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A MODEL BASED APPROACH TO THE DESIGN AND IMPLEMENTATION OF COMPUTER AIDED PRODUCTION MANAGEMENT SYSTEMS

by

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A model based approach to the design and implementation of computer aided production management systems

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Abstract

This work investigated the use of generic models in the early stages of the design and implementation of computer aided production management (CAPM) systems. A set of issues that affect the success of such CAPM systems was identified, using information obtained from literature and observations made by the author during an in-depth case study of the design and implementation of a CAPM system. The set of issues included the failure of many manufacturing companies to take a systemic perspective of CAPM and the importance of developing a thorough understanding of existing systems and how these systems are currently integrated. Requirements were proposed for an improved approach to the design and implementation of CAPM systems.

Taking the requirements into consideration the concepts underlying the use of and types of models were explored. In particular, the use of generic models and how generic models could help manufacturing companies were considered. The work also investigated the use of soft systems thinking and the concept of a business process to encourage a systemic perspective to be taken. A generic process model was proposed as a means of meeting the requirements of an improved approach. A generic model of an "order fulfilment" process in a manufacturing company was developed and a way of using it which embodies soft systems principles was proposed.

The model and its use was validated using five key needs of practitioners. The validation involved a review of the model by practitioners and the use of the model in a local company as part of a project to design and implement a CAPM system.

The originality of this work lies in the development by the author of a generic model which can be used as part of an improved model based approach to the design and implementation of CAPM systems. This should provide clear advantages over existing approaches.

CONTENTS

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My thanks are also due to my parents, family and friends, especially Maureen, for their support.

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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.

This research has been undertaken whilst the author has been employed in two different positions at the University of Plymouth, both of which were externally funded. The external funding was contributed by the Teaching Company Directorate and Paper Converting Machine Company Ltd during the author's employment as a Teaching Company Associate. Following that, the author was a member of a research team undertaking activities as part of a research grant (GR/J/95010) funded by EPSRC (Engineering and Physical Science Research Council) and British Aerospace (Systems and Equipment) Ltd.

Although the author has worked as part of a team during his employment, the research done and the contribution made as described in this thesis were the results of work undertaken solely by the author.

Some of the publications that have been produced as a result of this research form an appendix to this thesis.

The author attended a 3-day "Research Methods" workshop held at Churchhill College, Cambridge in March 1994 funded by EPSRC and a series of seminars held by British Computer Society on "Soft Systems Thinking" held in Bristol throughout Spring 1995.

The author also attended a number of conferences where he gave formal presentations of research undertaken, these included:

- Second International Conference on Computer Integrated Manufacturing (ICCIM'93), Singapore, 6-10 September 1993;

- Managing Integrated Manufacturing Conference, Keele University, 22-24 September, 1993;

- Tenth National Conference on Manufacturing Research, Loughborough University, 13-15 September 1994;

- Third International Conference on Computer Integrated Manufacturing (ICCIM'95), Singapore, 11-14 July 1995.

The author gave several other public presentations of the research undertaken to invited audiences for:

- Institute of Mechanical Engineers (South West Region) in April 1994;

- GINTIC Institute of Manufacturing Technology, Singapore in September 1994;

- Institute of Systems Science, National University of Singapore in July 1995.

Whilst employed on EPSRC Grant GR/J/95010, the author has made external contacts through:

- visiting a large number of manufacturing companies in the UK to discuss research findings;
- being involved in workshops held for Small and Medium Sized Manufacturing Enterprises;
- developing models in two local manufacturing companies;
- consulting with other research groups working in the same field.

Signed....................A.M.Weaver......................

Date....................16/11/95......................

Chapter 1. Introduction

The research described in this thesis was carried out whilst the author was employed by the University of Plymouth. During the first half of this research the author was employed as a Teaching Company Associate jointly funded by the Teaching Company Directorate and Paper Converting Machine Company Ltd. In the latter part of the research, the author was a member of a research team employed to undertake a research grant (GR/J/95010) jointly funded by EPSRC (Engineering and Physical Science Research Council) and British Aerospace (Systems and Equipment) Ltd. Both projects focused on the area of production and operations management within UK manufacturing companies.

This introductory chapter describes the background to the increased role that computers are playing in the management of production and some of the research concerning computer aided production management (CAPM) previously undertaken. The aims of this work are established and the concepts that will be used throughout are clarified. The final part of this chapter provides a summary of the structure of this thesis. The thesis has the overall aim of describing the research undertaken by the author and the resultant contribution to knowledge.

1.1 Background

A study of UK manufacturing companies commissioned by the Department of Trade and Industry (DTI) in 1993 predicted that

> the manufacturing business of the 1990's will need to differentiate itself from its competitors. This includes getting new products to market quickly, producing quality goods and services with a high degree of choice and high perceived value, lowering the cost base and offering reliable delivery and excellent customer service (DTI 1993).

This view of what manufacturing companies need to do in order to compete has been expressed in similar terms by many writers such as Skinner (1985) and Peters (1989). Some writers have focused on specific areas of the DTI statement. For example, Gerwin

(1987), Dooner (1988), De Meyer (1989) and Slack (1991) have emphasised the importance of flexibility to provide a high degree of choice, whilst Hayes and Wheelwright (1979), Buffa (1984), Stalk (1988) and Meyer (1993) concentrate on using responsiveness and the length of innovation cycles to offer improved customer service.

Manufacturing companies are also attempting to reduce known problems in the production system by seeking to improve key performance standards. Skinner (1985) identifies the key standards as "delivery responses, inventories, cycle time, cost and quality".

The implications of seeking to improve the competitiveness through differentiation or by attempting to address some of the known problems can be increased complexity and uncertainty in the production system (DTI 1993). This increase in variety often means that the management of the production system becomes more difficult (see for example, the Law of Requisite Variety (Ashby 1956)). There has been substantial growth in the use of computers as part of a production management system in UK manufacturing companies to help cope with the increased variety (Hodgson and Waterlow 1992, DTI 1993, Browne et al 1988, Tranfield and Smith 1990).

The role of computers in the production system of any manufacturing company can be categorised into two types (Browne et al 1988). The involvement of computers in the production system may be as part of an information and decision support system (Production Management System) that manages the production system. Alternatively computers may be involved in monitoring and directly controlling the machines that are part of the manufacturing process. The research work described in this thesis is predominantly concerned with the former, the involvement of computers in the production system as part of a production management system.

1.2 Previous research

Approximately eighteen months prior to the commencement of this work, a research grant[1] was completed which was part of the ACME CAPM Initiative (ACME 1991a). The aim of the grant had been to develop a methodology for the implementation of CAPM systems which would avoid many of the problems experienced by previous implementors. The grant resulted in a user-led methodology for the implementation of CAPM systems.

The methodology incorporated a generic task model developed by Childe (1991) that represented a hierarchy of tasks which were carried out by a manufacturing company. The purpose of the model was to enable manufacturing companies to identify the tasks that were required to be performed by the company. The selected tasks could then be used to assess the appropriateness of software packages to support the CAPM system and to establish the human requirements. The generic model did not show any information or physical flows and hence it did not show how the activities within a manufacturing company could be integrated horizontally to produce an output. The use and management of information and the integration of activities to produce an output are two important aspects of a CAPM system that were not adequately represented by Childe's task model.

Despite the success of the research undertaken as part of the ACME CAPM Initiative, the final report from the Initiative (ACME 1991a) proposed further areas of research concerning the design and implementation of CAPM systems. Evidence presented in Section 3.1 of this thesis also suggests that many manufacturing companies are still experiencing problems in the design and implementation of CAPM systems.

Access to the work carried out as part of the grant described above and the author's employment as a Teaching Company Associate provided the opportunity for research into

[1] The grant was jointly held by Professor D R Hughes of School of Computing, University of Plymouth (formerly Polytechnic South West) and Professor J S Smith and Professor D R Tranfield, Directors of the Change Management Research Unit, Sheffield Business School. The research project was entitled "The development of a user-led methodology for the implementation of integrated manufacturing systems within the electronics sector".

the approaches to the design and implementation of CAPM systems. The use of generic models as part of an approach was an idea that was of particular interest.

In the latter stages of this work the author's role as a member of a research team investigating Business Process Re-engineering (BPR) also contributed to this research. BPR concerns the use of the concept of a business process to radically redesign organisational systems (Hammer and Champy 1993).

1.3 Aims of this research

The need for computers to aid the management of production in an environment of increasing variety and the previous research work provided a background from which to undertake this research. The overall aim of this research was to develop new knowledge that would help manufacturing companies during the design and implementation of CAPM systems. To meet this aim, work was undertaken to:

- identify and understand any issues that manufacturing companies may be encountering during the design and implementation of CAPM systems which are leading to such CAPM systems failing to meet the companies' expectations;

- investigate alternative concepts and research that may be adapted for use as part of an improved approach to the design and implementation of CAPM systems;

- develop a generic model to be used as part of an overall approach to the design and implementation of CAPM systems that will address some of the issues that, at present, often result in a CAPM system failing to meet expectations.

1.4 Three important concepts

Before introducing the research carried out, it is necessary to clarify and describe three concepts that will be used throughout this work. These concepts are a "production system", a "manufacturing system" and a "Computer Aided Production Management (CAPM) system".

When considering CAPM which forms the main subject area of the thesis it is important to establish a view of what is meant by a "manufacturing system" and what is meant by a "production system". According to Checkland (1983) there is no

> ready made, agreed or well understood definition of either 'production system' or 'manufacturing system'.

1.4.1 A "manufacturing system"

Parnaby (1979) defines a manufacturing system as

> one in which raw materials are processed from one form into another, known as a product, gaining a higher or added value in the process.

This is the view that will be taken throughout this work.

It is noted that Checkland (1983) takes the view that a "manufacturing system" is part of a wider system, the "production system".

1.4.2 A "production system"

According to Checkland (1983), a production system is a system

> in which any input (which could be abstract or concrete) is transformed into an output of greater utility.

The transformation undertaken by a "manufacturing system" is only one type of transformation that is carried out by a "production system". The main inputs which are transformed into major outputs by a "manufacturing system" are raw materials. However, there are other "production systems" that transform concepts as opposed to raw materials and these include a bank and a post office. These companies can be viewed as having a "production system" as they transform abstract concepts such as money and information into an output of greater utility to a customer. According to this view a "production system" of a manufacturing company does not only transform raw materials, it may also transform information into an output of greater utility.

The view taken for the purposes of this work is that a "manufacturing system" is a subsystem of a "production system". A "production system" of a manufacturing company is managed by the "production management" system which is another subsystem that forms part of the "production system" itself.

If a "production management" system uses the computers as an aid, it can be referred to as a CAPM system.

1.4.3 A CAPM system

Many manufacturing companies use computers to aid the activities involved in the management of production. The computers use software that encapsulates some of the logic, policies and procedures by which the production system is managed. For example, a company could have a highly complex suite of software programs that makes automated decisions without human intervention or a company could have a P.C. based spreadsheet-type package that uses a simple set of logic rules to structure information to help a human make decisions. Either of these examples could be viewed as a CAPM system.

A CAPM system can be viewed as containing both human and computer elements that transform information and make decisions to manage the production system. These elements are guided by the "policies, procedures and practices" (Maull et al 1990) of the company.

The overall objective of CAPM is "to manage production, not to use computers" (Corke 1985). Production should be managed in such a way as to ensure that customers' orders are fulfilled "efficiently and economically" (Corke 1985) and the requirements of the stakeholders are met. Stakeholders can be defined as

> all those claimants inside and outside the organisation who have a vested interest in the problem and its solution (Mason and Mitroff 1981).

To meet this overall objective Waterlow and Monniot (1986) describe three areas of functionality that are required of a CAPM system. Paraphrasing Waterlow and Monniot, the areas are:

- *Specification* - to ensure that the manufacturing activities have been defined and the instructions planned;
- *Planning and Control* - to plan the schedule for production, adjust resources and priorities and control production activity;
- *Recording and reporting* - to record and report production status and performance for liaison with other departments, and for future use in specification, planning and costing.

The view of a CAPM system to be used for the purposes of this research work is that of Waterlow and Monniot (1986), Corke(1985) and Maull et al (1990) that CAPM systems extend beyond being simply the application of a set of software programs to manage production. CAPM systems are integrated systems of human and computer elements influenced by policies, procedures and practices. They specify, plan, control, record and report on the whole of the production system to meet the objective of fulfilling customer orders whilst balancing the requirements of all the company stakeholders.

Having established the background to this research, its aims and some important concepts, the next section will outline the structure of this thesis which describes the research work undertaken and the resulting new knowledge.

1.5 Structure of this thesis

Chapter 1 has established the reasons for undertaking this research work, stated the main aims of the work and defined the views of three concepts that will be adopted throughout this work.

Chapter 2 describes the research methodology used to structure this work and how the validity of the results of the research can be determined. The research methodology used has three phases. The initial phase is the Descriptive phase which begins with a literature survey of previous research work undertaken in the subject area.

Chapter 3 reviews previous research work on the design and implementation of CAPM systems found during the literature survey. It draws out many of the issues that are encountered by manufacturing companies during their design and implementation projects.

Chapter 4 also describes part of the Descriptive phase of the research methodology. The chapter recounts the observations of the author whilst participating in the design and implementation of a CAPM system in a manufacturing company. The overall approach used by the company and the problems that were observed are discussed. The experiences from this case study are combined with the issues identified in Chapter 3 to derive a set of requirements for an improved approach to the design and implementation of CAPM systems.

Chapter 5 looks at models, what a model is, how models relate to the concept of a system and how models help in the understanding of manufacturing companies. The use of systems thinking is explored and soft systems thinking is compared to hard systems thinking.

Chapter 6 focuses on soft systems thinking, a core method used in a particular soft systems methodology and the practicalities of using the principles of a soft systems methodology as part of an approach to be used in a manufacturing company.

Chapter 7 investigates how models have been used in model based approaches that have been proposed by earlier researchers. The use of a generic model to help understand existing systems and to help develop models of existing systems is also explored. The use of a generic model as part of an approach to address some of the requirements derived in Chapter 4 is suggested.

Chapter 8 considers the concept of a business process as an embodiment of systems thinking and how it can be used to encourage a systemic perspective to be taken during the design and implementation of CAPM systems. In particular, the relationship between an "order fulfilment" process and a CAPM system of a manufacturing company is discussed.

Chapter 9 looks at the development of a generic model of the "order fulfilment" process of a typical manufacturing company. The model combines the idea of a generic model with the concept of a business process. The "soft systems" approach to the development, the sources of information used and issues relating to the development are all described.

Chapter 10 identifies how the generic process model developed in Chapter 9 may be used. Three possible alternatives to the overall structure of an approach to the design and implementation of CAPM systems that could include the use of the generic process model are outlined.

Chapter 11 describes the work undertaken to validate the generic process model and its method of use as part of an approach to meet the needs of practitioners.

Chapter 12 concludes by evaluating the work undertaken and proposing ways in which the work may be developed in the future.

Summary

This chapter has shown that there is an increasing interest in the use of computers to aid the management of production due to the increased variety in the production systems as manufacturing companies attempt to remain competitive.

Although there has been extensive research in the subject area, there remain many issues that need to be addressed by improved approaches to the design and implementation of CAPM systems. The overall aim of this work is to contribute new knowledge which addresses some of these issues so that future CAPM systems that are designed and implemented meet the requirements of manufacturing companies.

Three concepts, a "manufacturing system", a "production system" and a "CAPM" system have been identified as being important to this work and their definitions for the purpose of this work have been clarified.

The next chapter will describe the research methodology that was used to structure this work.

Chapter 2. Research Methodology

The research work undertaken during this project lies within the field of Production and Operations Management (POM). Production and Operations Management is concerned with the integration of procedures, processes, operating decisions, company policies and technologies to maximise the competitiveness of the company (Voss 1984).

The activity of undertaking research work to gain new knowledge that will be of relevance to more than one company is made extremely difficult when

> the processes of any one organisation or social situation tend to be unique
> Warmington (1983).

The purpose of this chapter is to describe the research methodology used during this research. In identifying an appropriate research methodology, emphasis was placed on what companies may need from any new knowledge that results from the research work. For example, the new knowledge should be in such a format that it can be easily used by companies. Having identified these needs, the chapter will describe the research methods that could be used in a POM research project. The remainder of this chapter will discuss the particular research methodology used during this research project.

2.1 The objective of the research methodology

Meredith et al (1989), Buffa (1980), Chase (1980) and Susman and Evered (1978) are amongst many writers who have been critical of the research methods used in the study of companies in the POM field. One of the key themes found in the criticisms made by the above writers and others such as Platts (1993) and Hill (1987) is that there has been a lack of emphasis on the needs of the company and too much emphasis on the methods and techniques used in the research.

The objective of the research methodology used for this project should be to structure and guide the research project in such a way that the outcome aids companies undertaking the design and implementation of CAPM systems. The selection of a research methodology to meet this objective requires an initial understanding of what the practitioner operating within the organisational environment needs from the new knowledge.

2.2 The needs of the practitioner

Thomas and Tymon (1982) use the "needs of the practitioner" as a frame of reference to assess the success of a research project. The practitioner is

> any line manager, staff specialist, consultant or any other organisational actor (Thomas and Tymon 1982).

Using the practitioner as a point of reference Thomas and Tymon (1982) have identified five key needs that have to be fulfilled by the new knowledge. The five key needs are as follows:

1. "Descriptive Relevance";
2. "Goal Relevance";
3. "Operational Validity";
4. "Non-obviousness";
5. "Timeliness".

Descriptive Relevance - refers to how accurately the findings of the research project have succeeded in capturing the problem or phenomena encountered by the practitioner. It is concerned with how general or specific the new knowledge is, by questioning whether it is relevant to any practitioner with a specific type of organisational problem. It could also be described as the external validity (Campbell and Stanley 1963) of the research findings.

Goal Relevance - is concerned with the relevance of results gained from the practitioners applying the new knowledge. The practitioner has an objective to change or influence a problem or phenomenon within the company, the new knowledge should help the practitioner to meet this objective.

Operational Validity - is concerned with how easy it is for the practitioner to carry out the actions required to use the new knowledge.

Non-obviousness - refers to the degree by which the new knowledge resulting from the research work is not obvious to the practitioner or part of "common-sense" that is already used by the practitioner.

Timeliness - is a measure of whether the new knowledge is available to be used by the practitioner when required.

Irrespective of the content and type of new knowledge, the five key needs described above should be met. The new knowledge resulting from this research project should therefore:

- be generally applicable to the practitioners designing and implementing a CAPM system within a company (*Descriptive Relevance*);

- help the practitioner reach his or her objective (*Goal Relevance*) which is a successfully implemented CAPM system to meet the current and future needs of the business;

- be easy to operationalise and implement (*Operational validity*);

- be more than simple common sense to the practitioner (*Non-obviousness*);

- be available at a point in time when the practitioner is required to reach his or her objectives concerning the CAPM system (*Timeliness*).

The above lists the needs of practitioners with respect to the new knowledge gained from this research project. The next stage is to identify an appropriate research methodology that will structure and guide the research work to produce new knowledge that will fulfil those needs.

2.3 The Research Cycle

Meredith et al (1989) suggest that all research projects concerning POM generally involve a continuous cycle of "description, explanation and testing", which they call the "Research Cycle". This is similar to Kolb et al (1979) who propose an experimental learning cycle. The three phases of the "Research Cycle" are:

1. *Description;*
2. *Explanation;*
3. *Testing.*

Description Phase - is where activities are undertaken to gain experience of the phenomenon under study, to capture information about the phenomenon, its nature and even to consider previous concepts that have been used to describe and understand the phenomenon.

Explanation Phase - refers to the attempts to understand and explain observations by applying or developing abstract concepts and then attempting to extend the concepts to other instances of the phenomenon. The result of this phase is new knowledge which then needs to be tested.

Testing Phase - tests the new knowledge developed during the previous phases to determine to what extent the objectives of the concepts are met. The experience gained from the *Testing* phase results in the cycle starting again.

Although these are clearly defined phases in the cycle, the boundaries between the phases are rarely clear and distinct (Meredith et al 1989). They do however provide a useful and well tested structure on which to base a research methodology.

2.4 Research Methods

The purpose of a research methodology is not only to help us understand the process of the research work but also to describe appropriate research methods (Kaplan 1964).

A number of writers including Gill and Johnson (1991), Reisman (1988), Mitroff and Mason (1984) and Meredith et al (1989) have constructed frameworks to aid our understanding of the variety of research methods available. Using their framework, Meredith et al (1989) conclude that the type of research methods suitable for POM or

> more interrelated, more situation- or people-dependent topics in operations require the additional perspective afforded through the natural and existential methodologies.

In the above statement "natural" refers to research methods where the data is obtained from direct observation and "existential" refers to research methods where each observer may have a different interpretation of the direct observations made. Where research methods that form part of a "natural" and "existential" methodology are used the information gathered can not be assumed to be unaffected by the observer's own interpretations.

Research methods categorised by Meredith et al (1989) as "natural" include Field Studies, Action Research and Case Studies. The latter two are also considered to be research methods that can be used as part of an "existential" methodology according to the Meredith et al framework.

A CAPM system forms an integral part of a company; it is situation-dependent as every company can be regarded as being unique and it involves many elements including people. Considering these aspects of a CAPM system, research methods that are described by Meredith et al (1989) as being "natural" and "existential" are likely to be suitable methods to form part of a research methodology to structure this research.

2.4.1 Action Research

Action Research is one of the research methods that Meredith et al (1989) described as being both "natural" and "existential". It is defined by Warmington (1983) as

> research which aims to contribute both to practical concerns of people (including people in organisations) and to the goals of science, via joint collaboration within a mutually acceptable ethical framework.
>
> It is characterised by:
> 1. The immediacy of the researcher's involvement in action;
> 2. The intention of both parties to be involved in change.

There is support for the use of Action Research in the field of POM (Warmington 1983, Platts 1993, Meredith 1993 and Susman and Evered 1978) because of the joint collaboration and the involvement of the researcher in the change taking place. The collaboration of the researcher and the practitioner in undertaking activities to change a real system is guided by existing theories. The evaluation of the consequences of the change and the revision of the theory through the continued collaboration "generates theory grounded in action" (Susman and Evered 1978).

A research methodology that incorporates Action Research as a method should help ensure that the new knowledge gained meets the five key needs of practitioners (Section 2.2) because practitioners are involved in the generation of the new knowledge.

So far in this chapter, the objective of the research to generate new knowledge that meets the needs of practitioners has been identified and five important needs have been listed. A research cycle that provides a suitable structure for a research methodology of a research project in the POM field has been described and a research method that involves joint collaboration to generate new knowledge has been discussed. The remaining sections of this chapter outline the structure of the research methodology used and the main research activities that were carried out during this research.

2.5 Research Methodology used during this research

The structure of the research methodology is based on the three-phased research cycle described in Section 2.3. For each of the three phases the main activities and research methods used will be described.

2.5.1 Description Phase

The activities undertaken during this phase were to gain experience of the phenomenon under study, to capture information and to consider previous concepts that have been used in the CAPM field.

2.5.1.1 Literature Survey

The initial method of research was a literature survey of the general subject area of CAPM. The objectives of the literature survey were to gain a theoretical understanding of the CAPM field, to identify previous concepts that could be applied to gain an understanding of CAPM systems and also to gain information from the experiences of others working in the subject area.

After an initial survey of the literature, which provided a basic grounding in CAPM, it became evident that CAPM systems involve the integration of all aspects of POM. The literature survey concentrated on four areas which were:

- reasons for designing and implementing a CAPM system;
- production management techniques used in CAPM systems;
- previous work in the design and implementation of CAPM systems;
- model based approaches to systems development.

The information gained from the literature survey for each of these areas is described in the next five chapters along with the other work which was undertaken as part of the Descriptive phase.

Although the literature provides a basic grounding in the area, according to Meredith et al (1989)

> the most valid information is that obtained by direct involvement with the phenomenon.

As such, the next major activity that formed part of the research methodology was undertaken partly in parallel with the literature survey. It was the direct involvement by the author in a project to design and implement a CAPM system. The research method used was Action Research.

2.5.1.2 Use of Action Research

Action Research was used to guide the observations made and experience gained during the design and implementation of a CAPM system in real life. The study involved the author's full-time participation in a project to design and implement a CAPM system in a local manufacturing company over a period of eighteen months.

Playing a part in the project and the changes that were taking place the author was able to observe the situational relationships that may have influenced actions and events which an external observer could have missed. For example, certain decisions taken were influenced by working relationships between those attending meetings where decisions were made.

The subjective nature of the observations made during the project was recognised as observations made could have been influenced by the author's previous experiences of other situations. To reduce this influence, regular meetings were held with a number of colleagues who were not part of the company to discuss the observations made.

The use of Action Research provided a detailed insight into the design and implementation of a CAPM system in a particular situation. To develop a broader understanding of the nature of CAPM systems, the author was also closely involved in modelling and analysing parts of the CAPM systems operating in two other local manufacturing companies.

The literature survey and Action Research provided observations and information about CAPM systems, activities involved in designing and implementing a CAPM system and the problems faced by practitioners. The next phase of the research methodology was to reflect on the observations and information gathered in an attempt to provide explanations and new knowledge that would be useful to practitioners in similar situations.

2.5.2 Explanation Phase

The observations and information gained from the Description phase were reflected upon. A set of issues were identified that had affected the success of the design and implementation of CAPM systems studied by the author and other writers. From the set of issues, a set of requirements were derived for an approach that would address the issues identified.

Having derived the set of requirements, a generic model and its method of use were developed to deal with some of the perceived requirements. The generic model could be used as part of an approach to the design and implementation of CAPM systems. The generic model was developed using a "conceptual inductive process" (Meredith 1993) by which

> a number of occurrences of a phenomenon are analysed to infer the nature of a system Meredith (1993).

The CAPM systems and the design and implementation activities analysed as part of this process were those directly observed during the Action Research activities, case studies in literature and conceptual models of CAPM systems in literature.

The generic model represented new knowledge that was developed from subjective observations and experiences that focused on a small number of companies. The next phase of the research methodology was to determine whether the new knowledge met the five needs of practitioners and was generally applicable to more than the small number of companies from which the observations and information were gathered.

2.5.3 Testing Phase

To test the generic model that was developed in the Explanation phase validation was undertaken in two stages. The purpose was to determine how well the generic model represented new knowledge that met the needs of practitioners. The observations resulting from the testing also led to iterations of the research cycle and its use to further improve the generic model and its method of use.

The design and implementation of a CAPM system may extend over a number of years within a manufacturing company and may be subject to many external and internal changes that could corrupt the validity of the research. A longitudinal test by observing the whole of a design and implementation project that used the generic model was beyond the scope of this research project. In any case, the value of such a test is also questionable. A longitudinal test would only provide evidence that in that particular company, the generic model and its method of use contributed to the successful or unsuccessful implementation of a CAPM system.

A more practical test than the longitudinal test was to establish whether the generic model met the five needs of the practitioners identified above in Section 2.2, which would also cover more companies than a single case study.

The two stages used for the testing of the generic model and its method of use were the validation of the generic model and the concepts it used by practitioner review and by the use of the model in a manufacturing company.

2.5.3.1 Validation by review

The generic model was presented to practitioners with an explanation of its general purpose. The practitioners were independent from the research project. They included academics involved in POM research, consultants, managers in companies and other practitioners involved in bringing about change in companies.

The practitioners were asked to provide feedback on the generic model. The feedback included information that was used to improve the model. The validation by review was done in stages to allow for improvements to be made at the end of each stage.

The "validation by review" method enabled feedback to be obtained from a large number of practitioners. It provided useful information and opinions on how the generic model met some of the key needs of practitioners. Evidence that the model could be used successfully was not obtained at this stage but rather in the next stage which was "validation by use".

2.5.3.2 Validation by use

The "validation by use" involved the use of the generic model in a local manufacturing company as part of their approach to the design and implementation of a new CAPM system for the company. The author was not involved with the use of the generic model in the company to ensure that the new knowledge was encapsulated solely in the generic model. This was to prevent any part of the new knowledge being imparted by the author personally as opposed to being imparted through the use of the model alone.

The experiences of the practitioners using the generic model were recounted during meetings after its use in the company.

The information gained from the two validation stages was used to conclude whether the generic model developed during the research project represented new knowledge that met the five needs of practitioners to help with the design and implementation of CAPM systems.

Summary

This chapter has described the research methodology used during this research work. The objective of the research methodology and the five needs of practitioners have been identified.

The structure of the methodology was a three-phase research cycle. The Description phase of the research methodology involved a literature survey to establish background information and the use of Action Research to make detailed observations of the design and implementation of CAPM systems in real companies. The Explanation phase resulted in a generic model and its method of use which could be made a part of an overall approach to help practitioners. The Testing phase involved the validation of the generic model by practitioners reviewing the concepts used and by the use of the generic model in a manufacturing company. The feedback from the two stages to the validation was used to assess whether the new knowledge that resulted from the research project met the needs of practitioners.

The rest of the chapters in this thesis describe the work undertaken as part of the research methodology that has been described in this chapter.

Chapter 3. Design and implementation of CAPM Systems

The increased use of computers to aid the management of production systems and the concept of a CAPM system were described in Chapter 1. In addition, the role that CAPM systems can play in helping manufacturing companies address problems of increased variety within their production systems was identified. A CAPM system can also help the production system act as a source of competitive advantage (Skinner 1985). The success of the design and implementation of a CAPM system can therefore have a direct influence on the company's performance.

Unfortunately manufacturing companies face a dilemma. The improved production management that could be provided by a CAPM system can be seen but the route to gaining the benefits is unclear, unfamiliar and often results in failure (Kearney 1989). Many manufacturing companies make large investments in CAPM systems which later prove to be an "expensive and time consuming mistake" (Berry and Hill 1992).

The objective of this chapter is to identify some of the issues encountered by manufacturing companies whilst designing and implementing CAPM systems. The information used was gathered during the literature survey. To identify the issues, previous research describing the failure of CAPM systems to provide the expected benefits is discussed and the main activities involved in the design and implementing of CAPM systems are examined.

3.1 The failure of CAPM systems to meet expectations

On many occasions over the past fifteen years CAPM systems have failed to provide the benefits promised to UK manufacturers. A number of initiatives and studies have been undertaken to improve the success rate. A major initiative resulting from a study by

Waterlow and Monniot (1986) was initiated by SERC/DTI. This initiative consisted of a large number of collaborative projects between industry and academia under the direction of the SERC/DTI Application of Computers to Manufacturing Engineering Directorate (ACME) (ACME 1991b).

Seven years after the Waterlow and Monniot study, Webster and Williams (1993) reported on the success and failures of CAPM systems in UK industry and found that further development and understanding were required because 50% of CAPM implementations were still failing to meet expectations.

The view that many manufacturing companies in the UK lack the expertise to design and implement a CAPM system has been expressed by writers including Brennan et al (1990), Newel et al (1992), Hodgson and Waterlow (1992). Most production managers understand their own production environments intimately but they have little experience in defining and evaluating a CAPM system to meet their own requirements.

The lack of in-house expertise especially in the computer-based aspects of a CAPM system has resulted in the development of a variety of different CAPM systems which are on offer to manufacturing companies by a range of vendors. The CAPM systems being offered by vendors have a disproportionate emphasis on the computer aided side of CAPM due to the attempt to compensate for the lack of in-house technological expertise (Newel et al 1992, Webster and Williams 1993). In fact, the focus on computers to provide a solution can be a cause of failure according to Davenport (1993). From a study of CAPM systems using MRPII, Davenport concluded that

> they have failed because they viewed these technologies as solutions rather than enablers of radical change. These firms did not address the entire process affected by the systems, and neglected to change associated sub processes.

Davenport (1993) believes that manufacturing companies need to take a wider perspective and consider the relationships between all sub-processes. Taking a company-wide view was also suggested as one of the future research objectives in the concluding report of the ACME CAPM Initiative (ACME 1991a).

The project to design and implementation a CAPM system in many cases involves a partnership between the manufacturing company and software vendor at different levels over the period of the project. The next section will describe a common structure that can be used to view the life cycle of the project and to discuss the activities of the project, the involvement of vendors and other issues that may affect the success of a project.

3.2 Systems life cycle

The project to design and implement a CAPM system can be seen as a typical systems life cycle (Lee 1978). The stages of the systems life cycle are:

- Identification of problem/need;
- Investigation and analysis of the existing system and requirements;
- Design of the new system;
- Implementation of the new system.

The following sections consider each stage by identifying the activities that are carried out during that stage, how these activities have been carried out by companies or vendors and what influences they have on the success of the CAPM system implementation.

3.2.1 Identification of problem/need

The starting point is generally whether the need or problem can only be resolved by the implementation of a CAPM system. CAPM systems can successfully help manage the complexities of manufacturing but there may be methods to simplify the production system first. In the words of Burbidge (1985)

> complex production control systems do not, and probably never can, work effectively.

Two factors that can dictate the complexity of the CAPM system are the design of the product and the design of the overall production system (Browne et al 1988). An example of simplifying the production system before developing a CAPM system is given in Weaver et al (1993).

The need or problem should also be linked to the company's business and manufacturing strategies. Hodgson and Waterlow (1992) identify the

> necessity to understand the real goals and problems of the organisation... Only in an environment where the objectives of each functional area are consistent with these goals can computer-aided technology be introduced without also introducing additional organisational complexity and long-term difficulties.

The first stage is for the manufacturing company to establish that there is a need to design and implement a CAPM system that will address some of "the real goals and problems of the organisation". Once this has been done the manufacturing company must determine the type of CAPM system that will meet its strategic objectives and its other requirements. There are many possible options that the manufacturing company may consider. The options could include the enhancement of an existing system, integration of existing systems, a completely new CAPM system and the purchase of "off the shelf" software or customised computer software designed to incorporate the logic, procedures and information management required by the company as part of an improved CAPM system.

Many manufacturing companies consider purchasing the software for a CAPM system from a vendor because of the lack of IT expertise within the company (Forrester and Hassard 1992). To ensure that suitable options are selected it is important for the manufacturing company to understand its existing systems.

3.2.2 Investigation and analysis of the existing system and requirements

The objective of the investigation and analysis stage is to develop and specify the requirements of the CAPM system for the particular manufacturing company.

It is necessary to investigate and understand the company's existing production management system and the environment in which the production system exists. A CAPM system cannot bring benefits if it is implemented into an "inconsistently" managed environment (Doumeingts et al 1992). For example, if the machines are poorly maintained due to poor management, some benefits from an improved CAPM system may be lost through machine breakdowns.

Those individuals in the company that will be involved in the project need to understand the complexity of the administration and control within the existing system, how complex the manufacturing task is or could be and what level of detailed information is required. In the words of Corke (1985),

> the realisation of the benefits of designing and implementing a CAPM system is dependent on the management's knowledge of what is happening within the process and being prepared to manage on the basis of knowledge and understanding.

Once the existing system is understood then the definition of requirements is the next task. The definition of the company's requirements is critical to the successful implementation of the CAPM system (Maull et al 1990, Newel et al 1992). Maull et al (1990) found a number of factors (listed below) which may lead to the failure of CAPM systems, the first three of which related to the definition of requirements:

- Requirements were defined incorrectly.
- Requirements were defined correctly, but the wrong system was implemented.
- Requirements were defined correctly, the right system was implemented, but the requirements changed over time and the system failed.
- The correct system was defined and implemented, but implementation was badly managed resulting in failure.

The requirements defined need to ensure that a CAPM system designed to address them will meet the present "real goals and problems" of the company and will be able to adapt to meet future "real goals and problems" of the company.

It is at the point of defining the requirements of a CAPM system that the control approach for the overall CAPM system must be considered. The control approach decided upon will significantly influence the level of computerisation and the types of information and activities required. The main control variants that have been used over the past thirty years include MRP, MRPII, OPT, JIT (Ptak 1991, Hill 1993). Whichever variant or combination of variants is selected, it needs to fit in with the overall strategy of the company.

A description of the popularity of Materials Requirement Planning (MRP) and Manufacturing Resource Planning (MRPII) and the evolution from MRP to MRPII giving their different functionality is provided by Browne et al (1988)

> Material Requirements Planning (MRP) and Manufacturing Resource Planning (MRPII) have almost certainly, been the most widely implemented large scale production management systems since the early 1970s.
>
> Manufacturing resource planning represents an extension of the features of the MRP system to support many other manufacturing functions beyond material planning, inventory control and BOM control... MRP was extended to support Master Planning, Rough Cut Capacity Planning (RCCP), Capacity Requirements Planning and Production Activity Control (PAC).

OPT or Optimised Production Technology (Goldratt 1988) is based on the philosophy that the throughput of a manufacturing system is determined by the capacity of the bottleneck. OPT seeks to control the manufacturing process to always maximise the throughput through the bottleneck.

MRP, MRPII and OPT are based on the application of computer software and hardware to process large amounts of data. The inaccuracy of data used by the system is a main cause of failure of such systems (Browne et al 1988, Wight 1981).

JIT or Just-In-Time is a philosophy that seeks the total elimination of waste to improve the performance of the manufacturing process. Its goal is simply

> to produce the required items, at the required quality and the required quantities, at the precise time they are required (Doumeingts et al 1992).

Ptak (1991) believes that many manufacturing companies are under the misconception that JIT can be bought as a new piece of software. New business practices can be developed to incorporate JIT philosophy only in parallel with a co-operative effort from everyone in the company.

Browne et al (1988), Ptak (1991) and Doumeingts et al (1992) are a few of the many authors that have written about the selection of the most appropriate control approach. In the words of Ptak (1991),

> a company must draw from the entire gamut to extract what makes sense for that particular company.

With a lack of expertise in this type of system design and implementation projects, manufacturing companies have no choice but to rely on external advice to define requirements. Many manufacturing companies are aided by vendors to define requirements. Brennan et al (1990) were concerned to find that

> it appeared that the companies' information needs were defined by available systems suggesting that the system requirements were defined by vendors and not the companies themselves.

This finding is supported by Webster and Williams (1993) who report that

> CAPM suppliers have their own perspective on CAPM and are rarely able to fulfil all the functions needed by most users, particularly in the identification of requirements and development of a specification.

To ensure that the defined requirements are correct, manufacturing companies need to be provided with as much guidance as possible during the definition of requirements stage but without it being necessary to involve external parties. Without the set of requirements that are most appropriate for the individual company the designed CAPM system is unlikely to meet "the real goals and problems" of the company.

3.2.3 Design of the new system

The objective of the design stage is to design a CAPM system that will meet the requirements of the company. Few manufacturing companies have the expertise to develop the computer software-based part of a CAPM system solely in-house and hence choose to purchase this part from a vendor. The two main tasks for manufacturing companies are therefore to evaluate the generic software packages that are offered by vendors and to work with the vendor to ensure that the software is customised to meet the requirements of the company.

Without a detailed understanding of their current systems and definition of requirements, manufacturing companies are poorly placed to evaluate the software for CAPM systems on offer from vendors or to ask for a customised product from the vendor. The problem of customisation increases as the size of the company decreases according to Brennan et al (1990). Brennan et al found that vendors are less willing to modify their software for smaller manufacturing companies as the financial return to the vendors does not justify it.

The design of a CAPM system rarely starts from a "clean sheet of paper". Many manufacturing companies are reluctant to discard old systems (Forrester and Hassard 1992) and hence insist on additions to existing systems. The integration of the software-based part of the CAPM system with other parts of the CAPM system itself and other systems can be an important factor. Newel et al (1992) describe a case where

> the consultant emphasised the advantages of the new system but de-emphasised issues about the compatibility of the new system with existing organisational technologies and structures.

In that case, the company was relying on the consultant and the result was that the manufacturing company in question bought a system incompatible with its existing systems. The manufacturing company only discovered the incompatibility during the implementation stage of their project.

3.2.4 Implementation of the new system

The view of a CAPM system taken during this work is that there are more elements to a CAPM system than the computer elements, for instance the human elements. The implementation of a new or improved CAPM system involves changes in the roles of many individuals within the company because methods of working, collating data, materials ordering and scheduling, may need to be changed. This process of change is unlikely to yield overnight improvements.

Tranfield and Smith (1990) found that the most significant implementation problems were associated with the management and organisational issues involved rather than the technical issues. To implement a CAPM system faced with all these issues, a diverse range of experience, expertise and knowledge is required. Webster and Williams (1993) suggest that many CAPM vendors lack the knowledge of the individual company and are not able to supply the required expertise to help with the management and organisational issues and therefore attempt to disassociate themselves from the implementation process. Ultimately, the manufacturing company must be responsible for the implementation of its improved CAPM system.

There is a large amount of literature on the implementation of CAPM systems and managing change within companies, including results from the ACME CAPM initiative. The results include methodologies for the design and implementation of CAPM systems, some of which are especially focused on companies who lack expertise in implementation (ACME 1991b).

3.3 Issues identified

There is no single approach that will work for all companies since CAPM systems and their design and implementation are very much context driven.

There were a number of issues identified during a review of reported failures of CAPM systems. These included a lack of technical expertise and a failure to take a wide enough perspective of what the CAPM system would manage and interact with, that is, the context of the CAPM system.

The investigation and analysis stage that results in the definition of requirements involves many issues. The issues include fully understanding how the existing production system is managed, defining the requirements correctly, choosing the control variant and the vendor-client relationship. It is at this stage that manufacturing companies require as much knowledge and understanding as possible before making key decisions that influence the outcome of the project. Many vendors also lack the expertise to support the client company at this stage. The number of issues involved and the importance of this stage means that new knowledge which facilitates activities at this stage of an overall approach would be beneficial to many manufacturing companies.

Summary

In summary, many manufacturing companies increasingly need to use computers to aid the management of production. The lack of systems development experience means that they require wide ranging support in the design and implementation of CAPM systems which meet their needs. Many vendors of CAPM systems are unable to provide this support especially in the early investigation and analysis stages.

Any approach that aims to help manufacturing companies design and implement a new or improved CAPM system should ensure that the existing systems are understood from a company-wide perspective. It should also help the users of the approach to consider a variety of issues when attempting to define requirements of a new or improved CAPM system. These issues include possible simplification of the system, integration of the systems with other systems, the influence of policies, procedures and practices, the organisational relationships within the system and the future objectives of the company.

Chapter 4. Case study of the design and implementation of a CAPM system

The Descriptive phase of the research methodology involved two main activities. Chapter 3 reviewed some of the literature relating to CAPM which resulted from part of the first main research activity, the literature survey. The second main research activity was the full-time participation of the author in the design and implementation of a CAPM system within a manufacturing company. Action Research (Section 2.4.1) was the research method that was used to guide the author's involvement with the company undertaking the project.

This chapter will initially discuss the background to the design and implementation project, the activities that took place and the direct observations made by the author whilst participating in the project. The observations will be reflected upon to identify a set of issues that affected the project. From the set of issues identified and those issues described in Chapter 3, a set of requirements will be derived for an approach to the design and implementation of CAPM systems. The requirements should specify the attributes of an overall approach that addresses the issues and will hence improve the success of similar projects in other manufacturing companies.

Before the description of the activities that were carried out during the project, the role of the author in the project will be outlined and background observations about the context of the project will be made.

4.1 The role of the author in the project

The author was employed for a period of eighteen months as a Teaching Company Associate to work full-time in the company as part of a Teaching Company Scheme (GR/F94583). The scheme was jointly funded by the Teaching Company Directorate and the company in question. The author worked as a member of the team responsible for the design and implementation of an improved CAPM system in the company and participated in the activities that took place. The team consisted of three managers, four supervisors and the author. The author shared the common primary objective of the other team members to implement a CAPM system that met the changing needs of the company.

4.2 Background observations

The company produced engineer-to-order (Wortmann 1990) capital goods equipment for an international market. It was located on a single site and employed approximately three hundred people and was a subsidiary of a privately owned American company.

The Engineer-to-Order sector of manufacturing has historically been an area where production has been planned with a large degree of uncertainty. The company was experiencing a large and uncertain workload on its production function caused by a small volume of products with a high variety of parts, small batches and diverse manufacturing processes. In addition, some customers' orders called for a contractual commitment to delivery dates within a short time period despite having incomplete specifications of the product. Like many companies within the Engineer-to-Order sector all these influences contributed to a highly complex situation in which to plan capacity and schedule the work load (Kuhlmann 1991) and hence manage the production system.

These influences are becoming more relevant to all types of manufacturing as the flexibility that has been required by engineer-to-order companies to be able to cope with such problems is now becoming increasingly important in all sectors of the market (Slack 1991).

4.3 The design and implementation project

The description of the main activities carried out as part of the design and implementation project and the observations of the author whilst participating in the project will be structured using the four stages of the systems life cycle as used in Section 3.2:

- Identification of the problem/need;
- Investigation and analysis of the existing system and requirements;
- Design of the new system;
- Implementation of the new system.

4.3.1 Identification of problems

The company was experiencing a number of external pressures including a loss of market share to a European competitor and changed customer requirements. This forced the company to improve the functionality of its products, to reduce its lead times and to improve its adherence to promised delivery dates.

Internally, there was a lack of control within the Production function indicated by late delivery of orders, excessive subcontracting of work, a continual need to expedite the manufacture of certain parts and a low utilisation of machines. There was a large amount of work-in-progress (WIP), much of which was not being worked upon for long periods of time. The shop floor was arranged functionally, with groups of similar machines in the same area. The result was the need to control the complex movements of WIP between machines.

Other functions within the company showed a lack of confidence in the abilities of the Production function to meet delivery dates. For example, a result of this lack of confidence was that the Sales department added extra days to the scheduled delivery dates before making promises on delivery dates to customers. The purpose was to reduce the risk of the delivery to the customer being late by making allowances for the Production function not producing the products according to the schedule. The particular importance of meeting promised delivery dates in the Engineer-to-Order sector is highlighted by Kuhlmann (1991). Kuhlmann (1991) describes how repeat orders are frequently lost through poor delivery in the Engineer-to-Order sector.

4.3.1.1 Other changes to the production system

Given the perceived problems it was recognised by the company that an improved CAPM system could not address all the problems. The company sought to reduce the complexity of the manufacturing subsystem of the production system that transformed the raw materials into products before an improved CAPM system was designed and implemented. Simplifying the manufacturing system before designing and implementing a CAPM system to manage the production system was mentioned as a possible method in Section 3.2.1.

The company chose to introduce Group Technology (GT) (Burbidge 1975) with the help of two Teaching Company Associates and the University of Plymouth. The objective was to simplify the manufacturing subsystem by restructuring the manufacturing resources into semi-autonomous cells under GT. This would reduce the complex flows of WIP and allow a hierarchical control structure to be introduced. The restructuring is extensively described in Hallihan (1992) and Childe et al (1992). The new structure of the manufacturing subsystem meant changes needed to be made to the existing CAPM system.

The project to design and implement an improved CAPM system had two aims. These were to redesign the management of the production system to support the new structure and to address the failure of the existing system to manage production.

4.3.1.2 The problems to be addressed by an improved CAPM system

The company believed that a reduction in the complexity of the manufacturing system and an improvement in the management of the overall production system via a redesigned CAPM system would greatly improve overall control.

An improved CAPM system within the production system could help address a number of the perceived problems described in Section 4.3.1. It could:

- enable realistic delivery dates to be given which would improve confidence in the Production function;

- reduce the amount of subcontracted work by improving the accuracy of the planned use of available resources;
- reduce levels of WIP by having more accurate information on the time taken to manufacture parts and reducing the period of time material needs to be on the shopfloor;
- allow greater flexibility in the production system by enabling plans to be rapidly changed;
- reduce the need for expediting the manufacture of parts by more realistic planning and identifying problems earlier through improved feedback.

Having identified how an improved CAPM system might address the perceived problems and the decision taken to restructure the manufacturing system, the activities to investigate and analyse the existing systems and specify requirements for an improved CAPM system were initiated.

4.3.2 The investigation and analysis of the existing system and requirements

Once the changes to be made in the manufacturing system had been identified as a result of the decision to implement GT, the investigation and analysis of existing systems and the needs of the GT based manufacturing system began. The results of the analysis were to provide the basis for the specification of the requirements for a new CAPM system.

A model of the existing systems was created using $IDEF_0$ (FIPS PUBS 1993). The model (De la Pascua 1992) provided a description of the flows between the functions in the company and focused in particular on the subsystems that were involved in the production system. Limited time and resources meant the detail of the model was insufficient to carry out a detailed analysis of the existing systems.

A list of ideal modules that needed to be included in the CAPM system was developed from the specification. The importance of the modules was determined by the group using a set of criteria similar to the method described in Cleland and King (1983) as the "strategic implementation process".

Models of the activities that the CAPM system would carry out were used at the requirement definition stages with potential users of a new CAPM system to help communicate the functionality of the proposed system. Users were also encouraged to define the layout and content of reports they wanted the CAPM system to produce.

The specification of the overall control approach used the three levels of control described by Browne et al (1988). At the strategic level Materials Requirements Planning (MRP) was specified as the control strategy. At the tactical level Period Batch Control (Burbidge 1986) was specified as the control strategy model and at the operational level the control of production was to be organised by the cell leader to meet the objectives set by the tactical level. The full specification is presented by De la Pascua (1992).

It was observed that throughout the identification and analysis of the existing systems the team was under pressure to make changes as soon as possible. Many members of the company perceived the detailed analysis of the existing systems as unnecessary.

4.3.3 The design of the CAPM system

In contrast with many manufacturing companies, the company had a team of programmers and analysts who had designed information systems in-house. This was an advantage in that the programmers and analysts had an intimate knowledge of the existing systems that the new CAPM system would have to interface with. However, the association of the programmers and analysts with the poor performance of the existing systems could undermine confidence in any new system developed by the same team of programmers and analysts.

There was little evaluation of any other CAPM systems that could have been supplied by vendors because of the requirement to use in-house resources.

An approach employed during the design phase to compensate for the lack of analysis of existing systems was to base the design of the new CAPM system on the functionality of the CAPM system that already existed in the parent company. The company believed that this would also shorten the design phase of the project and meet another objective in the company which was to integrate the information systems of both the subsidiary and parent companies.

A modular design for the improved CAPM system was decided upon by the team. The module to be designed first was to allow the production function to plan production using a finite capacity.

An important factor that affected the design of the CAPM system was changing technology. All corporate computing systems in the company were being re-written in a 4th generation computing language and a new database management package was being installed in the company. The main databases that the CAPM system was required to access were in the process of being restructured in parallel with the development of the CAPM system thus causing an increase in the complexity of the design.

4.3.4 The implementation of the CAPM system

The implementation of the CAPM system was done using a phased approach which supported the modular design of the CAPM system and the three levels of control specified. The initial phase was to implement the modules which included the rough cut capacity planning module of the CAPM system to provide information to aid decision-making at the strategic level. The next modules to be implemented extended the supply of information for planning and control to the tactical level of control. Finally, the modules that supported the planning and control at the operational level of control were implemented. The implementation of the CAPM system included changes in the methods of working, collating data, materials ordering and scheduling, and is described in more detail in Childe et al (1993).

In addition to the implementation of the new software, changes to activities, procedures and responsibilities were required. There had been a policy of involving those individuals who would eventually be using the new CAPM system in the project as much as possible throughout its duration. The level of user involvement was increased further during the implementation of the CAPM system. This included presentations at various stages of design and implementation, establishing a framework to promote understanding and communication, training sessions and dealing with problems users had on a one-to-one basis.

4.4 The implemented CAPM system

The implemented CAPM system was welcomed by the Supplies function which had been formed part way through the project. The Supplies function bore responsibility for only part of the production system. The majority of the team were part of the Supplies function. The design and implementation project increased the interest within the function in obtaining information to enable better control to be established and to improve performance. The Supplies management encouraged the development of computing expertise within the function. Personal computer-based applications using information from the mainframe-based CAPM system were being developed within the function.

The Supplies Director described the benefits to the business derived from the implementation of both the GT and CAPM system as more realistic lead times, improved management of the workload within the machine shop and reduction of the amount of work-in-progress, which were some of the main objectives of the project.

Unfortunately the implemented CAPM system failed to meet some of the expectations of the company. It was not being utilised to the extent that was hoped at the outset of the project and did not fully meet the requirements of the users. The accuracy of information supplied by the CAPM system was limited by other systems supplying inaccurate data. Users in other functions were slow in utilising the capabilities of the CAPM system to help their activities. For example, the Sales function could have made use of capacity information to plan their activities to ensure that the impact of promising short delivery dates for non-urgent spares was understood.

