

Telekommunikationsriese die Aufteilung in unabhängige Gesellschaften angekündigt, um schneller und individueller auf Kundenwünsche reagieren zu können.

Der Wegfall von Handelsbeschränkungen und diverse Nischenanbieter zwingen Unternehmen, die sich eigentlich gegen eine internationale Marktpräsenz entschlossen haben, trotzdem diesen Weg zu gehen, da sie sich dem direkten Wettbewerb, der sich dafür entschlossen hat, stellen müssen. Zudem halten sich neu gegründete Firmen "nicht an die Regeln" (Hammer et. al.1995), was in diesem Zusammenhang bedeutet, daß diese Firmen schneller auf Marktanforderungen reagieren können, weil keine "Vergangenheit" sie daran hindert sich mit eingefahrenen, meist wenig flexiblen Strukturen auseinandersetzen zu müssen.

Eine eher unvorhersehbare globale wirtschaftliche Entwicklung wie zuletzt mit dem Zusammenbruch einiger asiatischer Märkte deutlich wurde, ein vereintes Deutschland und das zusammenwachsende Europa, führt die Unternehmer in eine Zeit ungeahnter Turbulenzen und Ungewißheit. Wie sich die Zukunft entwickeln wird ist unklar, was die Geschwindigkeit des wirtschaftlichen Wandels angeht, so wird diese zunehmen (Jackson, 1997).

Politische Faktoren

Politisch gesehen ist die Welt einem ständigen Wandel ausgesetzt, werden aus schwindenden Ländergrenzen übergreifende Märkte, staatliche Unternehmen privatisiert und Märkte liberalisiert. Viele Länder wie die USA und Großbritannien haben erfolgreich die Privatisierung seit Jahren voran getrieben. Seit dem Fall der Berliner Mauer, dem Niedergang des Kommunismus im Osten oder dem Ende der Apartheid in Südafrika haben nicht nur Fortschritte in Technologie und Wissenschaft, sondern gerade die Veränderung politischer Ideologien zur Globalisierung beigetragen. Frühere Ostblockländer öffnen ihre Grenzen, schaffen Infrastrukturen um sich mit den industriell etablierten Nationen zu messen. Dabei befürchten die reicheren Nationen dieser Erde, daß aufgrund steigenden internationalen Wettbewerbs und ungeschützter Märkte ihr Lebensstandard negativ beeinflußt werden wird. Dies scheint sich durch Beispiele der USA wo Löhne und Gehälter stagnieren oder der steigenden Arbeitslosigkeit in Europa zu bestätigen. Verursacht wird dies unter anderem durch unflexible Arbeitszeitmodelle, hohe Steuern und Abgaben sowie eines einseitigen und teils veralteten Bildungssystem einzelner Nationen (Sutherland, 1998).

Ständige Veränderung ist Gewißheit

Die Welt ist nicht wirklich anders geworden. Was sich verändert hat ist unser gesteigertes Verständnis der Dinge, unser Wunsch immer noch mehr in Erfahrung zu bringen und dies auch zu verstehen oder erklären zu können. Die hier erläuterten Faktoren sind uns sehr wohl bekannt, ihre möglichen Entwicklungen und Zusammenhänge nachvollziehbar und trotzdem erkennen wir sehr deutlich, wie wenig wir eigentlich darüber wissen. Das gesteigerte Wissen in der Gesellschaft und in den Institutionen wird immer wichtiger. Ein Grund dafür sind die existierenden Strukturen, welche sich als extrem komplex darstellen können und es so schwierig machen ihre Abhängigkeiten zu verstehen (Probst et. al.1997).

In der Managementlehre durchgesetzt hat sich das systemorientierte Unternehmensbild, wie bereits in den frühen siebziger Jahren, basierend auf Arbeiten von Professor H. Ulrich von der Hochschule St. Gallen, veröffentlicht wurde. Aus dem Systemcharakter ergibt sich, daß Systeme nur als Ganzheiten sinnvoll erfaßt, gestaltet und beeinflußt werden können. Unternehmen sind nicht einfach Systeme, sie sind vor allem hoch komplexe Systeme. Dies trifft nicht nur auf Großunternehmen oder multinationale Konzerne zu, sondern genauso auf kleinere und mittlere Unternehmen. Von entscheidender Bedeutung ist, daß diese Komplexität nicht etwa nur eine duldende Eigenschaft ist, sondern, daß Komplexität für das Leben der Organisation notwendig ist. Leider sind nur allzuviele Unternehmen und Managementkonzepte dabei diese Eigenschaft durch Regelungen und Kontrollmechanismen zu eliminieren (Jackson, 1997). Strategie, Früherkennung oder vernetztes

Denken bedeutet nämlich auch, wie man ein System unter Kontrolle bringt und zwar nicht ein einfaches, sondern ein komplexes System. Einen wesentlichen Beitrag zu komplexen Zuständen, Chaos und vernetztem Denken für das Management sind die Arbeiten von Ross W. Ashby (1957; 1960), Stafford Beer (1967; 1981; 1994) oder Ralph D. Stacey (1990; 1992; 1993; 1997), die zu diesen Themen ohne Zweifel zu den Vordenkern gehören.