4.5 Issues that affected the project

Participation in the project provided the author with a privileged insight into the reasons behind decisions made during the project. The general issues described in the sub-sections below are not intended to be critical of the company in question. The set of issues attempts to identify possible factors that contributed to the CAPM system not meeting all the expectations of the company. The issues identified will be used to provide a basis for deriving a set of requirements for an improved approach to the design and implementation of CAPM systems.

4.5.1 Lack of single ownership

The project was the responsibility of two senior managers within the company who had a conflict of interests. They were both measured using different performance measures. The Production manager was measured on delivery dates, lead times, productivity and cost of manufacturing parts, whereas the Management Services manager was measured on the successful implementation of the information systems.

4.5.2 Lack of a shared vision

A single vision and strategy that was supported by all the senior management team was not developed. As a result there was a lack of understanding and integration between the objectives of all the functions that may have been affected by the new CAPM system.

4.5.3 Changing time scales for the project

The time scale of the project was in a constant state of flux as other higher priority projects took precedence. Unfortunately, this provided another example of a lack of clear strategy and targets.

4.5.4 The mistrust of information provide by existing systems

There had always been a mistrust of the information supplied by the information systems within the company that had been developed by the Management Services department. This could be attributed partially to the lack of understanding and communication between users and developers of the information systems in the past.

4.5.5 Structural changes in the company

A significant organisational change that affected the project was the division of the management of the manufacturing activities and assembly activities which were originally managed by the production manager. The Production function was divided into two divisions; Supplies which included manufacturing, purchasing, process planning and Contract Services which included assembly, contracts and shipping. This change increased the functional boundaries which the CAPM system was required to cross and increased the number of senior managers with an interest in the project and so increased the chance of conflicting objectives.

4.5.6 Functionally driven project

The requirement for an improved CAPM system was justified by the vision of improved performance of the Production function. The ability of the improved CAPM system to address some of the perceived problems was found to be dependent on other functions maintaining accurate data. However, the managerial issues regarding maintenance of data by other functions was not considered until late in the project.

4.5.7 Failure to understand uniqueness of the production system

Using the functionality of the parent company's systems to reduce the analysis of existing systems and to reduce the time spent on designing a new system can be seen as a mistake. Even though the parent company manufactures similar products, the working practices and expectations of users within the parent company were considerably different. The differences caused difficulties in transferring the concepts and functions. For example, users in the parent company accepted the information supplied by the CAPM system in the parent company and worked strictly to its instructions. In contrast, users in the subsidiary were accustomed to being flexible and "adapting" instructions.

4.5.8 Challenging the "taken for granteds"

The basic "taken for granteds" of how the company operated and intended to operate were not reviewed or challenged at the beginning of the project. A fundamental review with a wider scope looking at the underlying assumptions of the company and how it operated and other changes that were happening would have focused attention on integrating all the changes with the impact that the new CAPM system was going to have.

4.5.9 System integration

There were changes to other systems which were regarded by the company as totally separate to the design and implementation of the CAPM system. On the contrary, the changes did have a significant impact on the project. For example, changes in other information systems affected the format and accuracy of data supplied to the CAPM system.

4.5.10 Investment in people as well as technology

The investment in people was only noticeable at the operational level. The users were frequently investing more of their own time on the project as they saw the advantages of the system whereas the management had reduced its support and were considering other projects of a higher priority.

4.5.11 Lack of management enthusiasm

The enthusiasm for the project was user driven, the cell leaders were seeing an improvement in the systems that they had had to use for many years. The team responsible for the project wanted to continue developing and implementing various modules of the CAPM system. Unfortunately the management responsible for the project was unable to maintain the momentum gained due to resource limitations and other projects being given a higher priority.

4.5.12 Loss of acquired knowledge

Following the implementation of the CAPM system within the company, the team of analysts and programmers who had worked on the project were made redundant. The investment in people and the knowledge acquired during the development and implementation was lost through an exercise to cut costs.

There was no formal review at any stage to ensure that lessons learnt during the project could be used to improve the development and implementation of future systems.

4.6 Conclusions from the project

The company and its employees invested a lot of time and effort in the project and it has had a number of positive benefits for the company. However, the design and implementation of the CAPM system studied did fail to meet some of the expectations of the company. The success of the project was affected by a number of issues from which a number of conclusions can be drawn.

There should be a single leader of a project responsible for meeting a set of consistent targets and performance measures because multiple leaders can lead to a conflict of interests. The leader should endeavour to establish a shared vision amongst those involved with the project and ultimately with all those who will have any involvement with the system in the future.

A CAPM system crosses many traditional functional boundaries. The relationship of the CAPM system with other major systems and organisational changes taking place should be considered at all stages of the project. To consider such relationships, participants require an understanding of how existing systems integrate to form the production system and of other systems that are part of the company which may be affected.

A CAPM system is only partly dependent on the computer-based activities or software. The human activities of the system, policies, procedures and practices that affect the system are also important. User involvement is essential and to maximise its benefit a framework and common means of communication and understanding are required.

Each production system should be considered to be unique even though the production system may be manufacturing similar products as part of the same overall company.

These conclusions can be used in combination with the issues identified in Section 3.3 to derive a set of requirements. The requirements should specify what is necessary for an approach to the design and implementation of CAPM systems that would address some of the issues described above and in Chapter 3.

4.7 The set of requirements of an approach

Chapter 3 identifies that manufacturing companies require additional support during the "investigation and analysis of existing systems" stage of a project to design and implement a CAPM system. It is during this stage that there is a failure to take a company-wide perspective by considering all the related systems. This failure can be attributed to both the lack of expertise of manufacturing companies in the area of CAPM system design and implementation and the fact that vendors focus on the computing elements of a CAPM system.

The conclusions from the issues identified in the present chapter stress the importance of encouraging participants in a project to take a company-wide view of the CAPM system and the other systems that interact with it. It is also concluded that there is a need for participants in a project to share a common vision and a common understanding of existing and future systems.

An approach that is to address the issues identified in Chapters 3 and 4 to improve the chances of future CAPM systems meeting the expectations of manufacturing companies will need to encourage:

- the definition of common objectives and business-related performance measures;
- the understanding of the existing systems and the definition of the requirements of the system from a company-wide perspective;
- a common understanding and view through communication between all parties involved;
- the participation of users throughout the project;

- the designed CAPM system to include the integration of all elements (human, procedures, organisational structure and technology);
- the implemented CAPM system to be integrated with its environment.

Summary

The participation by the author in a project to design and implement a CAPM system within a manufacturing company has been described. The observations made resulted in a set of issues that affected the success of the project.

Using the issues that have resulted from the two main activities in the Descriptive phase of the research, a set of requirements has been derived. The requirements specify what is required of an improved approach to the design and implementation of CAPM systems to address the issues identified. The requirements include the need for an approach to encourage the understanding of the existing systems from a company-wide perspective and to encourage a common understanding and view through communication between all parties involved.

The remaining chapters in this thesis will describe the research carried out to develop new knowledge that will contribute to such an improved approach to the design and implementation of CAPM systems that meets some or all of the requirements.

Chapter 5. Models and the concept of a system

Using information and observations gained as part of the Descriptive phase of the research work a set of requirements have been derived (Section 4.7). The set represents the requirements of an approach to the design and implementation of CAPM systems. The objective of this chapter is to consider how models may be used as part of an approach that meets some of these requirements.

This chapter will develop a working definition of a model to be used throughout this work and will then focus on conceptual models. The concept of a system and a particular type of system, the Human Activity system (HAS), will be discussed. The use of the HAS to understand and communicate ideas about the manufacturing companies will be considered. The last part of the chapter will compare two different ways of using systems and conclude with a proposal on how the use of conceptual models and systems thinking may be used as part of an approach to the design and implementation of CAPM systems.

Before discussing the use of a model, the first section briefly defines what a model is, and what types of models there are that could possibly be used.

5.1 Perspectives on models

To consider any real world problem situation relating to the management of production or to gain an understanding of it, there are an infinite number of variables that an observer could consider. According to Ashby (1965)

> any real "machine" has an infinity of variables, from which different observers (with different aims) may reasonably make an infinity of different selections.

Whether it is a "machine", a company or a problem situation relating to the management of production each has an infinite number of variables and possible states from which any observer may make a selection. For example, to observe and monitor the amount of work a human can do and to attempt to understand enough to predict future performance, an observer could measure the time and the amount of energy available. There are many other variables that could be considered such as human motivation, health, heat, humidity and metabolic rate.

The observer needs to establish which aspects of the problem situation should be taken into account and which can be left out (Von Bulow 1989). It would be impossible to consider all the variables that may affect a situation. The observer must therefore select the most relevant variables. This selection is dependent on the observer's view of a problem situation, the objective of the observer and his/her experience and knowledge. This act of selecting variables is an initial activity in defining a model.

5.1.1 Deriving a definition for a model

To derive a general definition of a model that will be used throughout this work, two recent definitions by authors working within the general area of production and operations management are described and contrasted.

Meredith(1993) defines a model as

> a simplified representation or abstraction of reality.

A model is created by an observer by the selection of what should be taken into account and what should be left out to provide a simplified representation. For example, if a model of a manufacturing company is created, the observer may decide to represent only the buildings used by the company. The buildings would be a simplified representation of the company. Meredith's use of the word "reality" limits the use of models to real things. Jorgenson(1992) believes a model can also represent a concept that does not necessarily exist in reality. According to Jorgenson

> a model is a structured representation of physical objects, concepts, or a system that helps organise and unify knowledge.

The final part of Jorgenson's definition (1992) also describes how a model "helps organise and unify knowledge". For example, an "organisation tree" may help employees understand the structure of their company.

The limitations of models as a result of the "list of variables nominated by an observer" (Ashby 1965) are emphasised by Meredith(1993) when he states that

> the primary difficulty in using models to analyse situations is obtaining adequate simplification, while maintaining sufficient realism.

The outcome of subjective decisions regarding the list of variables can be determined by a set of criteria and, according to Dubin (1969),

> there is an inverse relationship between the number of boundary criteria defining a model and the size of the domain covered by the model.

That is, the greater the number of selection criteria the smaller number of variables that will be in the model. Using the example of a company, even a model of a specific company would have an extremely large number of variables including humans, machines, buildings, finances etc.. By introducing more boundary defining criteria, for example, only human resources, and then further refining the criteria as only human resources who directly add value, the number of variables and hence the size of the model are both reduced.

A general definition of a model to be used in this work combines the Meredith definition, Jorgenson's wider view of what can be modelled and Dubin's emphasis on boundaries and the two goals of science which are to "predict and understand" Dubin(1969). The definition is as follows:

> *A model is a bounded representation or abstraction of a real event, object or concept. It describes, replicates, or reflects its subject with the objective of understanding and/ or predicting.*

5.2 Different types of models

Meredith(1993) classifies models into three categories depending on the level of abstraction from the real event, object or concept being represented. The three classes are as follows:

1. *Iconic models* - These are physical replicas of an event or object and are the least abstract. For example, a scale model of a building or a physical model of a plane in a wind tunnel.

2. *Analogue models* - These are not physical replicas but their behaviour replicates the behaviour of the event or object being modelled. For example, in a mercury thermometer the mercury rises as the temperature rises.

3. *Symbolic models* -These are the most abstract type of models, using symbols to represent attributes and properties of an event, object or concept. For example, Πr^2 as the area of a circle.

This classification is based on how the subject is represented by the model. In the study of problem situations within companies, for example, performance improvement, or improvements to methods of organisation or management, most models created use concepts which symbolically represent attributes and properties of events, objects or other linked concepts. The next section will describe models of concepts and how the use of such models may help understanding and communication in organisational situations.

5.3 Conceptual Models

It is important to define what is meant by the term "conceptual model" so that possible uses can be discussed.

5.3.1 The definition of a conceptual model

According to Meredith (1993)

> a concept is a bundle of meanings or characteristics associated with certain events, objects or conditions and is used for representation, identification, communication, or understanding.

For example, a production controller may apply a concept such as "employees get distracted from their work more easily on Friday afternoons, but generally work faster than normal on a Monday" derived from experience, to decide when to allocate work to employees.

The use of the term "conceptual model" can be ambiguous (Gregory 1993). It could be taken to mean that a model is conceptual or it could mean that it is a model of a concept. This thesis uses the term to refer to a model of a concept. This type of conceptual model is important for models concerning companies where "bundles of meanings or characteristics" (concepts) are often perceived by observers, for example, goals, values, informal networks, un-written rules. These are concepts that can be modelled using arbitrary symbols. For example, an informal network could be represented by arbitrary symbols such as circles for employees who are part of the network and lines indicating informal interactions between employees. An important assessment of a model of a concept is how well it communicates and promotes understanding.

This research work is primarily concerned with concepts in companies and will use the term "conceptual model" to describe a model of a concept. The next sections will consider the concept of a system and some of the ideas associated with a system.

5.3.2 A "system" as a concept

An important example of a concept is a "system", which is used to describe

> 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 (Checkland 1981).

A system ("bundle of meanings and characteristics") can be "used for representation, identification, communication, or understanding". A system is a defined from the viewpoint of an observer and it is abstract, that is, it does not exist in the real world (Von Bertalanffy 1968). For example, a set of elements such as humans, computers, information, procedures, policies and practices connected together which form a whole, with the purpose of managing the production system to fulfil customer orders and balance the requirements of stakeholders *can be described as a* CAPM system.

5.3.3 Four basic systems ideas

There are a number of basic ideas that are associated with systems. These are described by Checkland (1983) in two pairs:

emergence and hierarchy;
communication and control.

Emergence is the idea that a system "may have properties which refer to the whole and are meaningless in the terms of the parts which make up the whole" (Checkland and Scholes 1990).

Hierarchy is the ideà that all systems form part of a hierarchical order and each system is composed of lower level systems and itself is part of a higher level system.

Control is the idea that a system can adapt to a changing environment by taking control action.

Communication is that which enables control action to take place within a system by the "availability of communication between parts of the whole and between the whole and its environment" (Checkland 1983).

Given that all systems conform to the four basic ideas, Checkland (1981) describes four types of systems with each type having a set of characteristics. The four types of system are listed below with examples of each in parentheses:

1. "Natural Systems" (a man, an animal, a plant);
2. "Physical Designed Systems" (a bridge, a computer);
3. "Designed Abstract Systems" (Communism, mathematics);
4. "Human Activity Systems" (a company, a football team).

The remainder of this chapter will focus on the fourth type of system, Human Activity Systems (HAS) as the purpose of this research work is to propose an approach that is concerned with improving the way a company operates.

5.3.4 Human Activity Systems

A Human Activity system (HAS) can be defined as

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

The activities can be any type of human activity including decision-making, checking product quality, operating a machine etc..

A HAS can be characterised in terms of the four basic systems ideas, that is, a hierarchical structure, emergent properties, communication and control. Its characteristics are dominated by the human activities which form the system. It can be viewed as having a multiplicity of objectives depending on the observer of the HAS.

The modelling of a HAS can be highly problematic. Each observer may have a different interpretation of what purpose a HAS has and where the boundaries should be defined. Also the nature of a HAS is linked closely to the nature of the human element undertaking the activities (Checkland 1981) because

> at best, he is subjectively rational, not objectively rational (March and Simon 1970).

Despite the problems in developing models of HAS, it

> would seem to be the system type most relevant to improving real-world production systems (Checkland 1983).

Having defined what a model is and what a concept is, a system and, in particular, a HAS have been identified as having characteristics that may help in the structuring and understanding of problem situations in manufacturing companies.

5.4 Viewing manufacturing companies as Human Activity Systems

Any approach to studying the complex interactions within a company is based on specific assumptions (Daft and Weick 1984). A working assumption that is made throughout this work is that a HAS can be used to view and structure the complex interactions that happen within a company and its interactions with its environment.

The application of a system to conceptualise structures in companies has been well documented in literature, from Max Weber's account of bureaucracy in Grusky and Miller (1970); Selznick (1948) who viewed companies as co-operative systems; Boulding (1956) who concluded that companies are among the most complex systems imaginable; Emery and Trist's (1960) view of companies as socio-technical systems; Leavitt's Model (1965) of the four subsystems of an enterprise to the more specific work of Checkland (1983) on the HAS and its relevance to production systems.

Another working assumption that forms the basis for this work is that a CAPM system can be regarded as a HAS (Section 5.3.4) and is an integral part of another HAS, the production system. It is the human activities that significantly influence the behaviour of these systems and

> the essence of improving their efficiency and effectiveness lie in "engineering" the human activity which makes best use of the equipment in the best interests of the system as a whole (Checkland 1983).

This is a view taken by a number of writers including Wilson (1983) and Wang and Smith (1988).

The next section will describe how the concept of a HAS could be used as part of an approach to improve situations within companies.

5.5 Systems thinking

Systems thinking embodies a set of ideas. These include:

- the use of a system and the four basic systems ideas (Section 5.3.3) to construct a systems model of some part of the perceived real world in order to gain an understanding of the perceived real world;
- the idea of systemicity, that is, that something can be systemic or "concerning a system as a whole" (Checkland and Scholes 1990).

Despite these common ideas, different types of systems thinking can be identified. Checkland (1981) identifies two types of systems thinking, "hard" (HST) and "soft" (SST).

Two important differences between these types of thinking are the way in which the problem or problem situations are viewed and the way in which the idea of systemicity is used.

The first important difference between "hard" and "soft" systems thinking is the underlying problem or question that is being answered.

HST and traditional systems engineering methodologies (Hall 1962, De Marco 1979) attempt to answer "how" to a defined problem and hence find a solution. For example, a company may have decided to improve production performance and may decide that there is a need for a computer system to manage production. The problem has been defined, it is only a matter of "how" the need is to be met to provide a solution.

SST and methodologies incorporating SST are attempting to answer "what" and then "how" by a process of enquiry. For example, a company may be faced with the problem situation of declining production performance. There may be different factors influencing the declining production performance, the first task must to be to answer "what" the problem could be, what could be influencing the problem and then to propose "how" the problem situation can be improved.

SST views situations as having many ill-defined problems that are highly interrelated. In these situations or "problem situations" it would be misleading to consider a single problem without attempting to understand the many interrelated problems that have not yet been identified which may have an impact on the problem situation. This type of complex situation can often exist in companies and in general, are those problem situations where HAS may be involved (Wilson 1984).

The second important difference is that HST views the perceived real world as being systemic, that is, the real world consists of systems. For example, that *there is* a CAPM system. HST uses a systematic approach to solve problems. By contrast, SST views the real world as being problematic and ill-defined, which can be learnt about and understood through the use of the concept of a system and a systemic process of enquiry. For example, the humans, computers, policies and procedures etc. that interact to manage production can be *viewed* as a CAPM system and a "learning system" (Checkland and Scholes 1990) can be structured in many different ways to enquire about ill-defined problems concerning the management of production.

5.6 Outline of an approach

A set of requirements for an approach to the design and implementation of a CAPM system was derived in Section 4.7. Some of the requirements were to encourage the development of an understanding between all parties involved, about the business objectives, about the current situation and about what is required by the company. These initial activities are concerned with answering the "what" which suggests that the principles of SST may be useful as part of an approach.

To encourage an understanding of what exists, the ability to structure what is perceived to exist by taking a systemic view and to communicate this view is important. Concepts such as a HAS can be used to provide the structure. The use of the concept of a HAS would encourage a view of a company with respect to the most important element, the people.

Models could also be used in the design and implementation of a CAPM system

> to encapsulate the diverse knowledge required, thus reducing the complexity (Aguiar et al 1993).

By encapsulating the diverse knowledge and reducing the complexity level, there could be an increased user involvement in the design and implementation of a CAPM system. Using models would help the communication and understanding of the requirements of the users.

Summary

This chapter has stated and discussed some key issues for this work. The key issues are models, conceptual models, systems, human activity systems and systems approaches. An approach based on conceptual models and soft systems thinking appears to offer considerable advantages in addressing many of the issues raised in Chapters 3 and 4.

The application of SST and its relevance to CAPM and a model based approach will be discussed in further detail in the next chapter.

Chapter 6. Soft Systems Thinking

The previous chapter discussed the concept of a Human Activity System (HAS) and identified that Soft Systems Thinking (SST) and its underlying principles may be usefully incorporated into a model based approach for the design and implementation of CAPM systems. SST focuses attention on the initial activity of understanding the ill-defined existing situation, which was established as one of the main areas requiring improvement in Chapter 3. Soft Systems approaches include those described by Checkland (1981), Wilson (1984), Ackoff (1981) and Boardman (1995).

The purpose of this chapter is to describe SST and, in particular, Checkland's (1981) Soft Systems Methodology (SSM) and how the underlying principles and ideas may contribute to a model based approach for the design and implementation of CAPM systems. This chapter lists the general principles of SST and then focuses on the core method associated with SSM and what constitutes a use of SSM. The chapter also considers the practicalities of SSM and issues associated with the use of its principles in a manufacturing company.

6.1 Principles of "Soft Systems Thinking"

The "Soft Systems" approaches described by all of the writers above have a number of principles in common. Summarising Ackoff (1981) the principles are:

- *the principle of participation and debate* - people involved with the problem situation are encouraged by the approaches to participate in the methodology and to debate issues and views to help formulate an improved understanding;

- the *principle of continuity* - each approach describes the necessity for continuous iteration and review as the problem situation changes over time and the understanding of the problem situation increases;

- *the principle of systemicity* - the approaches are systemic. Each approach encourages the consideration of the interdependent parts and levels of a system simultaneously as a whole and in doing so encourages the use of many different parts of the approach simultaneously.

Given that all the approaches have these principles in common, the remainder of this chapter will focus on Checkland's (1981) Soft Systems Methodology (SSM). The underlying principles (or epistemology) of the methodologies described by Wilson (1984) and Boardman (1995) are based on Checkland's SSM.

Checkland and Scholes (1990) describe a language and a set of constitutive rules that form the epistemology of SSM. The purpose of the description of a language and set of rules is to enable practitioners to determine whether the work done can be described as a use of SSM.

The language elements listed include *the problem situation, root definitions, CATWOE, conceptual model, comparison, desirable and feasible changes*. These language elements will be described in more detail later in the chapter (Section 6.2) where SSM is discussed. The list of language elements is combined with a set of constitutive rules to enable SSM and its uses to be described completely. The 5 Constitutive rules summarised from Checkland and Scholes (1990) are:

1. SSM is a structured way of thinking which focuses on a problematic real world situation with the aim of improving it.

2. SSM's structured thinking is based on systems ideas.

3. The guidelines that should be followed include:
   a) No assumption that the real world is systemic.
   b) A distinction made between unreflecting involvement and conscious systems thinking.
   c) Holons (Purposeful Human Activity Systems) used in systems thinking phases.
   d) Holons used to enquire into the real world to understand, communicate and debate change.

4. Any potential use of SSM ought to be characterised by conscious thought about how to adapt it to a particular situation.

5. SSM is a methodology, not a technique, every use of it should yield learning that can be incorporated into its next application.

In summary, an approach to be used in a particular situation can be described as *using* SSM providing:

- its principles include the three principles described above;
- it can be described using the language set associated with SSM;
- its principles can be described by the 5 constitutive rules.

6.2 The core method within Checkland's Soft Systems Methodology

The Soft Systems Methodology originally proposed in Checkland (1981) had seven stages. In keeping with the principles of SSM the original methodology is being continuously developed as more knowledge is gained through its application in different problem situations. Thus, Checkland (1988) describes a developed SSM that no longer uses the seven stage structure, although the language set has remained almost constant.

Figure 6.1 is adapted from Checkland and Scholes (1990) and represents the core method. The next sections describe in more detail some of the stages.

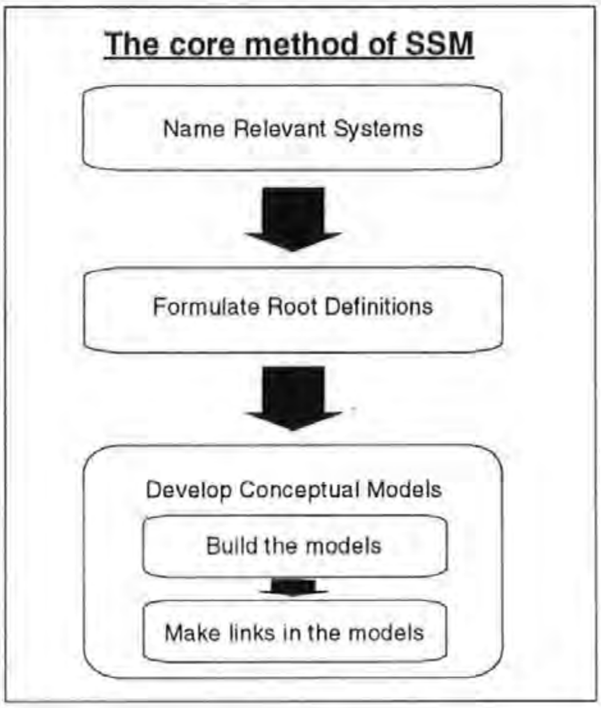

Figure 6.1 The core method of SSM adapted from Checkland and Scholes (1990)

6.2.1 Name relevant systems

Having become aware of a perceived problem situation, the initial stage in the core method is to identify the systems relevant to that problem situation.

There is a choice of how the relevant systems can be identified. The methods are by "primary task" or "issue based" analysis (Checkland and Wilson 1980). According to Wilson (1984)

> there are instances, ... particularly in relation to problems concerning the restructuring of organisations, or to information systems analysis where it is of value to consider a primary task choice.

The use of a "primary task" to define a system was described by Miller and Rice (1967) before its use was incorporated into SSM. The definition of the "primary task" allows the determination of the "dominant import-conversion-export system" and allows an exploration of the "ordering of activities"(Miller and Rice 1967). For example, the "primary task" of a manufacturing company could be taken as the transformation of raw materials into a manufactured product.

Deciding on the "primary tasks" of systems relevant to the problem situation to improve the management of a production system would help participants in an approach to the design and implementation of CAPM systems. It would help them clarify objectives and develop a shared vision of the tasks of the relevant systems.

6.2.2 Formulate Root Definitions

Once one or more relevant systems have been named, the next stage in the logic stream is to develop a root definition for each one. A root definition should be a "concise description of a human activity system which captures a particular view of it" (Checkland 1981). Checkland also developed a mnemonic CATWOE by which the six elements that should be covered in a root definition can be remembered. The six elements paraphrased from Checkland are:

> *Customers* of the system, beneficiaries or victims affected by the system's activities.
>
> *Actors* or agents who carry out or cause to be carried out the main activities of the system.
>
> *Transformation*, the means by which defined inputs are transformed into defined outputs.
>
> *Weltanschauung (Worldview)*, the outlook or framework that makes the root definition meaningful.
>
> *Ownership*, the agency having a prime concern for the system and the ultimate power to cause the system to cease to exist.
>
> *Environment*, features of the environment of the system that must be taken as given.

Developing root definitions as part of an approach to the design and implementation of CAPM systems would encourage an improved understanding of the existing systems and the development of a shared view of the systems involved.

The root definition describes *what* the system is. A conceptual model can be developed from the root definition that describes the set of activities that a system *must do* to be the system defined by the root definition (Wilson 1984).

6.2.3 Develop conceptual models based on a single transformation

The development of the conceptual models is represented in two stages in Figure 6.1 "Building the models based on one transformation" and "Making the links in the model".

- **Building the models based on one transformation**

  The building of the model is a logical expansion of the root definition. The model represents the activities that are required to perform the transformation or "primary task" (as far as they can be identified by the people who generate the model and according to the Worldview that the people share).

- **Making the links in the model**

  Making the links in the model involves the representation of the interactions between activities that are required for the transformation to take place.

The conceptual models that are developed from the root definitions of the relevant system as a result of the two stages above form a focal point of the process of enquiry in SSM. Von Bulow (1989) describes how the conceptual (systemic) models are used as part of the process;

> the learning takes place through the iterative process of using systems concepts to reflect upon and debate perceptions of the real world. ...The reflection and debate is structured by a number of systemic models. These are conceived as holistic ideal types of certain aspects of the problem situation rather than accounts of it.

These conceptual models of relevant HAS can be used to improve problem situations in a manufacturing company context (Checkland 1983, Rhodes 1985). The models can stimulate debate and understanding with the aim of identifying desirable and feasible changes in the particular problem situation. Wilson (1984) also suggests that other models that are intended to be generic may be used to aid the activity of developing the conceptual models. The example given by Wilson is the cybernetic model of Beer (1979). The idea of using a generic model to help the development of the conceptual models will be developed further in Section 7.5.

Developing conceptual models of the activities required to perform the transformation described in the root definition would enable participants in an approach to the design and implementation of CAPM systems to further understand the relevant systems and stimulate debate.

The next stage in the logic-driven stream of SSM is the comparison of the conceptual models with perceived reality and the resulting recommendations for desirable and feasible changes.

6.2.4 Comparison of the conceptual models with perceived reality

The use of the conceptual models to compare with perceived reality is

> only a means to an end, which is to have a well structured and coherent debate about the problematic situation in order to decide how to improve it (Checkland and Scholes 1990).

The aim of the comparison is not to improve the conceptual models so that they represent an improved model of reality, it is to initiate and structure debate about the problem situation.

Checkland (1981) and Wilson (1984) describe four ways of comparing the conceptual models with perceived reality and initiating and structuring the debate. The four ways are:

1. *Informal discussion*;
2. *Formal questioning*;
3. *Operating the models*;
4. *Model overlay*.

Informal questioning works best when all participants are familiar with the systems language (Wilson 1984). *Formal questioning* is the most commonly used according to both writers. The models are used to generate questions about the real world; answering the questions initiates debate about the particular situation. *Operating the models* involves notionally doing the activities in the order represented and comparing it with "some real world happenings" Checkland and Scholes (1990). The last of the four is *model overlay*, this involves restructuring the conceptual model so that it reflects as closely as possible the real world situation. Wilson (1984) comments

> I have used this method most successfully in studies concerned with organisation structure where one is comparing decision taking boundaries in a systems model with areas of authority in an actual organisation.

The result of the debate stimulated by comparing the conceptual model or set of conceptual models with perceived reality will (hopefully) be a set of suggested desirable and feasible changes that will improve the problematic situation.

So far in this chapter, the works of Checkland (1981), Wilson (1984), Checkland and Scholes (1990) and others have been used to describe the theory and principles of SSM. They have used it successfully on many occasions, some of which are documented in their work. In principle, the use of the core method described meets some of the requirements in Chapters 3 and 4. These include those relating to understanding objectives, initiating debate and communication, and also developing a better understanding of existing systems and the changes required. The latter part of this chapter will consider the practicalities of using SSM and how the principles may be relevant to a model based approach in the design and implementation of CAPM systems.

6.3 Practicalities of SSM

Questions have been raised about the practical application of SSM described by Checkland (1981). Rhodes (1985) believes that although SSM is a valid approach it is difficult to apply. A survey of practitioners carried out by Mingers and Taylor (1992) and other writers including Jackson (1982), Robson (1985), Mingers (1984) all seem to support this view.

According to Mingers and Taylor (1992), some practitioners:

- found the language in SSM "off-putting to users";
- perceived SSM as time consuming;
- believed SSM was weak in dealing with power structures.

In fact, some respondents to Mingers and Taylor (1992) had used their own modelling techniques in place of those originally suggested by Checkland (1981) and had either modified or added to the original seven stage process of enquiry described in Checkland (1981). Atkinson (1986) provides evidence that SSM can be modified successfully by describing five different versions of SSM using case studies.

Ultimately, Mingers and Taylor (1992) did find that the majority of respondents believed there were a number of benefits to using SSM. Respondents to the survey expressed the view that the structure SSM provided was particularly useful and that

> it led to greater understanding of other peoples' views and perspectives (Mingers and Taylor 1992).

Another important view expressed by respondents relating to the conceptual models used in SSM was that

> discussion can be centred on the models not the people - a very valuable way of reducing conflict (Mingers and Taylor 1992).

SSM encourages a cycle of learning, with each use of SSM practitioners are encouraged to modify and personalise their approach. This being so the activity of surveying people who have knowledge of SSM is made difficult.

6.4 Use of SSM in the manufacturing company

Wilson (1983) and Checkland (1983) both suggest that the concept of a HAS and SSM based approach represents a way of structuring the thinking about the real world situations in manufacturing companies. Providing some of the problems of applying SSM can be addressed, there are particular benefits to using an approach based on the principles of SSM for improving problem situations relating to a HAS view of CAPM. The benefits include:

- the focus on the initial understanding of the problem situation;
- encouraging a systemic view of the problem situation to be taken;
- the communication of user's different perspectives;
- the initiation of structured debate to improve the understanding of the relevant systems;
- the structured debate on possible improvements which may include simplification of existing systems, influences of other systems, policies, procedures and the requirements for computer aided production management.

These benefits will meet the requirements of an approach identified in Section 4.7, including:

- establishing a common set of objectives;
- supporting the investigation and analysis of their existing systems;
- encouraging a systemic perspective to be taken;
- increasing user involvement;
- focusing attention on methods of work organisation and organisational relationships.

Summary

Soft Systems Thinking, Checkland's SSM and their underlying principles have been described. The elements of an approach that can be said to *use* SSM have been defined. It has also been established that the conceptual models developed during an application of SSM are the focus of the method and can be used to initiate and structure debate.

The problems that practitioners had whilst using SSM have been discussed, and also the benefits that practitioners believed there were in using SSM. The benefits of using the principles of SSM to address some of the requirements of a model based approach to the design and implementation of CAPM systems have been stated.

The next chapter will consider the use of models as part of other model based approaches and most importantly, the use of generic models to develop conceptual models of manufacturing companies.

Chapter 7. The use of model based approaches

Many model based approaches have been used to facilitate the design and implementation of systems within manufacturing companies. The approaches include general systems analysis approaches such as SADT (Ross 1977) and notably approaches focusing on the design and implementation of Computer Integrated Manufacturing (CIM) systems (Jorysz and Vernadat 1990, Aguiar and Weston 1995) and CAPM systems (Wang et al 1993).

Chapter 5 concluded that the use of conceptual models as part of an approach could provide a simplified view of reality which could then be used for communication and understanding. The objective of this chapter is to identify how models may be used as part of an approach to the design and implementation of CAPM systems that will meet the requirements derived in Section 4.7. The requirements that this chapter will be particularly concerned with are those to encourage:

- a common understanding and view through communication between all parties involved;
- the participation of users throughout the project, where appropriate;
- the understanding of the existing systems and the definition of the requirements of the system from a company-wide (systemic) perspective.

To investigate how models may be used, some of the issues concerning the model based approaches described in literature will be discussed. The chapter concludes with the proposal of how models can be used as part of an approach that will address the above requirements.

7.1 Practicalities of model based approaches

Many of the model based approaches found in literature have been developed to support the whole of the design and implementation project, for example CIM-OSA (Computer Integrated Manufacturing - Open Systems Architecture) (Jorysz and Vernadat 1990) incorporates extensive guidance on the organisational architecture. Hodgson and Waterlow (1992) express doubts about the applicability of such extensive approaches that "may be seen at best to represent idealistic solutions to theoretical problems". They comment on the "need for a pragmatic approach" which could be of use to Small and Medium Sized Manufacturing Enterprises (SMEs).

The objective of this work is to contribute new knowledge that helps manufacturing companies with the design and implementation of CAPM systems. This work should therefore consider the needs of all manufacturing companies irrespective of their size.

SMEs face many of the same problems as large companies (Raymond and Magnenat-Thalmann 1981) and can benefit from the same types of technology (Brennan et al 1990). However SMEs often suffer from a "resource poverty" (Ibrahim and Goodwin 1986) characterised by financial constraints, a lack of expertise and short term competitive pressures. This "resource poverty" affects the ability of the typical SME to develop a CAPM system on its own and an SME may often rely on a software vendor for external expertise.

Any development of a part of an overall approach to the design and implementation of CAPM systems that is to be suitable for all manufacturing companies should consider the limitations imposed by the "resource poverty" that exists in some companies. The approach should therefore, in a short period of time, at a low cost, with a low reliance on expertise help manufacturing companies to understand their existing systems and define correctly their present and future requirements of a CAPM system. The models used as part of such an approach should provide a common framework for communication between vendors and companies where there is a lack of expertise in system development.

The activities of understanding and analysing existing systems and defining requirements have been identified above and in Section 3.3 as requiring improvement. Emphasis was placed on these activities when studying the approaches found in the literature survey.

7.2 Views represented by models

Some of the model based approaches described in the literature discuss the need for the development of "as-is" models that represent the existing systems within the company from multiple viewpoints. For example, IDEF (Le Clair 1982) creates "as-is" models from a function view and an information view, IDEM (Integrated Design and Modelling) (Wang et al 1993) creates "as-is" models from function, information and dynamics views.

The need for models of multiple views can be attributed to the recognition that systems that are defined in manufacturing companies are complex with many different types of components and it is not possible to create a model that represents all the components in a single useful model (Wang et al 1993).

The *function view* of a system represented by a model is the view that is the most important for the definition of requirements (Jorysz and Vernadat 1990). A model from a *function view* should describe:

- the whole system including boundaries and overall goals;
- the activities of the system at all levels required;
- the behaviour of the system (show procedural rules, events, outcomes of activities);
- the components that perform the activities (man, machine, computer etc.).

The *function view* relates specifically to activities of a system and the term *function* must not be confused with a functional view of a company describing a company divided into traditional "functions" such as Sales, Design, Production, Accounts etc..

To avoid a confusion in terms, the *function view* will be called the *activity view*. The activity view of a company will be focused on during this work as it is an important view during the initial stages of a model based approach.

7.3 Modelling systems hierarchies

The use of the concept of a system enables many model based approaches to describe a hierarchy of systems using modelling techniques, for example IDEF (Le Clair 1982), CIM-OSA (Jorysz and Vernadat 1990) and IDEM (Wang et al 1993). The ability to represent the system and its components at various levels of detail enables the model to represent the complexity of the systems at whatever level is appropriate (Aguiar et al 1993). For example, a model of the whole existing system at a high level of abstraction may be useful to communicate ideas to senior executives who do not need to know the detailed activities. A more detailed model of the activities, inputs, outputs, controls and resources will be required to communicate with software vendors in specifying requirements for new software as part of the system. According to Doumeingts et al (1992)

> a good model should amplify the important characteristics and conceal the details which are considered to be of low importance at a given level of abstraction.

The decision to amplify or conceal characteristics is made by the modeller. The decision will depend on what the modeller perceives to be required. Hence, two models of a system in a company with the same purpose may be different if produced by different modellers. The level of detail that is modelled should be given consideration and guidance should be given to practitioners on the level of detail necessary.

7.4 User involvement

Users are those individuals who will either form part of the system themselves, for example, the humans involved in making decisions in a CAPM system or those individuals who interface with a CAPM system. According to Robey (1979) the involvement of users in the design and implementation of management information systems has been researched extensively and it was found that the participation of users at all stages is a critical factor for the success of a project.

By contrast, Ives and Olson (1984) adopt the view that there is little empirical evidence to support the claim that participation of users at all stages is critical to the success of a project. However, they do conclude that "common wisdom" suggests that user involvement is appropriate for unstructured problems.

It is difficult to assess the level of involvement users have in a project (Ives and Olson 1984). The observations of the author during the project that he participated in support the view on the considerable benefit of users being involved throughout the project (Section 4.4). The involvement of users during the initial stages of the project was felt to be particularly important and the level of actual involvement was insufficient. It was at these stages that there was a lack of understanding and the problems were poorly defined. Where appropriate the users should also be involved in or at least kept informed of progress during the more technical design stages. The level of involvement of users is context driven. It is therefore important that no part of an approach should constrain the involvement of users, rather every part of an approach should encourage the involvement of users where the organisational context allows.

The use of multiple modelling techniques to create the models of different views described in approaches such as IDEM, CIM-OSA, IDEF assumes a considerable level of expertise equal to that of a professional systems analyst. For users to participate in such projects a single model from an *activity* view is often used (FIPS PUBS 1993).

7.5 Conceptual models

The design and implementation of a CAPM system in a manufacturing company will often involve a software vendor (Section 3.1). The initial analysis of existing systems and the requirements definition is often done by the company before the vendor is engaged. In such circumstances, it is desirable for any models created during the analysis and requirements definition phase to be of use to the vendor and to provide easy communication between the parties. Taking this into consideration, the literature survey concentrated on model based approaches that featured the development of structured models using a standard modelling technique that could be easily understood by both parties.

7.5.1 The purpose of developing conceptual models

The purpose of the structured model is to define the basic concepts, elements and relationships from a static point of view (Doumeingts et al 1992). Structured models used in this way are typically conceptual models. The application of a conceptual model is

> appropriate at representing the application domain as perceived by users and systems developers and thus it acts as a common reference framework to facilitate agreement on requirements (Dooner 1991).

The activity of developing a model is also important. The act of creating an "as-is" model that represents a shared view can help to develop the critical momentum to change behaviour (Meyer 1993). The "as-is" model may be the first step to understanding and changing the system (Ang et al 1994). This view is also supported by Hammer and Stanton (1995) whose work on the re-engineering of business processes is closely linked with the design of systems within companies. Although they consider the detailed analysis of what already exists in a company to be a waste of time and advocate starting from a blank sheet of paper so that the existing organisational processes do not limit the redesign, they do recognise the importance of understanding the existing situation, by stating that

> before an organisation can create new designs they do need to understand their current processes....Typically four to six weeks is enough time to achieve the level of understanding necessary for re-engineering.

There are two main approaches to developing conceptual models that may help the companies understand their existing systems and to define their requirements. The first approach is to create an "as-is" model of the existing systems starting from nothing. The second approach is to derive the "as-is" model of an existing system by using a generic model as a starting point and comparing the knowledge of what exists within the company to the generic model and hence to use it as a structure to develop a specific "as-is" model for the company.

7.5.2 The creation of "as-is" models

The creation of an "as-is" model of existing systems from nothing is described in a number of model based approaches including IDEF (Le Clair 1982), IDEM (Wang et al 1993), MMCS (Manufacturing Management Control System)(Erkes and Clark 1987) and general systems analysis approaches such as SADT (Structured Analysis and Design Technique) (Ross 1977) and SSAD (Structured System Analysis and Design) (Gane and Sarson 1978).

The creation of an "as-is" model of existing systems from nothing requires the boundaries of the model to be defined and the variables that are to be modelled to be selected. These tasks can be difficult especially if the existing systems are ill-defined and participants in an approach are not experienced in deciding what should or should not be modelled.

7.5.3 Deriving an "as-is" model

The second approach for developing an "as-is" model of an existing system is by using a generic model as a starting point (Harrington 1984). Generic models are based on the assumption that

> each manufacturing sector domain has a set of generic tasks, activities that provide a basic conceptual model for the domain (Wang and Smith 1988).

The generic model can be compared by practitioners to their knowledge of the company and a model of a similar system within the company can be developed. The generic model provides the structure to develop a specific "as-is" model of the company, guiding boundary definition and what view the model should represent. The use of generic models especially in the field of Enterprise Modelling is becoming increasingly popular (Fraser 1994).

A generic model will extend to a certain level of detail. For the purposes of this work "high level" means the decomposition of the company to a few levels of detail. Examples of generic models at a high level of abstraction include those used in CIM-OSA (Jorysz and Vernadat 1990) to represent an integrated view of the enterprise, by Ranky (1991) to represent the CIM system, by Harrington (1984) to represent a manufacturing system, and by Rhodes (1994) to represent business processes. These generic models can then be used as a guiding structure for the development of a model or set of models of specific systems within a particular company.

There are examples of generic models used in model based approaches which represent systems at lower levels of decomposition than those described above. For example Childe's (1991) task model of the manufacturing system and Colquhoun and Baines (1991) who developed a model of computer aided process planning. A generic model of this type is

> one that represents the generally accepted or intrinsic activities that exist within a defined process or system (Colquhoun and Baines 1991).

The purpose of these generic models is not just to provide a guiding structure to develop a specific model. These lower level generic models also present a complete generic view of a system that can be compared, at a low level of decomposition, to the components of the company specific system. In the comparison

> differences will appear. Some may be quite proper differences... other discrepancies in the structure will raise appropriate questions for further investigation (Harrington 1984).

Investing in the development of a model representing the activity view of the existing systems may mean considerable costs to a company (Fraser 1994). Low level generic models represent an opportunity to reduce the costs associated with modelling activities.

Unfortunately, the lower the level of decomposition the harder it is for a model to be generic. For example, at a high level the vast majority of manufacturing companies manufacture goods and plan their manufacturing activities, at a lower level of decomposition not all manufacturing companies will produce daily plans. Generic models that attempt to cover all manufacturing companies are likely to have some parts which are redundant. The level of redundancy depends on the particular manufacturing company in which it is being used.

The use of generic models to derive other conceptual models was also discussed in Section 6.2.3. A generic model that represents a purposeful system, its activities and the interactions between activities provides a view of a system. Such a model can be used to facilitate the activity of developing a conceptual model of a relevant system as part of the core method of SSM.

7.6 Modelling techniques

Evaluating the relative merits of different modelling techniques used by the model based approaches to create a model of an activity view of a system is beyond the scope of this work and has been addressed by Doumeingts et al (1992) and Franks (1993). To represent a model of a system using an activity view, a modelling technique should be able to represent all of the components listed in Section 7.2 and, paraphrasing Franks (1993), it should be:

- easy to use;
- re-usable in a wide range of applications;
- usable for generic models as well as specific company models;
- capable of supporting decomposition;
- able to be integrated into a set of modelling techniques supporting all phases of a design and implementation project.

$IDEF_0$ (FIPS PUBS 1993) part of the IDEF (Le Clair 1982) set of modelling techniques is capable of representing all the components in Section 7.2 which form part of an activity view. Writers such as Wang and Smith (1988) believe that $IDEF_0$ is

> easily implemented and communicable, relatively user friendly and easily learned

and in their extensive "State of the Art Review" on the use of $IDEF_0$, Colquhoun et al (1993) describe the

> significant amount of published work on $IDEF_0$, which reflects primarily its accessibility and its potential in a wide range of applications.

They also conclude that

> few authors are critical of the basic methodology and most support the basic tenet that the technique provides a means of understanding the complex interaction of men, machines and information and a means of communicating the understanding to others.

$IDEF_0$ would therefore seem to be able to meet the requirements and have the syntax to describe the components that form part of the activity view of a system.

If the model based approach uses principles based on Soft Systems Thinking then the modelling technique should support such principles. The modelling technique must facilitate the creation of conceptual models that represents the system described in the root definition (Section 6.2.3). The models should represent an activity view that provides a structure and encourages debate about changes and in so doing a greater understanding of other users' perspectives can be gained.

Mingers and Taylor (1992) found that many practitioners used their own modelling techniques in place of those originally suggested by Checkland (1981) and Wilson (1984) as part of a SSM.

In a conversation with Wilson (1995) it was agreed that $IDEF_0$ was a suitable technique for the development of conceptual models within an approach that uses SSM. Wu (1992) and Wang and Smith (1988) also link $IDEF_0$ with the development of conceptual models for soft systems based approaches.

7.7 Conclusion

The objective of this chapter was to identify an appropriate use of models that would meet some of the requirements derived in Section 4.7.

It has been identified that many manufacturing companies need a pragmatic approach that requires a low level of expertise especially during the understanding and analysis stage. The development of an "as-is" model of existing systems representing an activity view relevant to the problem situation provides a momentum for change and a method of communicating and understanding the problem situation. It can also act as a means of communicating with vendors to aid in the definition of requirements.

"As-is" models from an activity view can be derived from generic models of systems relevant to the particular situation. Depending on the level of decomposition the generic models can provide a structure to bound the "as-is" model and influence the view it represents. The detailed generic models can enable users to compare activities at the level the users work at, to develop an "as-is" model and a requirements definition. Generic models can also be used as part of an approach that uses SSM.

$IDEF_0$ has been identified as a modelling technique that can be used for the creation of "as-is" conceptual models of existing systems within companies and to represent conceptual models as part of a model based approach that uses SSM.

Summary

It has been established that a detailed generic model representing the activity view of relevant systems would provide structure, guidance and additional knowledge to aid the activity of producing "as-is" models of existing systems. Its use as part of an approach will help in meeting the requirements derived in Section 4.7.

The next stage of this thesis will describe the development of a detailed generic model using the principles of SSM which can be used to initiate and structure debate and assist the activity of producing "as-is" models of existing systems. The generic model developed will be suitable for use as part of a model based approach for the design and implementation of CAPM systems.

Chapter 8. Business Processes

The concept of a Human Activity System was identified in Section 5.3.4 as being one possible way of assisting practitioners to structure, understand and communicate views of situations in manufacturing companies.

Over the past five years there has been a dramatic increase in the use of the concept of the business process to help understand and analyse activities and flows within companies. The use has been popularised by such authors as Hammer (1990), Davenport (1993), Harrington (1992), Johansson et al (1993). The application of the concept of a business process is not a new approach. Its use is documented in The Toyota Production System in the 1960's and 1970's (Parnaby 1993) and in other examples including Rhodes (1988).

The objective of this chapter is to establish how the concept of a business process can be used to assist practitioners to structure, understand and communicate views of situations in manufacturing companies. This chapter will describe a view of a manufacturing company using the concept of a business process and discuss the relationship between a business process view and a systems view of the production management activities.

Before describing a view of a manufacturing company using a business process, a business process and the systems ideas that it embodies need to be defined.

8.1 Definition of a business process

A number of writers (Rummler and Brache 1990, Harrington 1992, Davenport 1993) have provided definitions of a "business process". These definitions generally take a form similar to Davenport's

> a process is simply a structured, measured set of activities designed to produce a specified output for a particular customer or market.

Such a definition provides useful guidance. It does not however make explicit a number of the important ideas associated with the concept of a business process. This research takes the view that the use of the concept of a business process can be grounded in the discipline of systems. This is a view shared by many authors including Rummler and Brache (1990), Alexander (1993), Meyer (1993), Earl (1994) and McHugh et al (1995).

8.1.1 A business process as a human activity system

A system is a concept that embodies four basic ideas (Section 5.3.3). These ideas are a hierarchical structure, emergent properties, communication between entities within the system and internal control. A business process also embodies the same basic ideas.

A business process has a hierarchical structure. As a whole, the business process can be broken down into a set of components or sub-processes each one embodying the same four basic ideas. These sub-processes can in turn be broken down into further sub-sets. There are interactions (communication) between the components that are consistent with the perceived purpose of the whole business process and also with an ability to respond to environmental changes which indicates an existence of control. The behaviour of one component will affect all the components that it interacts with and hence can influence the emergent properties of the business process. These emergent properties are the properties of the business process which result from interactions between its components and cannot be attributed to a single component. Subsequently, a change in an emergent property of the process may affect the ability of the business process to fulfil its purpose.

An example of a whole that can be viewed as a business process in manufacturing companies is the set of activities and flows that are involved in receiving a customer's order, planning the manufacture of the product, manufacturing it and finally delivering it to the customer. This business process may be described as the "order fulfilment" process. It is often intuitively recognised as a logical chain of events and will therefore be recognised as a process. In addition, it both begins and ends with the customer and can therefore be identified as a complete process.

There are four types of systems (Section 5.3.3) of which a human activity system (HAS) is one. The use of a HAS to view manufacturing companies was discussed in Section 5.4. Checkland (1981) defines nine components that a HAS should have. A business process can be described in the same terms and therefore for the purposes of this work the concept of a business process as used in BPR literature can be viewed as being a HAS. Paraphrasing Checkland (1981) and substituting business process for HAS, the nine components are:

- A business process has purpose.
- A business process has measures of performance.
- A business process contains decision-making elements that enable the process to adapt to meet the purpose of the business process.
- A business process has components (sub-processes) which themselves have all nine components.
- A business process has components which interact, which show connectivity such that the effects and actions are transmitted through the process.
- A business process exists within wider processes and/or the environment with which it interacts.
- A business process has a boundary separating it from wider processes and/or the environment. It is formally defined by the area within which the decision-taking elements have the power to cause action to be taken.
- A business process has physical and abstract (the knowledge of humans) resources, which are at the disposal of the decision-taking elements.
- A business process has a guarantee of continuity and can adapt to disturbances.

In summary the concept of a business process can be used to represent a set of integrated activities and flows that as a whole produces outputs that fulfil a purpose with respect to an external customer. The concept embodies four basic systems ideas and its characteristics are dominated by the human activities that form part of the integrated set of activities and flows.

Despite all the similarities between the concepts of HAS and a business process, there is more emphasis on the links between activities when using a business process to view a manufacturing company. A business process encourages those who use the concept to examine more closely the links between activities across the whole company especially those links between activities of different departments.

One of the requirements for a model based approach derived in Section 4.7 was to encourage "the understanding of existing systems and the definition of the requirements of the system from a company-wide (systemic) perspective". The use of a business process would encourage such a perspective to be taken and would enable an activity view to be modelled as a business process is concerned with activities and flows.

8.2 A business process view of a manufacturing company

Business processes exist as part of a hierarchy of processes. It is the use and awareness of a hierarchy and the relationships that exist between every part of each process and the company as a whole which ensures that any study of a company using the concept of a business process is systemic. Without taking a systemic view of the company there is the possibility that improvements made to one part of a business process may result in problems in other parts of the company. For example, increasing the degree of customisation that a customer can request may increase orders for products, however, without improving the production system to cope with the increased variety orders may be delivered late as the increased variety could slow down the production of the products.

With respect to CAPM systems and the observations made in Section 4.6, it was the lack of a systemic view in the company studied that contributed to the failure of the CAPM system to meet expectations. There were problems with the failure to consider all components of the CAPM system; with integration with other systems; with organisational changes that had an influence on the CAPM system; and with functional boundaries between departments reinforced by functional-based performance measures.

8.2.1 Identification of business processes

There are many examples of companies identifying a hierarchy of business processes. It is one of the initial activities in the majority of documented approaches that use a business process including those developed by Coopers and Lybrand (Johansson et al 1993), IBM (Kane 1986), British Telecom (Harvey 1994) and Lucas (Parnaby 1993). The number of business processes identified at the various levels within the hierarchy varies considerably from company to company. Davenport (1993) gives a number of reasons for this variation:

- Processes within companies are almost infinitely divisible.
- The identification of processes can be exploratory and revisionary.
- A company seeking to carry out incremental changes is likely to focus on improvements in subdivisions of processes whereas for radical changes a company should attempt to define processes as broadly as possible.

Examples of process identification by companies can be found in Davenport (1993) and the Business Intelligence report on BPR (Harvey 1994) and in many case studies in journal articles, for example Shapiro et al (1992) and Davenport and Short (1990).

8.2.2 Definition of business process boundaries

In systems thinking the definition of system boundaries can be problematic (Checkland 1981). The definition of process boundaries can also cause considerable difficulty (Arnstein and Dickerman 1992). The difficulties in deciding on the boundaries of a business process are made more complex by the basic ideas that business processes exist in a hierarchy and that a business process just like a HAS can have a multiplicity of objectives. Kaplan and Murdock (1991) and Hammer and Stanton (1995) provide sets of principles to help companies define their business processes. These principles include the following:

- for each business process there should be a set of specific inputs and outputs (Hammer and Stanton 1995);

- each process may cross a number of organisational boundaries (Hammer and Stanton 1995);
- there should be a focus on goals and ends rather than actions and means (Hammer and Stanton 1995);
- the boundaries of processes should make sense from an external (customer) perspective (Kaplan and Murdock 1991);
- dependencies between processes should be minimised (Kaplan and Murdock 1991);
- all the processes should relate to customers and their needs, either directly or as contributors to other processes (Kaplan and Murdock 1991).

The basic idea of a business process having a hierarchical structure of sub-processes and itself being part of a hierarchy of business processes is used in the next section. In addition, a view of a manufacturing company is defined that will enable a generic business process to be identified that relates specifically to production activities and production management.

8.2.3 Defining levels of business processes

If the company is regarded as a single process, the representation of the whole process may be described as level 0, the most abstract and general level. At the next level, level 1 of a hierarchy of business processes, most reported cases identify between 3 and 20 business processes. Business Intelligence's report (Harvey 1994) provides a table of the core process taxonomies of a number of consultants, the numbers range from 7 to 20 core processes. A number of leading companies have identified between 10-20 processes at level 1 including BT with 15 processes, Xerox with 11 processes and IBM with 10 processes.

Some authors describe a level 1 of between 3 and 5 processes, with between 10 and 20 processes at level 2. Parnaby (1993) describes 3 processes at level 1 and 16 at level 2 at Lucas. Other similar hierarchies are described by Pagoda (1993), Harrington (1984) and Veasey (1994).

The companies that define a small number (3-5) of processes at level 1 generally differentiate the processes using the concept of added value in a similar way to Porter (1985). Porter identifies "primary" and "support" activities in his "value chain" concept. The "primary activities" are those activities that interface with the external customer and add value to a product either by designing, manufacturing or by selling the product. The "support activities" are those activities that enable the "primary activities" to take place.

Porter does not deal expressly with those activities which do not directly add value to the customer such as the direction setting, enabling change or managing performance activities. These "management" activities represent a third type of process. For example, Veasey (1994) refers to "Management, Support and Value Adding" processes; Royal Mail have "External Customer, Support and Management" processes; Lucas have "Development, Delivery Operations and Support" processes; Pagoda (1993) have "Manage, Operate and Support" processes. The CIM-OSA standard (AMICE ESPRIT 1989) also groups processes into "Manage, Operate and Support".

8.2.4 The CIM-OSA Standard

The CIM-OSA standard provides a recognised framework within which to group the processes identified by companies. The first two types of processes are the "Operate" processes that add value and the "Support" processes that enable the "Operate" processes to function. "Operate" processes are viewed as those which are directly related to satisfying the requirements of the external customer, for example the transformation of an order into the delivered product. The "Support" processes include the financial, personnel, facilities management and information systems provision activities. The third type of process, the "Manage" processes, are the processes that develop a set of business objectives, a business strategy and manage the overall behaviour of the company. The value added by the "Operate" processes with the aid of the "Support" processes is

> the value defined by the firm's mission statement and strategy to the customer (Meyer 1993).

The "Manage" processes are therefore significant because the outputs of the "Manage" processes, for example the business strategy, define what value means to a specific company (Meyer 1993) and hence what value the "Operate" processes add to the product.

This research is concerned with management of the production activities that transform inputs into products to fulfil a customers' orders. This transformation can be viewed as being an "Operate" type of process because it is directly related to satisfying an external customer's requirements.

8.3 The "Operate" processes

The "Operate" processes are those processes which directly produce value for customers. Value is added if activities lead directly to the fulfilment of a customer's requirements. The core operational processes identified by Champy (1995) and Meyer (1993) for a company are "customer service", "product development", and "order fulfilment". The "customer service" process transforms knowledge of customer requirements and the market into customer orders. The "product development" process transforms the actual or perceived requirements of a customer into a design that can be manufactured. The "order fulfilment" process takes the order, manufactures and delivers the product to the customer.

According to Hammer and Champy (1993), Meyer (1993) and Johansson et al (1993) the "Operate" processes are the processes where greatest advances in competitive advantage can be made. The "Operate" process that is of particular interest to this work is the "order fulfilment" process that can be identified in all manufacturing companies.

The "order fulfilment" process has been described as being a business process that contributes to the company by directly adding value for a customer. It starts with a customer order and ends with the delivery of a product to a customer. The purpose of the "order fulfilment" process of a manufacturing company is to fulfil an order to meet the requirements of the customer whilst balancing the needs of all stakeholders. In a manufacturing company, part of the "order fulfilment" process will be the sub-process of manufacturing products by transforming the raw materials into products, other sub-processes include purchasing components and raw materials, planning the manufacture by transforming information into instructions and requirements.

8.4 "Order Fulfilment" Process and CAPM

The view taken during this work is that in the context of manufacturing companies the concepts of an "order fulfilment" process and a production system are analogous.

An integrated set of activities bound by the concept of an "order fulfilment" process or a production system perform a transformation with the purpose of satisfying the requirements of all stakeholders. A set of activities bounded by using either concept would have the same general inputs, for example, raw materials, engineering drawings, instructions to manufacture, bought-out parts. The transformation of the inputs by the set of activities in either case would produce outputs that include a product to meet the customer' s requirements and information and orders to suppliers.

A sub-set of the activities bound by either concept could be viewed as a manufacturing system, that is, the set of activities that transforms raw materials into products. Other sub-sets of activities that can be identified in the overall set of activities bound by either concept include for example, a "purchasing" subsystem or sub-process and a "internal transportation" subsystem or sub-process. Of particular interest to this work is the subsystem of activities that manages the overall set of activities and enables it to adapt to environmental changes. According to Checkland (1983)

> since the transformation process (T) is being taken to be a purposeful system, it will itself have to contain a control subsystem which will monitor the processes of T and take action if they are not in-line with the requirements according to some selected performance measures.

In the case of a production system, it was previously defined in Section 1.4.2 that a CAPM system may be regarded as a control subsystem of a production system. Given that the two concepts are analogous, the sub-set of activities that may be regarded as a CAPM system may also be identified as a control subsystem of an "order fulfilment" process.

The use of the concept of an "order fulfilment" process instead of the concept of a production system encourages the same general set of activities to be viewed with an emphasis on the linkages between activities. That is, the concept of a business process encourages a view of the set of activities that focuses on how the outputs are produced to meet stakeholders' requirements by an ordered interaction of activities linked by flows of entities such as information and materials.

The relationship between the "order fulfilment" process and the CAPM system that has been established enables the concept of an "order fulfilment" process to be considered as a appropriate concept to be used as part of an approach to the design and implementation of CAPM systems.

8.5 Using a "process" focus

The concept of a business process can be seen to be useful especially if one of the problems in developing systems such as a CAPM systems is coping with the traditional functional structure of companies, functional-focused performance measures and requirements. Such a problem was identified in Section 4.6.

The traditional functional structure has been established in companies throughout most of this century. It has been reinforced by incentive schemes, procedures and policies. In considering the business in terms of business processes there is the advantage of provoking thought about many underlying assumptions and providing a new perspective.

To help users understand the process context for their own activities within a new organisational context, that is, from a business process context, a model representing the new context and the activities being performed would be useful. Section 7.5.3 discussed the role of generic models in representing a set of generic activities that provide a conceptual model of a company or part of it and how "as-is" models can be derived from the generic model. In line with that, a generic model of the "order fulfilment" process would provide a model of activities and flows within a company that users could understand and in which they could see the context for their own activities in fulfilling a customer order. Such a model could be used to initiate and structure debate about the specification of a CAPM system.

8.6 Conclusion

The objective of this chapter was to establish how the concept of a business process can be used to assist practitioners. The benefits of using the concept of a business process to understand the part of the company controlled by the existing CAPM system and to specify what is required of a CAPM system are that:

- it encourages a systemic view that cuts across functional boundaries;
- performance measures that are used to assess the decisions taken by the CAPM system can be developed so that they are process-wide as opposed to functional;
- it provides a better view of how the transformation takes place, through an emphasis on the linkages between activities;
- it encourages the questioning of underlying assumptions before requirements are defined;
- it provides a logical structure within which users can identify their own activities and understand their involvement in the whole transformation from an order to a finished product delivered to a satisfied customer.

Summary

This chapter has established that a business process is a concept that embodies the same characteristics as a Human Activity System. A business process is a concept that gives particular emphasis to the transformation and the linkages required between activities to perform the transformation.

A view of a manufacturing company as a hierarchy of business processes has been presented with the "order fulfilment" process as part of the hierarchy. The view adopted for this work is that the "order fulfilment" process and the production system perform the same transformation to meet the same objective. Associated with such a view is that the concept of a CAPM system can represent the control subsystem of either the "order fulfilment" process or the production system.

A generic model of the "order fulfilment" process could be used as a method of getting users involved in the specification of a CAPM system. It could be used to initiate and structure debate about the activities and flows that are involved in the process of fulfilling a customer order and what is required of a CAPM system to control the process so that it meets the objectives of the company.

Having identified a suitable concept, a business process, and the method in which it can be used as part of an approach to meet the requirements derived in Section 4.7, the next stage of the work is to develop and validate a generic model of the "order fulfilment" process and to propose how it can be used as part of an improved approach to the design and implementation of CAPM systems.

Chapter 9. Research and development of a generic process model

This chapter will describe the development of a generic process model that can be used during the initial stages of a model based approach to the design and implementation of CAPM systems. There are a number of reasons for developing a generic model to be used during the initial stages of an approach. A generic model representing an activity view that is relevant to a situation can be used to initiate and structure debate between users and practitioners about the situation. The model provides a guiding structure to encourage those using the generic model to derive an "as-is" model by comparing the generic model with their knowledge of the existing situation.

By using the concept of a business process and in particular the concept of an "order fulfilment" process, the generic model will be relevant to the situation of designing and implementing a CAPM system. A business process view of the situation should encourage those undertaking the project to take a company-wide perspective; take a different view of the company that will encourage them to question underlying assumptions; focus on the transformation and linkages between activities; and identify specific activities carried out by users and the context of those activities within the overall transformation.

The overall result of using a generic model as part of an approach should be that the users will have an improved understanding of the situation because of improved communication and a shared perspective. This improved understanding should enable them to specify their requirements for an improved CAPM system.

This chapter will describe the approach that was used to develop a generic model of an "order fulfilment" process, the issues relating to its development and the modelling technique used to represent the model. A diagram extracted from the model representing a high level view of the generic "order fulfilment" process is presented at the end of the chapter whilst the complete model can be found in Appendix 1.

Before undertaking the development of the model, its purpose needs to be established together with what attributes it should have in order to meet that purpose.

9.1 Purpose of the generic process model

The purpose of the generic model representing the "order fulfilment" process is to initiate and structure the debate around the activities and flows that are involved in fulfilling a customer order within a particular company. The debate and activities associated with the comparison of the model to the users' view of their company should improve understanding and encourage a common systemic perspective from which to develop a set of requirements for a CAPM system.

To fulfil this purpose, the model should represent an activity view of the "order fulfilment" process showing the structure of the process, activities that are performed, who or what controls the process, what things it transforms and what it produces. It should represent the "order fulfilment" process in such a way that is simple, easy to understand and meaningful for users at all levels of the manufacturing company and other external parties that may be involved. The use of the model should help the users take a systemic perspective of how the integration of activities and flows contributes to the overall purpose of the process and company. The content of the model should be suitable for all types of manufacturing companies and control strategies they use or will use in the future.

The model to be developed is intended to be used in a way that embodies the principles of SSM. The model can be viewed as a conceptual model that represents one perspective of a situation in a manufacturing company. The approach used to develop the model should therefore use the underlying principles of SSM.

9.2 The development of the model

The approach to the development of the model was based upon the core method of SSM that was described in Section 6.2. The stages in the development of the model were as follows:

- Name the relevant process using "primary task".
- Formulate root definition meeting CATWOE requirements.
- Build model based on one transformation.
- Develop flow versions of the model (abstract or physical flows).

9.2.1 Assumptions

By using the approach that is described in the previous section, a generic model of the "order fulfilment" process was developed. The overall assumption was that the concept of a business process was to be used to enquire into the real world situation that was unstructured and problematic. There was an assumption that the relevant process for this work was the "order fulfilment" process. The first stage was to define the "order fulfilment" process as a whole and to understand the context within which it exists.

9.2.2 Naming the relevant process

The relevant process has already been named, that is, the "order fulfilment" process. It is determined by its organised purposeful action or "primary task" and its interaction with the other processes in the company to meet the objectives of the company.

The integration of the "order fulfilment" process with the other processes is important if the "order fulfilment" process is to contribute to the company's objectives. The first task is to identify a hierarchy of business processes that includes the "order fulfilment" process.

9.2.2.1 Integration with other processes

A view of a manufacturing company using the concept of a business process was described in Section 8.2. The view used the CIM-OSA standard (Jorysz and Vernadat 1990) of "Manage, Operate and Support". The same view was used as part of the development approach to define boundaries of those processes which directly contribute to the value added to a customer order by the company ("Operate" processes) and those processes that do not directly contribute as such ("Manage" and "Support" processes). The four "Operate" processes are defined and described in Childe et al (1995) and Maull et al (1995a), and they are Get Order; Develop Product; Fulfil Order and Support Product.

Culverhouse (1993) provides a framework based on the amount of new knowledge required, which helps to identify the interactions between the four "Operate" processes (Maull et al 1995b). This framework defines four "design routes" between arrival of a customer order and the manufacture of the product in terms of the amount of new knowledge required to meet a customer's requirements.

Having gained an understanding of the other company-wide processes that interact with the "order fulfilment" process, the process can be defined using the "primary task" and a root definition. The combination of the "primary task" and the root definition should provide anyone who wants to use or understand the model with a clear starting point.

9.2.2.2 Defining the "primary task"

The concept of a "primary task" (Miller and Rice 1967) can be used to determine what should be included within or excluded from inside the boundaries of the "order fulfilment" process.

The "primary task" of the "order fulfilment" process was defined as the fulfilment of a customer's order to the customer's requirements and satisfaction, whilst balancing all the stakeholders' requirements.

The "primary task" allows the "order fulfilment" process to be distinguished from other processes within a company by identifying those activities and flows that contribute to the "primary task".

9.2.3 Root definition of the "order fulfilment" process

To develop a rigorous definition of "order fulfilment" process, a root definition of the process was defined to ensure that the process as a whole was understood.

A particular company may have a unique root definition for its "order fulfilment" process depending on the perspective of the company in question. Any company may therefore identify a different set of activities that must be done in order to be the process defined by the individual company's root definition. For example, one company may only assemble products to fulfil a customer's order, another company may manufacture every single component from raw material to fulfil a customer's order and therefore the set of activities would be different for each company.

The objective of the root definition of the generic "order fulfilment" process is to describe a generally accepted view of the "order fulfilment" process from which a conceptual model of a generally accepted set of activities can be developed.

Rhodes (1985) provides a generic root definition for the manufacturing function of a manufacturing company. This provided the template from which the author developed the root definition for the "order fulfilment" process. The author's root definition underwent a number of development activities to ensure that it represented a shared view. It was reviewed by colleagues and published in a number of research papers (Weaver et al 1995, Childe et al 1995, Maull et al 1995a, Maull et al 1995b).

The root definition that captures the shared view of those who reviewed it, with respect to the "order fulfilment" process of any manufacturing company is as follows:

> *The "order fulfilment" 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 result in the fulfilment of the external customer*

order or enquiry. The process constantly seeks to fulfil customer requirements whilst balancing stakeholder requirements.

The "Actors" (Section 6.2.2) in the process are the people and machines within the manufacturing company under consideration. These cannot be defined more precisely, as the root definition has to preserve its generic nature. The "worldview" (Section 6.2.2) for the root definition is that it is intended to be acceptable to the majority of manufacturing companies. "Ownership" (Section 6.2.2) can only be expressed as the owner of the manufacturing company.

9.2.4 Develop conceptual models based on a single transformation

Once the root definition defining a generic view of an "order fulfilment" process had been established, a conceptual model that represented the set of activities that are required to produce the transformation defined by the root definition was developed. The task can be described in two stages, "Building the model based on one transformation" and "Making the links in the model". There was considerable iteration between the root definition and the development of the conceptual model.

9.2.4.1 Building the model based on one transformation

The concept of a business process embodies the idea of hierarchy, which means that there is a hierarchy of sub-processes or activities that form the business process itself. The conceptual model that is derived from the root definition could represent the process at many different levels of the hierarchy. Paraphrasing Wilson (1984), the first level of the model will usually contain between five and ten activities. Any attempt to develop models with more detail and which are hence more complex than this will make it difficult to defend the set of activities at further levels of detail as being the minimum number of activities necessary to perform the transformation.

A generic model of the "order fulfilment" process of between five and ten activities derived from the root definition would be too basic to be of more than little help to those using the model to compare with the activities undertaken as part of their own "order fulfilment" process. However, each of these activities defined at the first level can be decomposed into second level activities, and these can be decomposed into a third level of activities and so on. Such a decomposed model would still be a model of the "order fulfilment" process defined by the root definition. However, it would have to be accepted that it would be more and more difficult to defend the assertion that the activities and interactions at the lower levels still represent the minimum set of activities defined by the root definition.

One of the objectives of the model was to provide a starting point from which the company should be able to develop a model of its existing process before it defines its requirements for a CAPM system. The level of detail needed to be sufficient as to stimulate debate and promote understanding, yet it could not be too detailed so as to become less and less generally applicable to most manufacturing companies. The actual level of detail that activities were decomposed to in the generic model was based upon the experience gained from other models created for a number of manufacturing companies.

The information used to identify and understand the activities was extracted and assimilated from a number of sources. The sources included general models of manufacturing companies (Porter 1985, Meyer 1993, Jorysz and Vernadat 1990), generic models (Harrington 1984, Baines and Colquhoun 1991, Browne et al 1988, CAM-i 1985, Childe 1991) and models representing the "order fulfilment" process in real manufacturing companies in a variety of modelling techniques.

At the highest level of resolution a set of five activities was identified as the set of activities that was required to be defined as the process in the root definition. These were Plan Order Fulfilment; Obtain Required Items; Manufacture Products; Dispatch Customer Order; Manage Process Information. Having established the highest level of resolution, each of the activities were decomposed to further levels. During each decomposition the approach used was to identify the minimum set of activities that must be done for the activity being decomposed to carry out the transformation of its inputs to its outputs.

At the lower levels of decomposition many of the activities that are represented within the "order fulfilment" process were adapted from a generic task model developed by Childe (1991). Childe's task model was based on the proposition that there are a key set of tasks or activities which are common throughout manufacturing companies (all manufacturing companies order materials, take orders from customers etc.).

9.2.4.2 Making the links in the model

The activities represented what must be done to perform the transformation defined by the root definition. At this point, the model did not represent what needed to be transformed, what was produced or what constrained or controlled each activity.

To identify the interactions between activities, information was extracted from the literature sources described in the previous section and from models developed by the author and his colleagues. These models represented the "order fulfilment" process in a number of actual manufacturing companies using $IDEF_0$ and were developed for the purposes of understanding the "order fulfilment" process to enable improvements in the process to be made.

The types of flows that are represented in the generic model can initially be divided into physical and information flows. That is, flows of physical materials which are transformed by value adding activities and information flows where the value is in the information itself and not the medium of transmission, as in the case of a paper proforma or an electronic signal. The information flows can be further divided into seven categories of information described by Jorysz and Vernadat (1990). These seven categories of information are:

- *Product information* which describes what to produce, for example, drawings, parts lists;
- *Process Information* which describes how the product should be produced, for example, process plans;

- *Production Information* which describes the quantities to be produced and shop floor progress;
- *Planning Information* which describes the schedules, inventories and plans;
- *Resource Information* which describes the facilities that produce the products;
- *Administrative information* which describes management information, for examples, customer orders;
- *Organisation information* which describes responsibilities.

The generic model includes generic flows between activities representing the first six types of information. The seventh type of information relating to the company and responsibilities is company specific. The information flows between activities will be important considerations in the specification of any software that might be required as part of a CAPM system.

9.3 The generic "order fulfilment" process model

The approach to the development of the generic "order fulfilment" process model has been described in the Section 9.2. There was substantial iteration between each part of the development approach as the author gained more knowledge about the "order fulfilment" process and further models and information were found. Chapter 11 describes the validation stages of the model and the changes and improvements that were made as a result of more knowledge being gained. The model that was developed from the root definition using $IDEF_0$ can be found in Appendix 1.

The model attempts to represent the "order fulfilment" process of a manufacturing company that forms part of any of the four types of manufacturing companies identified by Wortmann (1990). These are Make-to-stock, Assemble-to-order, Make-to-order and Engineer-to-order. The "order fulfilment" process of a make-to-stock company will be significantly different from that of an engineer-to-order one.

To fulfil an order in a make-to-stock company, the process would involve little more than releasing the stocked products from the warehouse and delivery to a customer. There would then be a need for replenishment activities to manufacture more of the products that would have been sold.

To fulfil an order in an engineer-to-order company, the product must be designed to the customer's requirements, manufacturing methods may have to be agreed upon, the product needs to be manufactured and finally delivered to a customer. The amount of new knowledge required in such an order also means that more interaction is required between the processes and the "order fulfilment" process is generally more complex (Kuhlmann 1991).

Many manufacturing companies cannot be categorised as one particular type defined by Wortmann (1990). For example, the company described in Chapter 4 was involved in manufacturing products that were sometimes engineer-to-order and on other occasions, especially spares, were make-to-order. During any comparison between the generic model and the "order fulfilment" process in a particular company it is expected that the user and practitioners will find redundant activities in the model because of its generic nature.

In most manufacturing companies, there are many terms and names of documents that have a specific meaning within the company. The terms used in the model are as generic as possible, for example, an "enquiry feasibility report" could represent a verbal "yes" from the Production Manager to the Salesman or a detailed report giving an analysis of the capacity requirements, delivery date feasibility and additional capital costs for investment in new tooling. Each term used in the model is defined in the glossary in Appendix 1.

9.4 Modelling technique used to represent the model

The requirements for a modelling technique that was capable of representing an activity view of a business process and that was suitable for use within an approach that uses SSM were described in Chapters 6 and 7. $IDEF_0$ (FIPS PUBS 1993) was identified as a modelling technique that met the requirements.

$IDEF_0$ uses a simple syntax that consists of a small set of symbols including single sized boxes and arrows. Using a set of rules to guide the positioning, decomposition, indexing and labelling of activities and arrows a complex system can be modelled. The basic building block of $IDEF_0$ is an activity box, with inputs, outputs, constraints and mechanisms. This was the generic building block that was used in the model. Porter (1985) uses a similar building block for each *value activity* which uses information and adds values to products. It has inputs, resources in the form of either humans or technology to carry out the transformation of inputs into outputs. The basic building block of $IDEF_0$ is shown in Figure 9.1.

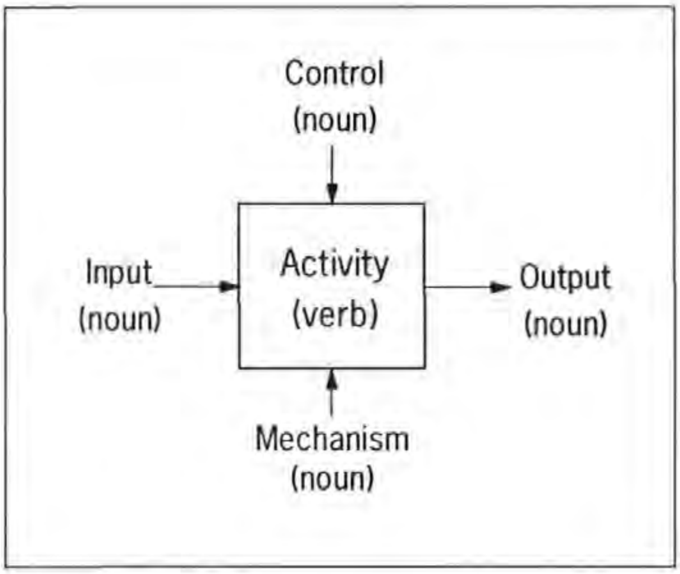

Figure 9.1. The basic building block of $IDEF_0$

The decomposition is used to break-up complex systems into smaller pieces which can be more readily understood and which are set in their proper context with respect to other system elements. An $IDEF_0$ model is an ordered collection of diagrams. Indexing ensures that diagrams are related in a precise manner to form a coherent model of the subject. The number of diagrams in a model is determined by the breadth and depth of analysis required for the purposes of that particular model. At all times the relationship of any part to the rest of the whole remains visible.

$IDEF_0$ provides the ability to show what is being done within a process, what connects the activities and what constrains the activities. It uses a structured set of guidelines based around hierarchical decomposition, with excellent guidance on abstraction at higher levels. If used well, this ensures good communication and a systemic perspective. An example of decomposition is shown in Figure 9.2.

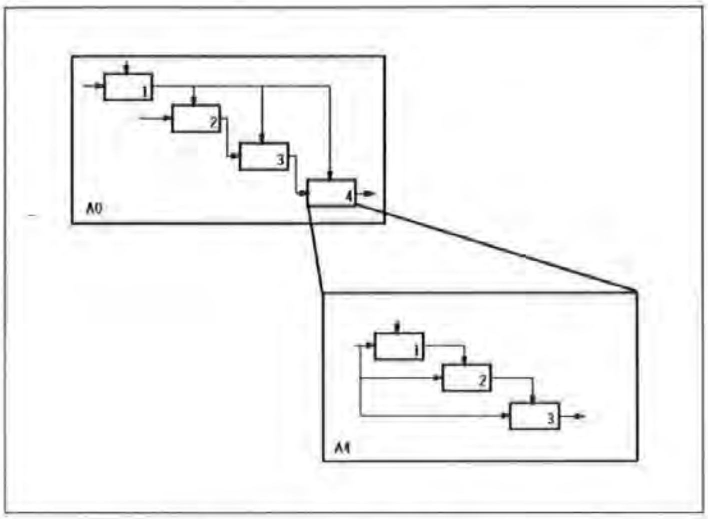

Figure 9.2. An example of decomposition.

Using $IDEF_0$ as a modelling technique ensures that the context for any part of a process model under analysis in relation to the whole of the process model is always known. Therefore, a company can focus on the part of a process model which it is particularly interested in and develop further levels of detail without losing its context within the whole process. A more detailed description of $IDEF_0$ can be found as part of the guidelines in Appendix 1.

One objective of the generic model is that it should allow knowledge and understanding to be shared or interchanged. This is particularly important if the company that is defining its requirements needs to communicate with vendors of the software required for the CAPM system. If the generic model is adapted to represent an "as-is" model of the company, then the "as-is" model is likely to be represented in $IDEF_0$. It would be advantageous if the model could be used by the chosen supplier of the software to understand the requirements of the company and if it could be translated into a form that was compatible with the software supplier's normal modelling techniques used for its own software development work. It has been noted that Lee et al (1994) have developed a "Process Interchange Format" syntax that purports to allow the translation of $IDEF_0$ models into object based models that are commonly used in software development (Jacobson et al 1994). This may provide the ability to translate $IDEF_0$ models into models suitable for use by software suppliers.

9.5 Diagram extracted from the model

The completed model consists of a set of diagrams, glossary and a node index that represents the structure of the model itself. Figure 9.3 shows the A0 diagram of the model which represents the five primary activities performed by the generic "order fulfilment" process. This is the most complex diagram in the model. It is the diagrams at lower levels of decomposition that would be used by participants undertaking a comparison to develop "as-is" models of their existing "order fulfilment" process.

The information that triggers the process is either a product enquiry (C1) or a product order (C2). Strategy (C3), is the overall controlling factor for the process. An order (C2) proceeds through the sub-processes until it is dispatched as the ordered product (O4). An enquiry enters the process (C1) and leaves the sub-processes as either customer communication (O3) or a request for product development (O1).

The five primary activities represented on the diagram shown as figure 9.3 are as follows;

- *Plan Order Fulfilment* - This activity establishes how the company is going to fulfil the customer's requirements. To accomplish this activity Product Information (Engineering Drawings and Process Plans), Process Management Information (Resource and Capacity Information), Customer Information and Business strategies are all required and the output of the activity is Planning Information and Purchase Requirements.

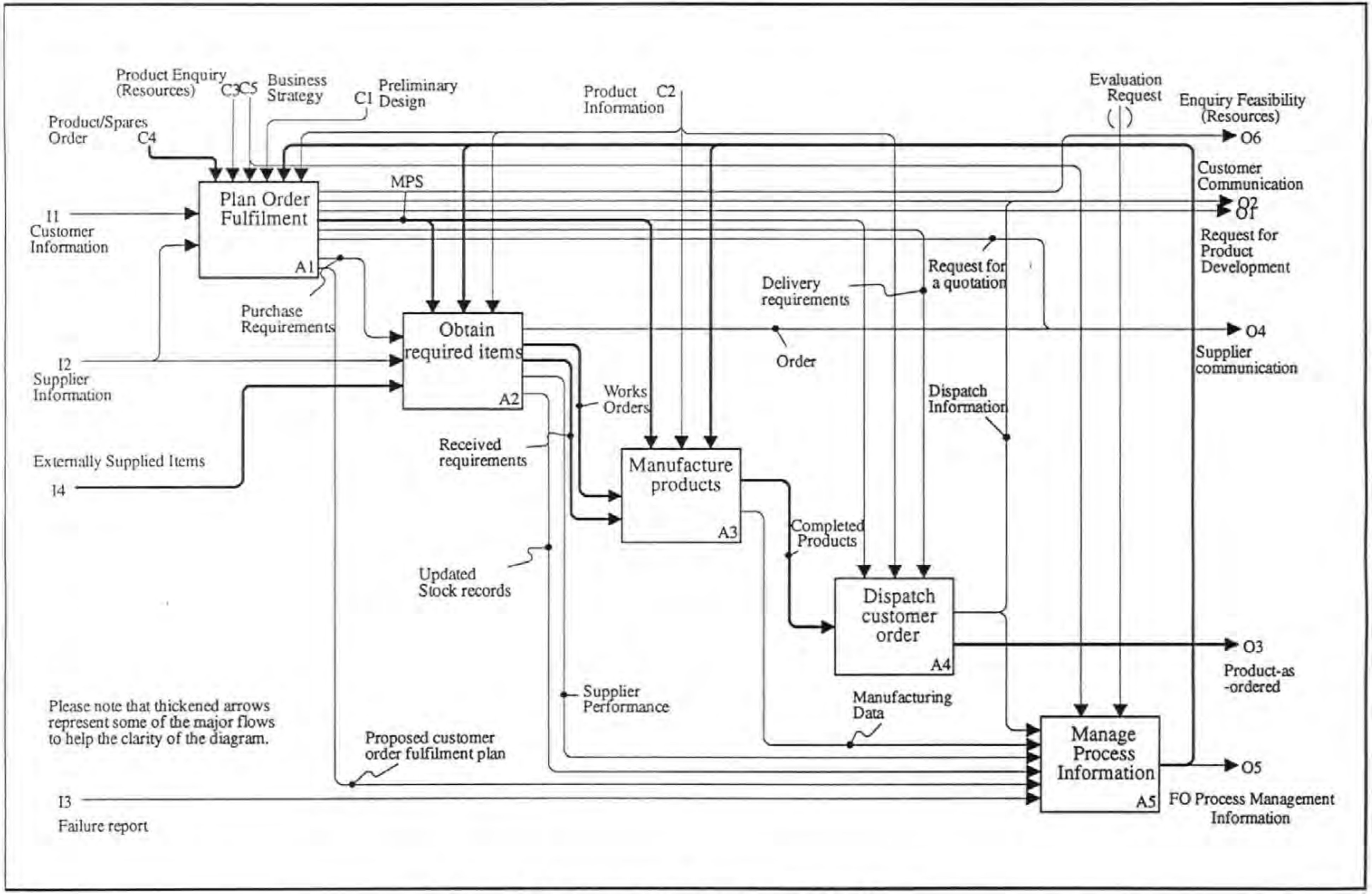

Figure 9.3 A0 diagram of the generic process model

- *Obtain Required Items* - This activity represents all activities that are involved in acquiring goods and services internally and externally to fulfil a customer's order. Planning Information controls this activity and Product, Supplier, Process Management Information are used. There is also the flow of physical items from suppliers into this activity. The outputs of this activity are orders to suppliers, and to the next activity, works orders and physical flows of externally obtained items.

- *Manufacture Products* - This activity represents the production activities together with the low-level scheduling on the shop floor, progress of work through the factory and monitoring performance. This activity is controlled by schedules and works orders. It uses Product, Process Management Information (Resources and Capacities) and transforms physical flows of materials into finished products.

- *Dispatch Customer Order* - This activity delivers the finished products to the customer. This activity is controlled by delivery requirements and transforms physical flows of completed products into collections of products to meet a customer's requirements.

- *Manage Process Information* - This activity evaluates supplier performance, manufacturing data, proposed plans from other activities to give information on process performance and up-to-date planning and capacity information to ensure the process meets the objectives of the company.

Some of these five primary activities are decomposed to a further four levels of detail and the complete model consists of over thirty-five diagrams.

Summary

This chapter has described the development of a generic model of the "order fulfilment" process of a manufacturing company. The model was developed using the core method of SSM.

The model is a conceptual model that was derived from a root definition. The root definition that was produced during the work defines a shared view of an "order fulfilment" process in a manufacturing company. The model provides an activity view of the "order fulfilment" process in a manufacturing company. It was developed using the modelling technique $IDEF_0$. Information from a variety of sources, including models from real manufacturing companies, was used to derive the set of generic activities and flows represented by the model.

The next chapter will propose how the generic model can be used and the structure of an overall model based approach to the design and implementation of CAPM systems in which the model could be used.

Chapter 10. Using the generic process model

The previous chapter described the development of a generic model of the "order fulfilment" process of a manufacturing company.

The objective of this chapter is to propose how the generic model should be used. This chapter will initially review the requirements of a model based approach and how it was suggested in previous chapters that the requirements could be addressed. The method of using the generic model to address some of those requirements will be discussed. This proposed method of use is based on soft systems principles. This chapter will then suggest alternative structures for an overall model based approach that could include the use of the generic model.

The objective of this chapter is not to develop an overall model based approach to the design and implementation of CAPM systems which on its own guides activities from strategy development through to an implemented CAPM system. Instead, the objective is to develop part of an overall approach that can be used to address some of the requirements that need to be met.

10.1 A review of requirements

A set of requirements of a model based approach was derived in Section 4.7. This would address issues that influenced the success of the design and implementation of CAPM systems. The approach is required to encourage:

- the definition of common objectives and business related-performance measures;

- the understanding of the existing systems and the definition of the requirements of the system from a company-wide (systemic) perspective;
- a common understanding and view through communication between all parties involved;
- the participation of users throughout the project;
- the designed CAPM system to include the integration of all elements (human, procedures, organisational structure and technology);
- the integration of the CAPM system with its environment.

Chapters 5, 6, 7 and 8 have identified ways in which some of these requirements could be met.

Chapter 5 proposed that the use of models could be a means of simplifying reality to improve communication, understanding and the ability of users to participate. Chapter 5 also suggested that the concept of a human activity system could be used to structure and understand manufacturing companies.

Chapter 6 proposed that an approach that was based on the principles of SSM would encourage a better understanding of the initial problem situation and objectives of those involved; a systemic view of the situation to be taken; and structured debate about relevant systems, different user perspectives and the many different elements that may be involved.

Chapter 7 proposed that a method that used a generic model of an activity view of relevant systems to help users derive "as-is" models of existing systems would improve the understanding of existing systems. The generic model could be used as part of an approach that used SSM.

Chapter 8 proposed that a generic model of the "order fulfilment" process of a manufacturing company represents a system relevant to the particular situation of designing and implementing a CAPM system. The model could be used as suggested in

Chapter 7 to encourage a systemic perspective to be taken; provide a different view that may result in new ideas from users; and allow the involvement of users.

A model based approach using the proposals above will help manufacturing companies to design and implement CAPM systems and address some of the issues that are currently being encountered. The next sections will proceed to describe how the proposals can be implemented.

10.2 The use of the generic process model

The requirements derived focus on the initial two stages of the systems life cycle that was described in Section 3.2, that is:

- Identification of problem/need;
- Investigation and analysis of the existing system and requirements.

The reasons given for focusing on these initial two stages were that many manufacturing companies lacked expertise in the initial two stages and it was at these stages that many decisions were made that could have resulted in the failure of the CAPM system to meet expectations. The use of the generic model is intended to help address some of the issues encountered during these initial stages.

The pre-condition to using the generic model is the realisation that there is a "possible" problem situation relating to the general area of fulfilling customers' orders and how the activities linked with fulfilling such orders are managed. The realisation may have emerged from a variety of circumstances, for example, through a strategic analysis that may form part of an overall approach to the design and implementation of CAPM systems, a change in manufacturing strategy or a failure to meet objectives or performance measures or changes in customers' expectations.

Having decided that there is a possible problem situation, any approach using SSM would consider the problem situation to be unstructured and so the next step would be to use concepts such as a system or a process to provide some structure. These ideas form the basis upon which the generic model can be used. It is suggested that the model will be used by a group of participants.

10.2.1 Participation in the approach

It is envisaged that there will be a facilitator or team leader who will guide a group of participants through the use of the model. This group of participants may be selected from amongst those individuals who have a direct involvement in the fulfilment of a customer's order (Meyer 1993). It is recommended that the group of participants using the generic model are users who will be involved throughout the whole of a model based approach to the design and implementation of CAPM system. This direct involvement of users helps initiate change and eases the implementation of the changes that may be decided upon (Meyer 1993).

10.2.2 The method of using the model

Having established some general principles regarding the participation of users in the use of the model, the method of using the model is suggested here. Its method of use will be validated in the next chapter.

Prior to the use of the model, it would be advantageous for the facilitator or team leader to be familiar with the model, its viewpoint, its purpose, how it was created using $IDEF_0$ as the modelling technique. There are guidelines that cover these points in Appendix 1 that accompany the generic model.

10.2.2.1 Understanding the "order fulfilment" process as a whole

The model could be presented to participants in a variety of ways by the facilitator or team leader. It is recommended that the root definition, the For Exposition Only (FEO) diagrams that set the context for the model and the A-0 diagram be introduced first. The viewpoint and purpose of the generic model should be clearly stated. Emphasis should be placed on the notion that it represents a view of the "order fulfilment" process of a manufacturing company and that it is not intended to be prescriptive. The model should be used as a starting point for discussion and debate about the "order fulfilment" process within the particular company. The facilitator should encourage the participants to compare the root definition and diagrams with their own perceptions of their company and to debate and make changes to the root definition and context diagrams accordingly.

10.2.2.2 Comparing the model with perceived reality

Once the context diagrams and root definition have been discussed and altered to represent the shared view of the participants, further diagrams from the model should be introduced to the participants. The introduction should be approached in a top-down manner from the A-0 diagram. This encourages the participants to take a systemic perspective by understanding the whole process first, and then any changes made at the highest level can be reflected at low levels as the team "walks through" the diagrams following the flow of the process.

The facilitator should point out any differences between the root definition and context diagrams developed by the participants and those of the model. This should help initiate a comparison between the participants' view of the situation and encourage changes to the model. For example, the types of changes made could include altering activities and information flows, removing activities, adding more activities, altering labels to reflect the terms used by the particular company. The model gives no indication of who is responsible for activities. One of the objectives of understanding and comparing the model with the participants' view of their "order fulfilment" process should be to establish who carries out or is responsible for the activities.

The participants should be able to develop their own model of the "order fulfilment" process using the generic model as a template. This can be described as "Model Overlay" (Wilson 1984) which was described in Section 6.2.4 as the activities of restructuring the conceptual model (generic process model) so that it reflects the participants' view of the real world situation and comparing the two models to generate ideas.

The participants may progress through different phases during their comparison activities. These phases can be described in terms of SSM (Section 6.2). The phases may include:

- the participants using their own perspective of reality and their own root definition to make changes to the model (*Changing the root definition and conceptual model*);

- the participants identifying what they believe to be missing activities or sub-processes that are relevant and subsequently changing the root definition and model (*Deciding on relevant systems, developing root definitions and conceptual models*);

- The participants identifying immediate desirable and feasible changes to the "order fulfilment" process and deciding to implement them (*Comparing conceptual model with reality, deciding on desirable and feasible changes, implementing changes to improve the problem situation*).

The text in italics and brackets uses the language of SSM (Checkland and Scholes 1990) to describe the possible phases.

Ultimately, the result of the method will be a shared view of the "order fulfilment" process within the company and an improved understanding by all participants of the overall "order fulfilment" process.

The model produced can be used for further analysis to define what activities need to be managed by the CAPM system and what information is required to meet the objectives. It could also be used to communicate ideas and views to other users or even to a third party software vendor in discussions about what software may be required.

Possible results from the use of the generic model may include the definition of requirements for an improved CAPM system including changes in procedures, policies, responsibilities and requirements of software. Another result could be changes to other aspects of the company that were not initially identified as affecting the situation under investigation.

The use of the generic process model is intended to form part of an overall model based approach to the design and implementation of CAPM systems.

10.3 Possible structures for the model based approach

According to Mingers and Taylor (1992) any attempt to change the general structure of the approach manufacturing companies use to improve systems is likely to encounter resistance. The ability of the generic model to be used as part of approaches that have different general structures is important if the model is going to be useful to many different manufacturing companies.

The next three sections will describe three different ways of including the use of the model in an overall model based approach to the design and implementation of CAPM systems. The three alternative structures of an overall model based approach are to use a structure similar to SSM, and two other structures that were described by Miles (1988), *grafting* and *embedding*.

10.3.1 Continuing the approach using SSM

The use of the generic model enables the participants to be introduced to some of the principles of SSM. By developing their own versions of the root definition and conceptual model from the generic versions given to them, they have undertaken part of the SSM. They have the means to continue using the SSM by comparing their conceptual model with reality and by deciding upon desirable and feasible changes that can be implemented. For example, having developed their conceptual model, the participants may identify activities involved in the "order fulfilment" process that are unnecessary and hence decide that it is desirable to remove them and they may then consider the improved problem situation that results, thereby continuing the SSM cycle.

10.3.2 Grafting

Grafting (Miles 1988) describes an approach that uses soft systems principles and techniques to structure an ill-structured problem situation before using a hard systems approach to develop a solution to the problem.

The use of the generic model is based on soft systems principles that encourages participants to reach a consensus and an understanding of an ill-structured problem situation. The model could be used before an approach using a hard systems structure is utilised to develop a solution to the problem.

For example, after using the generic model to reach a consensus and understanding and to develop a conceptual model of what activities and flows need to be managed, the participants can revert to a systems life cycle approach (a hard systems approach). This could take the form of identifying requirements for a CAPM system that will provide a solution to the understood and structured problem and then continuing with a hard systems approach through the design and implementation phases of the systems life cycle.

The grafting approach can be viewed as using SSM to transform an ill-structured problem into one that is well defined (Miles 1988).

10.3.3 Embedding

Embedding (Miles 1988) describes an approach that uses SSM at a meta-level which structures the overall approach and dictates the underlying systems thinking whilst hard systems thinking methods are used at a lower level when required by the participants in the approach.

The generic model could provide a starting point using SSM and enable the participants to continue using SSM. In cases where the desirable and feasible changes to the real world are identified during the use of the generic model or continued use of SSM which are of a procedural nature, hard systems methods can be used (Miles 1988) to carry out the changes. Having undertaken the hard systems methods, the meta-level SSM can be returned to and the improved problem situation investigated further. For example, if the participants used the model and identified some desirable and feasible changes to existing company procedures and computer based procedures, hard systems methods could be used to undertake the redesign of the procedures. The participants would then revert to a soft systems methodology to understand the improved problem situation.

10.4 Addressing the problems of using the principles of SSM

Some writers' concerns about the practicalities of using SSM were discussed in Section 6.3. These included:

- the language being regarded as "off-putting to users";
- SSM being perceived as time consuming;
- SSM being weak in dealing with power structures;
- the suitability of the modelling techniques suggested.

The use of the generic model as part of an overall model based approach attempts to address these concerns in a number of ways.

The use of the generic model in the way described in Section 10.2 enables participants to consider a conceptual model at the beginning of the approach which should reduce the concern of SSM being time consuming. The use of the generic model as a template for their own conceptual model should also reduce the time taken to develop a model (or tangible result to show to a manager).

The generic model provides a practical and applicable example that can be used to encourage a soft systems way of thinking, whilst avoiding concerns of using the "off-putting" language. The generic model also provides an independent view of the "order fulfilment" process that participants should feel able to criticise.

The concern about power structures and their influence in SSM is difficult to address and depends mainly on the skills of the facilitator or team leader.

The use of $IDEF_0$ as the means of representing the generic "order fulfilment" process addresses the concern of modelling technique suitability (Section 7.6).

Summary

This chapter has proposed how the generic process model can be used. The use of the model involves presenting the participants with the model and root definition that was developed using SSM. The participants are encouraged to compare the model with their view of their company's "order fulfilment" process and to alter the root definition and generic model to reflect their shared view of their "order fulfilment" process. This method of using the model has adapted SSM so that some of the criticisms about SSM have been addressed for the particular situation within manufacturing companies where they are seeking to improve the management of production activities.

Three alternative structures for an overall model based approach to the design and implementation of CAPM systems have been proposed. Each alternative structure could include the use of the generic model as part of such an approach.

The next phase of the research work, the testing phase, will validate the generic model of the "order fulfilment" process and test whether the model can be used to meet the requirements and key needs of practitioners.

Chapter 11. Validation of the generic process model

The Explanatory phase of this work has resulted in the development of a generic process model and proposed how the model could be used as part of a model based approach. The next phase in the research cycle is the Testing phase. The objective of this phase is to determine if the model and its use meet the needs of a wide group of practitioners.

This chapter will describe the research undertaken to validate the model and its proposed method of use. The two stage validation of the model will be described and the findings from each stage and the further development work will be discussed. This chapter concludes with the overall validity of the model and its proposed method of use.

11.1 Validation Approach

The objective of the research described in this thesis was to develop a generic model to be used as part of an approach to the design and implementation of CAPM systems. The use of the model should contribute to the overall approach by addressing some of the issues that can result in the failure of CAPM systems to meet expectations. Section 2.5.3 discussed the difficulty of carrying out a longitudinal test by observing the whole of a design and implementation project that used the generic model. Instead, it was proposed in Section 2.5.3 that the reference framework of Thomas and Tymon (1982) should be used to assess the success of this research project in terms of "the needs of the practitioner". The five key needs listed in the framework are:

1. *Descriptive Relevance*;
2. *Goal Relevance*;
3. *Operational Validity*;
4. *Non-obviousness*;

5. *Timeliness.*

The method of validating the model and its use must therefore focus on an assessment by practitioners.

There were two main stages to the validation of the generic model and its use. The first stage involved the assessment of the model by practitioners including academics, industrialists and consultants. It would have been difficult to assess the use of the model until it had been assessed by practitioners. If the practitioners found the model to be difficult to understand, lacking in descriptive relevance or believed that it would not be useful then the use of the model could not be fairly assessed. The main objectives of the first stage were therefore to assess:

descriptive relevance - did the model represent a typical "order fulfilment" process?
goal relevance - could the model be used?
operational validity - was the model easy to understand?
Non-obviousness - was the model more than simple common sense already used by the practitioner?

The fifth need, *timeliness*, was not assessed because stage one was not concerned with whether the model was available to the practitioner to be used. The stage was concerned with whether the model was a good representation of the "order fulfilment" process and whether it could be understood. *Timeliness* was assessed in the second stage.

The second stage was to test the use of the model by practising managers using the model as part of the model based approach in a local company. The objective of the managers was to develop a model of their own "order fulfilment" process to help them specify their requirements for a CAPM system. The main objective of this stage was to determine whether the model could be used in a real situation. To do this, the needs of practitioners were again assessed:

descriptive relevance - did the model generally represent their "order fulfilment" process?

goal relevance - did the results of using the model meet the goals of the company?

operational validity - how easy was it to use the model as suggested?

non-obviousness - was the use of the generic model an improvement on the method that may otherwise have been used to understand the existing situation?

timeliness - was the model and its ability to be used as part of a model based approach available at the right time?

11.2 Stage One: Assessment of generic process model by practitioners

It would have been extremely difficult to take a statistical sample of practitioners across a diverse range of manufacturing companies or to distribute the model to practitioners without their prior agreement. Any constructive assessment of the model requires a practitioner to spend some time reviewing the model. The aim was therefore to distribute the model to as many practitioners as possible who were interested in reviewing the model.

11.2.1 Information distributed to practitioners

The information that was distributed to practitioners who were interested in reviewing the model consisted of a generic process model pack which contained the following:

- Context information that described the context of the "order fulfilment" process within a typical manufacturing company.
- $IDEF_0$ information that briefly described the syntax of the modelling technique.
- Generic process model diagrams.
- Supporting glossary of terms for use with the diagrams.
- Feedback sheet with eight questions. (Appendix 2)

The generic process model pack was distributed either as a paper copy or by compressed print files via electronic mail.

11.2.2 Stages of distribution to practitioners

The generic process model was advertised for review through a variety of mediums including the mailing list of EPSRC (Engineering and Physical Science Research Council) Grant GR/J/95010, personal contact with practitioners by the author and colleagues, publication of the first draft model in a number of conference proceedings (Childe et al 1995, Weaver et al 1995, Maull et al 1995b) and using discussion groups on the Internet.