Unser Leben basiert eigentlich auf der Tatsache, daß die Zukunft ein Fortbestand der Vergangenheit sein wird. Trotzdem sehen wir in der Wirtschaft eine zunehmende Bereitschaft existierende Strukturen und Managementsysteme durch neue Ideen zu ersetzen. In der Vergangenheit wurde Veränderung in der Regel durch externe Krisen wie neue Technologien oder politische Entwicklungen, herbeigeführt. Heute zeigt sich, daß sowohl in der Gesellschaft als auch in den Organisationen nicht nur die Bereitschaft, sondern auch der Wille für Veränderung vorhanden ist. Mit anderen Worten, wir entwickeln uns von einer reaktiven Haltung hin zu einer proaktiven Einstellung. Wir brauchen neue Ideen, die das Veränderungsmanagement der Unternehmen nachhaltig unterstützen.

Managementsysteme in Theorie und Praxis

Die allseits favorisierten Konzepte Total Quality Management (TQM), Lean Management oder Business Reengineering, werden tatsächlich nur in seltenen Fällen einer wirklich objektiven Analyse unterzogen. Dabei könnte aufbauend auf dem bekannten St. Galler Management-Konzept Ulrichs (1971) die von Seghezzi und Binder (1995) entwickelte Analysenmethodik brauchbare Ergebnisse zeigen. Ausgangspunkt dabei ist die Grundstruktur des St. Galler Modells mit den Punkten Aktivitäten, Strukturen und Verhalten, die jeweils durch 4 Begriffspaare konkretisiert werden. Dabei unterliegt jedes Begriffspaar einem Spannungsfeld, z. B. ist den Aktivitäten das Spannungsfeld >Kundenorientierung versus Innenorientierung< zugeordnet, der Struktur >Prozeßorientierung versus Funktionsorientierung< oder dem Verhalten >kontinuierliche Verbesserung versus episodenhafte Verwerfung<. Damit lassen sich jetzt Konzepte wie TQM, Lean Management, Time based Management, EQA, ISO 9001 oder ISO 9004 auf Ganzhaltigkeit hin untersuchen.

Anderson Consulting nennt die 90er Jahre "das Jahrzehnt der Integration". Sind die gängigen Managementmodelle darauf vorbereitet, bieten sie genügend Substanz für die Praxis? Die Integration von Normen kann ein erster praktikabler Schritt sein, das Umsetzen umfassender Managementmodelle wie EFQM oder MBNQA der zweite. Tatsächlich besteht für ISO 9000 die dringende Notwendigkeit der gründlichen Überarbeitung. Einigkeit in Industrie und Wirtschaft besteht darüber, daß eine Verknüpfung von Qualität und Umwelt unnötige Redundanzen und Ressourcenverschwendung vermeiden hilft. Diese Verknüpfung ist in der Regel mit ISO 14000 problemlos möglich. Das bestehende Managementsystem wird entweder auf vertikale oder horizontale Weise erweitert bzw. ergänzt. Die Zusammenführung von zertifizierbaren Qualitäts- und Umweltmanagementsystemen ist in Europa stärker entwickelt als in den USA oder Asien. Wesentlich unterstützt wurde dies durch die EU-Öko-Audit-Verordnung. Nach einer Umfrage von "Quality Systems Update" in den USA glauben die meisten Zertifizierer, daß weniger als die Hälfte ihrer registrierten Kunden derzeit an einer ISO 14001 Zertifizierung interessiert sind.

Ständige Verbesserung als Integrationsziel

Bei Unternehmen, die um eine Restrukturierung ihrer Organisation nicht umhin kommen, zeigt sich, daß die Struktur der ISO 14000 unter Berücksichtigung der ständigen Verbesserung die bessere Alternative ist. Aber auch sie unterstützt nicht das Verständnis derer, die sich in den Strukturen täglich zurechtfinden müssen, nämlich der Mitarbeiter. Gaitanides (1994), Tranmer (1996) proklamieren deshalb eine prozeßstrukturierte Organisation, auch als Notwendigkeit für die Integration weiterer Anforderungen. Mit Prozeßorganisation können Organisationsstrukturen geschaffen werden, die es erlauben, ein Managementsystem, ausgerichtet an den Unternehmenszielen, einzuführen, das nicht auf Normenkonformität beschränkt ist, sondern nachhaltiges Erreichen der Kundenwünsche aktiv unterstützt. Malorny (1996) beobachtete, daß nur wenige Unternehmen die erfolgreiche Transformation in eine prozeßstrukturierte Organisation realisieren konnten. Er sieht die Ursache im Rückfall der Führungsmannschaft in alte Verhaltensmuster während der kritischen Realisierungsphase.