Initially the model was distributed to academic colleagues for assessment. Having received encouraging feedback from colleagues the model was developed further. It was then distributed to a number of practitioners who had expressed an interest in the model and with whom the author or his colleagues had had previous contact. Again, following further development as a result of the feedback received, the last level of practitioners to assess the model were those who expressed an interest in the model after it was advertised on the Internet.

The model was also reviewed and discussed by an EPSRC Review panel as part of a set of standard business processes developed during the author's work on EPSRC grant GR/J/95010. The review panel included representatives from EPSRC and industrial collaborators.

11.2.3 Summary of feedback received from practitioners

The practitioners were employed in a variety of areas including manufacturing companies, consultancy and academia and many were from outside the UK. A list of practitioners who contributed to the work by commenting on the model can be found in Appendix 2. Sample copies of the comments provided by practitioners can also be found in Appendix 2.

In total over 85 copies of the generic process model packs were distributed to practitioners who had expressed an interest in reviewing the model. Comments were received from 29 of these practitioners in a variety of forms, including the feedback sheet, altered diagrams, and in some cases, 4-5 pages of detailed comments.

The feedback from the practitioners was encouraging. Although there was a diverse range of comments, a number of issues and areas were identified where the model and overall pack required improvements. Comments about the information pack that was sent to the practitioners provided useful advice that was used in the development of the guidelines to accompany the model. The following sections will discuss the main issues raised by practitioners and actions taken with respect to the issues raised. Where appropriate, actual comments from practitioners have been included.

11.2.3.1 Alterations to the model

The feedback sheet encouraged practitioners to identify any areas of the model that they believed to be incorrect or that did not represent activities and flows relating to their experience. There was little consistency in the alterations suggested by practitioners, which was taken as a positive indication that the model was, in general, a good representation of the "order fulfilment" process of a typical manufacturing company.

There were a number of alterations made to the model where there had been definite mistakes in the model that had been spotted by practitioners.

During the initial stages of assessment there were comments about some activities that related specifically to Materials Requirement Planning and Re-order Point stock control. Some practitioners felt that for the model to be generic, activities relating to one control strategy should not be included. These activities were removed from the model and more general control activities were then included.

11.2.3.2 The terms used to describe activities and flows

A few practitioners commented that some of the terms used were "sufficiently vague as to leave doubt as to what they mean" (Kearns and Vlemmiks). This was an issue that was noted not just from specific comments but also from comments of other practitioners who had interpreted the meaning of a term differently from the meaning intended by the author.

A number of terms used in the model are very general. In creating the model the author has attempted to reduce the complexity of the model at higher levels by combining families of data into single arrows. It is often difficult to find precise general terms which correctly express the required meaning to all individuals. The terms and the glossary were reviewed in an attempt to eliminate any ambiguity especially in those identified as being ambiguous by practitioners.

11.2.3.3 Level of abstraction

The level of abstraction was an issue during the initial development of the model. The greater the level of decomposition the harder it is to claim that it represents a shared view. Some practitioners felt that no more than three levels of decomposition were appropriate, other practitioners would have liked to see more detail in some areas such as the "Dispatch Customer Order" [A4] activity.

11.2.3.4 Application of generic process models

The majority of practitioners who responded felt that the model could be used as part of a process-focused change programme. Some practitioners (Campbell, Bradley) also expressed the view that if the model was to be used as part of a change programme it "should be at a reasonably high level" (Bradley). That is, they believed that the model would only be useful as a generic model to three levels of decomposition.

The model was developed to give sufficient structure and content to help users to develop an understanding of the situation within their company. There was a conscious effort to achieve a balance between the content necessary to help understanding and too much content which would make the model too detailed, complex and intimidating. The structure of the model allows its users to choose the level of decomposition to which they wish to use the model. The model can be extended by a particular company by the development of their own $IDEF_0$ diagrams to be incorporated into an altered generic process model that represents a view of their "order fulfilment" process. The rigorous structure of $IDEF_0$ ensures that the context of any alterations or additional detail is not lost and their relationship to other entities at all levels of the whole process can be seen.

11.2.3.5 Explicit statement of viewpoint

It was evident from some comments from practitioners that they had understood the generic model as being intended to represent what the author believed *should* be happening in the "order fulfilment" process. In these cases, the information supplied with the model had failed to convey that the model is supposed to represent a shared view of what *typically* happens in the "order fulfilment" process and not what should happen.

The guidelines which accompany the model attempt to ensure that the purpose of the model is made clear and the viewpoint it is intended to represent. In addition, an explicit statement of the viewpoint has been added to the A-0 diagram of the model.

11.2.3.6 Type of manufacturing company

The model is intended to cover all types of manufacturing companies. A few practitioners felt that the model "skewed towards make-to-order, engineer-to-order" (Moulding). To represent all types of manufacturing companies, it has been necessary to include activities and flows that may not be undertaken by a particular type of manufacturing company. For example, a make-to-stock manufacturing company may not undertake many of the activities in the model whilst undertaking the process of fulfilling an order, manufacturing activities and procuring resources. The model attempts to represent all the types of manufacturing companies and to enable individual manufacturing companies to cross out that which does not apply to their circumstances leaving a tailored generic model.

11.2.3.7 Context of "order fulfilment" process

The importance of understanding the context of the "order fulfilment" process within the whole company was an issue that was considered during the development of the model in Section 9.2.2. A number of practitioners (Rumens, Waterlow, Carrie) also pointed out its importance.

The For Exposition Only (FEO) diagrams used to describe the context of the "order fulfilment" process have been improved and the contextual description has likewise been improved as a result of suggestions from practitioners.

11.2.3.8 IDEF$_0$ as a modelling technique

Approximately two thirds of the practitioners who responded were familiar with IDEF$_0$ as a modelling technique, providing further evidence that it is a widely known modelling standard. A number of practitioners were complimentary about the use of IDEF$_0$ as the chosen technique including Rumens who commented that

> IDEF$_0$ is a fine tool for getting to know how it all works... I believe packages would generally be of better quality if IDEF$_0$ was used.

One or two practitioners seemed to assume that an IDEF$_0$ diagram represented a step by step process. Although there is a general flow from top left to bottom right the model is not intended to represent a rigid step by step process.

Kearns and Vlemmiks comment that the

> charts do not distinguish between stocked customised and standard items (though the charts implicitly appear flexible enough to cover these issues).

They express an important point about the model in that its scope is wide enough to cope with each type of item and each type of manufacture.

11.2.3.9 General comments

The overall reaction of the practitioners who responded was very positive. A number of them commented on the model in general and how it met the objective of representing the "order fulfilment" process of a manufacturing company. The comments included:

- "excellent job" (Waller);
- "I found your work to be very thorough and an accurate reflection of a typical manufacturing operation" (Hough);
- "I commend your use of manage/ operate/ support notation" (Carrie);
- "the work done is excellent and well researched" (Bradley).

11.3 Stage Two: Use of the generic process model in a local company

The objective of this stage of the validation was to find out if the model could be used as proposed by a company as part of a model based approach. The idea of the generic process model and its use was introduced to a local manufacturing company that was at the point of initiating a project to design and implement a new CAPM system. The IT manager agreed to use the model as a starting point to develop a model of the company's existing "order fulfilment" process.

11.3.1 Background of the company

The company manufactures printed circuit boards (PCBs) under contract for a variety of customers. The quantity and complexity of individual PCBs per order can vary considerably. The company had expanded rapidly over the last 5 years and was seeking to improve the management of orders throughout the business.

11.3.2 Use of the model

The IT manager was the main point of contact within the company and was responsible for the design and implementation of any new system. He acted as the team leader for the project. The model and the way that the model was proposed to be used was introduced to the IT manager during a single meeting that lasted approximately 2 hours. A developed set of guidelines to accompany the model describing how it could be used was not available at that time so a brief outline of the context, viewpoint, structure of the model and method of its use was given verbally.

One of the main concerns was to investigate whether the model could be used by the company without the help of the author. If the author had been involved in the use of the model it would have been difficult to ascertain whether it was the model itself or the detailed knowledge of the author that had helped. It was therefore agreed that no further contact would be made until the IT manager had decided the model of the existing "order fulfilment" process was nearing completion.

In the follow-up meeting to discuss the use of the generic model, the IT manager described how the model was used in the company.

The generic model was used by the IT manager as a template. Key personnel were interviewed and during the interviews, the IT manager described the activities that the model represented and their context in the overall process. The IT manager focused on those activities which were similar in nature and content to those activities actually undertaken by the individual. This part of the interview could be described as "walking through" the process. The description of the activities initiated debate concerning whether the activities represented by the model were performed, who performed them, what outputs were produced and what controlled the activities. The result was an understanding and consensus between interviewer and interviewee about which actual activities were performed and the flows between the activities.

During these meetings the model was tailored to represent the "order fulfilment" process of the company. The tailored model was then presented to the management team upon completion of the first draft. Further alterations were then made using the feedback received from the team.

11.3.3 Feedback on the use of the model in the company

During the follow-up meeting, the IT manager explained some of the issues that had been raised by using the model and also suggested improvements. He was interested in seeing further generic models that were being produced by the author as part of the EPSRC GR/J/95010 grant. A letter from the IT manager summarising his comments can be found in Appendix 2.

Issues that were raised during the meetings while "walking through" the model and altering it to represent the existing "order fulfilment" process included:

- **Allocation of responsibility** - When adding mechanisms to indicate who carried out activities, it was necessary to clarify who was responsible for doing them. This initiated discussions about who was and should be responsible for activities and supplying information.

- **"Taken for granteds"** - Walking through the model, interviewees were provoked into thinking about some of the activities that they did but had never really considered properly before. For example, "Produce simulation for decision making" [A132] was initially dismissed, however, upon reflection the interviewees realised that they did in fact simulate "what if" scenarios although the activity was not formally documented. This realisation provoked ideas on how some of the knowledge could be captured in the future.

- **Ideas for Improvements** - Discussing the activities represented by the model resulted in the identification of activities that the company did not carry out and which were agreed that the company should be doing. For example, no one in the company had responsibility for performing the activity "Confirm order to customer" [A1233] under circumstances where there were no queries relating to an order. The procedure for confirming to a customer that the company was accepting the customer's order was later reviewed.

11.3.4 Usefulness of the model

The IT manager found the model to be useful and a good representation of an "order fulfilment" process. He commented that the use of the model had saved many weeks of work and was a lot easier to use than starting from a blank piece of paper. It had provided a structure within which the company had been able to quickly develop their own model in $IDEF_0$.

The model of the company's "order fulfilment" process showed few alterations to the activities represented in the generic model. Mechanisms had been added to the activities and names of information flows had been altered to reflect names used internally for such information flows by the company. In some areas the company's model did not use all the levels of decomposition. In a number of areas, activities represented by the generic model had been decomposed to further levels of detail, such as the activity "Dispatch Customer Order" [A4].

11.3.5 Improvements recommended by the company

The IT manager identified a number of improvements that could be made to the model. These included the further decomposition of the "Dispatch Customer Order" [A4] activity, the inclusion of a node tree and context diagrams.

The "Dispatch customer order" activity was identified by some practitioners in the Stage 1 validation as an activity that could be decomposed further whilst still maintaining the model's generality. The model has been decomposed a further level in the model in Appendix 1. The other improvements have been incorporated into both the model and the guidelines. The IT manager has since seen the finished version of the guidelines and extra explanatory diagrams and believes that these guidelines will be useful to anyone attempting to use the model.

11.4 Overall validity of the generic process model and its use

The objective of the validation was to assess the generic process model and its use against the set of key needs described in Section 11.1.

11.4.1 Descriptive Relevance

The general comments by practitioners suggest that the model does represent a typical "order fulfilment" process. The alterations recommended by practitioners were varied and hence did not indicate any major flaws in the generic model. The level of alterations made by the company in Stage 2 to the generic model before they felt it represented their particular "order fulfilment" process and the comments from the IT manager indicated that it did provide a good representation of a typical "order fulfilment" process.

11.4.2 Goal relevance

The majority of practitioners believed that a generic process model can be used as part of a process focused change programme. The use of the model in Stage 2 indicates that it can be used successfully to meet the goal of practitioners to bring about understanding and change. The use of the model initiated debate that resulted in an improved understanding of the process and stimulated ideas for change.

11.4.3 Operational validity

Two thirds of the practitioners who responded were familiar with the $IDEF_0$ syntax. Practitioners who were not familiar with $IDEF_0$ showed that this did not hinder their understanding of the model. A number of terms were found to be very general. The terms have been reviewed in an attempt to remove any ambiguity.

The company in Stage 2 found it easy "to walk users through" the model, enabling the debate to be initiated and structured around the activities the users carried out. The IT manager had no difficulty in understanding the way in which the model was intended to be used. The use of model saved the company time in developing their own model and also generated a number of ideas.

11.4.4 Non-obviousness

The overall interest in reviewing the generic model provided a good indication that practitioners were interested in looking at a generic process model, as did the detailed feedback that was received and further offers of help.

The use of a generic process model was something that the company involved would not have normally considered. They were pleased with the results of using the model and were keen to see other generic models of processes that interacted with the "order fulfilment" process.

11.4.5 Timeliness

The model and its method of use have been developed during a period of interest in the use of the concept of a business process (Section 8.0) and at a time when manufacturing companies are seeking to improve their operations to remain competitive (Section 1.1).

The model and its method of use was available for the company in Stage 2 at the right time. The generic model was successfully used by them to reduce the time taken to develop a model of their existing "order fulfilment" process, to stimulate ideas and the momentum for change.

The generic model and its use can be seen to have addressed the key needs of practitioners and hence the objectives of the research work. In the view of the practitioners who responded, the generic process model is a good representation of a view of an "order fulfilment" process. The company in Stage 2 found the model easy to use as part of an approach. It helped them reach their goal of understanding and changing their "order fulfilment" process as part of their project to design and implement a new CAPM system. The model and its proposed use were found to be non-obvious and available at the right time by the company in Stage 2.

11. 5 Conclusion

The generic process model and its proposed use have been validated using a set of five needs and a small group of practitioners. The validation results do not suggest that the model could be used successfully in every situation or could meet five key needs of every practitioner. However, the validation results from the company in Stage 2 show that the model and its use have proved useful to that company and may therefore be useful to other companies.

The intention is to publish the use of the model during the Stage 2 validation as a case study to generate interest in the use of the generic process model in other companies.

Summary

The work described in this chapter has provided evidence that both the generic process model and its proposed use are able to meet the five needs of practitioners that were defined. The generic model has been validated by a broad cross-section of practitioners and has been found to be a view of a typical "order fulfilment" process within a manufacturing company that can be easily understood. The comments from practitioners resulted in improvements being made to the model.

The generic process model has been used successfully in one company. The use of the model helped initiate and structure debate amongst users about their view of their company's "order fulfilment" process. The result was an improved understanding of the "order fulfilment" process, a model of the existing process that represented a shared view and ideas for improvement, in significantly less time than would normally have been the case, according to the IT manager of the company.

Chapter 12. Conclusions

This work has identified a set of requirements for an approach to the design and implementation of CAPM systems. After investigative work, a generic process model was developed and how it could be used was proposed. The model and its use have been validated by practitioners and have been shown to meet the five key needs of practitioners described in Section 2.2. The use of the generic model as part of an overall model based approach to the design and implementation of CAPM systems can help meet some of the requirements identified.

The purpose of this chapter is to consider the correctness of assumptions made, the validity of the methods used and the contribution of the work to the development of improved approaches to the design and implementation of CAPM systems.

12.1 The research methodology

The research methodology that was used was a three-phase research cycle, Description, Explanation and Testing. There was considerable iteration between all the phases. The Description phase included a literature survey and the use of Action Research. The activities guided by the principles of Action Research provided an opportunity for the author to be closely involved with a project to design and implement a new CAPM system. The experience gained and observations made supported the information from the literature survey.

The Explanation phase began with the identification of issues and requirements from the information obtained in the Description phase. An investigation was then undertaken to get information as to how the requirements could be met. The outcome of the Explanation phase was a generic process model and the proposed way in which the model could be used.

The Testing phase was carried out in two stages, a review of the model by practitioners and the use of the generic model in a local company. The two stages enabled the model to be improved using information gained in the first stage before the model was put to use in the second stage. The first stage enabled the model to be reviewed by a cross-section of practitioners to test the validity of the representation of the "order fulfilment" process which was particularly important for a generic model. The second stage tested whether the model could be used successfully in a real company.

The research methodology provided a useful structure that guided the work to ensure that it produced an outcome that represented new knowledge and met five key needs of practitioners.

12.2 The need for an improved approach

Initial research showed that many manufacturing companies who are seeking to improve their competitiveness through differentiation or through attempting to address known problems have found that managing the production system could become increasingly difficult. There has been a growth in the use of computers as part of production management to cope with the difficulties (Section 1.1).

It was identified (Section 3.1) that many implemented CAPM systems failed to meet expectations and a number of writers had previously given reasons for the failure of the implemented CAPM systems. The information gathered was supported by the observations made during the author's involvement in a project to design and implement a CAPM system. There is evidence in the literature and also from the author's own observations that many companies have limited experience of and limited expertise in making improvements to CAPM systems. The observations of the author during the Action Research activities provide evidence that there was a failure to take a systemic perspective when trying to change CAPM systems. This supported a similar observation made by Davenport (1993).

The research demonstrated that there was a need for an approach that focused on the initial activities of understanding the existing systems from a systemic perspective, developing a common vision and involving users wherever possible. The approach should also be easy to use and facilitate the involvement of other parties such as software vendors.

12.3 Conceptual models

Having identified the need for an approach, research was undertaken to understand the basic principles that many approaches to the design and implementation of CAPM systems are based upon. The research resulted in the conclusion that models of concepts could be used to provide a simplified view of reality that could then be used for communication and to help understanding. The concept of a Human Activity System was found to be a useful concept when attempting to understand manufacturing companies.

Two types of thinking that used the concept of a system but had different sets of underlying principles were compared. It was concluded that Soft Systems Thinking provided some useful principles that could be incorporated into an approach that needed to focus on gaining initial understanding and communication through the use of a systemic perspective.

12.4 Soft System Thinking

The underlying principles of Soft Systems Thinking and the methodology which used the principles were considered. Benefits from using the principles and the core method of Checkland's Soft Systems Methodology (SSM) were established. There was also evidence of problems being encountered by practitioners using soft systems methodologies.

It was concluded that an approach to the design and implementation of CAPM systems would benefit from the use of SSM's underlying principles and the core method. However, the approach would have to adapt SSM to the particular situation in a particular manufacturing company and the problems in using SSM described by other writers would have to be addressed.

12.5 Model based approaches

Other model based approaches have been used in manufacturing companies to facilitate the design and implementation of systems. How these other approaches used models was considered in conjunction with the requirements that had been established.

It was judged that an "as-is" model of the existing systems from an activity view should be developed to encourage understanding of the existing systems. After a consideration of the requirements and studying different model based approaches, it was decided that the use of a generic model to help develop the "as-is" models could provide structure and guidance for companies that lacked expertise. Generic models are an established tool that has been used as part of many previous model based approaches to provide structure and guidance. It was also reasoned that a method using SSM principles could incorporate a generic model from an activity view, which could then be used to initiate debate and encourage understanding.

12.6 "Order fulfilment" process and CAPM system

This thesis has established that the concept of a business process embodies many of the same characteristics as a Human Activity System and hence can be used in SSM or in an approach based on SSM principles.

A view of a manufacturing company using the concept of a business process was assumed and the "order fulfilment" process was presented as one of business processes representing part of a manufacturing company. It was concluded that the concept of a business process could assist companies to take a systemic perspective, understand the transformation taking place and encourage underlying assumptions to be questioned.

The view of a CAPM system defined in this thesis is that it is a subsystem that controls the "order fulfilment" process. This was evidenced by comparing the transformations and objectives of both the "order fulfilment" process and the production system.

The use of the concept of the "order fulfilment" process to structure and understand the activities and flows managed by a CAPM system was proposed. The development of a generic model of the "order fulfilment" process was decided upon and its use as part of an overall model based approach was identified.

12.7 The generic process model

The generic model of the "order fulfilment" process that was developed during this research provides a detailed model representing (from one perspective) the activities and flows within the "order fulfilment" process of a typical manufacturing company. It was developed using the core method of SSM that encourages a systemic perspective to be taken and a shared view to be established. Information to construct the model was derived from a variety of sources, including literature, other generic models and models of the "order fulfilment" processes of a number of manufacturing companies. The completed model provides a level of detail that will allow it to be used to initiate debate and encourage understanding at different levels of the company.

$IDEF_0$ was used to represent the "order fulfilment" process. Evidence was presented that $IDEF_0$ can be easily understood and is an internationally recognised standard. It allows a systemic representation to be created through the use of hierarchical decomposition and structured indexing notation.

12.8 Validation of the model

The generic process model was validated by 29 practitioners to ensure that it represented the "order fulfilment" process within a typical manufacturing company. The validation assessed the generic process model against five key needs of practitioners. It was shown that the generic process model did provide a view of a generic "order fulfilment" process, that could be understood by practitioners. The generic process model was developed using the principles of SSM and hence it must be recognised that the model reflects the author's subjective view of the "order fulfilment" process and the author's interpretation of the comments made by practitioners.

Most of the practitioners who commented did agree that a generic process model could be used a part of an approach to change systems and the use of $IDEF_0$ as a modelling technique received positive comments. Some practitioners did feel that the model may need to simplified to enable it to be used by inexperienced users.

The validation of the model provided evidence that supported the earlier conclusion that the use of the concept of a business process could assist practitioners in understanding their company.

12.9 Validating the use of the model

The generic process model was developed with the intention of using it as part of an overall model based approach. A method of using the model was proposed which was based on the principles of SSM. The ability of the generic model to be used in three alternative structures of an overall model based approach was suggested.

The use of the model was validated by its use in a local company. The model provided a useful starting point and enabled participants to understand the concept of the "order fulfilment" process and the context within which it exists. The generic model was used to help develop a model of the existing "order fulfilment" process in order to determine the requirements for a new CAPM system. The use of the generic model resulted in a company model that represented the shared view of participants and that was developed in considerably less time than would normally have been the case. The debate that was initiated and structured using the model resulted in a better understanding of the activities undertaken by users and also helped to generate ideas for improvement.

The use of the model has proved successful in one manufacturing company. The model helped participants gain an improved understanding of the company's "order fulfilment" process and despite the idiosyncrasies of companies it is hoped that future applications of the model will be just as useful.

Further production and operations management research using the generic model of the "order fulfilment" process and generic models of the other "Operate" processes developed as part of EPSRC Grant No. GR/J/95010 is being carried out by a number of research groups. The models are currently being used as part of EUREKA Time Guide Project (EU 1157) (Laasko and Bredrup 1995) and by researchers at University of Maryland, USA.

12.10 Future Work

The generic process model has been used successfully in one company. Future applications of the model as part of model based approaches in companies will enable further experience to be gained which will help the future development of the model as part of an overall model based approach.

Despite the considerable value of the model some practitioners indicated that the usability could be improved through the role of the facilitator and simplification of the model. The author would suggest observation of the use of the generic process model as part of an overall model based approach during a number of case studies. This would enable the use of the model to be studied and may provide further evidence as to whether it encourages a "softer more systemic" overall approach to the design and implementation of CAPM system in these cases. Understanding the role of the facilitator and how different companies decide to use the model would enable the guidelines that accompany the model to be further developed and the requirements for any simplification of the model to be identified.

The generic model of the "order fulfilment" process was primarily developed to be of use in companies where there was a lack of expertise during the initial stages of the design and implementation of CAPM systems. This thesis and further observations may contribute to the development of a more generally applicable approach for the improvement of any problem situation. Such an approach could be based on SSM and incorporate the use of generic process models.

Chapter 13. Overall Conclusion

This work demonstrates that the use of the concept of a business process and the knowledge contained within the generic model of the "order fulfilment" process can help users, lacking in specialist expertise, to understand the context of their own activities and how all the activities contribute to the fulfilment of a customer order. The generic model was developed using the core method of Soft Systems Methodology (SSM) from a generic root definition based on the primary task "order fulfilment".

This work also presents evidence that an approach to the design and implementation of CAPM systems based on a systemic perspective of the "order fulfilment" process increases the likelihood of a CAPM system meeting the requirements of a particular company.

The contribution to knowledge is the demonstration that in the use of SSM the generic model is a useful starting point. It simplifies the process of SSM without preventing the identification and accommodation of the wider, critical, context-dependent issues which ultimately determine success.

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Appendix 1

A Generic "Order Fulfilment" Process

Model and Guidelines

A Generic "Order Fulfilment" Process

Model and Guidelines

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INTRODUCTION

The objective of this document is to introduce the generic "order fulfilment" process model and describe how it may be used to help understand the activities and flows that need to be managed by a CAPM system within a manufacturing company.

The business process represented by the model is part of a high level business process architecture that can be used to understand the structure of a manufacturing company.

A Business Process

Any business process has an hierarchical structure and is itself part of a hierarchy of business processes within a company and beyond. Each business process has the following:

- a specific set of inputs that are transformed to outputs;
- a purpose and set of goals that should be linked to the overall strategy of the company;
- boundaries that make sense from an external customer's perspective
- a set of activities and internal flows that as a whole meet the purpose of the business process.

Business Process Architecture

Business processes in a company form a hierarchical structure. A view can be adopted of a high level business process architecture. This architecture has the whole of the company at level 0. The company has a purpose and carries out a number of transformations to meet that purpose.

At level 1, there are three groups of business processes, "Manage" processes, "Operate" processes and "Support" processes.

"Manage" processes are those processes that transform information into business objectives, a strategy and instructions to manage the overall behaviour of the business.

"Operate" processes are those processes that transform information and physical entities into products to fulfil external customer's requirements. These processes produce value for external customers.

"Support" processes are those process that enable the "Operate" process to operate. They include activities and flows involving financial, personnel, facilities management and information systems provisioning.

"Operate" Processes

A view can be adopted that in a manufacturing company there are four "Operate" processes. The processes are

- Get Order;
- Develop Product;
- Fulfil Order;
- Support Product.

Each process can be described using a root definition. It describes the customers, major transformation, who carries out the process and what the objective of the process is. To understand the activities and flows within the "order fulfilment" process, it is important to consider how the process integrates with other business processes.

Root Definitions

The root definition for each process is intended to provide a concise description of the process.

"Get Order"

The "**get order**" process contains activities performed by humans and machines. Its principal transformations are to transform a concept of a product into a customer order, to translate customers' requirements into a form meaningful to the other processes and includes the use of market data to identify potential requirements for new products. It includes the flow of information that is required to satisfy a customer by providing information to the customer and to the other Operate processes. The process constantly seeks to ensure that customers' requirements are met and that there are sufficient orders of the correct type to meet the stakeholders' requirements.

"Develop Product"

The "**develop product**" process contains activities performed by humans and machines. Its principal transformation is from knowledge into the specification of a product that can be produced to meet customers' requirements. It includes the flow of information to enable the development of the specification of a product that can be manufactured and the development of product concepts that may fulfil future customers' requirements. The process constantly seeks to provide specifications for products that will meet the requirements of customers whilst balancing stakeholder requirements.

"Fulfil Order"

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 result in the fulfilment of the external customer's order or enquiry. The process constantly seeks to fulfil customers' requirements whilst balancing stakeholders' requirements.

"Support Product"

The "**support product**" process contains activities performed by humans and machines. Its principal transformation is from a need for support into a product that once again continues to meet the requirements of a customer. It includes the flow of the resources and information that are required to meet the customer's support requirements. The process constantly seeks to fulfil the customer's support requirements whilst balancing stakeholder requirements.

-

The generic "order fulfilment" process that is modelled is a representation of the "fulfil order" process. The business process architecture described above provides the basis from which to describe the "Operate" processes of any manufacturing company in greater detail. The model of the "order fulfilment" process includes a For Exposition Only (FEO) diagram that shows how the business processes may interact in a typical manufacturing company.

THE GENERIC "ORDER FULFILMENT" PROCESS MODEL

The generic "order fulfilment" process model has been developed to represent a typical structured set of activities and flows that any manufacturing company may undertake to fulfil an order.

The model represents a hierarchical structure of the activities and flows that form the process. The model uses $IDEF_0$ as a technique to represent the activities and flows.

The model was developed from information obtained from literature, models from specific companies, other generic models of companies and models of the "order fulfilment" process in a number of manufacturing companies.

The complete model consists of 120 activities and 153 different flows shown on 33 diagrams that are all indexed to form an integrated model. The model has been validated by 29 practitioners representing a broad section of companies. The model was found to be a good representation of the "order fulfilment" process of a manufacturing company in the view of the practitioners.

Purpose

The purpose of the model is to represent the "order fulfilment" process in any manufacturing company. It is not intended to represent how a manufacturing company should operate. The model should help a manufacturing company identify and understand their activities and flows that need to be managed by a CAPM system.

The model has a secondary purpose. It can be used by a company to help develop their own model of their "order fulfilment" process.

$IDEF_0$

$IDEF_0$ is the modelling technique that has been used to represent the generic process model. The following paragraphs describing $IDEF_0$ have been adapted from a document supplied by Dynamic Research Corporation. A comprehensive manual "Federal Information Processing Standards Publication 183" is available from The National Institute of Standards and Technology, USA.

The Theory

$IDEF_0$ is a process modelling methodology. The objective of an $IDEF_0$ model is to provide a complete, concise and consistent description of the activities and flows that form a system or process. The model is developed from a particular viewpoint for a particular purpose.

The structure of a model

Each model consists of up to five main parts:

- a node index
- the context diagram
- a set of activity diagrams
- "For Exposition Only" (FEO) diagrams
- a glossary

The Node Index

The node index is an indented listing showing all the activities or nodes in an $IDEF_0$ model in "outline" order. The node index provides both a written summary of the hierarchy of the process and a way of rapidly identifying particular activities.

The Context Diagram

The context diagram establishes the scope and purpose of the model as well as the particular viewpoint. It defines the process boundaries with the outside world. Everything in the model comes from a decomposition of the context diagram.

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 of the process being modelled. Box labels are named using imperative verbs. Each activity is defined by a written description in the glossary.

Arrows connect boxes together and represent interfaces or interconnections between the boxes. Arrows may be split (branch) or may be joined together (bundle). 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 an associated meaning with each side of the box where an arrow enters it or leaves it.

- The left side is reserved for **inputs,** things transformed into outputs by the activity.

- The right side is reserved for **outputs,** 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, **I**nputs, **C**ontrols, **O**utputs, and **M**echanisms are referred to as ICOMS. Each ICOM is defined in the glossary. Figure 1. shows an $IDEF_0$ representation of an activity.

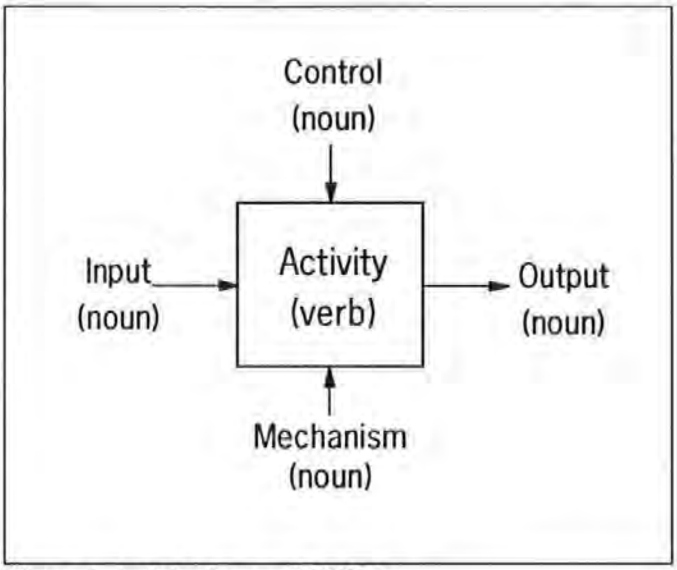

Figure 1. Activity box and ICOMs

Decomposition

$IDEF_0$ models show a top-down decomposition from the context diagram. The first level of decomposition breaks the context diagram (A-0) down into three to six subordinate activities. These subordinate activities may then be decomposed in the same way. There is no limit to the number of levels of decomposition. The title of a decomposition diagram is taken from the box it decomposes. Activities can be described as being a parent or a child. An example of this decomposition is shown in Figure 2.

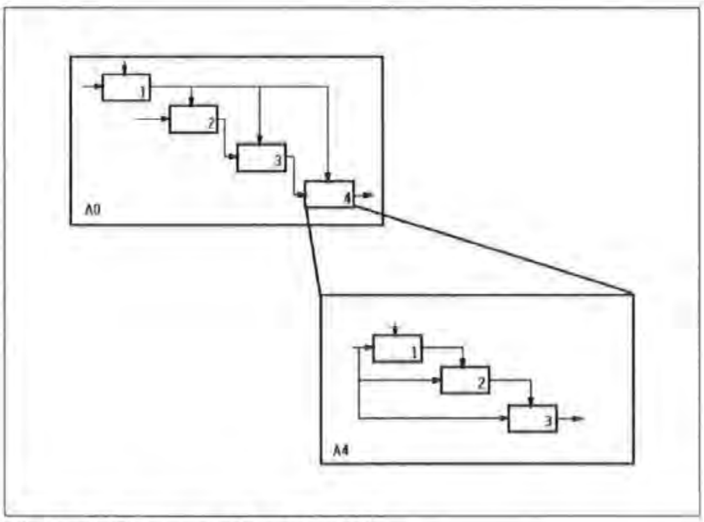

Figure 2. Decomposition example

In Figure 2, Activity [A4], the parent, is decomposed into three children [A41], [A42] and [A43].

The result is a model whose top diagram describes a system in general "black box" terms and whose bottom diagrams describe very detailed activities of the system.

"For Exposition Only" Diagrams

"For Exposition Only" (FEO) diagrams do not conform to the normal $IDEF_0$ syntax. FEO diagrams can provide additional detail about specific areas of the process being modelled that the modeller believes to be important. FEO diagrams can also be used to remove components of diagram to improve the clarity of the more complex diagrams and help the activities and flows to be understood more easily.

The Glossary

The glossary entries provide textual descriptions of all the activities and ICOMs represented by the model. This allows the text on diagrams to be kept to a minimum to aid clarity.

Interpretation of a model

There are a number of points that should be remembered when interpreting $IDEF_0$ diagrams.

1. An $IDEF_0$ model should be read top-down, by considering each diagram in the context of its parent activity.

2. The node index provides a good starting point from which to understand the structure of a model and identify the high-level diagrams.

3. There is a general flow from top left to bottom right in most $IDEF_0$ diagrams.

4. For a particular diagram:
    - scan the activity boxes to gain an overall impression;
    - refer back to the parent diagram to note the most important ICOMs 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..

5. For a transformation to happen in the parent activity it may 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.

6. ICOMs do not show the volume of information flowing between activities.

7. $IDEF_0$ diagrams do not show time. For example, queues or waiting periods are not shown.

Generic "order fulfilment" processes model

The generic process model that is contained within this document has a number of features that are different from an $IDEF_0$ model that would represent a business process in a particular company.

No Mechanisms

The generic process model covers all manufacturing companies. It does not show the means used to carry out activities, which will vary from company to company.

Context Diagrams

The context diagram in the model is [A-0], there are additional context diagrams labelled using "FEO", which indicates that those diagrams are "For Exposition Only" Diagrams. The reason for this is that the general context of the "order fulfilment" process in the company is important but it has not been modelled as a consistent part of the hierarchy of activities. Diagram FEO [A-1] is a child of FEO [A-2] which is a child of FEO [A-3]. FEO [A-1] to FEO [A-4] show the context of the "order fulfilment" process in the overall company.

Type of manufacturing

The model is intended to cover all types of manufacturing; Make-to-stock, Assemble-to-order, Make-to-order and Engineer-to-order. The model does not imply that all activities shown in the model are undertaken or that all the flows are required during each transformation by the process. There are many routes through the model that may result in the required transformation. The model can be tailored to meet an individual company's needs, for example by removing activities and flows or by replacing a diagram showing a level of detail with one that is a better representation of the sub-process within the company.

GUIDELINES FOR THE USE OF THE GENERIC PROCESS MODEL

The model has two purposes that were described in the previous section. The primary purpose was to help manufacturing companies identify and understand their "order fulfilment" process. The secondary purpose was to help manufacturing companies create a model of their existing business process.

To identify and understand

The model can be used by a company to identify their "order fulfilment" process. The model represents the "order fulfilment" process and how they are bounded in a typical manufacturing company. These boundaries can be used to provide a starting point for the particular company to identify the boundaries of their "order fulfilment" process.

The model shows the activities that typically happen and the flows that are typically required in a manufacturing company as part of the "order fulfilment" process. By studying the model it should help the company understand what is typically contained within a business process, especially the focus on transformations and the external customer. The model uses terms that are commonly used in manufacturing companies and a simple syntax.

The diagrams should be read as described under "Interpretation of an $IDEF_0$ model" in the previous section. Activities and flows that are not normally carried out (depending on the type of manufacturing) may be deleted.

To develop a model of an existing process

The secondary purpose of the model was to help a company develop a model of their existing processes. The following sections are intended to provide guidelines for the use of the model to meet this purpose. The sections do not represent a formal methodology and are based on the assumption that all team members are familiar with $IDEF_0$.

A facilitator

It is envisaged that any company undertaking a project to develop a model of their "order fulfilment" process would require a team of individuals to produce the model. It is recommended that a chosen individual be made familiar with the model, its context, these guidelines and if necessary $IDEF_0$. This individual can then act as a facilitator to the team as they use the generic process model.

Establish the context

The model can be presented to the team in a variety of ways by the facilitator. It is recommended that the root definition and FEO diagrams that set the context for the process model are introduced first. The viewpoint and purpose of the model should be clearly stated.

The viewpoint is that the model is not a model of how a manufacturing company should operate; it is a model of a typical manufacturing company from a process perspective.

The purpose is to help understanding. To represent the view of the team concerning their own company, the model must be tailored.

Change the context

The facilitator should encourage the participants to compare the root definition and context diagrams with their own perceptions of their company and to debate changes to the root definition and context diagrams.

Once the context diagrams and root definition have been discussed and altered to represent the shared view of the team, the complete model can be introduced to the team. The introduction should be approached in a top-down manner using the A-0 diagram first. The facilitator should point out any differences between the root definition and context diagrams developed by the team and the original generic model. This should help initiate comparison and changes to the model.

Removing activities and ICOMs

Removing any activities and ICOMs that the team believes are not applicable to their company or viewpoint should be one of the initial tasks undertaken by the team, so that the complexity of the model is reduced as much as possible.

By taking the [A0] diagram first and working down the levels of decomposition, a possible question set that could be used to determine the required activities and ICOMs is as follows;

- Do we do the activity?
- Who does the activity?
- Why do we do the activity?
- Should we be doing the activity, if we do not already do it?
- What is the main output?
- Are all the inputs and constraints necessary?

Adding mechanisms

The model gives no indication of who is responsible for activities. One of the objectives of understanding the model should be to establish who carries out or is responsible for the activities.

Adding activities

The team should be encouraged to identify what they believe are missing activities or sub-processes that are relevant to their company.

Adding flows

The inputs, outputs and constraints for an activity may be different. The model should be changed to represent the actual flows in the company.

Changing the order of activities

The order that activities are performed in may be different and may need to be changed by the team.

Changing labels

Many of the terms used will be peculiar to the particular company. The team should change the labels and write their own glossary descriptions for the labels they have changed.

Idea generation

During the tailoring of the generic model into a model specific to their company teams frequently see problems with their existing processes and/or identify ideas for improvements. This should be recorded and acted upon wherever and whenever possible.

The resulting tailored process model

After using the guidelines suggested above, the team should have an $IDEF_0$ model of the "order fulfilment" process within their company. The model developed by the team should represent their shared view of their company's "order fulfilment" process.

Once the first draft of a model has been produced, it is recommended that the team be encouraged to present the model to key personnel who are involved in the processes being modelled to ensure that the models are a good representation.

THE NEXT STAGE

The result of the method will hopefully be a shared view of the "order fulfilment" process within the company and an improved understanding by all participants of the overall "order fulfilment" process including its constituent activities and flows that need to be managed.

The method may also result in a detailed model of the "order fulfilment" process from an activity view for the particular company from the perspective of the participants.

The model produced can be used for further analysis to define what activities need to be managed by the CAPM system and what information is required to meet the objectives. It could also be used to communicate ideas and views to other users or even to a third party software vendor in discussions about what software may be required.

Possible actions resulting from the method may include the definition of requirements for an improved CAPM system including changes in procedures, policies, responsibilities and requirements of software. Another action could be the making of changes to other aspects of the company that were initially not identified as affecting the situation under investigation.

The model and guidelines do not represent a complete methodology. They can be used to provide manufacturing companies with help when attempting to establish a process view of their company.

An overall model based approach to the design and implementation of a CAPM system can take a number of possible directions once the generic process model has been used. A choice needs to be made about the overall structure of an approach. It will be dependent on a variety of influences including the results of intervention using the generic process model, the participants experience and background, knowledge of the different alternatives available and the facilitator.

The thesis to which these guidelines and model are appended suggests three possible alternatives structures for an overall model based approach to the design and implementation of CAPM systems.

$IDEF_0$ model of the generic "order fulfilment" process

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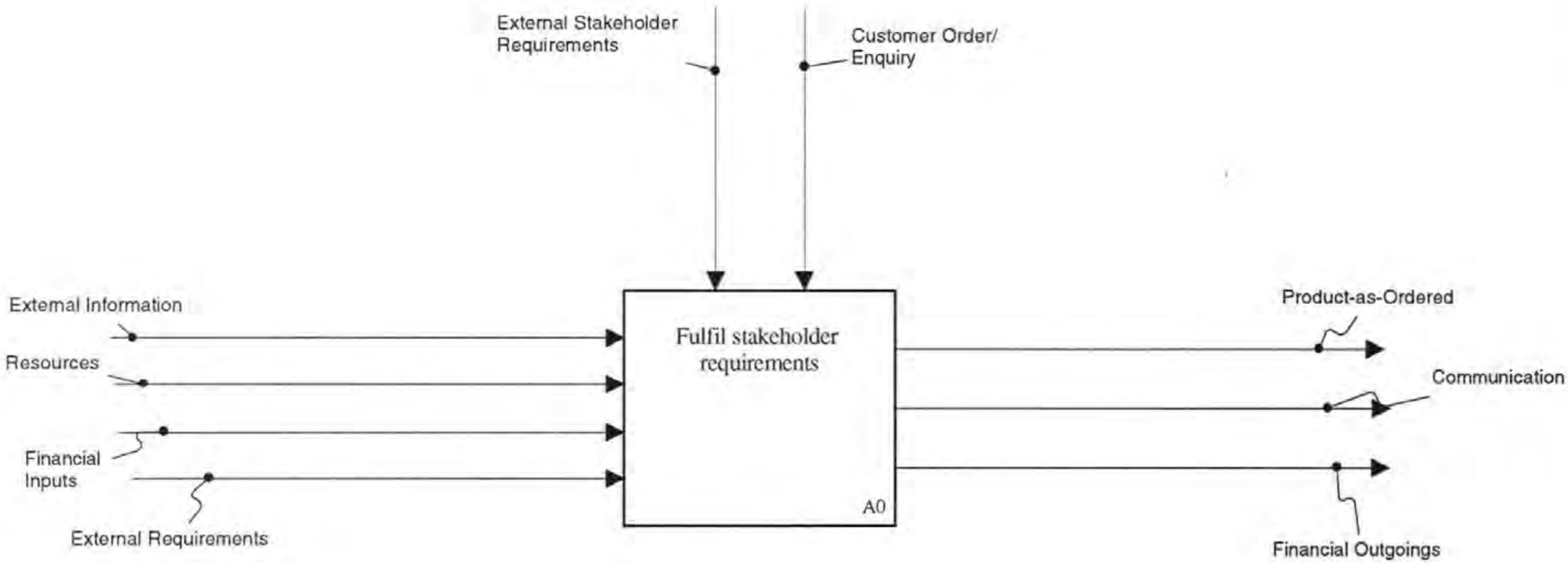
School of Computing University of Plymouth Drake Circus Plymouth PL4 8AA UK	PROJECT: Generic Process Model	REV:		DRAFT			Top
				RECOMMENDED			
	NOTES: 1 2 3 4 5 6 7 8 9 10		X	PUBLICATION			



Viewpoint:
This context diagram has been produced from the viewpoint that any manufacturing company seeks to meet the requirements of external and internal stakeholders

Notes
1. This is a FEO Diagram and does not conform to normal IDEF0 syntax

NODE: FEO A-4	TITLE: Context Diagram for the generic process model	NUMBER:

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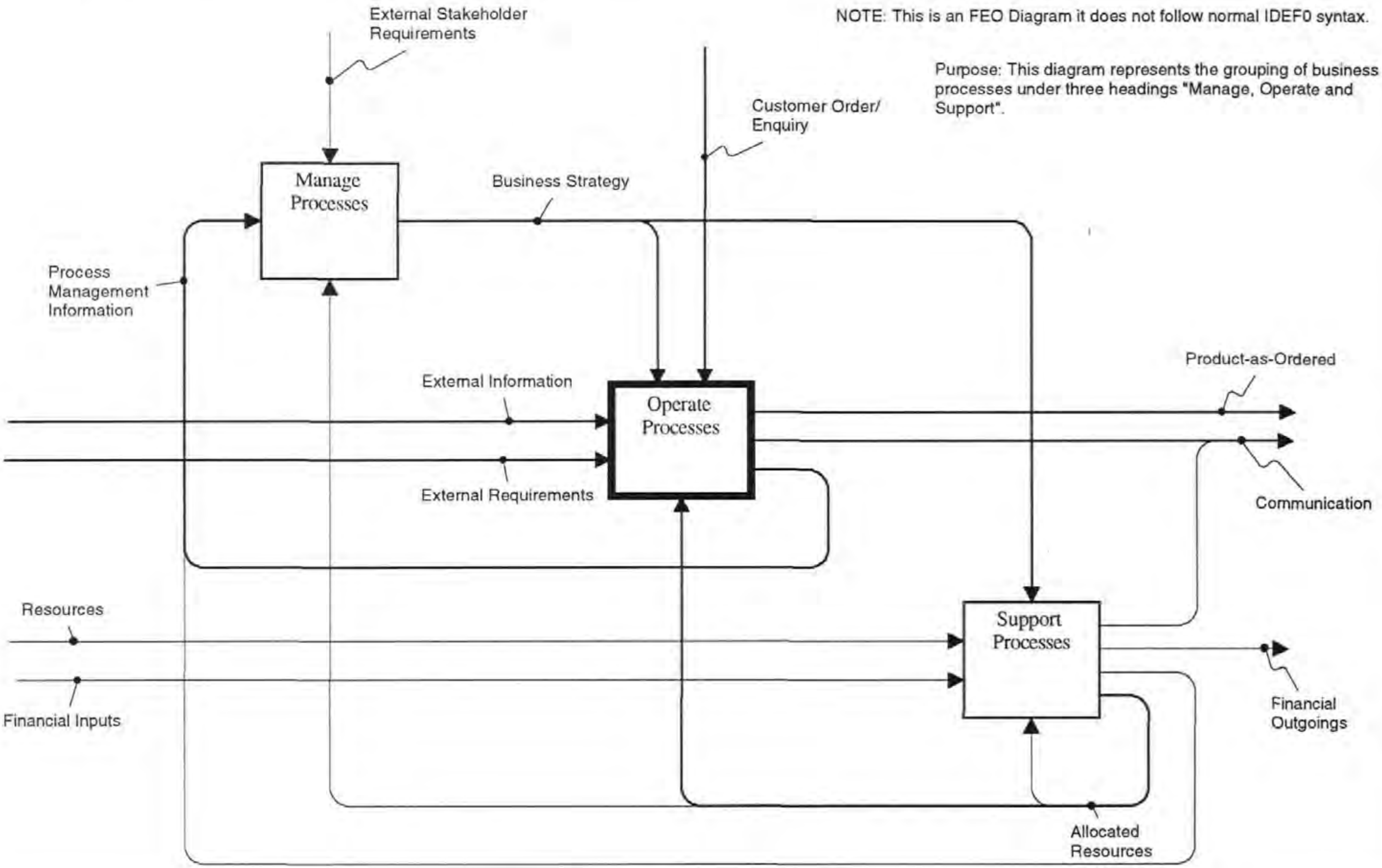
NOTE: This is an FEO Diagram it does not follow normal IDEF0 syntax.

Purpose: This diagram represents the grouping of business processes under three headings "Manage, Operate and Support".



NODE: FEO A-3 | TITLE: Context Diagram for the generic process model | NUMBER:

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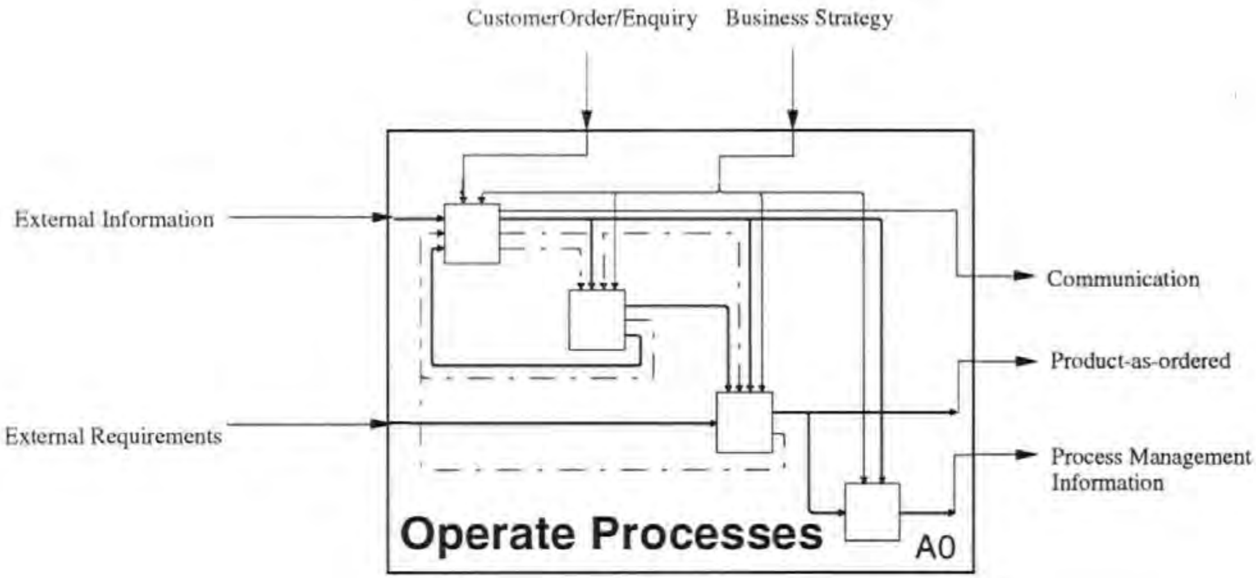
				RECOMMENDED			
	NOTES: 1 2 3 4 5 6 7 8 9 10		X	PUBLICATION			



Note: This is an FEO Diagram, it does not conform to normal IDEFo syntax.

Purpose : This diagram represents the group of four standard Operate processes.

NODE:	TITLE:	NUMBER:
FEO A-2	Context Diagram for the generic process model	

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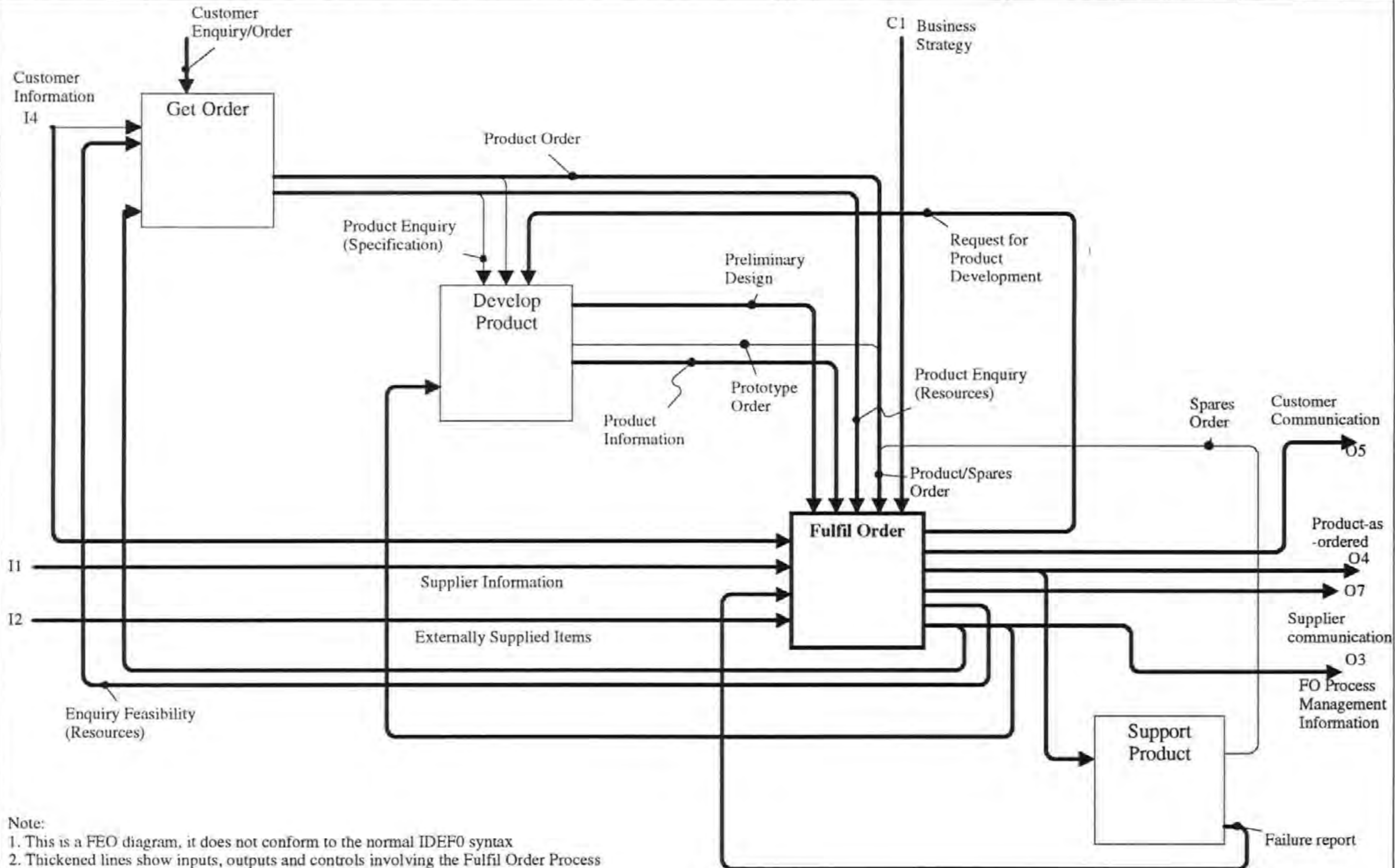

Note:
1. This is a FEO diagram, it does not conform to the normal IDEF0 syntax
2. Thickened lines show inputs, outputs and controls involving the Fulfil Order Process
3. ICOMs not directly involving the Fulfil Order process are not shown.

NODE: FEO A-1 | TITLE: Context Diagram - Operate Processes - Flows involving the Fulfil Order Process | NUMBER:

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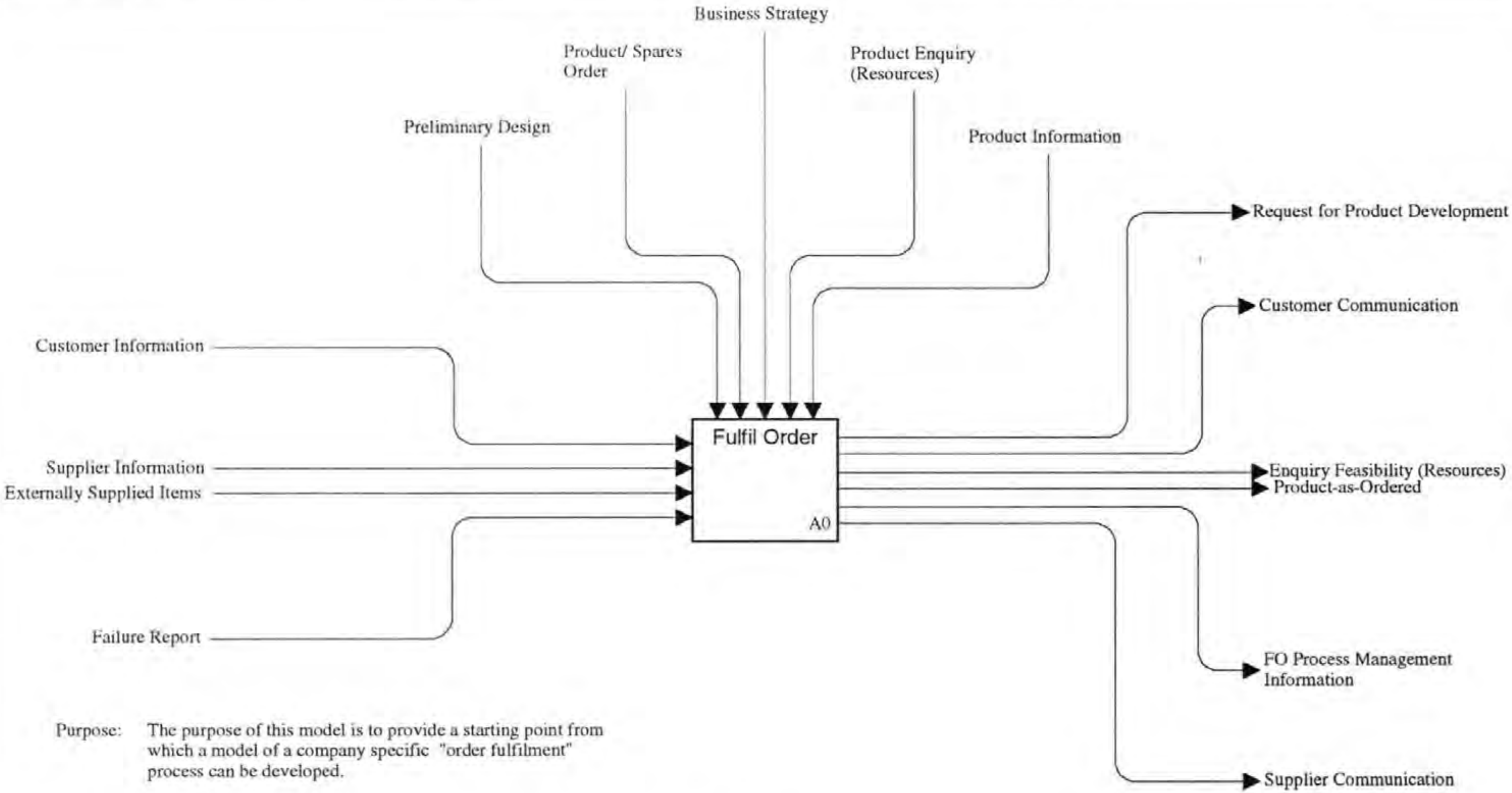

Purpose: The purpose of this model is to provide a starting point from which a model of a company specific "order fulfilment" process can be developed.

Viewpoint: This generic model represents the activities and flows which in the view of the author form part of the "order fulfilment" process within a typical manufacturing company.

NODE: A-0

TITLE: Generic Order Fulfilment Process Model

NUMBER:

USED AT:	AUTHOR: Adam Weaver	DATE:		WORKING	READER	DATE	CONTEXT:
School Of Computing University Of Plymouth Drake Circus Plymouth PL4 8AA United Kingdom	PROJECT: Generic Process Model	REV:		DRAFT			
				RECOMMENDED			
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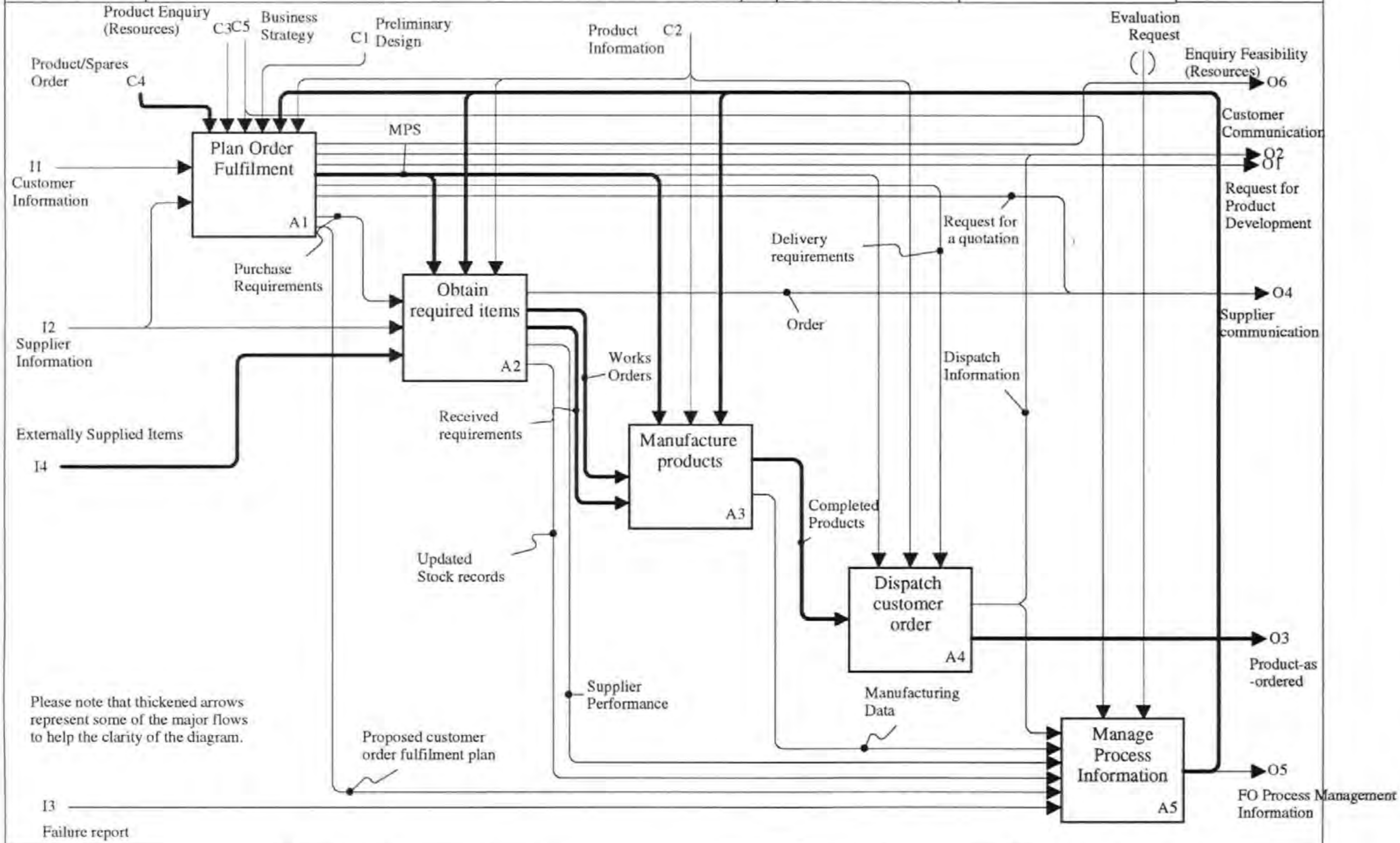

NODE: A0	TITLE: Fulfil Order	NUMBER:

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NOTES: 1 2 3 4 5 6 7 8 9 10

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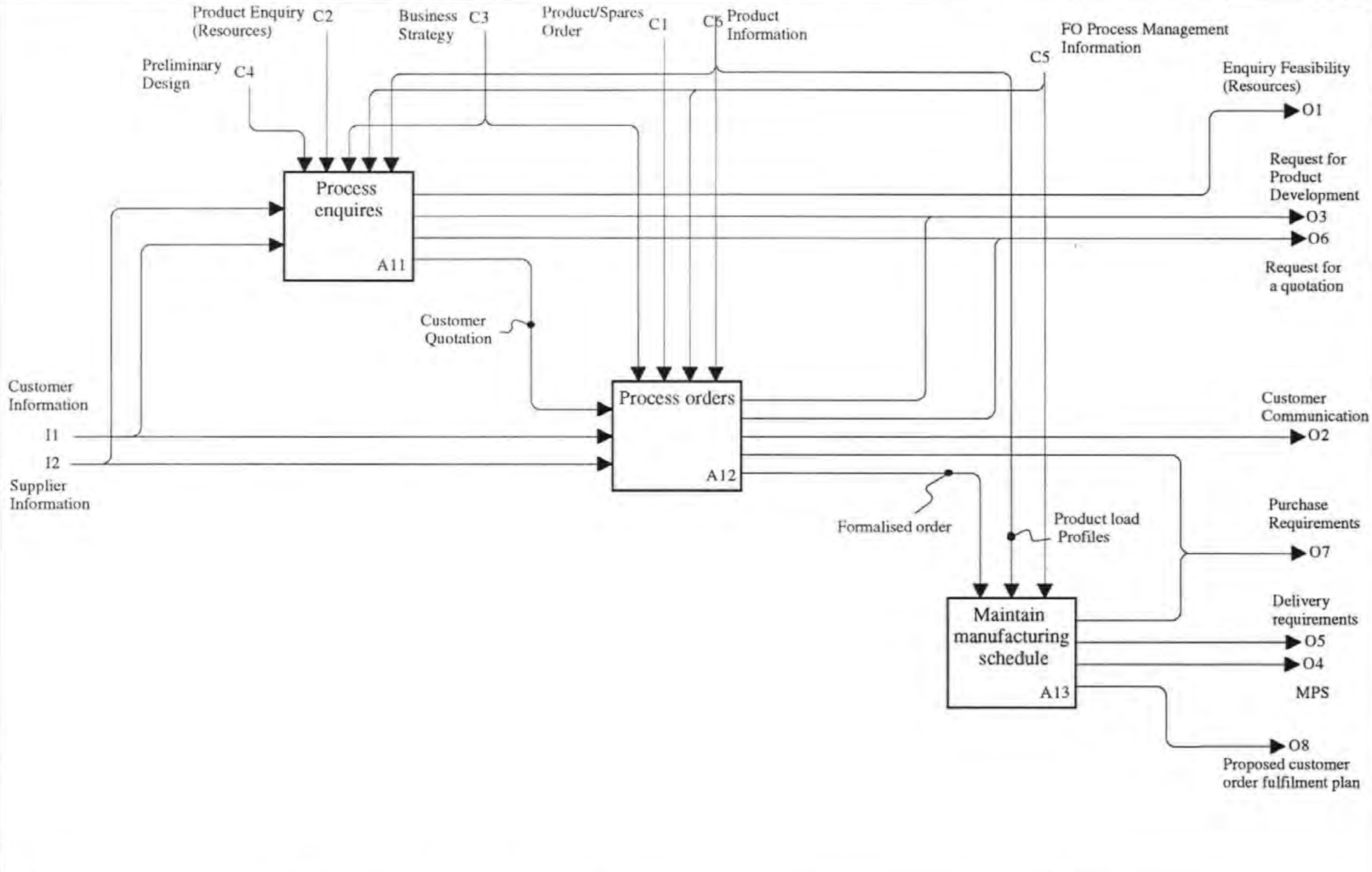

NODE: A1 TITLE: Plan Order Fulfilment NUMBER:

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AUTHOR: Adam Weaver
PROJECT: Generic Process Model
REV:
NOTES: 1 2 3 4 5 6 7 8 9 10

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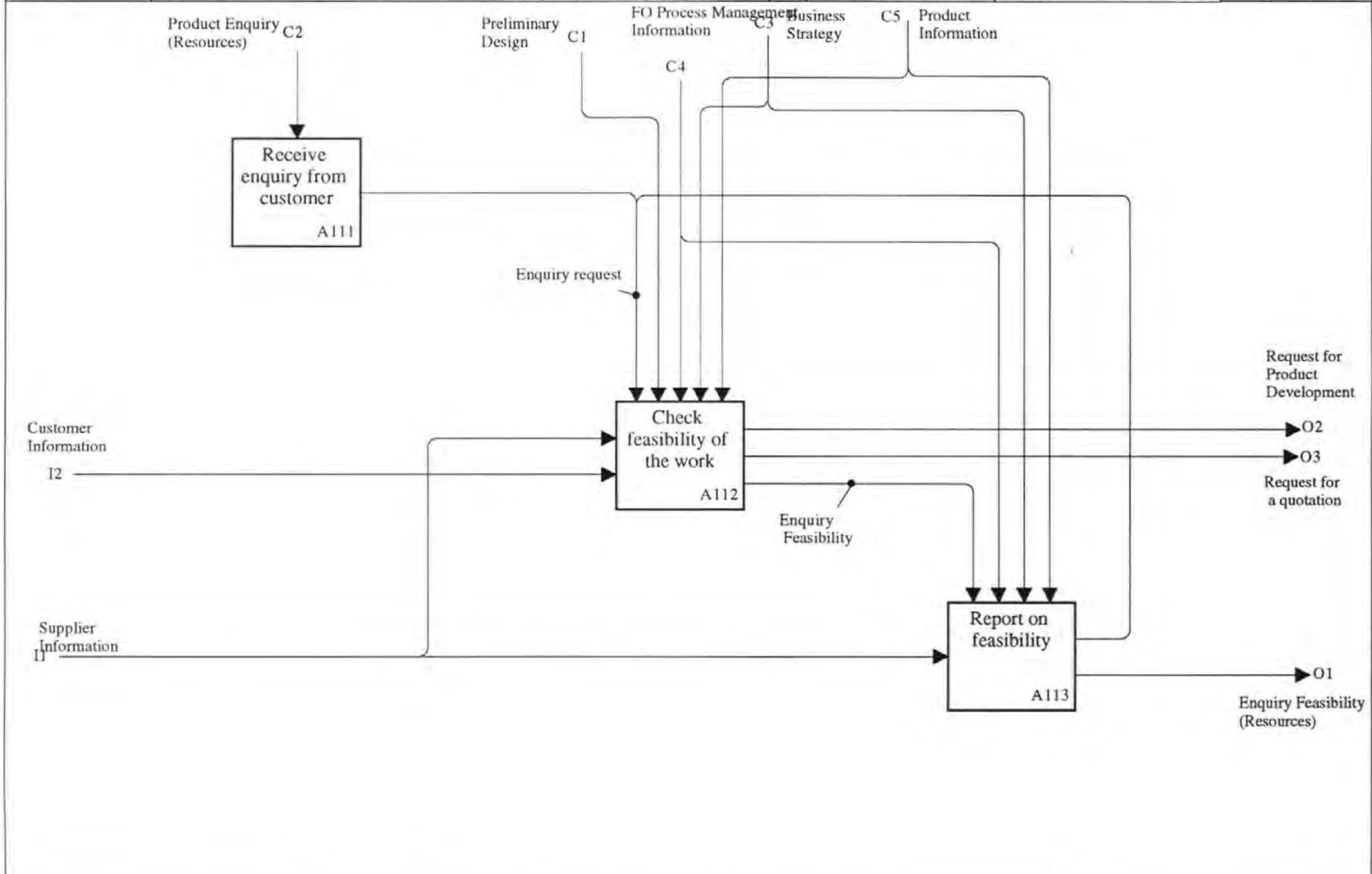
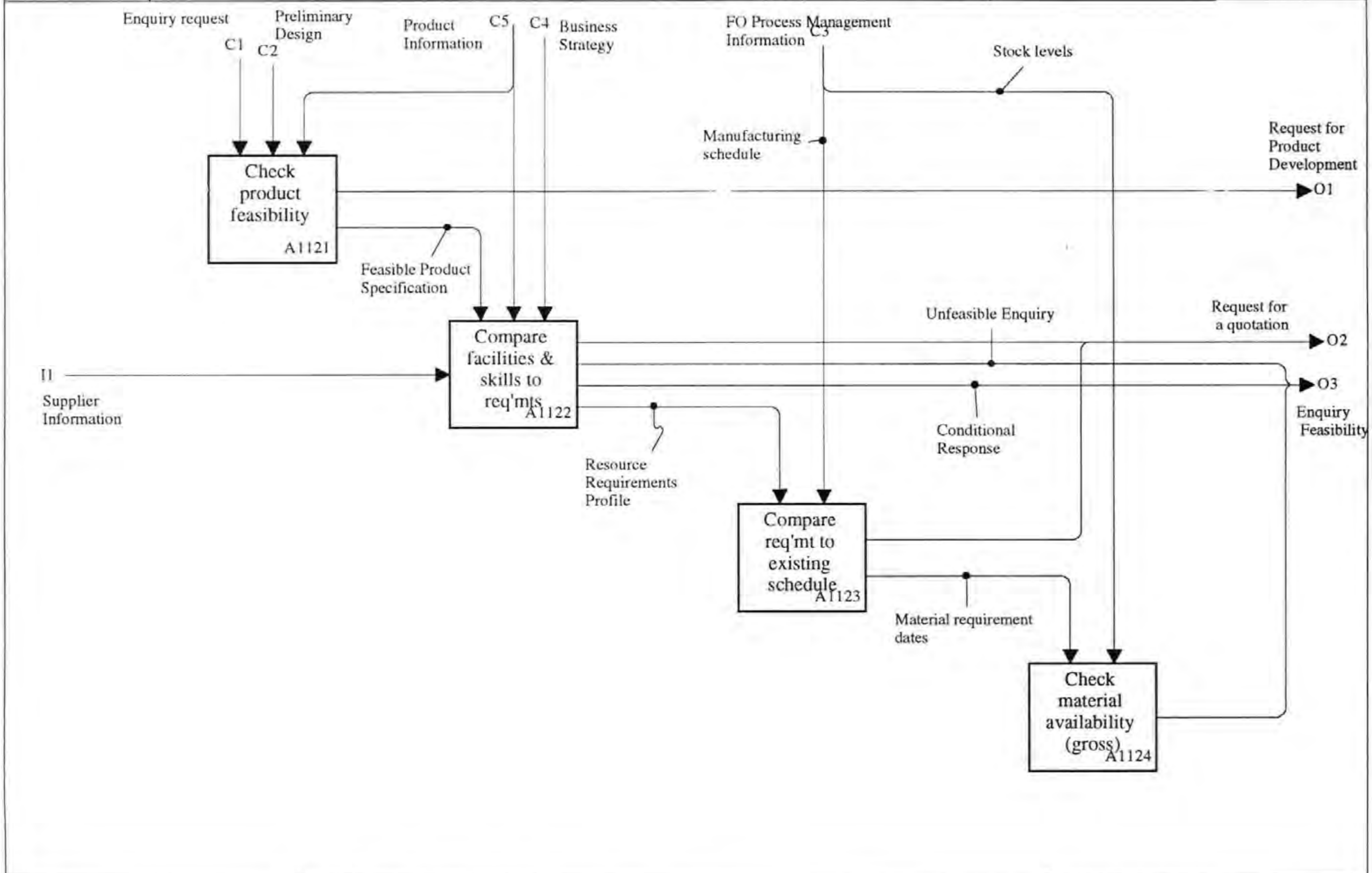


NODE: A11 | TITLE: Process enquires | NUMBER:

School Of Computing University Of Plymouth Drake Circus Plymouth PL4 8AA United Kingdom	PROJECT: Generic Process Model NOTES: 1 2 3 4 5 6 7 8 9 10	REV:	DRAFT RECOMMENDED X PUBLICATION



NODE:	TITLE:	NUMBER:
A112	Check feasibility of the work	

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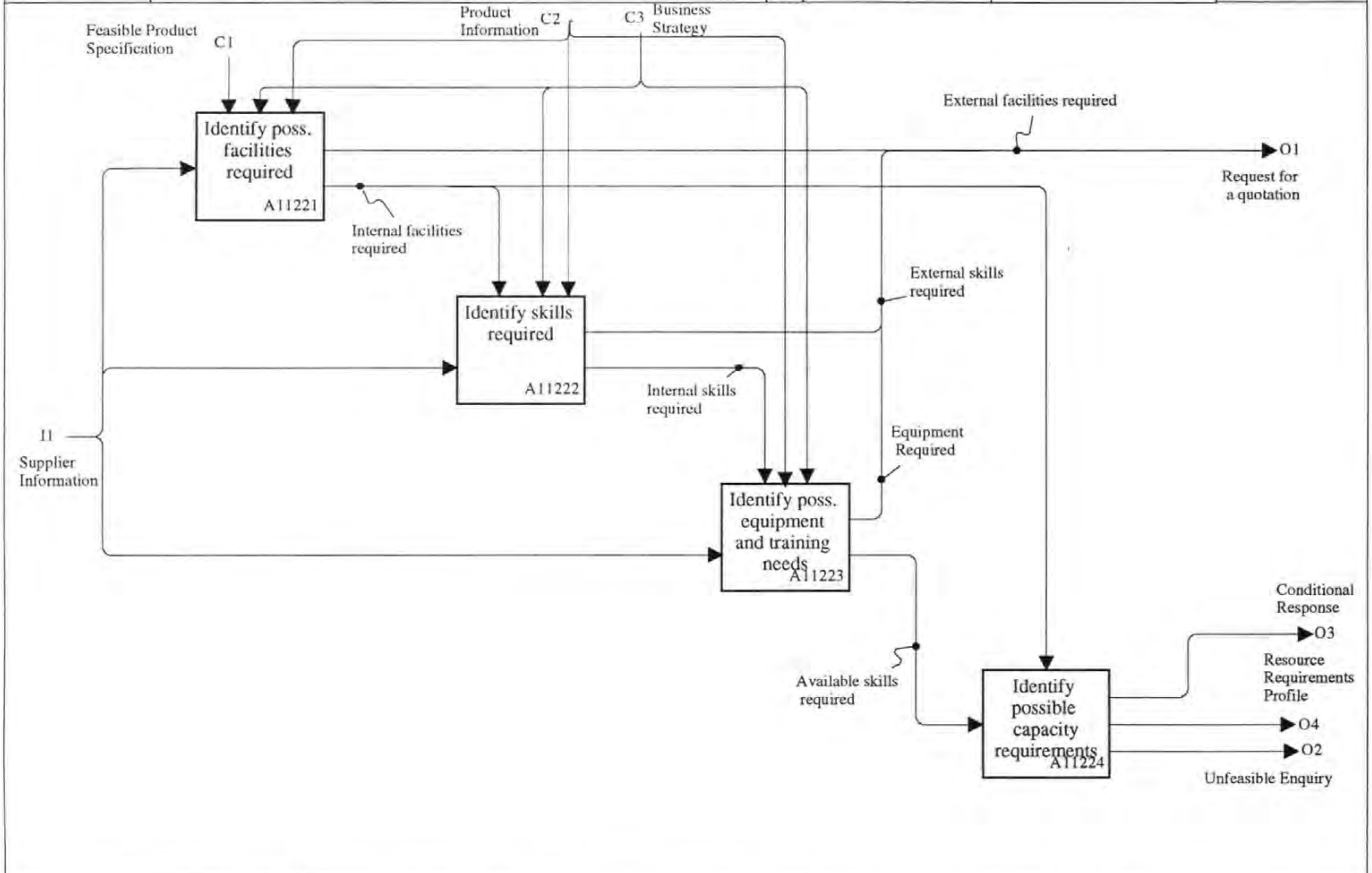

NODE: A1122 | TITLE: Compare facilities & skills to req'mts | NUMBER:

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United Kingdom

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REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

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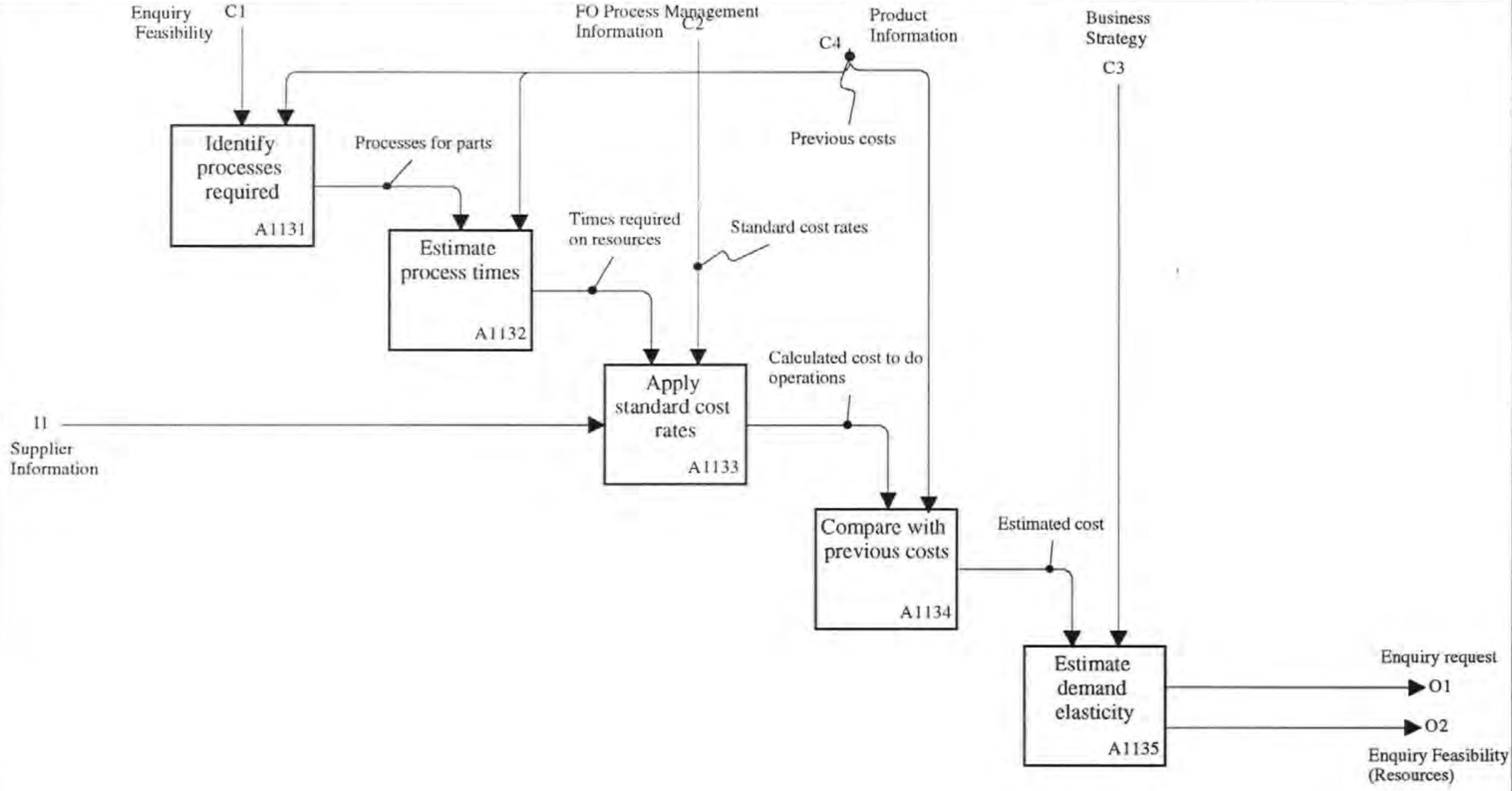

NODE: A113

TITLE: Report on feasibility

NUMBER:

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United Kingdom

Adam Weaver

PROJECT: Generic Process Model

REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

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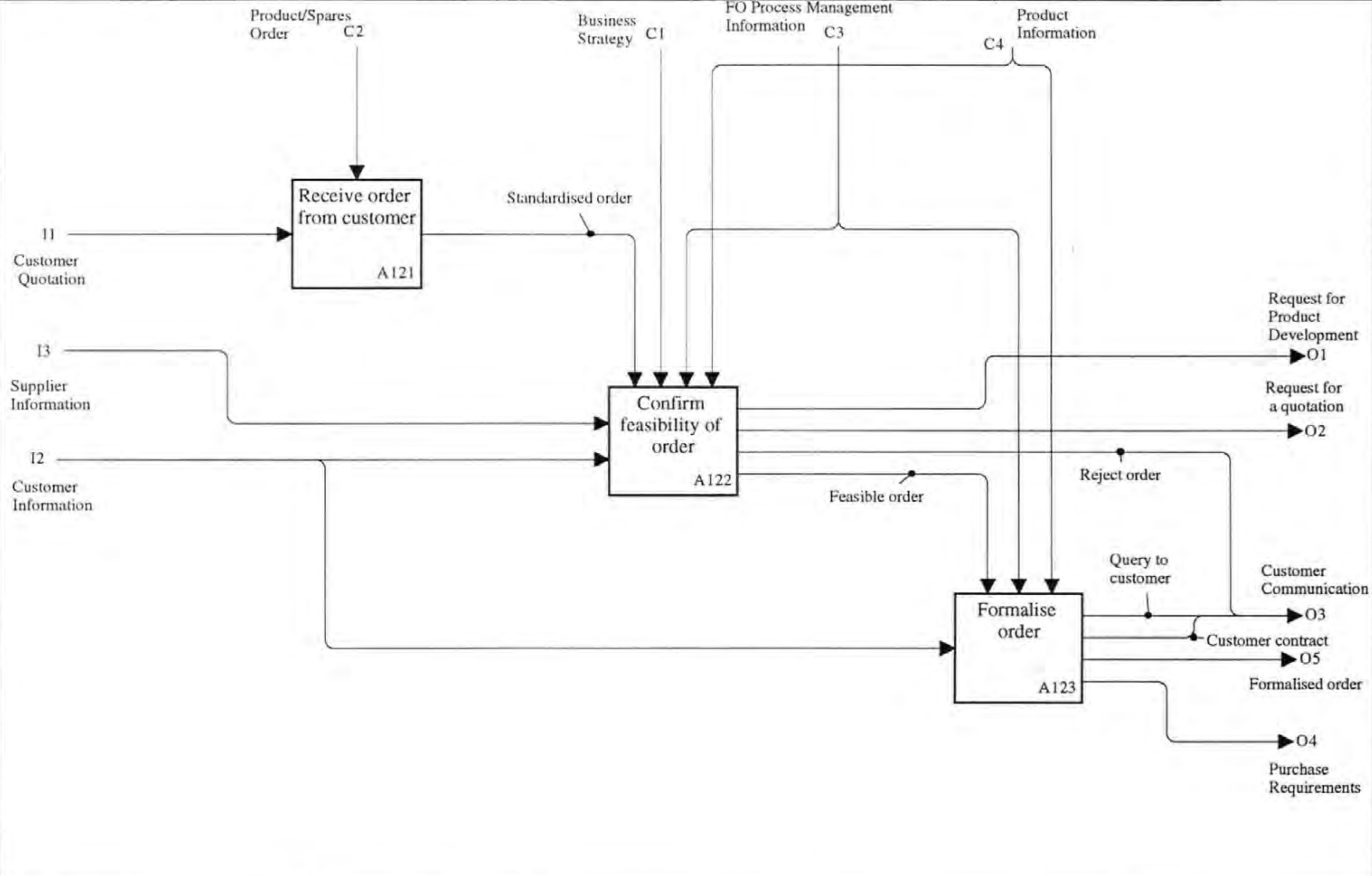

NODE: A12 | TITLE: Process orders | NUMBER:

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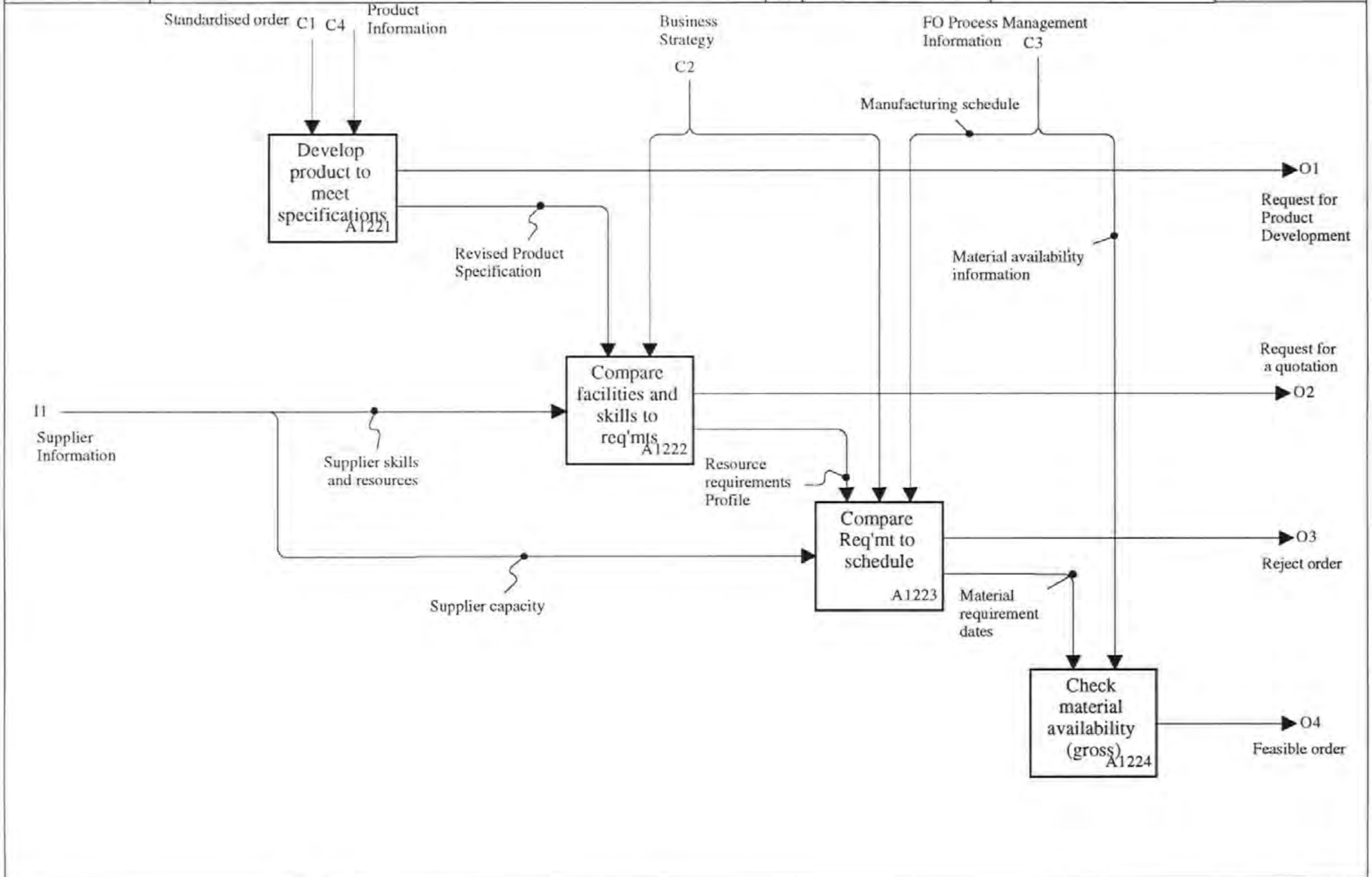

NODE: A122 TITLE: Confirm feasibility of order NUMBER:

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PROJECT: Generic Process Model

REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

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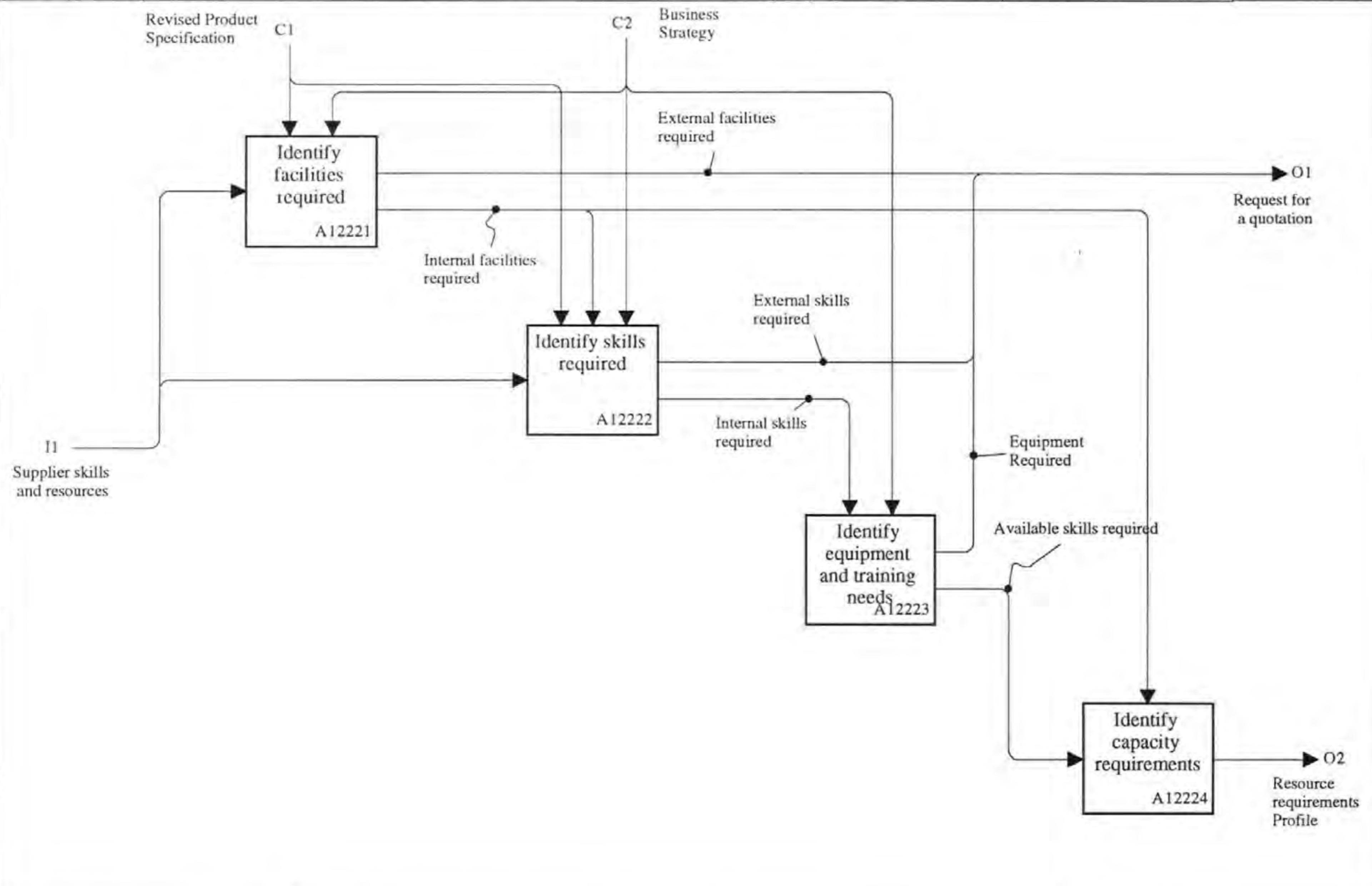

NODE: A1222

TITLE: Compare facilities and skills to req'mts

NUMBER:

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United Kingdom

PROJECT: Generic Process Model

REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

DRAFT

RECOMMENDED

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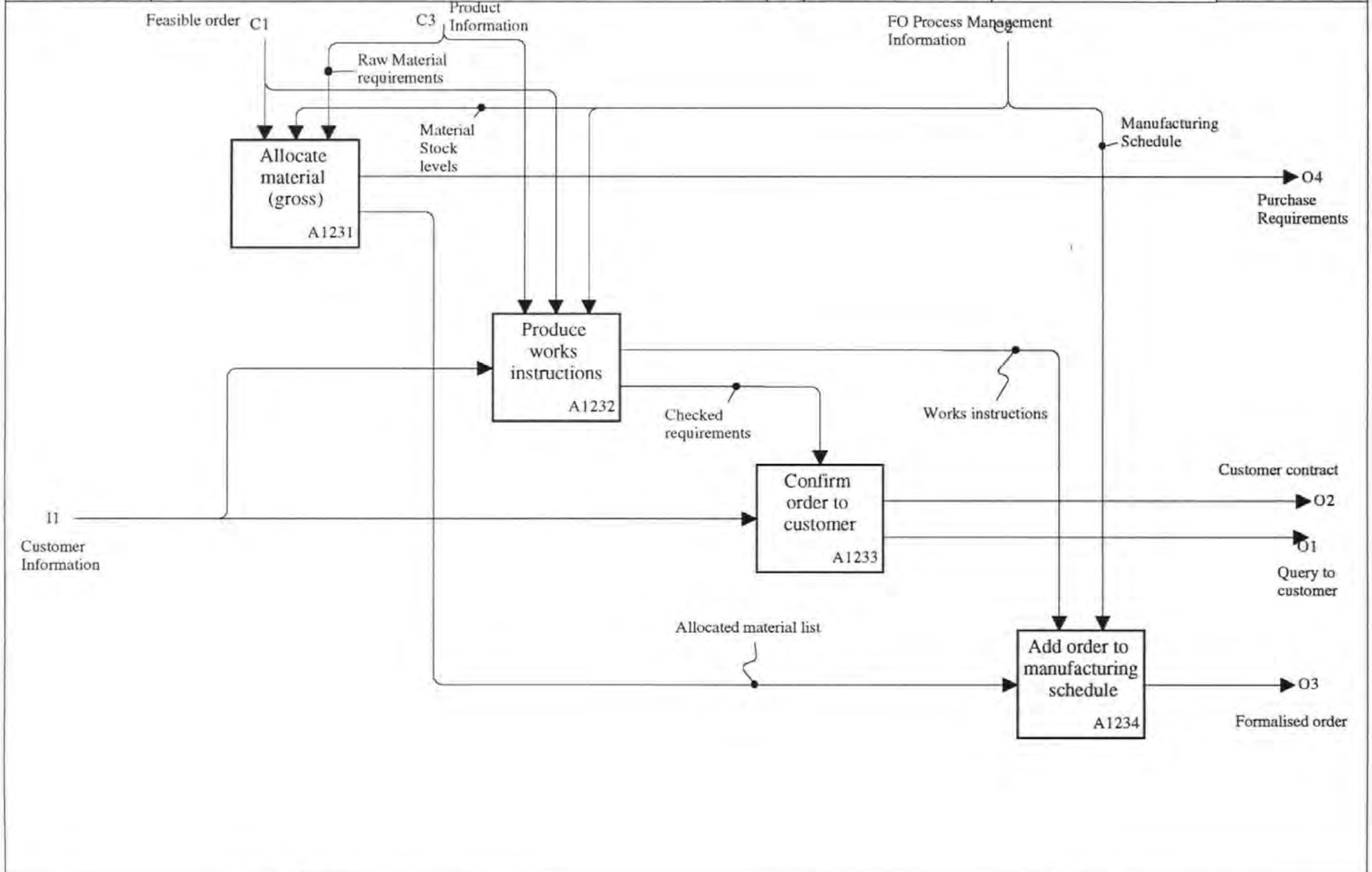

NODE: A123

TITLE: Formalise order

NUMBER:

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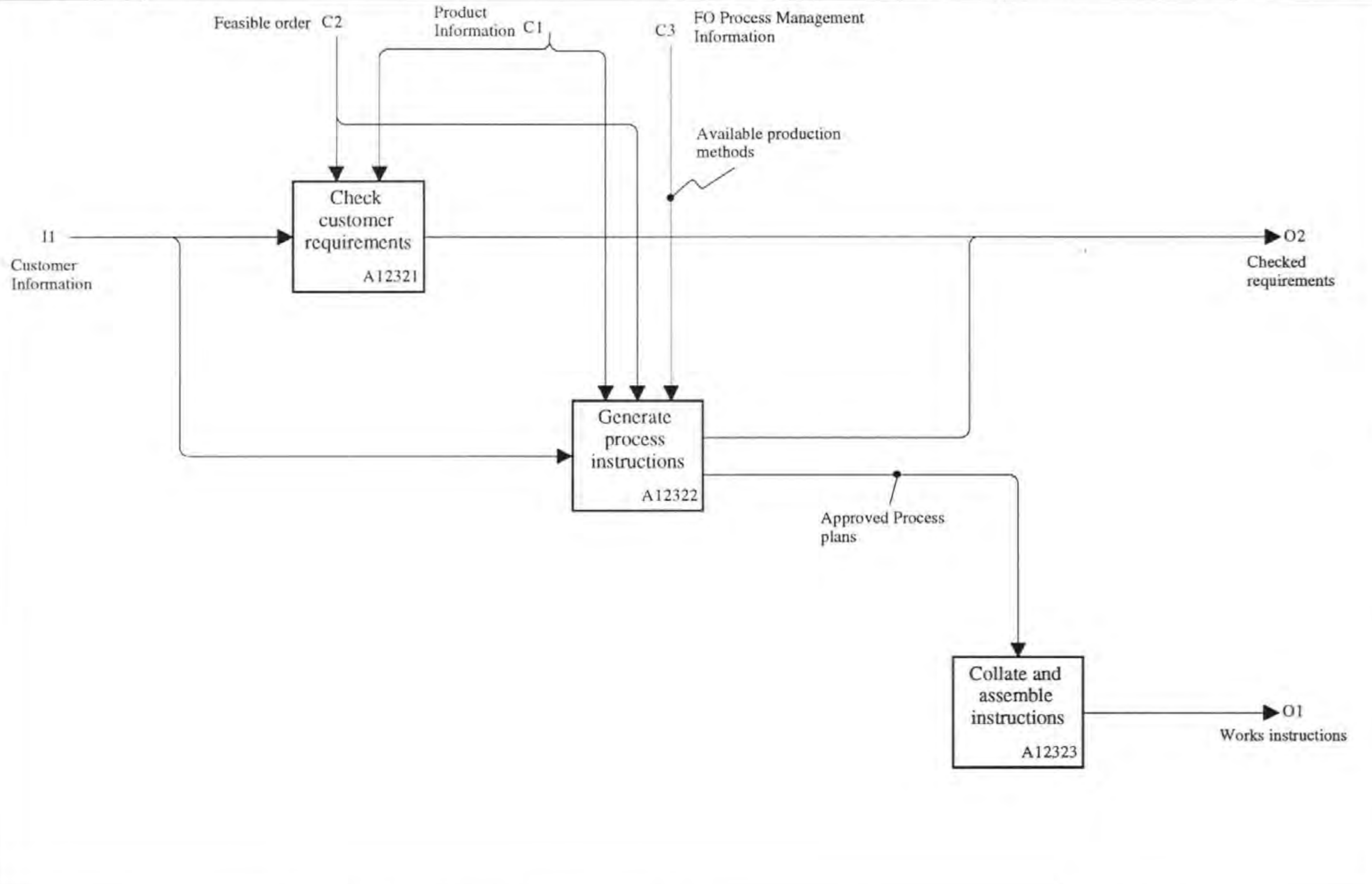
	PROJECT: Generic Process Model	REV:	DRAFT
			RECOMMENDED
	NOTES: 1 2 3 4 5 6 7 8 9 10		X PUBLICATION



NODE: A1232	TITLE: Produce works instructions	NUMBER:

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AUTHOR: Adam Weaver | DATE:

PROJECT: Generic Process Model | REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