Ein gemeinsames Konzept - Qualität, Umwelt, Gesundheit

International werden Modelle wie QUENSH (Quality, Environment, Safety&Health) (Renfrew et. al.1994) oder OHS (Occupational Health and Safety) diskutiert. Häufig wird QUENSH mit dem Begriff des "Integrierten Managementsystems" gleichgesetzt. Kritik kommt von verschiedenen Seiten deshalb, weil wirkliche Integration weit über die drei genannten Hauptbegriffe hinausgehen muß (Roberts, 1997). Äußerst kontrovers wird derzeit die Normung im betrieblichen Arbeits- und Gesundheitsschutz diskutiert. Die Befürworter einer internationalen Norm wollen verhindern, daß ihre wichtigen Forderungen möglicherweise in anderen Normen untergehen. Großbritannien, Irland, Australien, Neuseeland, Norwegen und Spanien verfolgen deshalb ihre eigenen nationalen Normentwicklung. In den USA fürchten die Vertreter der Industrie und Gewerkschaften, daß wirksamer Arbeits- und Gesundheitsschutz in einem Wirrwarr von Vorschriften und Auflagen enden könnte, schlimmer noch als es bereits durch die nationale amerikanische Verwaltungsbehörde OSHA geschieht.

Sehr weit fortgeschritten ist die Umsetzung in der Petrochemie. Dies zeigte die internationale Konferenz der Society of Petroleum Engineerings in New Orleans, USA, 1996. Die Ölförderindustrie hat vor allem aus dem Unglück der Ölplattform Alpha Piper 1988 und dem Untersuchungsbericht, dem Cullen Report, sehr viel gelernt. Dieser enthält explizite Forderungen nach einem detaillierten Sicherheitsmanagement.

Sharp Electronics in Großbritannien kann als Vorreiter eines integrierten Managementkonzepts gelten. Um die gesteckten Geschäftsergebnisse des Mutterkonzerns in Japan zu erreichen, wurde die Richtlinie SIQS 100 (Sharp Integrated Quality Specification) für alle Sharp-Händler in Großbritannien entwickelt. Sie enthält die Forderungen der ISO 9002 (Qualität), ISO 14001 (Umwelt), BS 7850 (Total Quality Management), MQA (Marketing Quality Assurance), BS 8800 (Occupational Health and Safety Management Systems) und IIP (Investors in People).

Die Ideen der integrierten Managementsysteme sollten in einem Normenwerk (General Principles of Management Systems) ihren Niederschlag finden. Ziel einer Arbeitsgruppe der CSA (Canadian Standards Association) und Deloitte&Touche war es, allgemeine Führungsprinzipien zu generieren, mit denen es Managern erleichtert werden soll, Funktionen innerhalb der Organisation besser zu steuern und Geschäftsziele wirkungsvoll umzusetzen. Die Arbeit an diesem Entwurf ist jedoch seit 1993 ausgesetzt.

European Quality Award

In den letzten Jahren haben sich die Kriterien des EQA (European Quality Award) der European Foundation for Quality Management (EFQM) zu einem tragfähigen Managementmodell entwickelt. Meist ist der direkte Übergang vom klassischen Qualitätssystem zum EQA für die Unternehmen zu groß. Dies zeigen Studien mit langjährig zertifizierten Unternehmen, die nach abgeschlossenen Selfassessments eine Bewerbung für den Award verschoben haben. Das Stufenmodell nach Seghezzi und Dahlem (1997) ermöglicht die schrittweise Erweiterung bestehender Managementstrukturen in die Kriterien des EQA. In drei bis zehn Stufen kann die Weiterentwicklung des Systems erreicht werden, ohne die Zertifizierbarkeit in Frage zu stellen.

Malcolm Baldrige National Quality Award

In den Vereinigten Staaten gilt seit 1987 das Modell des amerikanischen Qualitätspreises MBNQA (Malcolm Baldrige National Quality Award), also vor der ISO-Zeitenwende. Auch wenn die Anzahl der Bewerbungen rückläufig ist, so zeigen sich die Verantwortlichen optimistisch und verweisen auf die steigende Anzahl verschickter Kopien der Award-Kriterien. In Sachen ISO 9000 ist in den USA eine positive Entwicklung erkennbar. Während zumindest in Deutschland das Geschäft mit ISO 9000 rückläufig ist, befindet sie sich durch die QS-9000 der amerikanischen Automobilindustrie und durch die Wichtigkeit des europäischen Exportmarktes auf dem Vormarsch. Experten sagen für die USA über 100,000 Zertifizierungen bis zum Jahr 2000 voraus.

Fazit

Die wissenschaftliche Durchdringung des Themas Managementsysteme scheint noch nicht so weit zu sein, daß Unternehmen, die heute auf dem Markt um ihre Kunden und ihre Aufträge kämpfen, daraus schon praktikable Modelle erwarten können. Die bisherigen pragmatischen Ansätze zeigen den dringenden Bedarf für offene, auf alle zukünftigen Anforderungen vorbereitete äußerst flexible und effektive Führungssysteme. Hierhin wird der Weg weitergehen und erste gute Ansätze zeigten bereits das 4. EOQ Forum mit dem Thema "Quality in Integrated Management" (1997) oder das TQU-Symposium "Integrierte Managementsysteme in der Praxis" (1996).

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