	WORKING	READER	DATE
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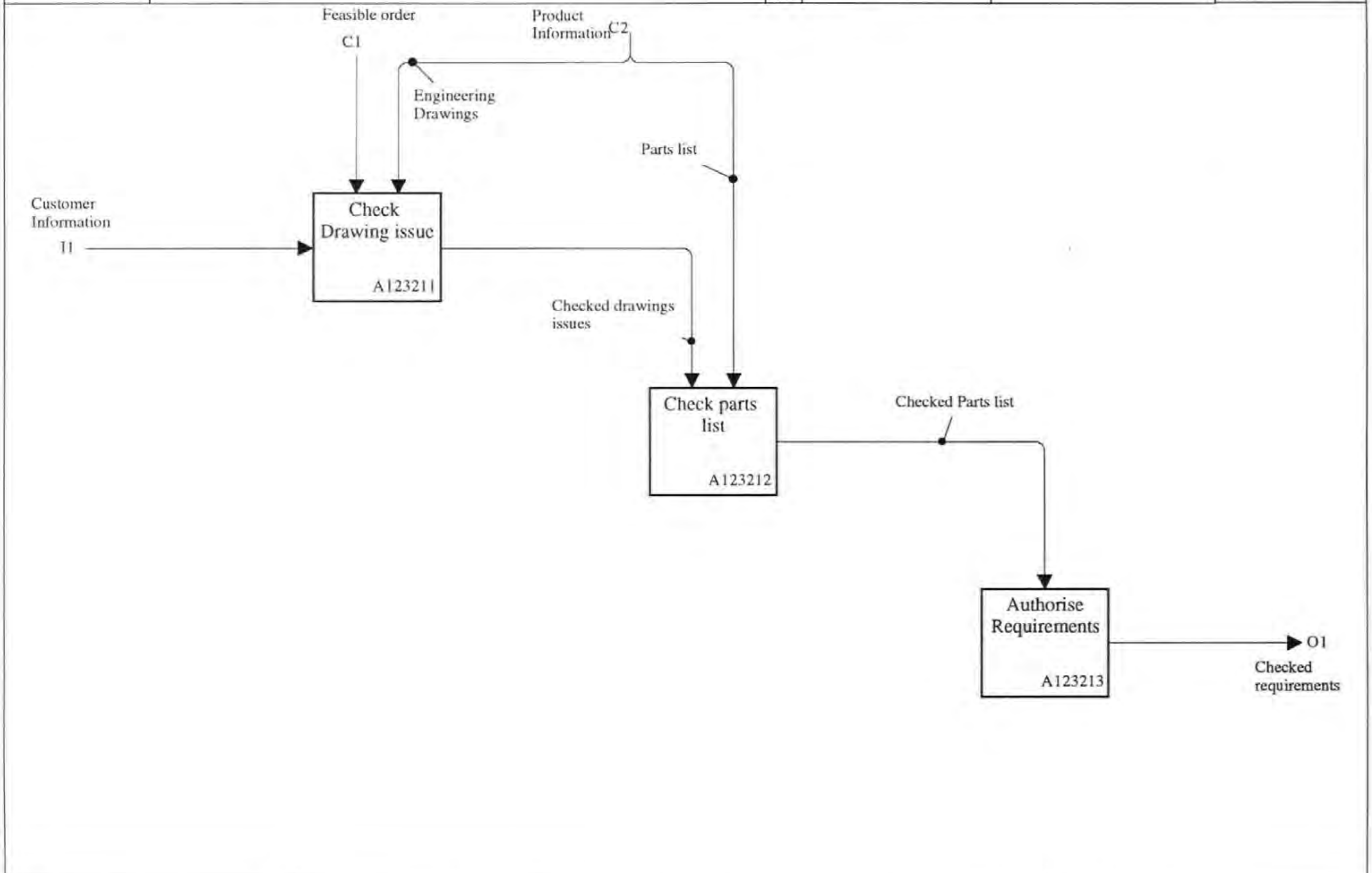

NODE: A12321 | TITLE: Check customer requirements | NUMBER:

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United Kingdom

Adam Weaver

PROJECT: Generic Process Model

REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

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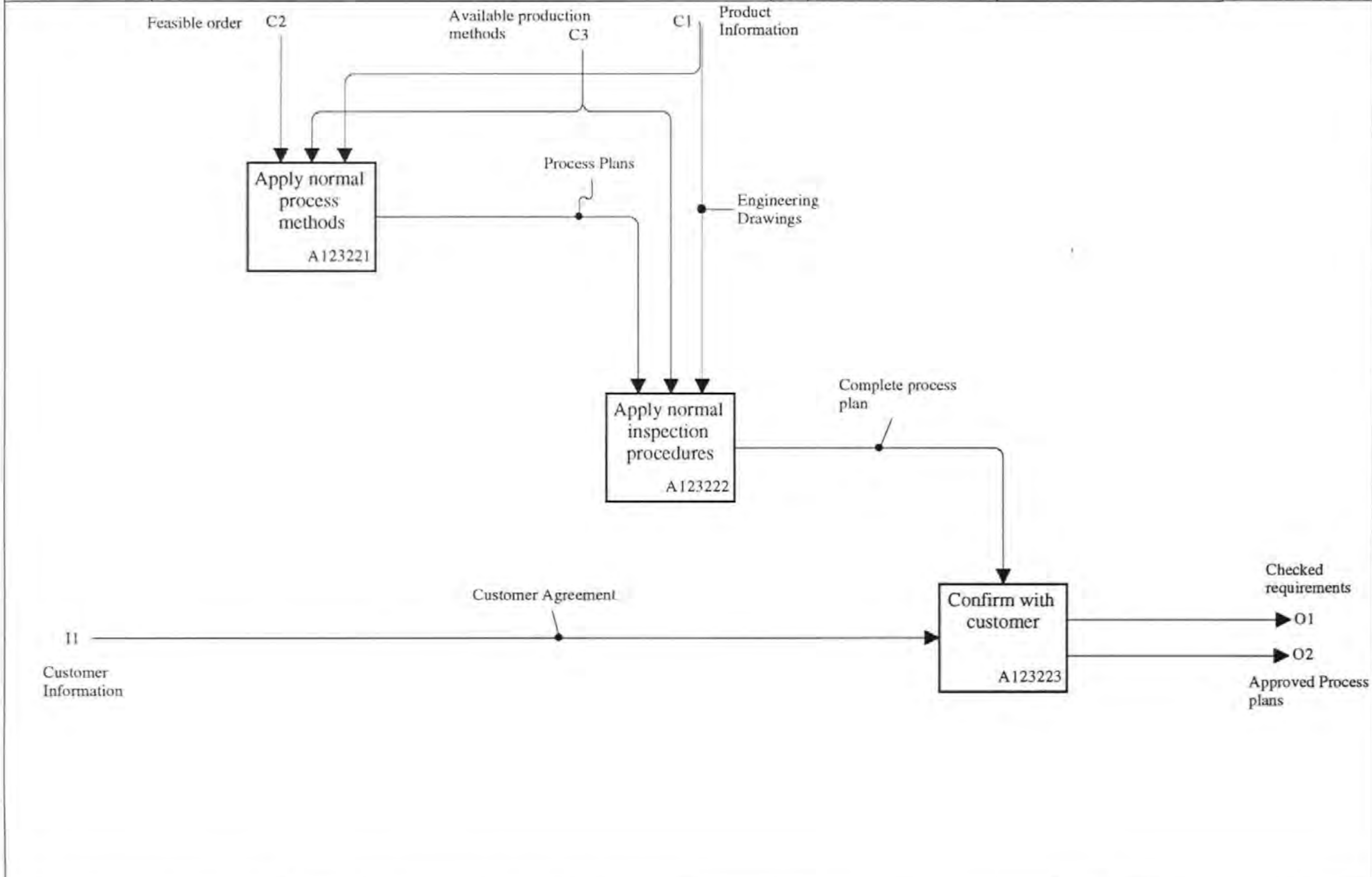
	RECOMMENDED
X	PUBLICATION



NODE: A12322

TITLE: Generate process instructions

NUMBER:

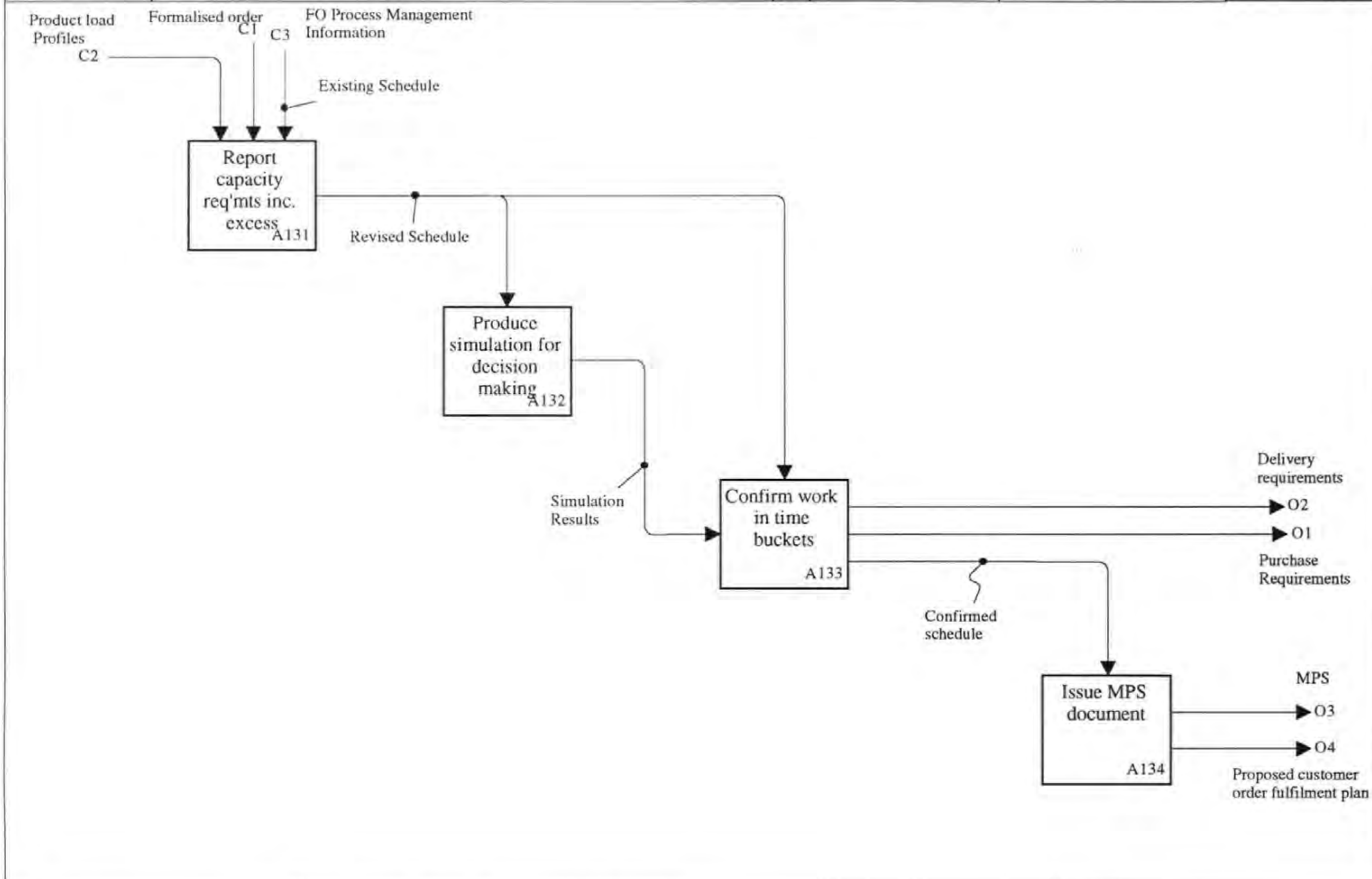
School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

PROJECT: Generic Process Model

REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

	DRAFT
	RECOMMENDED
X	PUBLICATION



NODE: A13	TITLE: Maintain manufacturing schedule	NUMBER:

School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

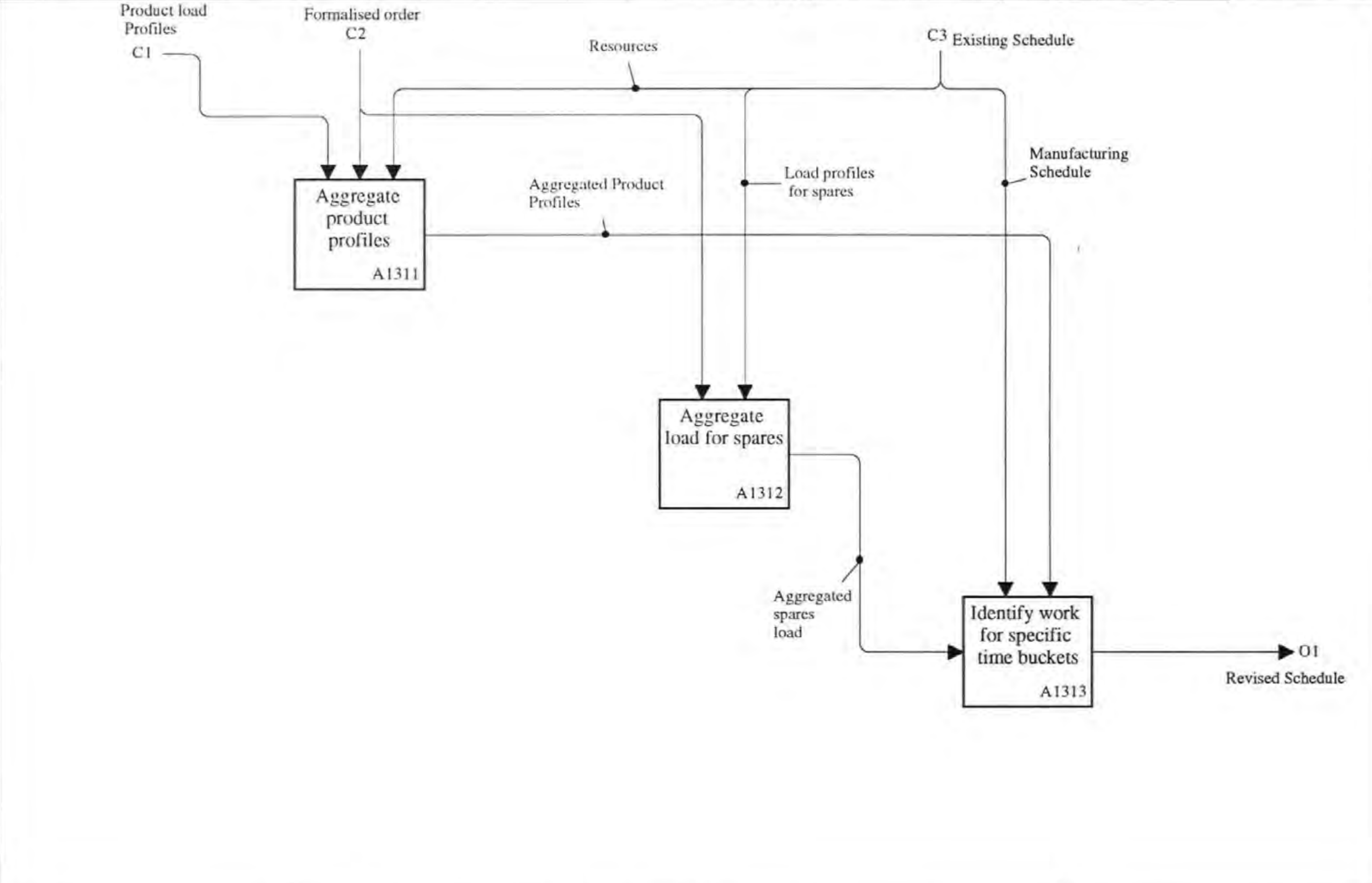
Adam Weaver

PROJECT: Generic Process Model

REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

	DRAFT
	RECOMMENDED
X	PUBLICATION



NODE: A131

TITLE: Report capacity req'mts inc. excess

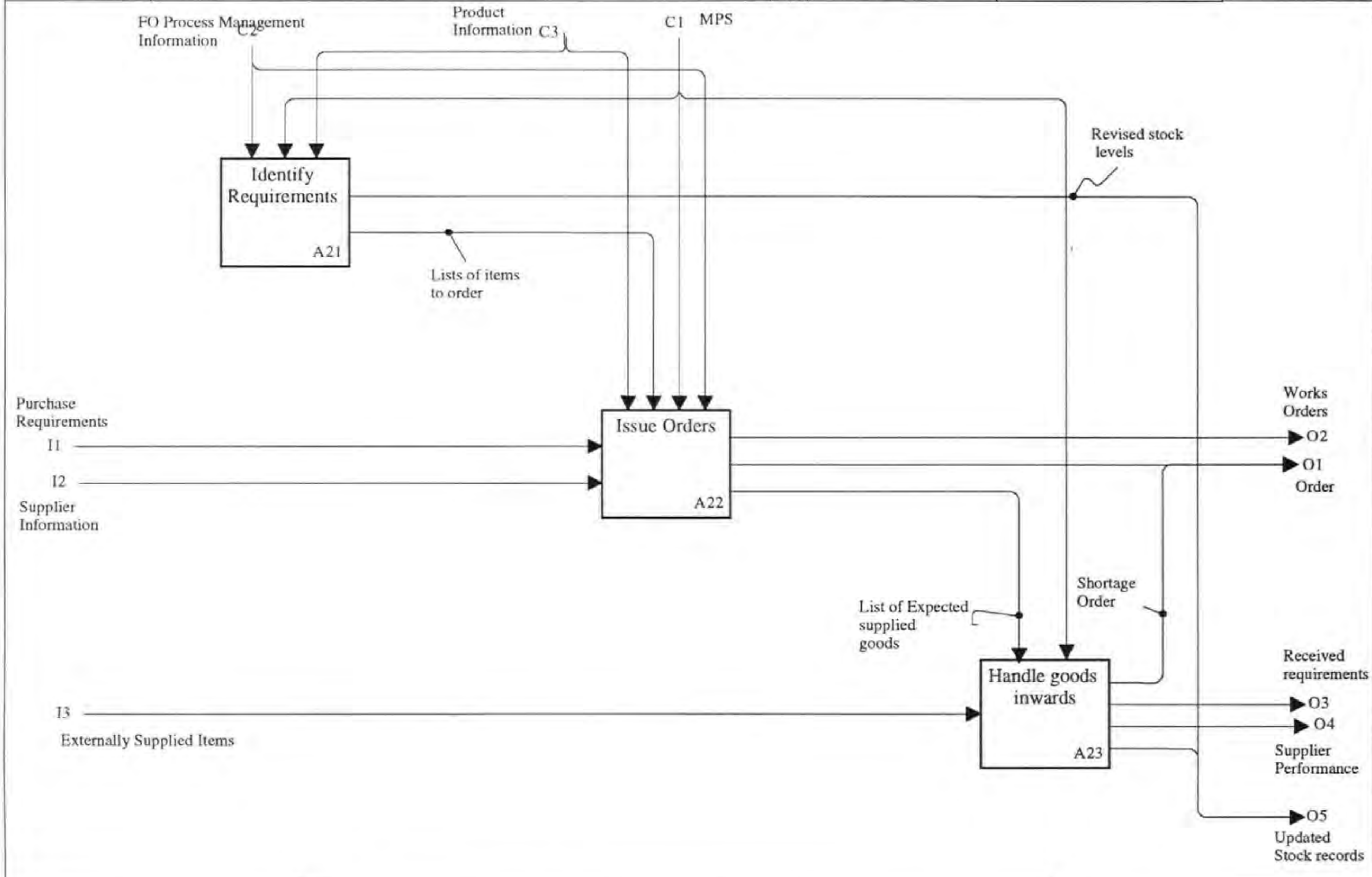
NUMBER:

School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

PROJECT: Generic Process Model | REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

	DRAFT
	RECOMMENDED
X	PUBLICATION

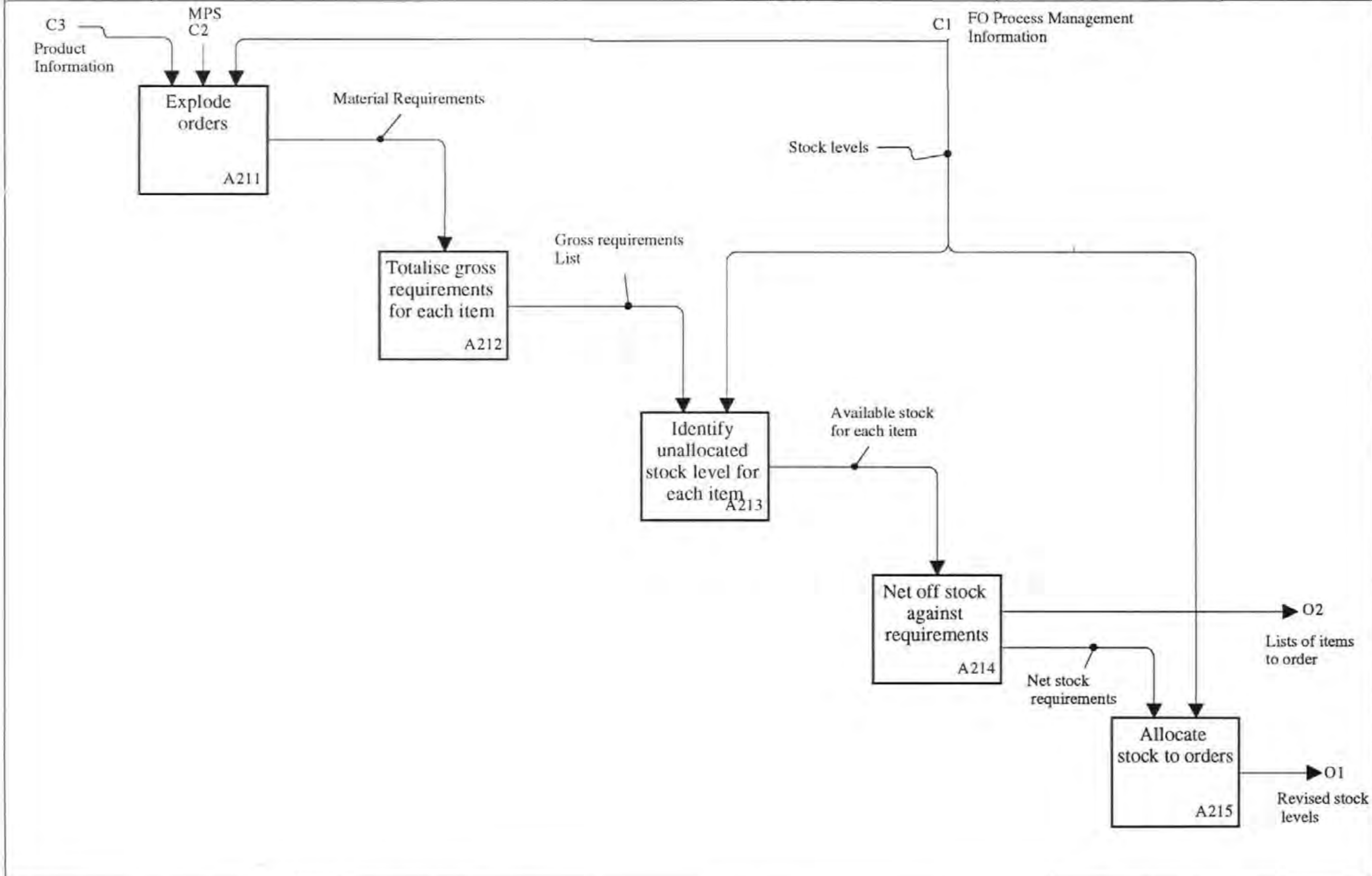


NODE: A2 | TITLE: Obtain required items | NUMBER:

School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

AUTHOR: Adam Weaver
PROJECT: Generic Process Model
REV:
NOTES: 1 2 3 4 5 6 7 8 9 10

	WORKING
	DRAFT
	RECOMMENDED
X	PUBLICATION



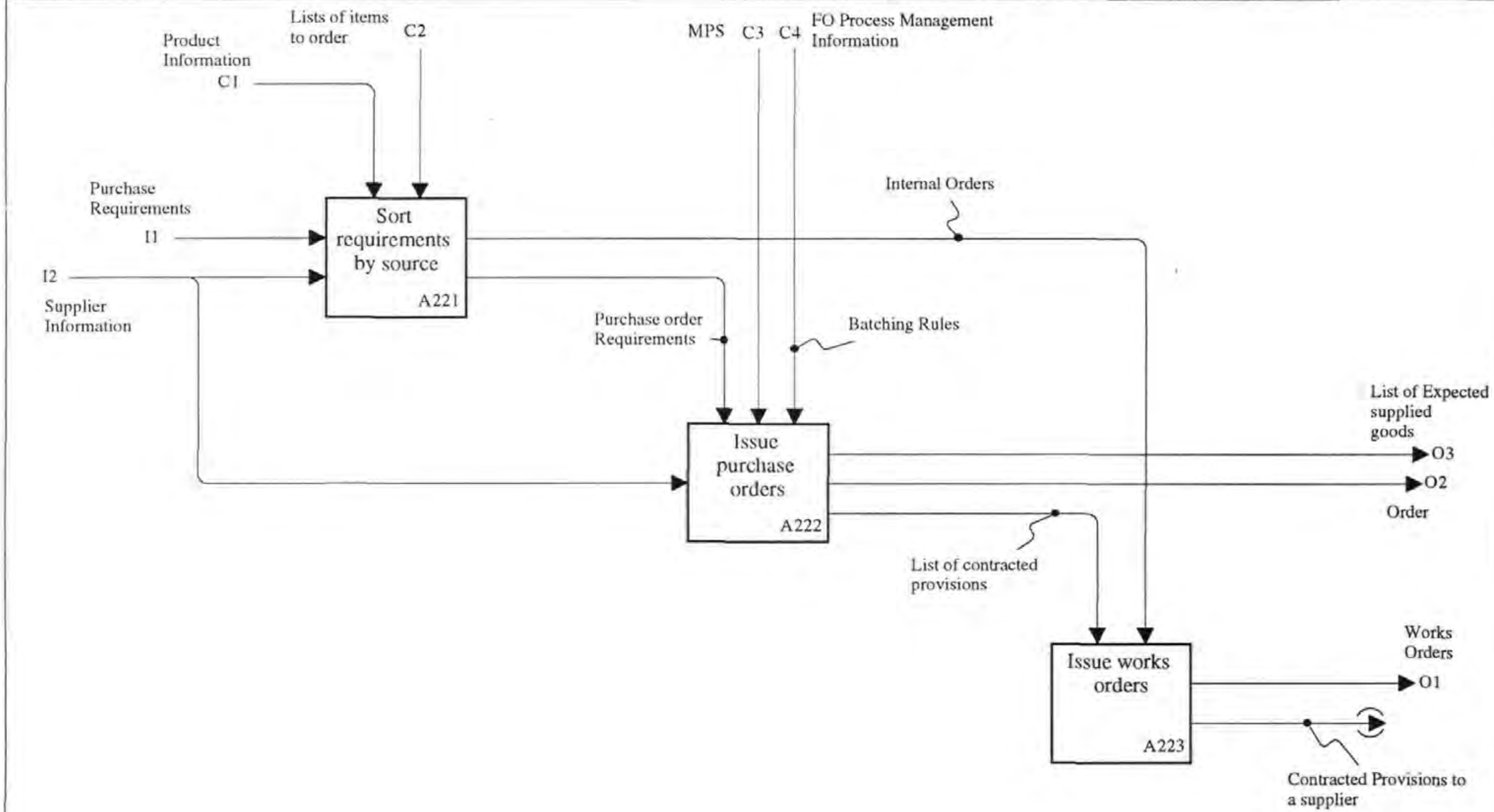
NODE: A21
TITLE: Identify Requirements
NUMBER:

School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

PROJECT: Generic Process Model REV:

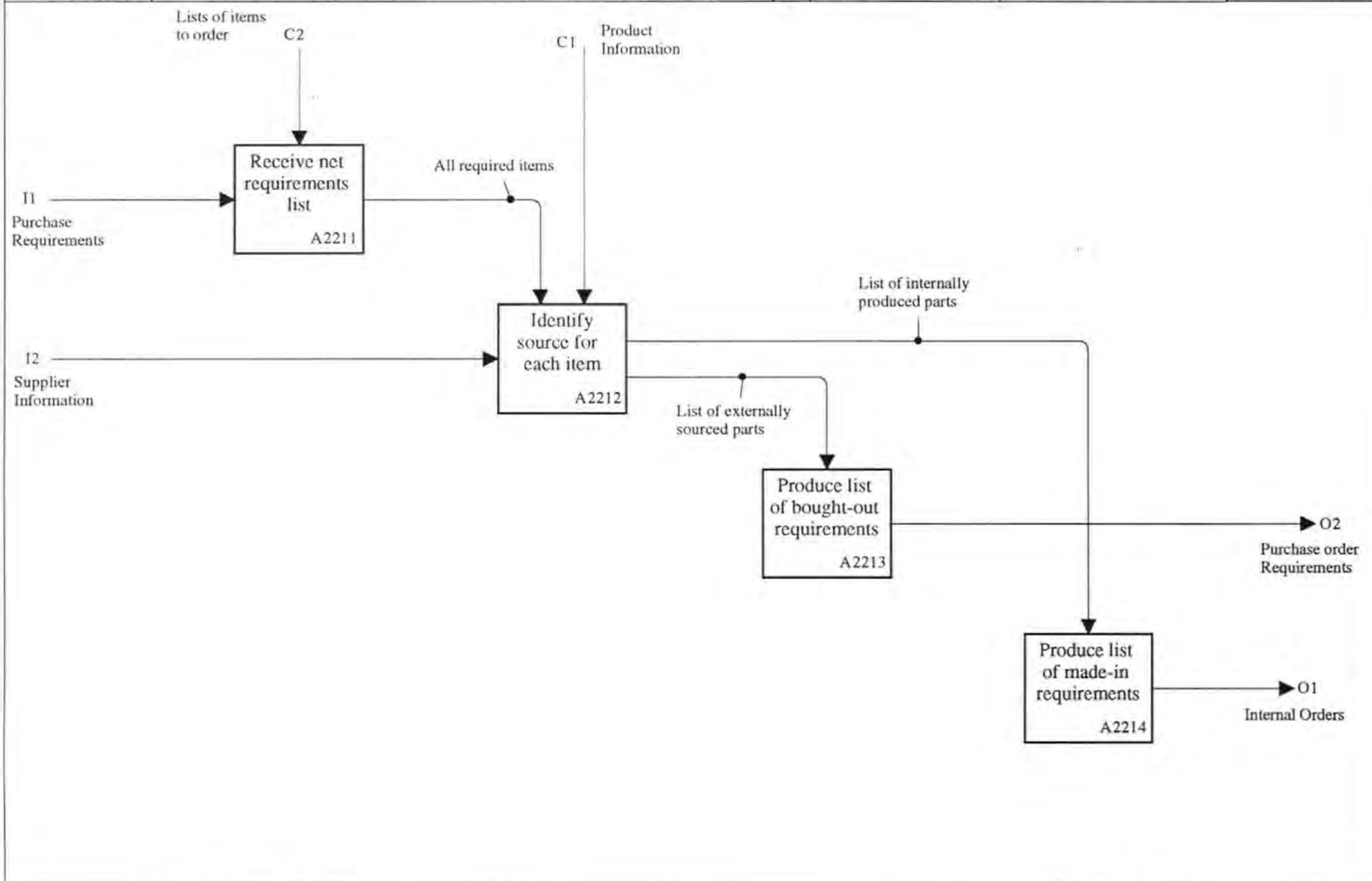
NOTES: 1 2 3 4 5 6 7 8 9 10

	DRAFT	
	RECOMMENDED	
X	PUBLICATION	



NODE: A22 TITLE: Issue Orders NUMBER:

School Of Computing University Of Plymouth Drake Circus Plymouth PL4 8AA United Kingdom	Adam Weaver PROJECT: Generic Process Model NOTES: 1 2 3 4 5 6 7 8 9 10	REV:	DRAFT RECOMMENDED X PUBLICATION	



NODE: A221	TITLE: Sort requirements by source	NUMBER:

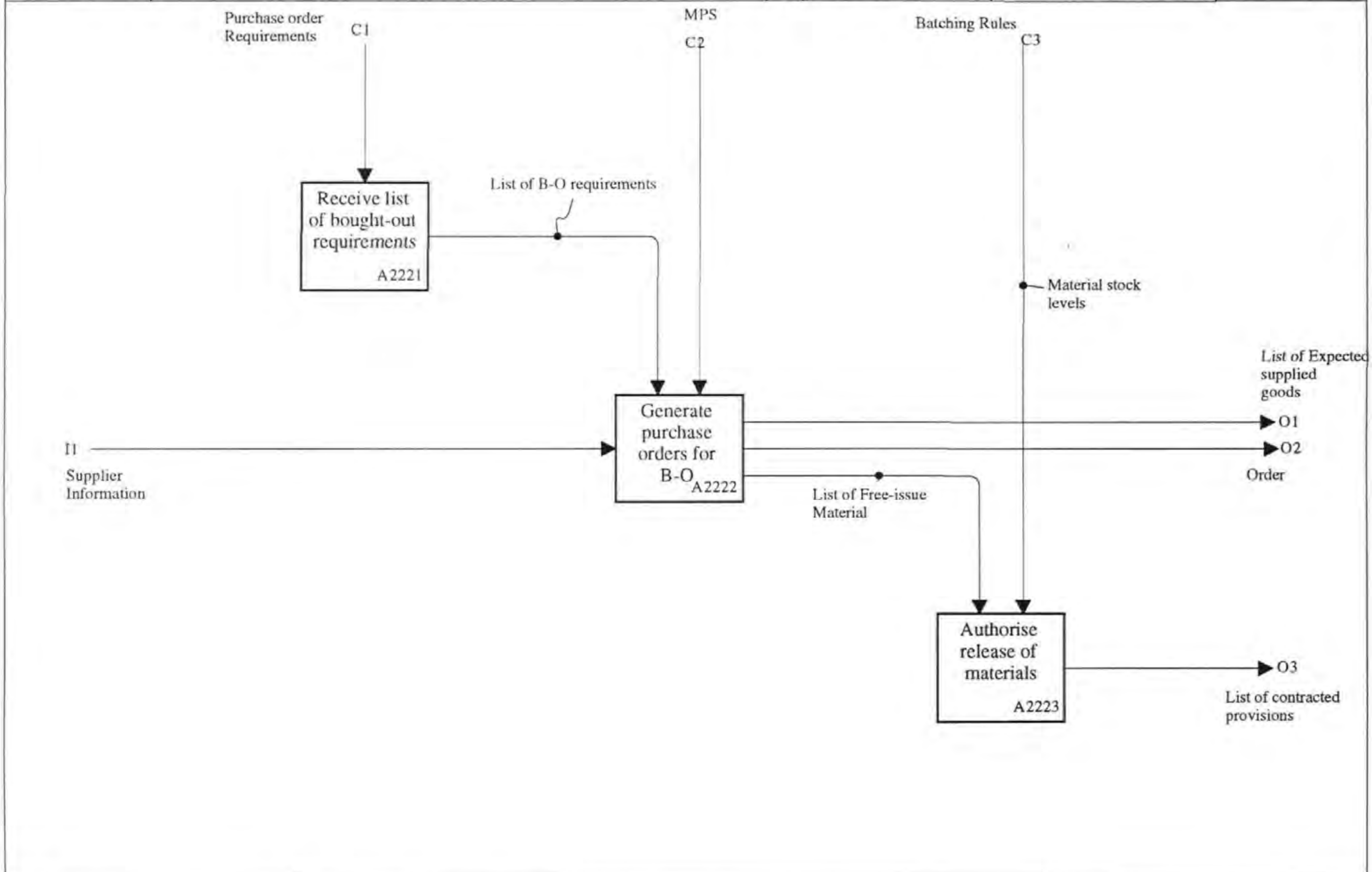
School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

PROJECT: Generic Process Model

REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

	DRAFT
	RECOMMENDED
X	PUBLICATION



NODE: A222

TITLE: Issue purchase orders

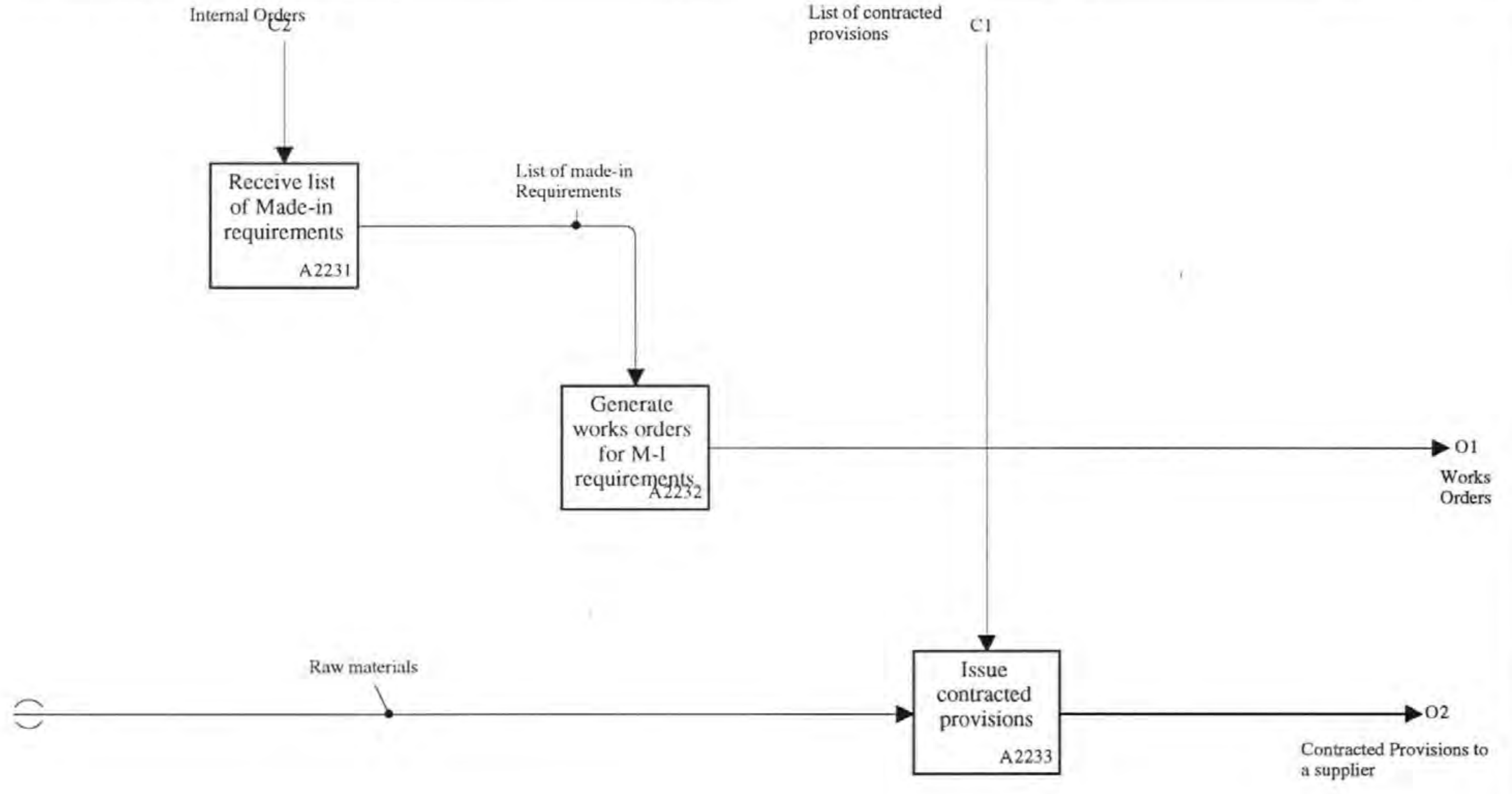
NUMBER:

School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

PROJECT: Generic Process Model REV:

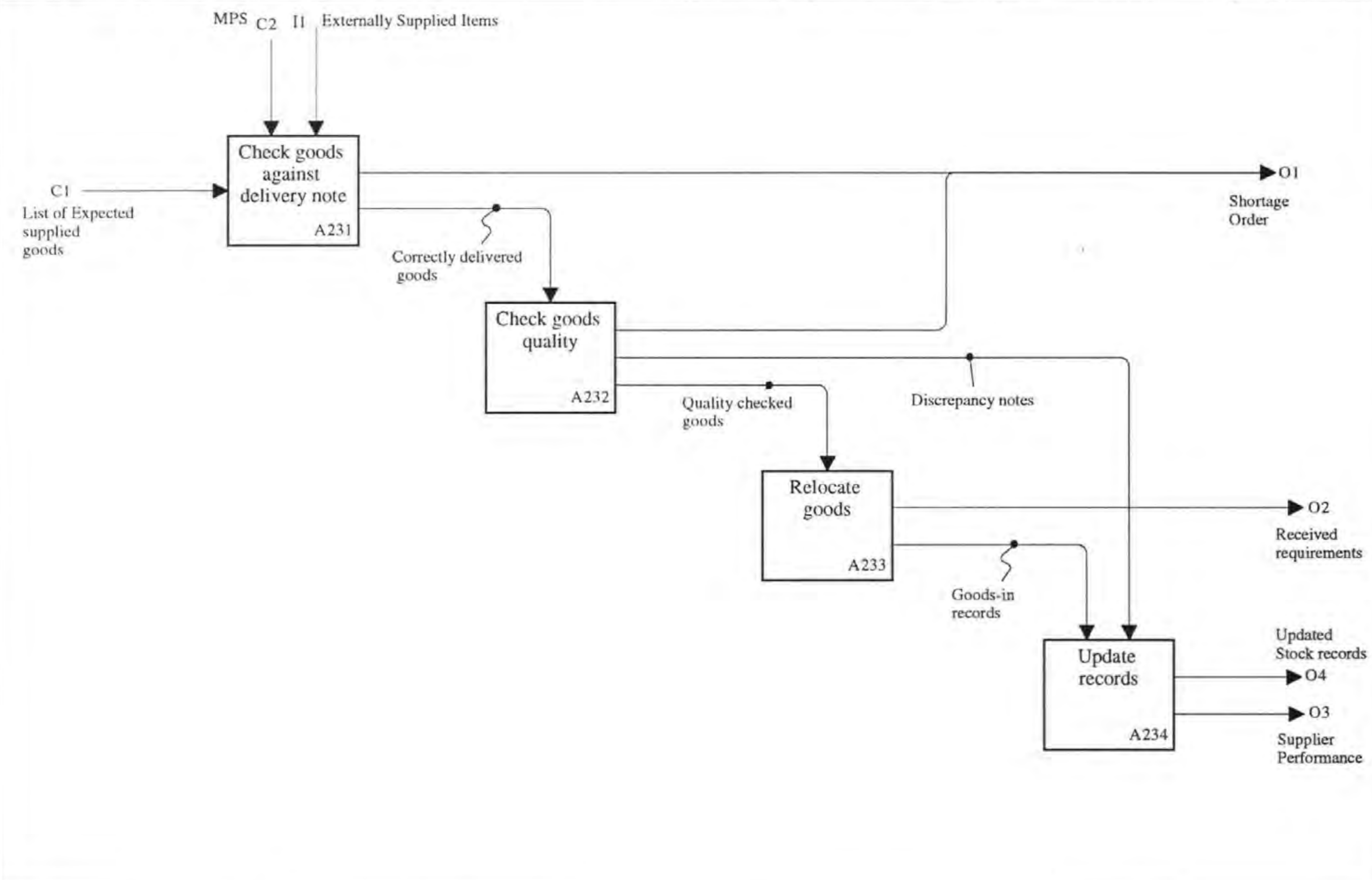
NOTES: 1 2 3 4 5 6 7 8 9 10

	DRAFT
	RECOMMENDED
X	PUBLICATION



NODE: A223 | TITLE: Issue works orders | NUMBER:

USED AT:	AUTHOR: Adam Weaver	DATE:		WORKING	READER	DATE
School Of Computing University Of Plymouth Drake Circus Plymouth PL4 8AA United Kingdom	PROJECT: Generic Process Model	REV:		DRAFT		
	NOTES: 1 2 3 4 5 6 7 8 9 10			RECOMMENDED		
			X	PUBLICATION		



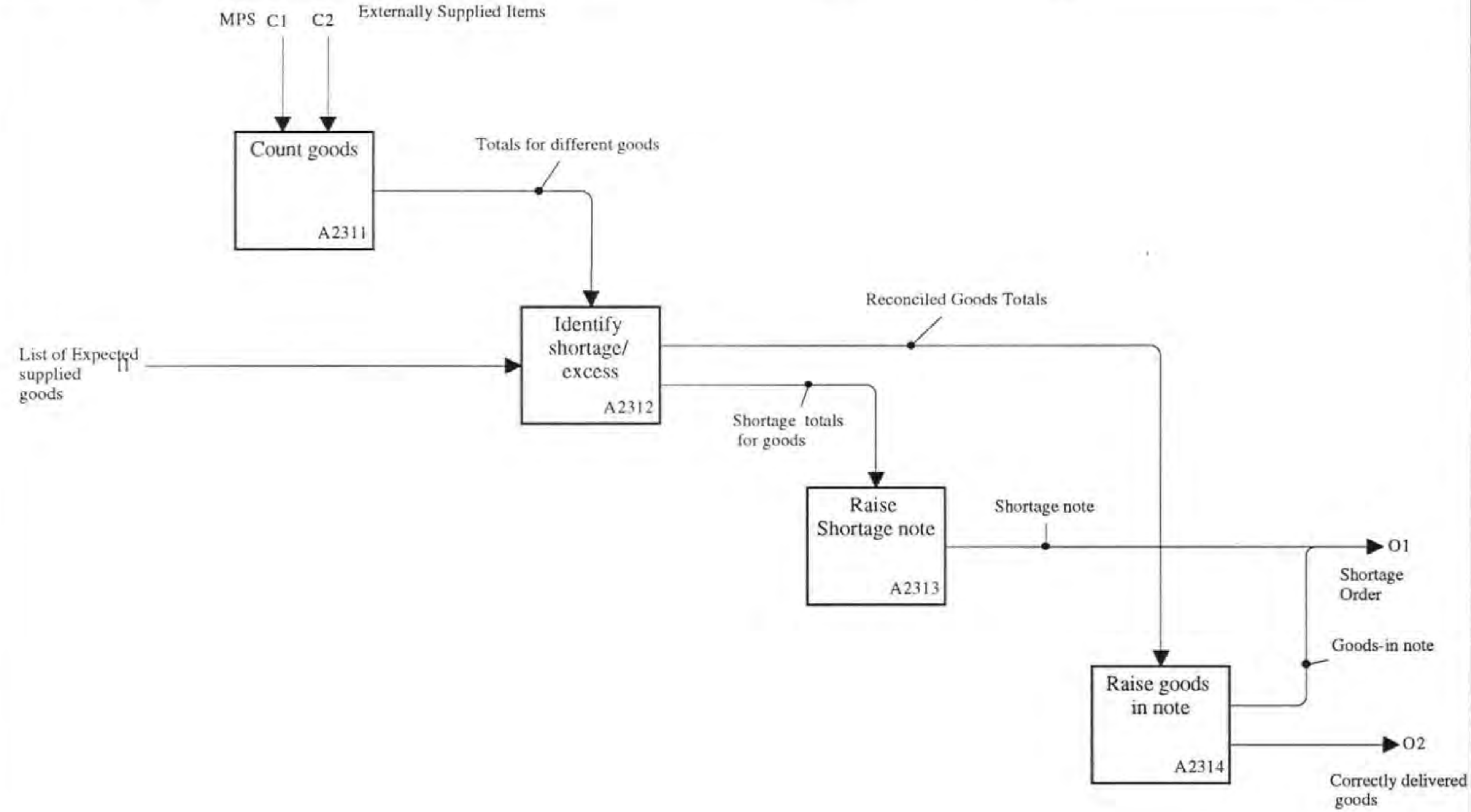
NODE: A23	TITLE: Handle goods inwards	NUMBER:

School Of Computing
University Of Plymouth
Drake Circu.
Plymouth PL4 8AA
United Kingdom

PROJECT: Generic Process Model REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

	DRAFT
	RECOMMENDED
X	PUBLICATION



NODE: A231 TITLE: Check goods against delivery note NUMBER:

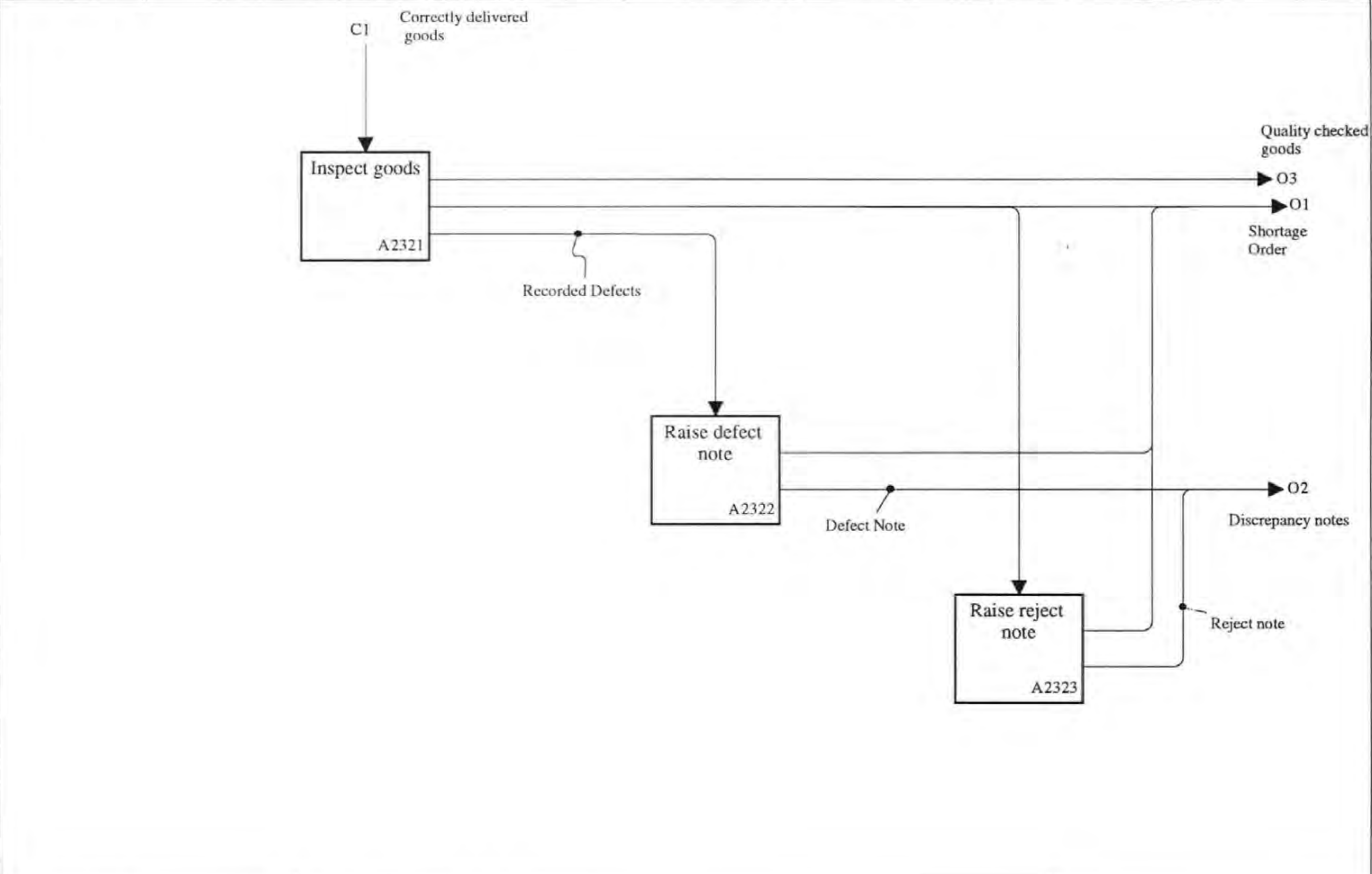
School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

PROJECT: Generic Process Model

REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

	DRAFT
	RECOMMENDED
X	PUBLICATION



NODE: A232

TITLE: Check goods quality

NUMBER:

School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

Adam Weaver

PROJECT: Generic Process Model

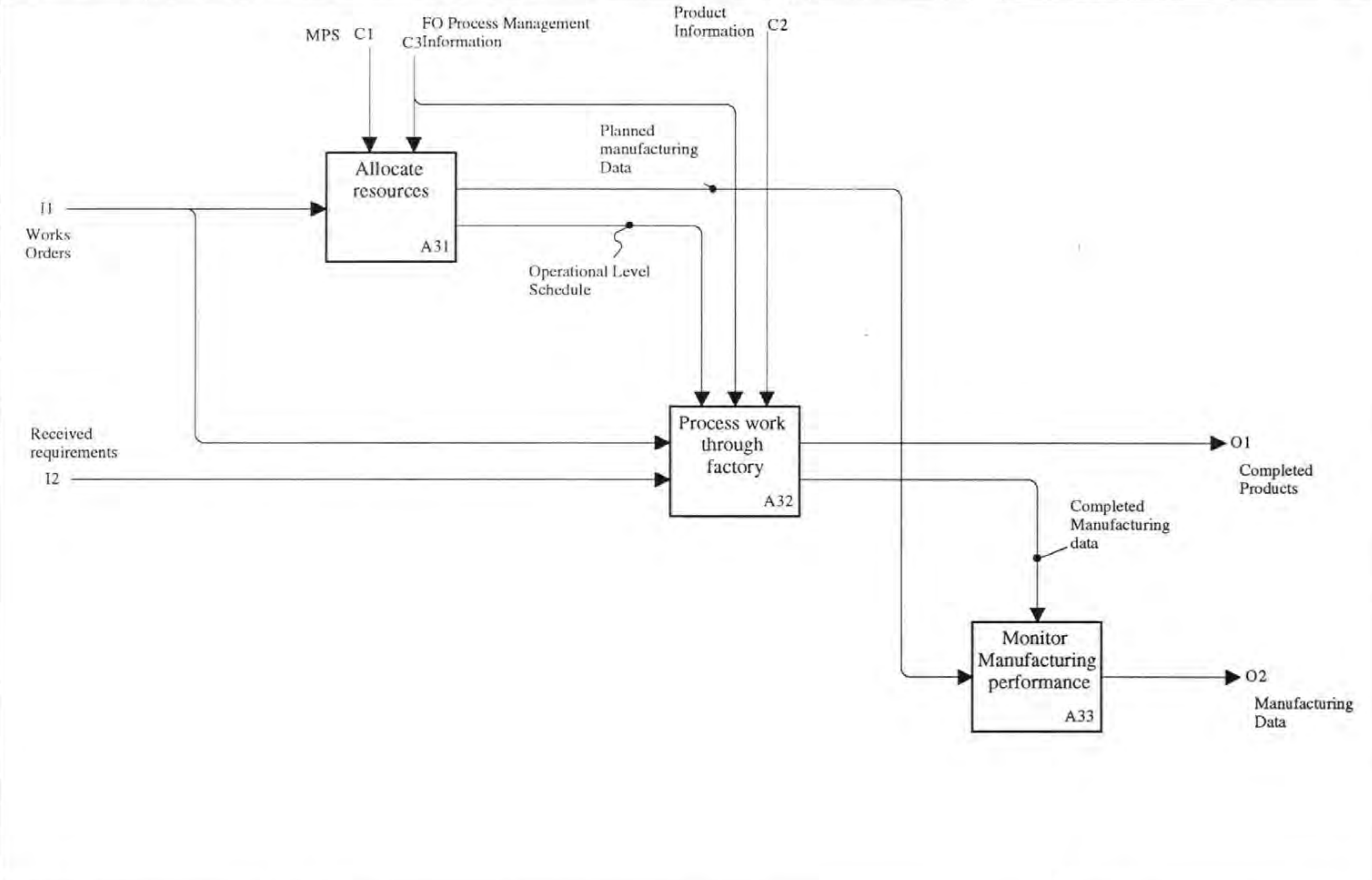
REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

DRAFT

RECOMMENDED

X PUBLICATION



NODE: A3

TITLE: Manufacture products

NUMBER:

School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

Adam Weaver

PROJECT: Generic Process Model

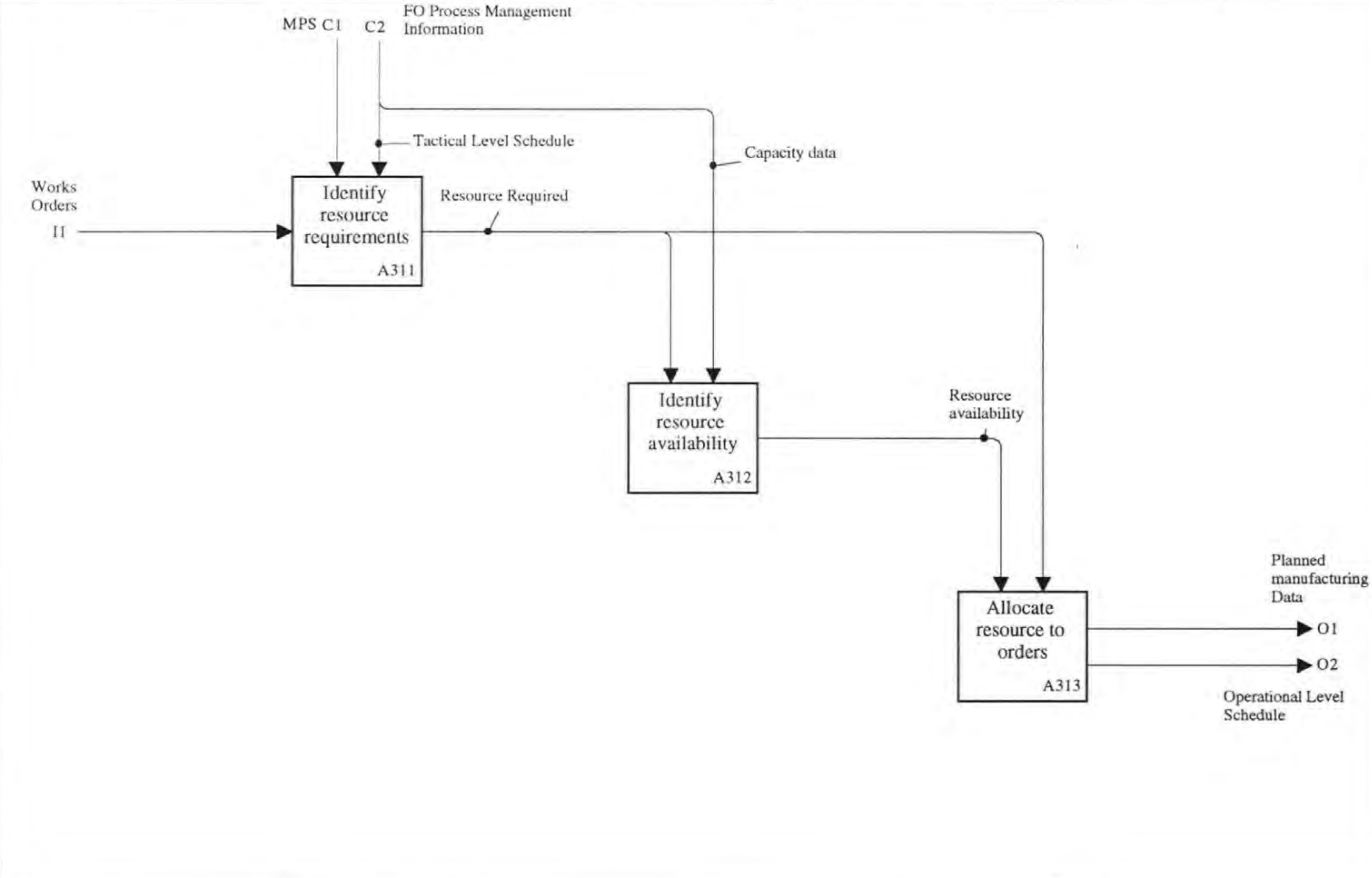
REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

DRAFT

RECOMMENDED

X PUBLICATION

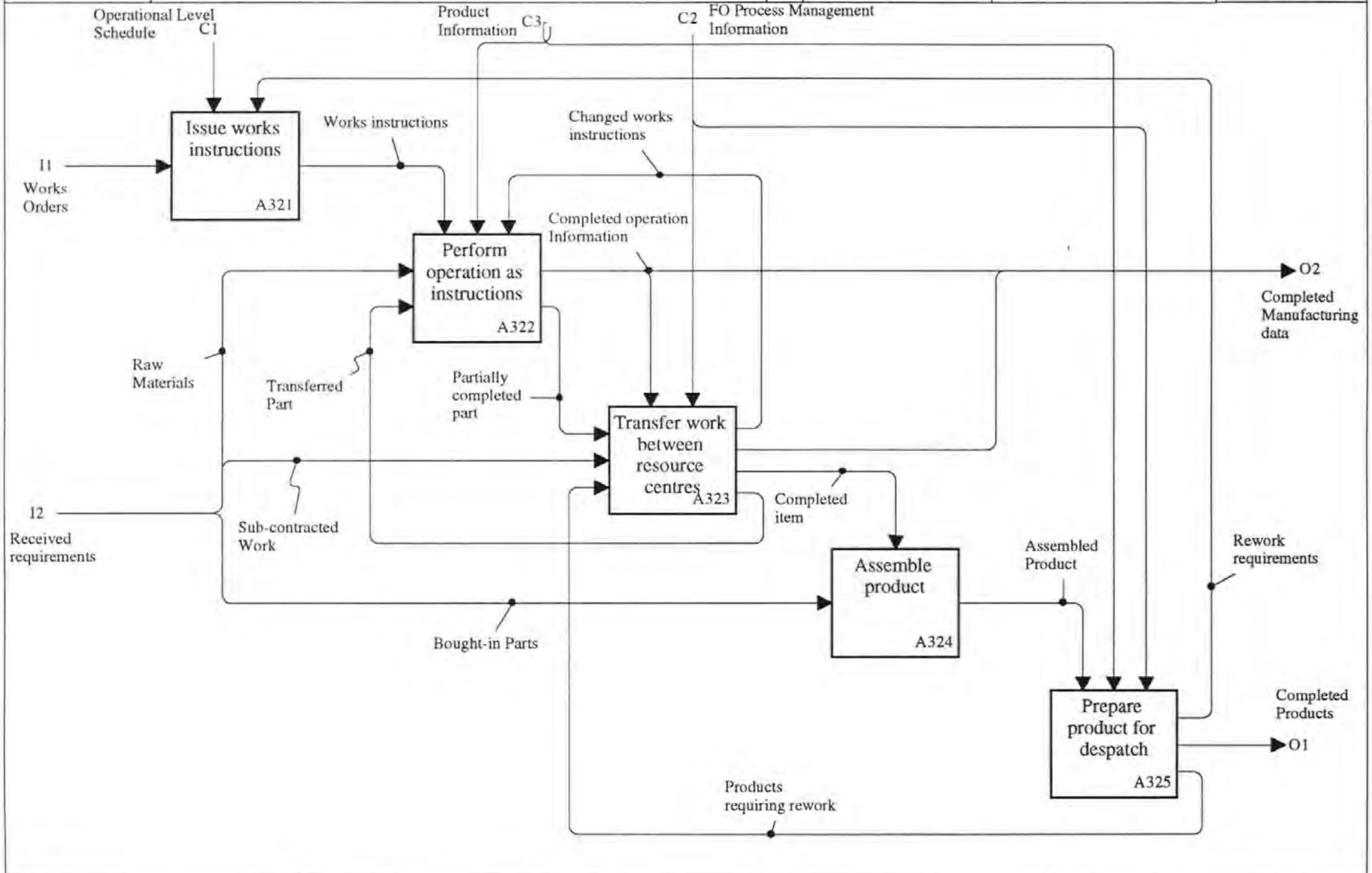


NODE: A31

TITLE: Allocate resources

NUMBER:

USED AT:	AUTHOR: Adam Weaver	DATE:	WORKING	READER	DATE
School Of Computing University Of Plymouth Drake Circus Plymouth PL4 8AA United Kingdom	PROJECT: Generic Process Model	REV:	DRAFT		
			RECOMMENDED		
	NOTES: 1 2 3 4 5 6 7 8 9 10		X PUBLICATION		



NODE: A32	TITLE: Process work through factory	NUMBER:

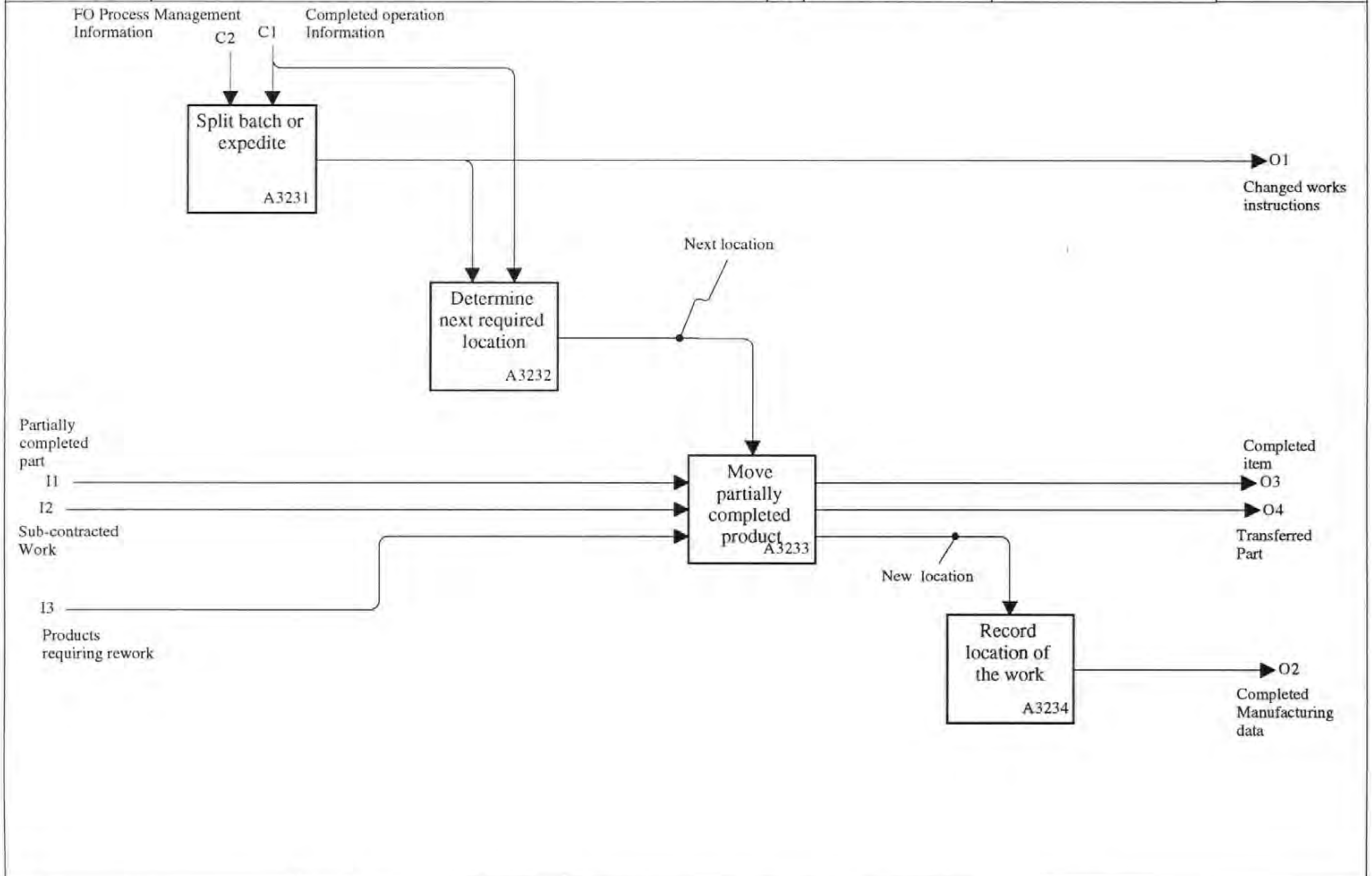
School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

PROJECT: Generic Process Model

REV:

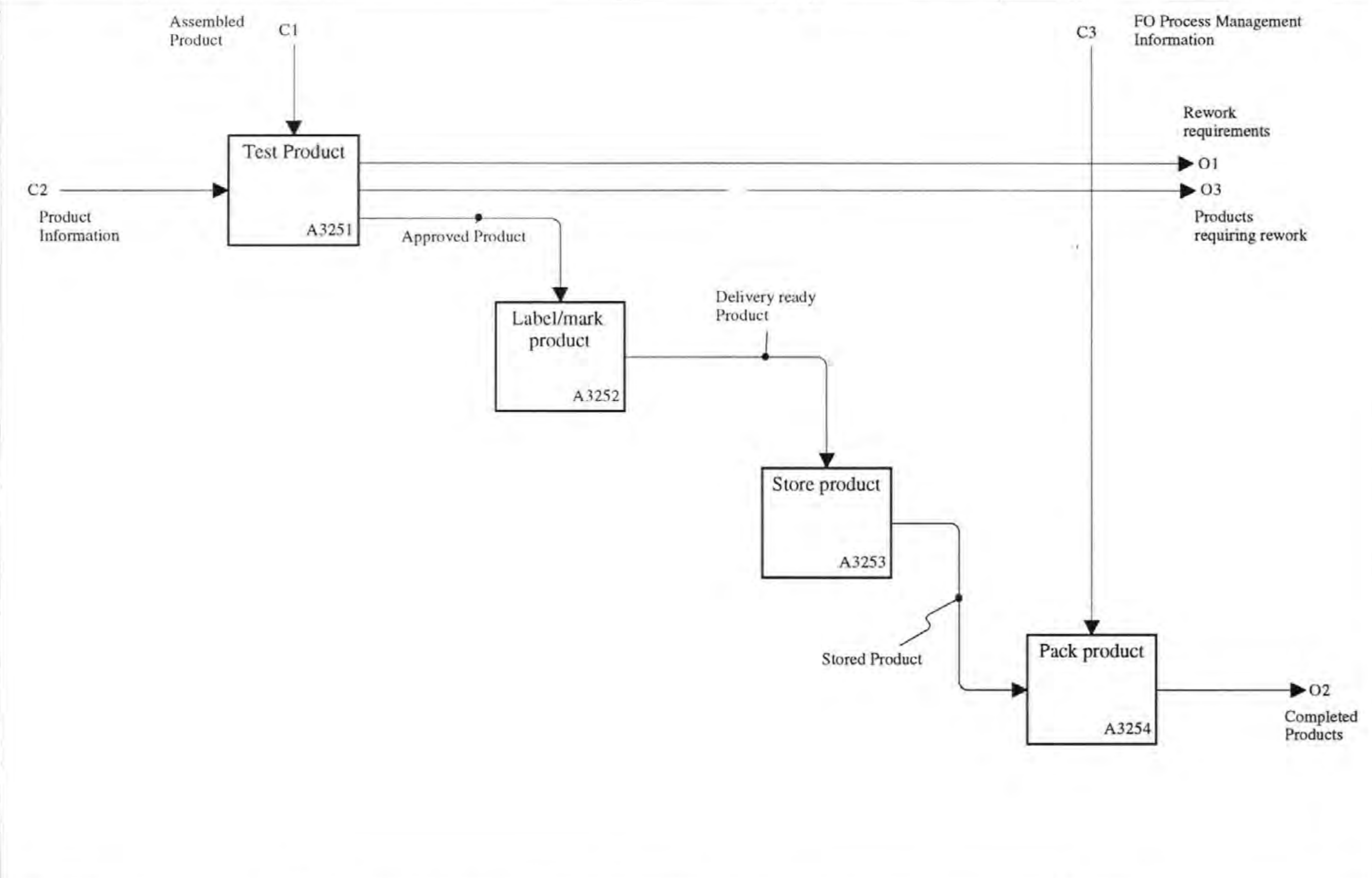
NOTES: 1 2 3 4 5 6 7 8 9 10

	DRAFT
	RECOMMENDED
X	PUBLICATION



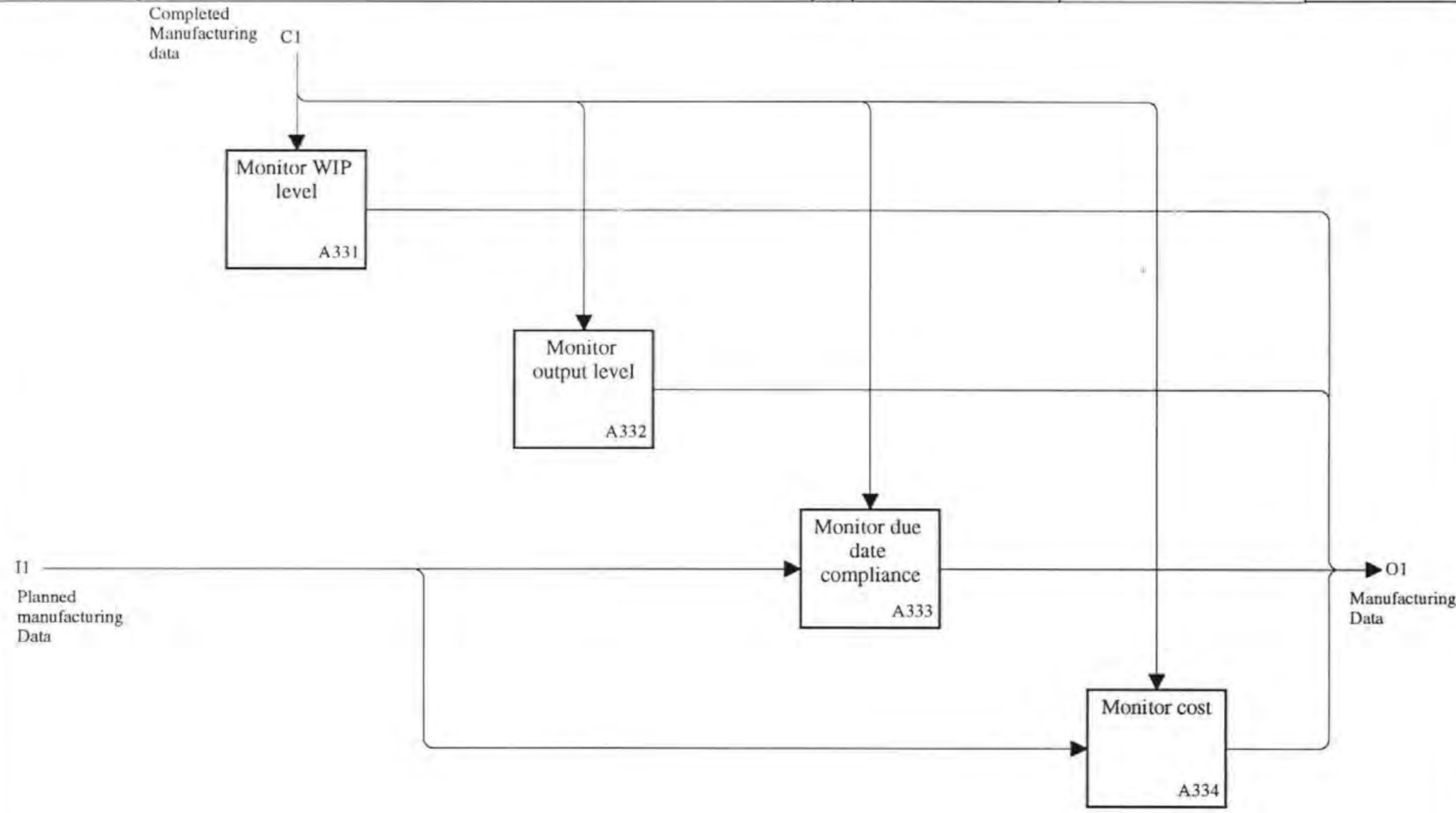
NODE: A323 | TITLE: Transfer work between resource centres | NUMBER:

School Of Computing University Of Plymouth Drake Circus Plymouth PL4 8AA United Kingdom	AUTHOR: Adam Weaver PROJECT: Generic Process Model NOTES: 1 2 3 4 5 6 7 8 9 10	DATE: REV:	 X	DRAFT RECOMMENDED PUBLICATION	



NODE: A325	TITLE: Prepare product for despatch	NUMBER:

USED AT:	AUTHOR: Adam Weaver	DATE:	WORKING	READER	DATE	CONTEXT:
School Of Computing University Of Plymouth Drake Circus Plymouth PL4 8AA United Kingdom	PROJECT: Generic Process Model	REV:	DRAFT			
	NOTES: 1 2 3 4 5 6 7 8 9 10		RECOMMENDED			
			X PUBLICATION			



NODE: A33	TITLE: Monitor Manufacturing performance	NUMBER:

School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

Adam Weaver

PROJECT: Generic Process Model

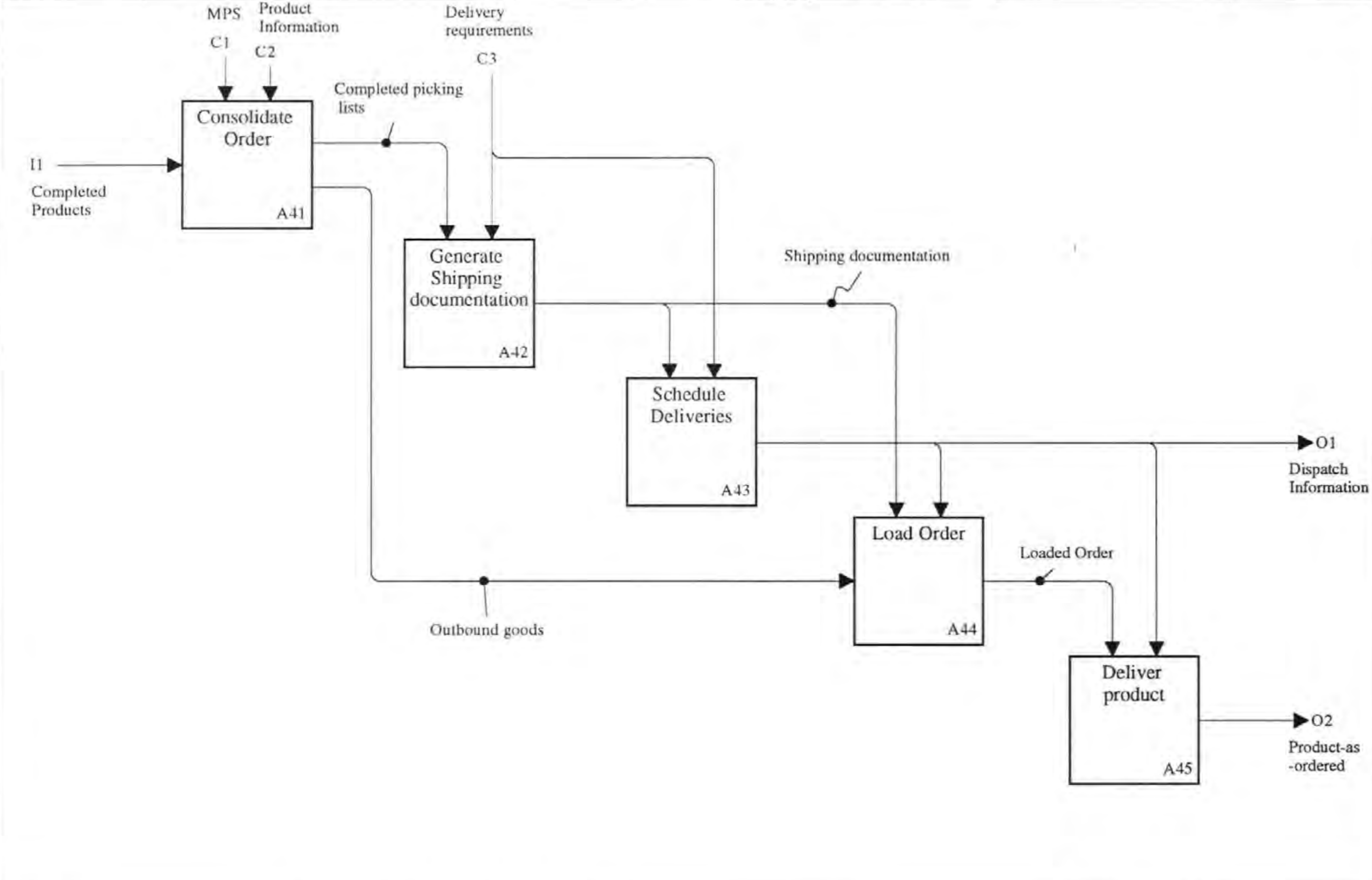
REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

DRAFT

RECOMMENDED

X PUBLICATION



NODE: A4

TITLE: Dispatch customer order

NUMBER:

School Of Computing
University Of Plymouth
Drake Circus
Plymouth PL4 8AA
United Kingdom

Adam Weaver

PROJECT: Generic Process Model

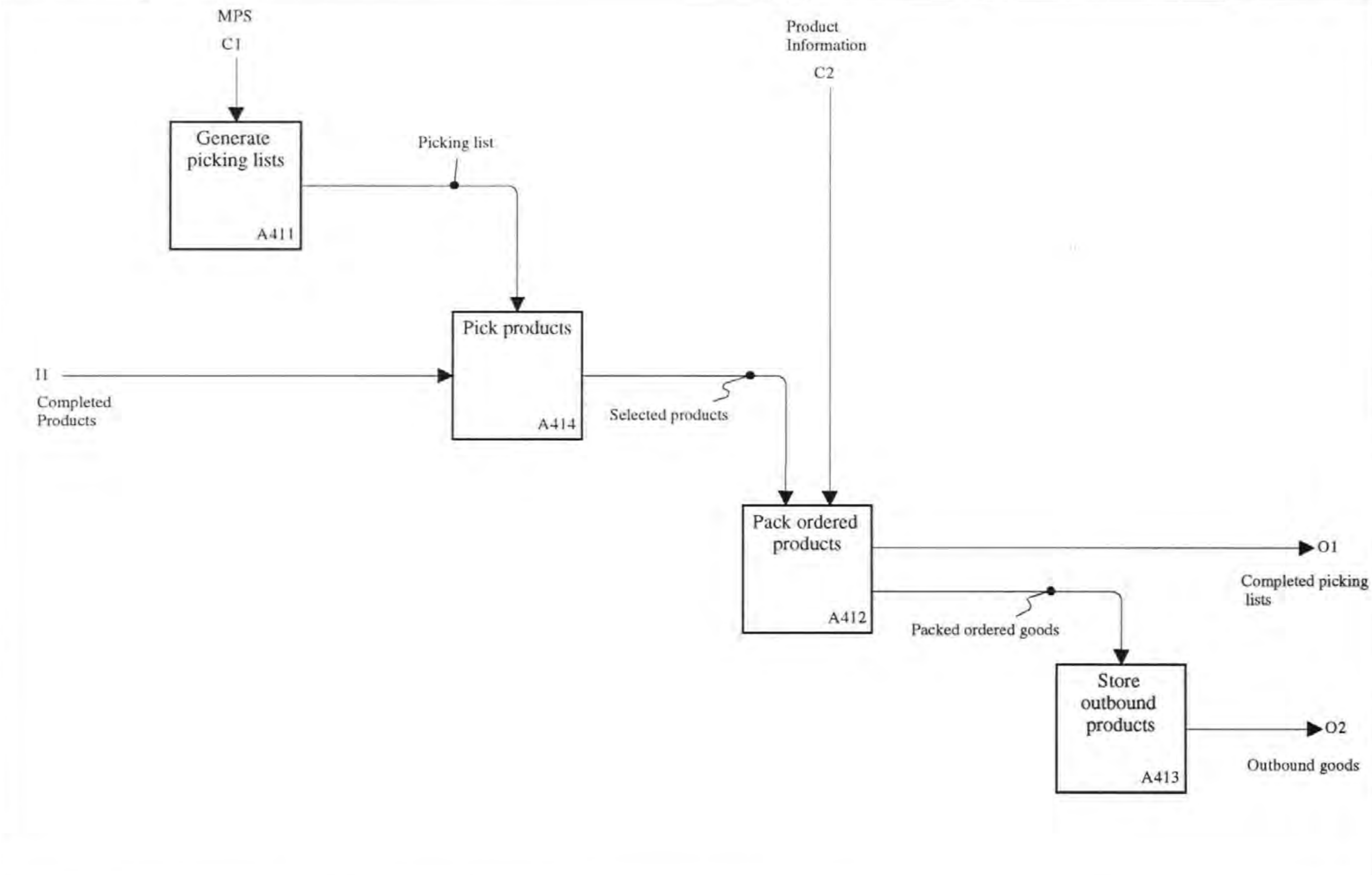
REV:

NOTES: 1 2 3 4 5 6 7 8 9 10

DRAFT

RECOMMENDED

X PUBLICATION



NODE: A41 | TITLE: Consolidate Order | NUMBER:

Node Index

Node Tree for E:\ADAM\GPMHBK\ORDFUL.IDD

- [A0] Fulfil Order
  - [A1] Plan Order Fulfilment
    - [A11] Process enquires
      - [A111] Receive enquiry from customer
      - [A112] Check feasibility of the work
        - [A1121] Check product feasibility
        - [A1122] Compare facilities & skills to req'mts
          - [A11221] Identify poss. facilities required
          - [A11222] Identify skills required
          - [A11223] Identify poss. equipment and training needs
          - [A11224] Identify possible capacity requirements
        - [A1123] Compare req'mt to existing schedule
        - [A1124] Check material availability (gross)
      - [A113] Report on feasibility
        - [A1131] Identify processes required
        - [A1132] Estimate process times
        - [A1133] Apply standard cost rates
        - [A1134] Compare with previous costs
        - [A1135] Estimate demand elasticity
    - [A12] Process orders
      - [A121] Receive order from customer
      - [A122] Confirm feasibility of order
        - [A1221] Develop product to meet specifications
        - [A1222] Compare facilities and skills to req'mts
          - [A12221] Identify facilities required
          - [A12222] Identify skills required
          - [A12223] Identify equipment and training needs
          - [A12224] Identify capacity requirements
        - [A1223] Compare Req'mt to schedule
        - [A1224] Check material availability (gross)
      - [A123] Formalise order
        - [A1231] Allocate material (gross)
        - [A1232] Produce works instructions
          - [A12321] Check customer requirements
            - [A123211] Check Drawing issue
            - [A123212] Check parts list
            - [A123213] Authorise Requirements
          - [A12322] Generate process instructions
            - [A123221] Apply normal process methods
            - [A123222] Apply normal inspection procedures
            - [A123223] Confirm with customer
          - [A12323] Collate and assemble instructions
        - [A1233] Confirm order to customer
        - [A1234] Add order to manufacturing schedule

- [A13] Maintain manufacturing schedule
  - [A131] Report capacity req'mts inc. excess
    - [A1311] Aggregate product profiles
    - [A1312] Aggregate load for spares
    - [A1313] Identify work for specific time buckets
  - [A132] Produce simulation for decision making
  - [A133] Confirm work in time buckets
  - [A134] Issue MPS document
- [A2] Obtain required items
  - [A21] Identify Requirements
    - [A211] Explode orders
    - [A212] Totalise gross requirements for each item
    - [A213] Identify unallocated stock level for each item
    - [A214] Net off stock against requirements
    - [A215] Allocate stock to orders
  - [A22] Issue Orders
    - [A221] Sort requirements by source
      - [A2211] Receive net requirements list
      - [A2212] Identify source for each item
      - [A2213] Produce list of bought-out requirements
      - [A2214] Produce list of made-in requirements
    - [A222] Issue purchase orders
      - [A2221] Receive list of bought-out requirements
      - [A2222] Generate purchase orders for B-O requirements
      - [A2223] Authorise release of materials
    - [A223] Issue works orders
      - [A2231] Receive list of Made-in requirements
      - [A2232] Generate works orders for M-I requirements
      - [A2233] Issue contracted provisions
  - [A23] Handle goods inwards
    - [A231] Check goods against delivery note
      - [A2311] Count goods
      - [A2312] Identify shortage/ excess
      - [A2313] Raise Shortage note
      - [A2314] Raise goods in note
    - [A232] Check goods quality
      - [A2321] Inspect goods
      - [A2322] Raise defect note
      - [A2323] Raise reject note
    - [A233] Relocate goods
    - [A234] Update records

- [A3] Manufacture products
  - [A31] Allocate resources
    - [A311] Identify resource requirements
    - [A312] Identify resource availability
    - [A313] Allocate resource to orders
  - [A32] Process work through factory
    - [A321] Issue works instructions
    - [A322] Perform operation as instructions
    - [A323] Transfer work between resource centres
      - [A3231] Split batch or expedite
      - [A3232] Determine next required location
      - [A3233] Move partially completed product
      - [A3234] Record location of the work
    - [A324] Assemble product
    - [A325] Prepare product for despatch
      - [A3251] Test Product
      - [A3252] Label/mark product
      - [A3253] Store product
      - [A3254] Pack product
  - [A33] Monitor Manufacturing performance
    - [A331] Monitor WIP level
    - [A332] Monitor output level
    - [A333] Monitor due date compliance
    - [A334] Monitor cost
- [A4] Dispatch customer order
  - [A41] Consolidate Order
    - [A411] Generate picking lists
    - [A412] Pack ordered products
    - [A413] Store outbound products
    - [A414] Pick products
  - [A42] Generate Shipping documentation
  - [A43] Schedule Deliveries
  - [A44] Load Order
  - [A45] Deliver product
- [A5] Manage Process Information

Glossary

Appendix 1

Add order to manufacturing schedule (Activity A1234)

This activity involves adding the manufacturing requirements of an order to the existing manufacturing schedule.

Aggregate load for spares (Activity A1312)

Load profiles for the production of spares requirements are aggregated to give a picture of the required capacity over a time period. This is only required by those companies that supply spares or replacement units. There may also be allowances added in for manufacture and repair of tooling.

Aggregate product profiles (Activity A1311)

Product load profiles which describe the capacity requirements are aggregated together to give a picture of the capacity demands generated by the scheduled orders.

Aggregated Product Profiles (Icom)

Represents the load on resources required to manufacture a number of products during the period of manufacture for the orders.

Aggregated spares load (Icom)

Represents the total load on resources over a period required to manufacture the spares identified as being needed. The period of time does not have a specific start and finish date/time, it is covers the relevant planning horizon for the company.

All required items (Icom)

Represents a list of all the items required to be either purchased or manufactured to enable the customer order to be fulfilled.

Allocate material (gross) (Activity A1231)

Material allocation depends on the type of order (ETO, MTO, MTS) and the material handling methods. Material requirements may be based on gross material requirements for orders received over a given time period.

Allocate resource to orders (Activity A313)

Allocate resources to manufacturing operations of items i.e. specific operators and specific work centres as opposed to general types. This creates a low level manufacturing schedule.

Allocate resources (Activity A31)

Resources must be allocated to orders as work progresses.

Allocate stock to orders (Activity A215)

Stock which is available and required for the order must be allocated to the order so that it can no longer be counted as available

Allocated material list (Icom)

Represents information that lists all the material from stock that has been allocated to fulfil the customer order.

Apply normal inspection procedures (Activity A123222)

A selection from the company's normal inspection methods, suitably modified, are specified for the parts required for the order.

Apply normal process methods (Activity A123221)

A selection from the company's normal working methods, suitably modified, are specified for the parts required for the order

Apply standard cost rates (Activity A1133)

Use the standard costs supplier by the financial controllers of the business to calculate the cost of performing operations.

Approved Process plans (Icom)

Represent the list of operations for each part that have to be carried out to manufacture the products to meet the customers order.

Approved Product (Icom)

Represents a product that the company is satisfied will meet the requirements of the customer.

Assemble product (Activity A324)

The products to fulfil the order may have to be assembled from parts that are manufactured in-house and also purchased from suppliers.

Assembled Product (Icom)

Represents a product that has been completely assembled in accordance with the engineering drawings.

Authorise release of materials (Activity A2223)

Issue materials that have been agreed to be supplied to a sub-contractor. ("Free issue materials")

Authorise Requirements (Activity A123213)

There is frequently either a formal authorisation or signing off procedure or an act of issuing the requirements by a person in a particular position is considered an act of authorisation.

Available production methods (Icom)

Represents a list of all the manufacturing methods available within the company e.g. milling, engraving, heat treatment; and the limitations of each method e.g. size of material, tolerance etc.

Available skills required (Icom)

Represents a list of all the skills that are required for the order and that are currently available within the company to carry out manufacturing operations. The available skills may not correspond to the available resources i.e. there may be a CNC available but no-one with the skill to operate it.

Available stock for each item (Icom)

Represents the numbers in stock of each type of item that can be assigned to be meet the requirements of the customer's order.

Batching Rules (Icom)

Rules that determine how the orders for suppliers should be grouped together before being sent out.

Bought-in Parts (Icom)

Represents the items/parts that have been supplied by external sources which are needed to complete the order for the customer.

Business Strategy (Icom)
The strategy of the company detailing how it should meet its business objectives.

Calculated cost to do operations (Icom)

Represents the estimated cost of carrying out the manufacturing operations to produce the products required for the customer order.

Capacity data (Icom)

Represents the resources and the time periods that the resources are available to be used for manufacturing products.

Changed works instructions (Icom)

Represent works instructions that have been changed due to many possible reasons including changed schedules, broken machines, engineering changes.

Check customer requirements (Activity A12321)

Identify the customer needs for the specific order e.g. quality, customisation requirements

Check Drawing issue (Activity A123211)

Either the drawing number and issue number may be specified in the contract with the customer or there may have been engineering changes. It is therefore common practice to check the drawing and issue numbers.

Check feasibility of the work (Activity A112)

This activity is to ensure that the order can be met. This assumes that the order cannot be fulfilled from stock. Manufacturing capability and capacity must be checked together with the material availability.

Check goods against delivery note (Activity A231)

Incoming goods are normally accompanied by a delivery note. This document details the order as despatched by a supplier. It is standard practice to check the delivered quantity against the purchase order in companies where suppliers cannot be trusted. JIT and TQ companies may make this task unnecessary.

Check goods quality (Activity A232)

The need for this activity is dependent on the supplier relationship. If there is a high level of confidence in the quality level of the incoming goods, then a goods-in inspection may not be required.

Check material availability (gross) (Activity A1124)

This activity is related more closely to companies that carry out MTO or ETO since it could effect the delivery time of the possible order if there is a material shortage.

Check material availability (gross) (Activity A1224)

This activity confirms that the materials required to fulfil the order are available in stock or can be ordered from suppliers in time.

Check parts list (Activity A123212)

Where there have been engineering changes it is important to ensure the parts list corresponds to the correct issue of the drawings.

Check product feasibility (Activity A1121)

Establish that the specification of the product requested by the customer can be designed.

Checked drawings issues (Icom)

It may have to be confirmed that the drawing issues correspond to those specified in the contract with the customer.

Checked Parts list (Icom)

Represents the list of parts to fulfil the order that has been checked against the parts listed on the drawings of the correct issue.

Checked requirements (Icom)

In some companies the checked requirements which include the parts, skills and resources required to fulfil the order need to be checked and authorised. It may simply be just the approval of the MPS or it could be in the form of a detailed contractual report to the customer.

Collate and assemble instructions (Activity A12323)

This activity is required to ensure all the information needed to manufacture the product to the required quality standards has been prepared. It should be in sufficient detail to allow the operators to manufacture the product.

Compare facilities & skills to req'mts (Activity A1122)

This activity is performed to ensure that not only can the order be manufactured but also that it can be produced to the customers required quality standard.

Compare facilities and skills to req'mts (Activity A1222)

This activity is performed to ensure that not only can the order be manufactured but also that it can be produced to the customers required quality standards.

Compare req'mt to existing schedule (Activity A1123)

Compare the existing manufacturing schedule to the resource requirements profile for the enquiry. Work may need to be subcontracted and hence quotations from sub-contractors are needed to help respond to the customer. Materials requirements dates can also be identified that enable a possible delivery date to be calculated.

Compare Req'mt to schedule (Activity A1223)

This activity is performed to check that the order can be fitted into the manufacturing schedule for completion by the due date, or to determine the date by which the order could be delivered. The resources required are compared to the existing schedule and identify any over-capacity that may occur from meeting the date required.

Compare with previous costs (Activity A1134)

This activity may not be required. It is a verification that the predicted costs are in line with previous costs for a similar if not identical product.

Complete process plan (Icom)

Represents a list of all the operations required to manufacture the part.

Completed item (Icom)

An item that has had all its manufacturing operations completed.

Completed Manufacturing data (Icom)

Represents manufacturing data of a completed operation. It could just indicate an operation has been completed or it could give a detailed report of time taken, quality, any problems etc.

Completed operation Information (Icom)

Indicates that an operation has been completed, it may include times etc.

Completed picking lists (Icom)

Completed picking lists may have information about missing quantities of products that will have to be sent in later.

Completed Products (Icom)

All the products required to fulfil a customer order ready for dispatch.

Conditional Response (Icom)

A response to an enquiry indicating that an enquiry can be met but only if certain changes to the initial enquiries conditions are accepted. e.g. later delivery date or reduced performance.

Confirm feasibility of order (Activity A122)

It may have already been done if there was a customer enquiry so information can either be transferred or updated. In some cases however the feasibility of the order may have to be fully checked against available resources and skills.

Confirm order to customer (Activity A1233)

For some products and customers especially MTO & ETO a formal contract may be required informing them of all the processes and methods to be used.

Confirm with customer (Activity A123223)

For some products the process and inspection methods may have to be agreed with the customer.

Confirm work in time buckets (Activity A133)

The first stage of confirming the master production schedule is to check that the allocation of work to time buckets conforms to capacity and other requirements.

Confirmed schedule (Icom)

The schedule for the product has been added to the master schedule for the company and it has been agreed by all necessary parties within the company.

Consolidate Order (Activity A41)
This activity collects together all the different products that have been ordered by a customer from different stores locations etc.

Contracted Provisions to a supplier (Icom)

Materials and even resources that the company has agreed to supply to a sub-contractor in a contract that are required for the sub-contractor to deliver items required to fulfil a customer order.

Correctly delivered goods (Icom)

Goods that have been checked against the quantity requirements specified to the supplier and are correct.

Count goods (Activity A2311)

Check the quantities of goods supplied.

Customer Agreement (Icom)

Information indicating that the customer agrees to the proposed contract, specifications and processes to be used.

Customer Communication (Icom)
Any communication with the customer or the customers representatives e.g. telephone calls, faxes, contracts

Customer contract (Icom)

The formal contract with the customer outlining all the terms of the contract e.g. delivery dates, costs and specifications of products, liabilities etc.

Customer Information (Icom)
Information about a customer. It can take many forms including, address, contacts, past orders, preferences etc.

Customer Quotation (Icom)

The quotation supplied to the customer for the cost of fulfilling a possible order to the customer's specifications.

Defect Note (Icom)

A document that indicates that an item does not meet the specifications agreed with the supplier, it may give in some detail the nature of the defect.

Deliver product (Activity A45)

Deliver the product to the customer.

Delivery ready Product (Icom)

The product that is ready to be dispatched to the customer.

Delivery requirements (Icom)

Represents how and when the products should be delivered to the customer.

Determine next required location (Activity A3232)

Control often relies on knowing the status of every order and what will happen to the order next. This activity is less necessary when there is a defined flow of work along a production line.

Develop product to meet specifications (Activity A1221)

If the company is either customising an existing product or engineering to order product development work will have to take place.

Discrepancy notes (Icom)

Represents any information that is produced reporting that the items supplied do not conform completely to the specification requested in the contract with the supplier.

Dispatch customer order (Activity A4)

Ship the products specified in the order to the customer.

Dispatch Information (Icom)

Information giving what has been dispatched and how it was dispatched.

Engineering Drawings (Icom)

The set of drawings that specify how the product or part of the product should be made.

Engineering Drawings (Icom)

The set of drawings which specify how the product or part of the product should be made.

Enquiry Feasibility (Icom)

An enquiry regarding a possible order that has been checked and it has been found that the company is capable of fulfilling the possible order.

Enquiry Feasibility (Resources) (Icom)
Request to see if the company has the resources to meet the customers requirements

Enquiry request (Icom)

All the information required to provide a quotation to a customer in a form suitable to check the feasibility of the possible order.

Equipment Required (Icom)

A list of equipment that needs to be obtained to fulfil the customers order.

Estimate demand elasticity (Activity A1135)

This activity involves considering the price the market can tolerate for the product concerned.

Estimate process times (Activity A1132)

This activity involves the estimation of how long operations will take e.g. according to previous history, estimates, speed and feed rates etc.

Estimated cost (Icom)

The estimated costs of the order, combines the costs of materials, processes and overheads to produce the products.

Evaluation Request (Icom)

A request e.g. an internal memo, computer on-line request or a timetabled item, to evaluate a specific aspect of the process using the data obtained and supply the relevant resulting information.

Existing Schedule (Icom)

The most up-to-date version of the schedule before other items are added.

Explode orders (Activity A211)

The bill of materials, which describes the components required for each product, is used to identify the quantity of each item required for an order

External facilities required (Icom)

A list of all the external resources required to fulfil the order and the supplier to provide the resources e.g. engraving, heat treatment of large parts.

External skills required (Icom)

List of external skills that are not available in-company and are needed for the fulfilment of the customers order.

Externally Supplied Items (Icom)
Materials, parts and skills that are purchased by the company in order to produce the products to fulfil the customers requirements.

Failure Report (Icom)
Report describing how a product failed to meet requirements.

Feasible order (Icom)

Contains information on product quantities, specifications and product numbers, delivery dates etc. and may have a restricted period that the feasible order is valid for.

Feasible Product Specification (Icom)

A report confirming that a product that is specified in an enquiry can be made.

FO Process Management Information (Icom)

All information that is required to manage the order fulfilment process in accordance with the business strategy.

Formalise order (Activity A123)

This activity is used to formally load a firm order onto the schedules and issue formal documentation to place orders and allocate capacity

Formalised order (Icom)

An order that has been agreed with the customer and the company is to proceed with fulfilling the order.

Fulfil Order (Activity A0)

See the Root definition for the process of fulfilling a customer request.

Generate picking lists (Activity A411)

This activity produces the picking list for the order. The picking list will generally give information on the order, quantity of different types of products required and the location in the stores where the completed products can be found.

Generate process instructions (Activity A12322)

This activity is required to generate the process instructions required to manufacture the product.

Generate purchase orders for B-O requirements (Activity A2222)

Sort and combine the supplier information with the list of bought -out requirements and generate purchase orders

Generate Shipping documentation (Activity A42)

This activity generates the shipping documentation. It requires a comparison with what was picked and the delivery requirements. The total order may also be shipped in parts at intervals defined by the delivery requirements.

Generate works orders for M-I requirements (Activity A2232)

Orders are generated, This may be done by a computer, especially where MRP is in use, or by manual means. Orders for made-in requirements may be in the form of batch cards, travellers, work-to-lists etc.

Goods-in note (Icom)

The document contains information concerning the amount of goods delivered and when it was delivered.

Goods-in records (Icom)

Records the quantities of goods received, supplier, location of goods etc.

Gross requirements List (Icom)

A list of the total requirements for each item that is required to fulfil the order.

Handle goods inwards (Activity A23)

Goods received from suppliers must be checked and recorded so that necessary actions such as payment or rejection can be initiated

Identify capacity requirements (Activity A12224)

Having identified the available skills required and the internal facilities required, it is then possible to calculate the capacity required to fulfil the order.

Identify equipment and training needs (Activity A12223)

This activity determines whether or not to carry out investment in equipment and training to fulfil the order. There may be the skills to operate certain equipment but no equipment or vice versa.

Identify facilities required (Activity A12221)

Identify what machines, space (if a large product) etc. are required to make the products and use the business strategy to determine if external facilities are to be used. If external skills etc. are required it may be necessary to request a quotation from a supplier.

Identify poss. equipment and training needs (Activity A11223)

This activity identifies equipment or training that is needed to fulfil the order. These potential costs may be assessed against the business strategy and available external skills and equipment.

Identify poss. facilities required (Activity A11221)

Identify what facilities are required. This requires knowledge of the product to be manufactured and also if there needs to be work done externally the suppliers who can carry out the work. e.g. A large oven for heat treating an exceptional large component.

Identify possible capacity requirements (Activity A11224)

Using the available skills and internal facilities requirements it is possible for the company to identify the capacity requirements in terms of resources to fulfil the order. At this stage a decision can be made whether the customers enquiry is feasible and a response can be made.

Identify processes required (Activity A1131)

Identify the manufacturing processes that are required in the manufacture of parts for the products.

Identify Requirements (Activity A21)

The material requirements for each of the orders scheduled for a particular period are identified with reference to the bill of materials , and aggregated to identify the gross requirements. These are then "netted off" against any available stock to determine the ordering requirement.

Identify resource availability (Activity A312)

The availability of resources must be identified so that a viable schedule can be created. Variations in resource availability may arise from a wide range of factors including machine breakdown, absence of operators etc.

Identify resource requirements (Activity A311)

The exact resource requirements in terms of type of resource required and the time required must be identified. This information may come from works instructions.

Identify shortage/ excess (Activity A2312)

Identify if the correct quantity of goods has been supplied and whether any action is required to correct and notify discrepancies.

Identify skills required (Activity A11222)

Identify what skills are required to manufacture the product to fulfil the customers order. Skills requirements are likely to be related to available facilities as well.

Identify skills required (Activity A12222)

Look at the constituent parts and operations required to fulfil the order and identify the skills required. Also if the skills are not available internally whether the business strategy allows the use of external skills etc.

Identify source for each item (Activity A2212)

Identify the supplier for each of the required items.

Identify unallocated stock level for each item (Activity A213)

Stock which has already been allocated to orders but which has not yet been issued must be subtracted from the total stock level of each item to give the amount of stock available.

Identify work for specific time buckets (Activity A1313)

The aggregate demand for specific processes for each time period.

Inspect goods (Activity A2321)

The degree to which goods are inspected is determined by the relationship with the supplier.

Internal facilities required (Icom)

List of internal resources that will be required to fulfil the order e.g. vacuum, chamber, 5-Axis milling machine.

Internal facilities required (Icom)

A list of the internal resources that will be required to fulfil the order e.g. Vacuum chamber, 5-Axis Milling machine etc.

Internal Orders (Icom)

Documentation to be used internally to request the production of items to fulfil a customer order.

Internal skills required (Icom)

The skills available internally that will be required to fulfil the customer order.

Internal skills required (Icom)

The skills available internally that will be required to fulfil the customer order.

Issue contracted provisions (Activity A2233)

Issue materials etc. that were agreed in the contract with suppliers to enable them to make the parts required.

Issue MPS document (Activity A134)

Once all the time buckets have been checked the MPS document can be issued. This provides a view of the requirements on production as they appear at present. Each MPS document is an update of a previous issue.

Issue Orders (Activity A22)

This activity is used to generate orders to authorise production or purchase of the net requirements for each item.

Issue purchase orders (Activity A222)

Orders to suppliers are raised. If this task is computerised there may be a manual check on orders before they are issued.

Issue works instructions (Activity A321)

Works instructions may be issued with works orders, or separately. In some businesses, work is processed according to standard instructions which are only used when changes occur.

Issue works orders (Activity A223)

Orders authorising manufacture are issued. Live orders may be stored until the start date is reached, or the computer may hold orders until they are due before printing them out.

Label/mark product (Activity A3252)

Product marking may be a final operation to provide certification of quality or customise the product for the customer.

List of B-O requirements (Icom)

List of bought-out requirements that have been sorted in a format to enable the goods to be ordered. e.g. by supplier.

List of contracted provisions (Icom)

List of those materials that have to be supplied to sub-contractors. ("free-issue" materials)

List of expected supplied goods (Icom)

List of goods that are expected to be received from suppliers. This could be in the form of a copy of a order form or possibly a detailed specification of the goods if they need specialist inspection.

List of externally sourced parts (Icom)

List of parts that have to be bought from suppliers.

List of Free-Issue Material (Icom)

List of material that will be issued to suppliers to enable parts to be made to fulfil the order.

List of internally produced parts (Icom)

List of parts that can be produced in-company by the company's manufacturing facilities.

List of made-in Requirements (Icom)

List of parts to be made in-company in a standard format to allow works orders to be generated.

Lists of items to order (Icom)

List of items to order either to replenish stocks or especially to fulfil a customer order.

Load Order (Activity A44)

This activity loads the outbound goods and accompanying shipping documentation on to the scheduled transportation according to the dispatch information.

Load profiles for spares (Icom)

Profiles of the load on internal resources that will be required to manufacture spares. Some companies estimate the seasonal requirements for spares.

Loaded Order (Icom)

Loaded outbound goods as ordered by the customer with accompanying shipping documentation

Maintain manufacturing schedule (Activity A13)

This involves rescheduling and adding new orders to the master schedule in such a way as to allow all orders to be completed by their due dates.

Manage Process Information (Activity A5)

Evaluate the data supplied to provide comparisons to give performance of the process and information to enable the process to be managed.

Manufacture products (Activity A3)

This activity represents the production activities together with the closely related management tasks. This includes low level scheduling activities, the processing of work through the factory, and the monitoring of factory performance.

Manufacturing Data (Icom)

The data provides all the information on the manufacture of parts to fulfil the customers order. It could include start and finish times of operations, operators, resources used, quality of the parts, concessions etc.

Manufacturing schedule (Icom)

The schedule for manufacturing all the products currently required to either fulfil orders or to be stored according to the business strategy.

Manufacturing schedule (Icom)

The schedule for manufacturing all the products currently required either to fulfil orders or to be stored, according to the business strategy.

Manufacturing Schedule (Icom)

The schedule for manufacturing all the products currently required either to fulfil orders or to be stored, according to the business strategy.

Manufacturing Schedule (Icom)

The schedule for manufacturing all products currently required to either fulfil orders or to be stored, according to the business strategy.

Material availability information (Icom)

This information details the material that is available for use within the company and also the lead times to acquire the required material.

Material requirement dates (Icom)

Dates by which material is required so that the customers order can be fulfilled.

Material Requirements (Icom)

Represents the detailed list of materials needed to produce the products required to fulfil the customer order.

Material Stock levels (Icom)

Levels of materials kept in-company that can be allocated to fulfil customer orders.

Monitor cost (Activity A334)

Monitoring the costs of producing products is an essential exercise to control the pricing policy of the company and monitor the cash flow of the company.

Monitor due date compliance (Activity A333)

The compliance to due dates demonstrates a that the manufacturing operations under control.

Monitor Manufacturing performance (Activity A33)

This activity monitors the performance of the manufacturing operations in the company against the planned manufacturing data. It provides the data that is fed back to control the manufacture .

Monitor output level (Activity A332)

To meet a customer's orders it is the output level of the manufacturing that needs to be monitored.

Monitor WIP level (Activity A331)

The level of work in progress is a meaningful monitor of performance in companies where the flow of work is not constant either because of changing product mix or because of a variety of routes through the factory.

Move partially completed product (Activity A3233)

The partially completed product needs to move to its next operation location. This may in some companies be a separated operation. It depends on the control and type of arrangements for moving work.

MPS (Icom)

Master Production Schedule: High level plan of all orders that are currently incomplete or to be started.

Net off stock against requirements (Activity A214)

Available stock is subtracted from the gross requirements for each item, to give the amount of each item for which orders must raised

Net stock requirements (Icom)

Total quantities of items that must be ordered to fulfil the customer order.

New location (Icom)

Information giving the new location in-company of goods supplied.

Next location (Icom)

Information giving the next location that a part under manufacture should be moved to. The location could be another work centre for another operation, storage point etc.

Obtain required items (Activity A2)

This activity represents all activities that are involved in acquiring goods and services internally and externally to fulfil the order.

Operational Level Schedule (Icom)

Represents the time periods allocated on specific resources schedules in order to manufacture the products to fulfil the customer order.

Order (Icom)

A request to a supplier to supply goods.

Outbound goods (Icom)

Goods that are to loaded on the transportation.

Pack ordered products (Activity A412)

This activity involves packing the selected products of the order to ship them. Specialist instructions may be found in the product information regarding how the products should be transported. Packing may also depend on international regulations and the mode of transport.

Pack product (Activity A3254)

Packing may be a separate task, especially where goods are for export or a fragile. This activity depends on the nature of the product.

Packed ordered goods (Icom)

The packed goods ready to be stored and wait for when transportation of the goods is scheduled.

Partially completed part (Icom)

A part that has not completed all the operations listed on the process plan for the part.

Parts list (Icom)

List of all parts required to make a complete product.

Perform operation as instructions (Activity A322)

Progress of work through the factory generally consists of a series of discrete operations and inspection operations, which may be carried out in different areas by different operators.

Pick products (Activity A414)

This activity involves locating and collecting the products listed on the picking list that are required for the order.

Picking list (Icom)

The picking list will give information about the order being picked for, the type of product, quantities required and where the products can be found in the stores.

Plan Order Fulfilment (Activity A1)

The activity of establishing all the plans of how the company is going to fulfil a customers order.

Planned manufacturing Data (Icom)

All the data describing how the part was planned to be manufactured e.g. planned start and finish times on resources, planned resources etc.

Preliminary Design (Icom)
The design of a product describing the modules and components required to meet the technical specification.

Prepare product for despatch (Activity A325)

There may be detailed contractual details on how a product is to be tested and dispatched to the customer. It may even have to be dispatched and then assembled at the customers location.

Previous costs (Icom)

Information on costs of manufacturing similar or identical parts in the past.

Process enquires(Activity A11)

The processing of enquires entails a range of activities from producing a quotation for a complex or new product to reading a price from a catalogue

Process orders (Activity A12)

Orders received from customers are processed to appear on the manufacturing schedule.

Process Plans (Icom)

The list and order of operations and the type of resource required for the manufacture of a part(s).

Process work through factory (Activity A32)

Work must be processed through the factory according to the low level schedule in order to produce a product which is ready for despatch to the customer.

Processes for parts (Icom)

Details of the production processes for each part that is required.

Produce list of bought-out requirements (Activity A2213)

Produce a list of all the parts and materials that are required from external sources. It enables the costs of external supplies to be calculated.

Produce list of made-in requirements (Activity A2214)

Produce a list of all parts etc. that will be made using the company's manufacturing facilities.

Produce simulation for decision making (Activity A132)

In some circumstance there may be the facility to simulate changes to determine the most suitable loading of resources.

Produce works instructions (Activity A1232)

Works instructions provide the detailed processing needs of a given product. The information provided should be of sufficient detail for the operators to perform the tasks required to complete the order.

Product Enquiry (Resources) (Icom)
A request from a customer to the company enquiring if the company is able to fulfil a possible order to the customer's specification.

Product Information (Icom)
All the information that is required to produce a product e.g. engineering drawings, suppliers etc.

Product load Profiles (Icom)

The distribution of load over the lead time for the product on in-company resources.

Product-as-Ordered (Icom)
The product or products that fulfil the customers order.

Product/ Spares Order (Icom)
An order for either a product or spare parts.

Products requiring rework (Icom)

Parts of products that require manufacturing errors correcting.

Proposed customer order fulfilment plan (Icom)

The plan supplied to the customer, informing the customer when the products to fulfil the order will be delivered to the customer.

Purchase order Requirements (Icom)

Information describing all the items that need to be purchased.

Purchase requirements (Icom)

Purchase requirements contains information on:
Quantities of BO parts that are required to fulfil the order and subcontracted work normally required
It does not contain order information as requirements have not been compared with stock levels etc. of bought out parts

Quality checked goods (Icom)

Goods received from suppliers that have been checked for acceptable quality.

Query to customer (Icom)

A request to the customer to supply information or make a decision on an aspect of the specification of the order.

Raise defect note (Activity A2322)

Defect notes may be used to indicate the reasons for which goods are unacceptable or where the quality of the goods means that they can only be used in special circumstances.

Raise goods in note (Activity A2314)

A goods-in note is generally raised to record the quantity of goods actually received from a supplier for a given order. This information is used for the settlement of incoming invoices from the supplier.

Raise reject note (Activity A2323)

Reject notes may be used where part of an order is defective and the defective goods are to be returned to the supplier.

Raise Shortage note (Activity A2313)

Shortages in delivery are likely to impact on the manufacturing lead time of an order. The relevant authority in manufacturing is notified of these shortages so that appropriate action can be taken.

Raw Material requirements (Icom)

The list of types and quantities of raw materials required to fulfil the customers order.

Raw Materials (Icom)

Materials before they have been cut to size or had manufacturing operations carried out.

Receive enquiry from customer (Activity A111)

Company receives an enquiry from a customer. It may be transferred to a standard enquiry form.

Receive list of bought-out requirements (Activity A2221)

The receipt of the list may result in a requirement to translate the list into an appropriate format.

Receive list of Made-in requirements (Activity A2231)

On receipt of the list it may be reviewed and possibly converted into a different format .

Receive net requirements list (Activity A2211)

Receive and collate all the lists of required items generated from previous activities.

Receive order from customer (Activity A121)

Orders received through various means from customers and are normally recorded in a standard format for internal processing.

Received requirements (Icom)

Goods that have been ordered from suppliers and have been received.

Reconciled Goods Totals (Icom)

Total quantities of goods that have been checked against the orders issued to suppliers.

Record location of the work (Activity A3234)

Work locations must be recorded where there is no defined production/process line in existence. This is especially important where different jobs can take different routes and have long lead times.

Recorded Defects (Icom)

Information describing the defects found once the goods have been received and inspected.

Reject note (Icom)

The document that records that certain goods received from a supplier have been rejected as unsatisfactory.

Reject order (Icom)

Communication to a customer that the company is unable to enter into an agreement to fulfil the order requested by the customer.

Relocate goods (Activity A233)

Goods supplied may need to be moved to the appropriate manufacturing area or to the stores. This is not required in a company operating a JIT philosophy where the goods arrive at the time and place required.

Report capacity req'mts inc. excess (Activity A131)

Capacity requirements can change for a variety of reasons; Product mix changes, holiday periods, machine failure. It is essential where utilisation is high that capacity requirements are monitored frequently.

Report on feasibility (Activity A113)

Establish whether the company can meet the requirements of a customer outlined in an enquiry.

Request for a quotation (Icom)

A request to a supplier to give the company a quotation for goods or services. The request will give the specification of the order e.g. deliver date, possibly engineering drawings etc.

Request for Product Development (Icom)

Request asking for changes to a products design.

Resource availability (Icom)

Information indicating when resources are available to have possible work loads allocated to them. For example a resource may have a maintenance schedule, or it may have broken down, or the required tooling is unavailable.

Resource Required (Icom)

The list of resources required to manufacture the products.

Resource Requirements Profile (Icom)

The type of resources that will be required over the period of production to fulfil the order.

Resource requirements Profile (Icom)

The type of resources that will be required over the period of production of the products to fulfil the order.

Resources (Icom)

List of in-company resources.

Response to customer (Icom)

Response to customer enquiry. It could a decline or quotation.

Revised Product Specification (Icom)

A product specification that has been changed because of a requirement, either from a customer or another activity e.g. the product needs to be changed so that it can be manufactured in tolerance.

Revised Schedule (Icom)

Manufacturing schedule after changes have been made.

Revised stock levels (Icom)

Stock levels after the items to fulfil the order have been allocated to the order.

Rework requirements (Icom)

The information detailing the rework operations that have to be carried out to get the item within specification.

Schedule Deliveries (Activity A43)

This activity needs to schedule the transportation of packed orders to customers. There will be generally an attempt to reduce the transport costs whilst meeting delivery dates.

Selected products (Icom)

These are the products located and collected that form the order.

Shipping documentation (Icom)

Shipping documentation will contain information on what goods have been packed, type of transportation, insurance and legal documents required for international transportation. It may also contain information for the customer.

Shortage note (Icom)

Information detailing the missing quantities of items that have not been delivered as ordered from a supplier.

Shortage Order (Icom)

An order to a supplier who has supplied too few required items.

Shortage totals for goods (Icom)

Total shortages of goods delivered against goods ordered.

Simulation Results (Icom)

Information describing predicted performance of the process given estimated initial values of key variables.

Sort requirements by source (Activity A221)

The supplier of each item, whether external or in-house manufacture, must be identified. Items from the same supplier will be thus dealt with together. The source of an item is often stored in the item master file

Split batch or expedite (Activity A3231)

Conditions may dictate the need to split batches in order to process a smaller number of items more quickly, or to make special arrangements to expedite certain work. This activity represents the failure of the low-level schedule, brought about by changing circumstances.

Standard cost rates (Icom)

Costs that the financial function attributes to production activities.

Standardised order (Icom)

Information required to fulfil an order presented in a standard internal company format.

Stock levels (Icom)

Quantities of items held in stock.

Store outbound products (Activity A413)

This activity stores the packed goods until they are required for loading on the transportation scheduled.

Store product (Activity A3253)

Finished goods may be stored before despatch routinely in make-to-stock companies or temporarily in make-to-order companies.

Stored Product (Icom)

A product that is to be held in a store before delivery to the customer.

Sub-contracted Work (Icom)

A list of manufacturing operations that will be performed externally.

Supplier capacity (Icom)

Information giving the capacity of the supplier to process sub-contracted work.

Supplier Communication(Icom)
Information and requests exchanged with the supplier to enable the supplier to fulfil its contract with the customer.

Supplier Information (Icom)
Information about a supplier inc. contacts, quality, reliability, capabilities etc.

Supplier performance (Icom)

Information on how the supplier has performed against planned targets.

Supplier skills and resources (Icom)

Services(skills and types of manufacturing capabilities) that the supplier is able to perform for the company.

Tactical Level Schedule (Icom)

Schedule that allocates resources to orders up to approx. a greater than a week into the future.

Test Product (Activity A3251)

Product testing may be performed separately from production, especially where specialist equipment is required and products may be only partially assembled before dispatch.

Times required on resources (Icom)

The operation times that an item will require on each resource listed on the process plan for that item.

Totalise gross requirements for each item (Activity A212)

Requirements are grouped by item type to give the total or gross requirement for each item.

Totals for different goods (Icom)

The total number of items received from a supplier.

Transfer work between resource centres (Activity A323)

Different companies will have different arrangements for moving work between processes ranging from no movement or static build through production lines , AGVs to works movement operators. The arrangements are usually related to product and process complexity

Transferred Part (Icom)

Part that is transferred from one resource to another resource or location during its manufacture.

Unfeasible Enquiry (Icom)

A response to a customer indicating that the company cannot meet the needs of a customer.

Update records (Activity A234)

Stock records must be updated when stock is received for two reasons; To initiate payment and to allow the stock level to be monitored and made use of by a computerised stock system.

Updated Stock records (Icom)

Records with updated quantities of stocked items.

Works Instructions (Icom)

Works instructions includes the instruction to issue materials and all information that is required to manufacture the product.

Works orders (Icom)

Orders to manufacture parts/products using in-company resources.

Appendix 2

Validation Feedback

Appendix 2 Contents

Stage 1: Validation by review

List of practitioners who reviewed the generic process model

A blank copy of the feedback sheet used

Sample feedback from practitioners

Stage 2: Validation by use of the model

Letter from IT Manager of Patronics Ltd

Practitioners who contributed to the validation of the model

Practitioner	Organisation	Position (where known)
Lawerie Rumens	Pilkington PLC	
Chester Chai	Protek Chemicals	Managing Director
Ian Livingston	British Rail	Director of Quality
Matthew Waller	University of Arkansas	Assistant Professor
Dr Andrew Kearns,	Lucas Engineering and Systems Ltd	
Frans Vlemmiks		
Neil Campbell	British Aerospace (Systems and Equipment) Ltd	Technology Manager
Dr Robert Macintosh	Glasgow University Business School	Lecturer
Terry Hough	ICL	Business Consultant
John Hutchinson	JBA Software Products Ltd	Product Manager
Peter Gould	Peter Gould Associates	Consultant
Gerry Waterlow	Henley Business Centre	Systems Consultant
Prof Alan Carrie	University of Strathclyde	
Rod Moulding	Ross Systems (UK) Ltd	Regional Consulting Manager
Neil Corder	IBM	Quality Advisor
Padraig Bradley	CIMRU Galway	Senior Research Engineer
Laurence Crack	TSB Bank PLC	Head of New Business Processing
Clauss	Clintec	Vice President
Tony Ward	British Aerospace (Defence)	Head of BPR Services
Dr S K Banerjee	University of Strathclyde	Senior Lecturer
Chet Turner,	Dynamics Research Corporation	
Jarvis Bailey,		
Denis Cushman,		
David Payne		
Anil Jambekar	Michigan Technological University	
Ned Kock	University of Waikato	Tutor
Josef Hofer-Alfeis	Siemens	
Gilles Pilon	Asea Brown Boveri Inc.	Continuous Improvement Manager

Feedback Sheet

Please return to:

Adam Weaver
School of Computing
University of Plymouth
Drake Circus
Plymouth
PL4 8AA

From:

Name:

Position:

Organisation:

General Questions

1. Are you participating in any Business Process Re-engineering projects at present or have participated in any in the past?

☐ **Yes** ☐ **No**

2. Do you believe that the generic process models can be used as part of a process focused change programme?

☐ **Yes** ☐ **No**

3. Were you familiar with IDEFo as a modelling tool before receiving the models?

☐ **Yes** ☐ **No**

Generic Process Models

4. Did the "architecture of business processes" establish the context for the operate processes sufficiently?

☐ **Yes** ☐ **No**

5. Did you have any difficulty understanding the models?

☐ **None at all** ☐ **In some areas** ☐ **In most areas**

6. Do you believe the generic process models represent the generic activities and flows within the Operate processes in most manufacturing companies? (Please answer in the boxes provided below)

Please specify any areas of the models that you believe to be incorrect: (Please continue on a separate sheet or return the diagrams with comments if necessary)

⇒PTO

Please specify any areas of the models that you believe do not relate to all manufacturing companies:

(Please continue on a separate sheet or return the diagrams with comments if necessary)

7. How would you like to see the generic process models improved?

Please specify any areas of the models that you would like to see developed further:

(Please continue on a separate sheet if necessary)

8. Any other comments?

(Please continue on a separate sheet if necessary)

Thank you for your time. Your comments will be considered and a final report and copies of the final generic process models will be forwarded to you during Summer 1995.

2

Feedback Sheet

Please return to:

Adam Weaver
School of Computing
University of Plymouth
Drake Circus
Plymouth
PL4 8AA

From:

Name: LAURIE RUMENS

Position: MANUFACTURING MANAGEMENT GROUP

Organisation: PILKINGTON PLC

General Questions

1. Are you participating in any Business Process Re-engineering projects at present or have participated in any in the past?

☑ Yes ☐ No

2. Do you believe that the generic process models can be used as part of a process focused change programme?

☑ Yes ☐ No

3. Were you familiar with IDEFo as a modelling tool before receiving the models?

☑ Yes ☐ No

Generic Process Models

4. Did the "Hierarchy of business processes" diagram establish the context for the operate processes sufficiently?

☑ Yes ☐ No

5. Did you have any difficulty understanding the models?

☑ None at all ☐ In some areas ☐ In most areas

6. Do you believe the generic process models represent the generic activities and flows within the Operate processes in most manufacturing companies? (Please answer in the boxes provided below)

Please specify any areas of the models that you believe to be incorrect:
① I believe that "Obtaining items" or perhaps you could call it "Developing Suppliers" is a separate fourth process. Your activity 3.2 is "plan material" then with a linking line to a new process "Order material". The reason for this is that Node 3 is all "order" based. Purchasing uses netted requirements and is commodity based. Leaving it order based prevents partnership sourcing benefits.
(Please continue on a separate sheet or return the diagrams with comments if necessary)

② The Sales & Operational Planning process is omitted. At the A0 level this would give capacity & time fence information as an input. You do show an activity at A3112 but S&OP is more important than that.

⇒PTO

③ On A3 the I3 input should be into A33.

④ There is no real indication of process control or maintenance information

Please specify any areas of the models that you believe do not relate to all manufacturing companies:
The model is written around batch / line environments. The model for a process environment would be simpler, excluding much of the planning / estimating / spares type detail but being stronger on bringing process control tools into the model.
(Please continue on a separate sheet or return the diagrams with comments if necessary)

7. How would you like to see the generic process models improved?

Please specify any areas of the models that you would like to see developed further:
I would like to see A0 being the model in IDEF of "the company". Too many companies (and consultants) work on reengineering companies into 4 processes without a top model of how these processes are linked. I believe that this model suffers that difficulty as well.
Also your current A0 must show A1 & A2 as well to get the overall process of operation
(Please continue on a separate sheet if necessary)

8. Any other comments?

Well done.
IDEF is not widely used or understood but is a fine tool for getting to know it all works.
The idea of a generic model is sound - not new! Most packages work on this basis. I believe packages would generally be of better quality if IDEF was used
(Please continue on a separate sheet if necessary)

Thank you for your time. Your comments will be considered and a final report and copies of the final generic process models will be forwarded to you during Summer 1995.

(13)

Feedback Sheet

Please return to:

Adam Weaver
School of Computing
University of Plymouth
Drake Circus
Plymouth
PL4 8AA

From:

Name: Prof Alan Currie

Position:

Organisation: University of Strathclyde.

General Questions

1. Are you participating in any Business Process Re-engineering projects at present or have participated in any in the past?

☑ Yes ☐ No

2. Do you believe that the generic process models can be used as part of a process focused change programme?

☑ Yes ☐ No

3. Were you familiar with IDEFo as a modelling tool before receiving the models?

☑ Yes ☐ No

Generic Process Models

4. Did the "Hierarchy of business processes" diagram establish the context for the operate processes sufficiently?

☑ Yes ☐ No but might have been expressed differently (e.g. none at top level)

5. Did you have any difficulty understanding the models?

☑ None at all ☐ In some areas ☐ In most areas

6. Do you believe the generic process models represent the generic activities and flows within the Operate processes in most manufacturing companies? (Please answer in the boxes provided below)

Yes;

Please specify any areas of the models that you believe to be incorrect:
Obviously some activities might not occur in some firms, and conceivably some firms might have specific activities not included in the model
(Please continue on a separate sheet or return the diagrams with comments if necessary)

⇒**PTO**

Please specify any areas of the models that you believe do not relate to all manufacturing companies: For example, A3324 would not occur in a small jobbing m/c shop.

(Please continue on a separate sheet or return the diagrams with comments if necessary)

7. How would you like to see the generic process models improved?

Please specify any areas of the models that you would like to see developed further:

The usability of a 30 page pack of diagrams & glossary is limited.

(Please continue on a separate sheet if necessary)

8. Any other comments?

I commend your use of the operate/change/support notation.

(Please continue on a separate sheet if necessary)

Thank you for your time. Your comments will be considered and a final report and copies of the final generic process models will be forwarded to you during Summer 1995.

To what extent have you validated the generic model. i.e. on how many companies is it based?

[illegible signature]

(26)

X-Authentication-Warning: sbea3.sbea.mtu.edu: Host sbea17.sbea.mtu.edu claimed to be sbea17
X-Sender: abjambek@sbea3.sbea.mtu.edu
Date: Tue, 06 Jun 1995 10:42:27 -0400
To: adamw@uk.ac.plymouth.school-of-computing (Adam Weaver)
From: abjambek@edu.mtu (Anil Jambekar)
Subject: Re: Generic Process Models

>
>###
>
> FEEDBACK
>
>###
>
>Name:
>Position:
>Organisation:
>Address:
>
>---
>--------------
>General Questions:
>
>1. Are you participating in any Business Process Re-engineering projects at
>present or have participated in any in the past?
>
>YES or NO [yes]
>
>2. Do you believe that the generic process models can be used as part of a
>process focused change programme?
>
>YES or NO [yes, but with care]
>
>3. Were you familiar with IDEFo as a modelling tool before receiving the
models?
>
>YES or NO [not as much as I would like to]
>
>---
>---------------
>
>Generic Process Models:
>
>4. Did the working paper help set the context for the models?
>
>YES or NO [yes]
>
>5. Did you have any difficulty understanding the models?
>
>NONE areas / SOME areas / MOST areas [My difficulties were in

keeping wholistic perspective at the same time understanding some details
]
>
>6.Do you believe the generic process models represent the generic activities
>and flows within the operate processes in MOST manufacturing companies?
>
>#Please specify any areas that you believe are incorrect
>I have shared the work paper with on eof my former students working at a
manufacturing firm to see how he may find it useful.

I personally cannot find anything in correct.
>
>
>
>#Please specify any areas that you believe do not relate to most
>manufacturing companies
>
>
>
>
>
>7. How would you like to see the generic process models improved?
>
>Simplification may help. The details may be overwhelming at times.
>
>
>
>
>8. Any other comments?
>
>If one of the purpose of re-engineering is to reduce cycle times, we cannot
ignore mechanics and the arrows. Your work stimulated a line of inqury I
may follow. One of my fields of interests is system dynamics. I wonder if
these two fields can be fused to overcome limitations of either when viewed
independently.
>
>Adam Weaver
>Research Fellow
>Manufacturing and Business Systems Group
>School of Computing
>University of Plymouth
>Drake Circus
>Plymouth PL4 8AA
>UK
>
>Email: adamw@soc.plym.ac.uk
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>

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Mr Adam Weaver
Research Fellow
School of Computing
University of Plymouth
Drake Circus
Plymouth
PL4 8AA

17/07/95

Dear Adam,

I am writing to confirm the comments that I made about your generic model during our meeting on 28th June 1995.

We have been using the model as a template to develop an IDEF0 model of our existing "order fulfilment" process.

We found that it was a good representation of an order fulfilment process, and only had to make a few changes to the model before it represented our own order fulfilment process. The structure of the model allowed various areas to be developed separately and the terms used in combination with the glossary could be easily understood by our production team.

The improvements that we would suggest are a node tree (as discussed at the meeting) and further detail on the activities involved in despatching orders to customers.

In summary, the generic model has proved very useful. We believe that it has saved us a significant amount of time in developing a model of our own process.

I look forward to receiving a copy of your other generic models in the near future.

Yours sincerely.

N. Byers

Nick Byers
I.T. Manager

Publications

List of Appended Publications

1. Weaver A M, Maull R S, Childe S J, A focused approach to production control within an engineer-to-order company, in Sen A, Winsor J, Gay R (Eds.), 1993, *Computer Integrated Manufacturing, Proceedings of the 2nd International Conference (ICCIM'93)*, Singapore, World Scientific Publishing Co. Pte.

2. Weaver A M, Childe S J, Maull R S, A hierarchical approach to production control within an engineer-to-order company, in Bramley J, Mileham T (Eds.), 1993, *Advances in Manufacturing Technology VII, Proceedings of the 9th National Conference on Manufacturing Research*, University of Bath, UK

3. Weaver A M, Childe S J, Maull R S, A critical appraisal of functional and flow analysis methods used to improve the manufacturing process in a make-to-order company, in *Proceedings of the Managing Integrated Manufacturing Conference*, Keele University, 22-24 September, 1993

4. Childe S J, Maull R S, Weaver A M, The application of hierarchical control systems to reduce lead times in one-of-a-kind production (OKP), in Pappas I A, Tatsiopoulos I P (Eds.), 1993, *Proceedings of the International Conference on Advances in Production Management Systems (APMS'93)*, IFIP Transactions B13, Elsevier North Holland

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15. Maull R S, Weaver A M, Childe S J, Smart P A, Bennett J, Current issues in Business Process Re-engineering in UK Manufacturing Companies, to be published in *International Journal of Operations and Production Management*, 1995, Vol 15 No 11

Other Publications

The author of this thesis has also contributed to the following publications produced for the Engineering and Science Research Council as part of the research from EPSRC grant GR/J/95010 entitled "The specification of a Business Process Re-engineering methodology for Small and Medium Sized Manufacturing Enterprises".

1. Maull R S, Childe S J, Bennett J, Weaver A M, Smart P A, 1994, *Report on the State of the Art in Business Process Re-engineering within Manufacturing*, WP/GR/J95010-1, EPSRC Grant GR/J/95010, University of Plymouth, UK

2. Maull R S, Childe S J, Bennett J, Weaver A M, Smart P A, 1994, *Report on Good Practice in Business Process Re-engineering in Manufacturing Industry* , WP/GR/J95010-2, EPSRC Grant GR/J/95010, University of Plymouth, UK

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5. Maull R S, Childe S J, Bennett J, Weaver A M, Smart P A, 1995, *Redesign Guidelines Report*, WP/GR/J95010-5, EPSRC Grant GR/J/95010, University of Plymouth, UK

6. Maull R S, Childe S J, Bennett J, Weaver A M, Smart P A, 1995, *Different types of manufacturing processes and $IDEF_0$ models describing standard business processes*, WP/GR/J95010-6, EPSRC Grant GR/J/95010, University of Plymouth, UK

Weaver A M, Maull R S, Childe S J

A focused approach to production control within an engineer-to-order company

in

Sen A, Winsor J, Gay R (Eds.), 1993, *Computer Integrated Manufacturing, Proceedings of the 2nd International Conference (ICCIM'93)*, Singapore, World Scientific Publishing Co. Pte.

A Focused Approach to Production Control within an Engineer-to-Order Company

A M Weaver, R Maull, S J Childe
School of Computing, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, United Kingdom.

ABSTRACT

The paper describes the approach used to simplify the highly complex manufacturing system of a company in the Engineer-To-Order sector of the Capital Goods industry. A framework is defined for the improved production control system and the key attributes of the improved system are identified. The radically changed production control system is designed to ensure plans and schedules are robust to uncertainty through the distribution of responsibility and efficient use of available information. The implemented system has enabled the company to re-establish control within its manufacturing function and meet its strategic objectives of reduced costs and improved due date conformance.

1. Introduction

The Engineer-to-Order[1] sector of manufacturing has historically been an area where production has been planned with a large degree of uncertainty. The Capital Goods manufacturer discussed in this paper experiences a large and uncertain load on its manufacturing function caused by a small volume of products with a high variety of parts, small batches and diverse manufacturing processes. Additionally customers orders with incomplete specifications need a contractual commitment to delivery dates within a short time period. Like many companies within the Engineer-to-Order sector these influences create serious problems in the planning of capacity and scheduling the work load.

The approach used to improve the production control system aimed to simplify the manufacturing infrastructure hence reducing the complexity of controlling manufacturing and reducing the degree of internal uncertainty.[2] Using a defined framework key issues were identified. These included the reduction of uncertainty through formal and informal feedback, decision support, devolving decision making and the application of the solutions to the constraints existing within the company.

2. Background

The paper results from a collaboration between the University and a capital goods manufacturer. The company was experiencing increasing competition in a market where most products are unique. The company had identified that to continue to compete it must reduce its product lead times, maintain delivery date conformance and reduce costs. Manufacturing was perceived as the major contributor to the problems. To establish a mutual trust between functions to facilitate a company wide improvement process, manufacturing was identified as the function to give the process momentum, hence enabling the strategic aims of the company to be achieved.

Originally the shop floor was arranged in a traditional job shop layout with groups

of similar machines together. A complex production control system had developed and capacity planning was minimal and inaccurate. Costs were inevitably high due to the long lead times, the need to subcontract work and the use of large buffers to reduce uncertainty.

The production control system was mistrusted by the production staff since most parts required expediting at some stage in their manufacture.

Many of the reasons outlined by Kuhlmann[3] for failure of production control could be seen within the example company. These include the determination of the schedule in too great detail at an early stage, attempting to control the whole manufacturing hierarchy and not providing sufficient feedback.

3. The approach to simplification

The approach to simplification was based on distributing the decision making responsibility to the level where the supporting information existed to control the process and act on any disruptive events. Attention was given to the need for integrating each level into the overall hierarchy to ensure optimisation of the complete system.

Initially, the physical process of manufacturing was analyzed and simplified. The principle for the initial simplification of the physical process can be found in Ashby's Law of Requisite Variety[4]. This law concludes that the control system must be capable of identifying every possible state of a process, and generating a response to control the state of the process to achieve the required output. Applying this law to the manufacturing system to be improved, a simplified manufacturing process will require a simplified control system to control it.

Burbidge concludes that a functional layout of a shop floor produces an "extremely complex material flow system"[5]. The reduction in material flow by limiting part manufacture to a cell would reduce the complexity of the system required to control manufacturing.

The framework used in the analysis and the radically changed control system comprises of three levels of abstraction used based on the work by Browne et al[6]. The strategic level is concerned with decisions about the company's position within its markets especially with respect to its customers. The middle level is the tactical level where orders are scheduled and capacity planning is done. The lowest level is the operational level, which is concerned with the day-to-day operations of the shop floor.

Each level is a subsystem with a number of key attributes. Table 1 describes the attributes of each level with respect to the example company. The suggested attributes are intended to provide the basis of a simplified control system to meet the strategic aims of the company.

A simple hierarchical manufacturing control structure, focused at each level, enables employees from many functional areas to have a consistent mental model. A consistent model facilitates the integration of information and decisions across the functional boundaries.

4. The Simplified Manufacturing Infrastructure

The manufacturing process was simplified using Group Technology (GT)[7]. Cells were designed and implemented changing the shopfloor radically from a complex, functionally organised layout.

The high variety and low volume of parts manufactured to produce the company's products presented a problem in identifying the mix of machines to form cells. The method used to identify the configuration of the cells is detailed by Hallihan et al[8].

Table 1. A simplified hierarchical production control system

Key Attributes	Strategic Level	Tactical Level	Operational Level
Objectives	Profitability Cost Customer satisfaction	Part Required Dates Minimum WIP Minimum Subcontract	Completion of work Productivity Quality Resource availibility Employee Motivation
Product	Product/Order	Component Type	Operations
Time	1 to 3 Years	Monthly/Production Period	Real Time
Resource	Factory	Cell	Machine/Operators
Decision Function	Management	Production Controller/ Cell Leader	Cell Leader/ Team
Decision Support System	RCCP using historical data	Back Schedule algorithm	P.C based scheduling tool
Internal Feedback (Mechanism)	Customer Orders (mainframe) Stock Levels (mainframe) Factory Performance (mainframe) Aggregate Capacity (Mainframe)	Performance of cells (mainframe) Capacity (mainframe) Engineering Changes (Manual/Mainframe)	Capacity (informal) Work Flow (visible) Labour Booking (mainframe/P.C) Performance (visible/P.C) Quality (visible) Employee Motivation (informal)
External Feedback (Mechanism)	Customer Specifications (formal) Market (informal) Service Engineers (informal)	Subcontractor Performance (formal)	
Feedback Data Sampling	Discrete	Discrete	Continuous
Output	Quotations MPS Purchasing Req'ments Long Term Capacity Plan	Production Period Load Subcontract Req'ments Performance Info	Components Performance Info

Group technology gives the cell a sense of ownership and enables a focus to be applied to the workload. It provides the basis for the provision of the "complexity of capabilities" that is required in the "non-standard and fuzzy situations" [9] which exist within Engineer-to-Order companies. The use of the human aspect in GT is discussed by Wortmann[10].

5. The focused manufacturing control system

5.1. Strategic level

The complexity of the products manufactured at the example company leaves little alternative to the use of MRP logic at the strategic level. This is needed to generate a list of requirements and dates by which they must be met. The facility for the calculation and ordering of economic batch quantities which exists in many MRP systems would not be needed in OKP as it is often uncertain when parts or sub assemblies may be required again.

At the strategic level the master production schedule is produced. A rough cut capacity planning system (RCCP) was developed with the aim of providing accurate promises to customers and allowing the load on the factory to be smoothed.

The RCCP holds an up to date profile of the existing load on the machine shop, the estimated load of orders in the design stage and estimated load profiles for any quotations that have a strong possibility of becoming firm orders.

The most important feature of the RCCP is that it uses data from past orders to estimate loads. The company has created a load profile model for each type of product section or subassembly using the data from actual times taken to complete similar subassemblies in the past. The load generated by an order can be predicted by the "assembly" of these models. The use of this data and human experience makes full use of all the information existing on past orders.

The effects on the machine shop load of a quotation can be seen on a personal computer (PC) within minutes. The PC has the up to date loading of the machine shop transferred to it from the mainframe computing facilities. This has improved the speed and accuracy of quotations given by the sales representatives to customers.

5.2. Tactical Level

At a tactical level many methodologies, for example MRP and OPT, make scheduling decisions to produce a schedule of work over a horizon of a number of weeks. The complexity of the task required to produce this schedule would have meant that in the example company feedback and adaptation to the changes would have to be restricted. The existing estimated times for manufacturing operations can be incorrect by as much as 30-200%. More accurate estimates could be obtained, but more accurate information for parts which may be never used again would be expensive.

Period Batch Control (PBC) was chosen as the control strategy for the tactical level. It does not attempt to control the whole of the manufacturing process but assigns a period's worth of work to a cell for completion by the end of the period. The scheduling of individual operations for parts is done at the operational level within the cell. PBC is the simplest method of implementing finite capacity planning[11]. It provides a schedule at a level of abstraction equal to the accuracy of data available, providing predictability for strategic level planning and robustness to inaccurate data through aggregation of individual manufacturing operations.

The combination of PBC and GT is recommended by Burbidge as "fundamental to the success of Group Technology".

The work is initially assigned to a cell for a production period by a "first pass" back scheduling algorithm performed by the company's mainframe, loading the cells assuming infinite capacity. The load for a cell for a production period is then smoothed by the production control department in conjunction with the cell leader. They apply experience and up to date knowledge to ensure commitments to complete parts within the production period can be met. The decision process to smooth the load can take place until the day before the load is allocated to the cell at the start of the production period thus allowing decisions to be made when the maximum amount of information exists.

5.3 Operational level

At the beginning of each production period the cell leader schedules the work by individual manufacturing operations. The cell leader uses his experience and knowledge of the available resources and skills within the cell. Time savings can be made by the cell leader by batching follow-on operations of similar parts to reduce the set up times between operations.

The cell team share responsibility for maintenance, quality and meeting the schedule. The objectives of the cell and the work load placed on the cell are both focused on the cell's products. Each cell member has the same mental model of the cell's role within the manufacturing system and can work as a team member to meet the objectives.

A personal computer based interactive scheduling tool is used by the cell leader. The quantity of information however various can be assimilated by the cell leader with the support of the package and the decisions can be made to change schedules for the production period in real time.

The package has similar elements to both the Leitstand discussed by Adelsberger and Kanet[12] and the interactive scheduler by Jackson and Browne[13]. It contains a graphic interface with the ability to edit schedules, a database, a performance monitor and algorithms to schedule work. The scheduling algorithms are simple and are intended as starting points for the cell leader to use his knowledge and experience to edit the schedule using the graphical interface.

6. Conclusion

This paper has outlined the approach used to simplify the highly complex manufacturing system of a company in the engineer-to-order sector of the capital goods industry. Group Technology has been applied successfully to a manufacturing system which has to deal with high variety, low volume parts and limited often inaccurate data to use in planning its operations. This has led to the lead time for the production of spare parts being reduced from eight weeks to one week for most spares.

The control system, consists of a hierarchy of three levels, using MRP at a strategic level integrating with Period Batch Control at a tactical level and an interactive cell scheduling tool at the operational level. At all three levels human intelligence and experience are used to make decisions. The control system is focused at each level to make the decisions and the resulting plans robust to a changing environment. Planning decisions are devolved to the lowest level where the actions take place and uncertainty can be reduced by real time

feedback. The control system utilises human flexibility and experience with data processing power of computers[14] rather than a scheduling algorithm dominated control system.

The company has been provided with the tools to meet its strategic aims and maintain a competitive edge within its market sector through reduced lead times and improved due date conformance. Its simplified and focused manufacturing infrastructure will allow the company to adapt to the changing demands of the market place, and remain oriented towards meeting its customers needs.

7. References

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Weaver A M, Childe S J, Maull R S

A hierarchical approach to production control within an engineer-to-order company

in

Bramley J, Mileham T (Eds.), 1993, *Advances in Manufacturing Technology VII, Proceedings of the 9th National Conference on Manufacturing Research*, University of Bath, UK

A Hierarchical Approach to Production Control within an Engineer-to-Order Company

A M Weaver, R Maull, S Childe

School of Computing, University of Plymouth, Drake Circus, Plymouth PL4 8AA

Abstract

The paper describes the approach used to simplify the manufacturing infrastructure of an Engineer-To-Order company in the Capital Goods industry. The infrastructure prior to the simplification is discussed and the key issues experienced due to the nature of a Engineer-to-order company are identified. The design and implementation of the simplified manufacturing infrastructure uses a hierarchical approach. The implemented system has enabled the company to move towards meeting its strategic objectives of reducing product lead times, improving its after sales service and improving due date conformance.

1. Introduction

Production control within the Engineer-to-order sector of the capital goods industry must meet a complex set of strategic requirements. Changing market conditions dictate that companies competing in this market need an infrastructure that is flexible and responsive to change.

Important characteristics of the Engineer-to-order sector are small volumes of orders, a high degree of demand variability, long cumulative lead times, lead times in excess of time scales promised to the customer and engineering changes (McClelland, Maruchek 1986). These characteristics can present considerable problems when determining the manufacturing strategy and controlling production.

There are a number of other factors which need to be considered including the company's size, available supporting infrastructure, financial resources to fund change and the company's internal culture.

The paper describes the background to the project including some of the strategic objectives of the company and previous manufacturing infrastructure. The simplification process and the radically changed production control system are then outlined and to conclude the paper the benefits to the company and future improvement work are reported.

2. Background

The University has been in partnership with the example company for a number of years.

The Plymouth based company is the subsidiary of a privately owned United States manufacturer. It employs three hundred and thirty people and has an annual turnover that varies between £10m and £20m.

The objective of the project was to help the company regain its position as a leader within its product market place. The company designs, manufactures and sells a wide range of high specification machines to manufacturing companies around the world.

The company had identified that to continue to compete successfully its order lead times must be reduced while maintaining delivery dates and the individuality of its products. The importance of short lead times and promise date conformance in winning repeat orders from customers is discussed by Marucheck & McClelland (1986).

On average a third of the company's annual turnover is from orders for spare parts for machines already in service. The company includes in its strategic aims continuous improvement of its after sales service.

Before the improvement project the machine shop was laid out in a typical job shop arrangement of groupings of similar machines. The schedules and plans produced by the production control system were mistrusted by production staff. Planning and scheduling was done using inaccurate data, consequently many parts had to be expedited, large buffers were added to hide the problems and high levels of WIP existed at all stages of the manufacturing process.

Recently, the current economic climate has forced the company to win orders by shortening delivery times to maintain its work force. Ironically this means that to meet the short lead time the company's production department needs to subcontract work.

Infinite capacity had always been assumed and a four week buffer for subcontracting was included in the schedule for each part. Planning to a finite capacity to keep the subcontracted work to a minimum and identify possible overloads proved difficult as there was no mechanism for this to happen.

3. The Simplification Process

The process of simplification entailed a detailed analysis of the company's products and the markets in which the company competed. This enabled the company to define its strategic objectives and continue the process of simplification with the strategic objectives clearly defined.

3.1 The simplification of the physical manufacturing infrastructure

The existing shop floor was organised into functional groups of machines with a complex material flow as the shop had expanded over a number of years. There was a number of material handling and temporary storage areas for Work-In-Progress (WIP) to queue while waiting to be machined.

Group technology (GT) was chosen as the approach to simplify the physical manufacturing process. It would reduce the complex flow pattern of WIP through the shop, reduce the number of temporary storage areas and minimize the material handling required. There were concerns that GT may not be suitable for the high variety of complex parts that the company manufactured.

The identification of a suitable mix of machines to form cells was difficult due to the 100,000 different parts that the company had produced for past orders which could be conceivably be required to be manufactured again in the future. The method used to identify the configuration of the cells is detailed by Hallihan et al (1992).

The company decided that a step by step implementation of GT would be the most suitable approach to minimize the upheaval of the machine shop. The step approach also allowed the cell teams to be trained in the skills they would require and enabled supporting functions to focus on problems which would arise during the transition period.

The first cell to be put into place was set up to manufacture spare parts. The configuration of the cell consisted of mainly manual machines which would allow the flexibility required to manufacture most common spare parts. The cell enabled urgent spares to be controlled within a small area, reducing the need for continual monitoring and removed any possible disruption to new orders in other cells.

The implementation of a cylindrical and a prismatic cell is continuing.

3.2 The design and implementation of the simplified control system

The implementation of GT has reduced the complexity of the physical manufacturing process, the next stage of the project was to design and implement a production control system which would allow the advantages of GT to be exploited to meet the company's strategic objectives.

Three important factors for planning and control are materials, customer orders and capacity. It is difficult to focus on all three at the same time within a company manufacturing customer orders of a one-of-a-kind nature (Riis, Mortensen & Johansen 1991). The implemented production control system should try to optimise the balance between these factors to meet the strategic objectives of the company.

To analyze and develop a radically changed production control system for the company a control system with three levels of control (Browne et al 1988) was defined. The strategic level is concerned with decisions about the company's position within its markets and a planning horizon of one to three years. The middle level is the tactical level where orders are scheduled and capacity planning for the next few months is done. This level provides the integrating link between the strategic planning and the day to day planning at the third level or operational level. The operational level controls the manufacturing operations in real time.

3.2.1 Strategic level control

At the strategic level, the objectives of the planning process are to plan simultaneously customer order delivery dates and capacity at the factory level (Kuhlmann 1991). In the example company this has to be done with aggregated data which is inaccurate and is subject to frequent changes. It was described earlier that infinite capacity had always been assumed. The importance of strategic level planning had been recognised by the company as a small department existed to provide quotation dates to the sales engineers and monitor the status of orders within every function in the company. Decisions were made based on experience and no rough cut capacity planning system existed.

A rough cut capacity planning (RCCP) system was developed to enable the company to predict more accurately the effects of a promise date for an order and to identify the need to subcontract which would mean a reduction in subsequent profit margins. The RCCP system was developed in-house using a Fourth Generation computer language on the company's mainframe. It uses archive data of actual loads on manufacturing from past orders. A load profile for a potential order can be built from modules of past orders and scheduled using the company's scheduling system to see the resulting load on manufacturing. This has improved capacity planning ability and the confidence in the quotations given to customers.

The balance between customers orders and capacity planning at the strategic level has been improved. The focus is now moving towards improved materials and component procurement strategies using the improved planning capability at the strategic level.

3.2.2 Tactical level control

At the tactical level work must be allocated to cells and any work which can not be done in the cells due to capacity problems must be identified and subcontracted to meet the promise dates for customer orders. MRP and OPT as control logic were eliminated because accurate times do not exist for individual jobs on work centres. Typical "laws" of MRP call for data accuracy levels above 95% as a pre-requisite for successful implementation (Meredith 1981).

Planning using finite capacity is made difficult in the example company through the inaccuracy of the estimated manufacturing times, which can be incorrect by as much as 30-100%. A new computer aided process planning system is being implemented. There will be a transition period before a large percentage of the new orders have improved estimates.

Period Batch Control (PBC) was chosen as the control logic for the tactical level. PBC does not attempt to control the whole of the manufacturing process. It assigns an amount of work to a cell to be completed within a given period of time assuming a finite capacity. It provides a simple form of finite capacity planning and aggregates the inaccurate estimated times hence enabling decisions regarding the need for subcontracting to be made. It is also considered by Burbidge as "fundamental to the success of Group Technology". The system is described in more detail in De La Pascua et al (1992).

The parts for manufacture are allocated to a cell production period by a "first pass" back scheduling algorithm performed by the company's mainframe assuming infinite capacity. The load on a cell for a production period is then smoothed to the capacity limit by the production controller in conjunction with the cell leader. This task is assisted by a graphical representation of the load against capacity. The graphical representation shows the load over a number of production periods broken down into load which has been processed planned and estimated load due to orders in the design stages or possible orders. The estimated load comes from the load profiles generated by the RCCP system.

Using PBC and up to date load and capacity graphs, capacity planning and the manufacturing due date conformance has improved. Material flow has improved through the implementation of GT therefore all three of the key factors to be focused on have been improved at the tactical level.

3.2.3 Operational level control

The cell leader is responsible for ensuring that the parts for a production period are completed by the end of the period. The cell leader is able to create and manipulate in real time a schedule for the work to be done in the production period. In manipulating the schedule the cell leader can use experience to batch similar parts and make optimum use of the skills of the operators. To support this process a personal computer based interactive scheduling package has been developed.

The P.C. based interactive scheduling tool was developed in-house using Microsoft Visual Basic. It provides a graphical user interface for the cell leader to edit schedules, produce work-to-lists, plan capacity at a low level, a performance monitor and algorithms to schedule work. These are similar to the elements in the Leitstand (Adelsberger, Kanet 1991) and the interactive scheduler (Jackson, Browne 1989). The use of Microsoft Visual Basic has enabled users to be involved in the development of a package which is tailored to their needs and it can be maintained to provide optimum support as the manufacturing infrastructure changes.

4. Conclusion

The paper has outlined the radical changes made to the example company's manufacturing infrastructure. Group Technology has been applied successfully within the high variety, low volume environment of a Engineer-to-order company. The spares cell has reduced the quoted manufacturing lead time for non urgent spare parts from eight weeks to one week.

A hierarchical production control system has been designed and implemented. At each level the key factors of capacity planning, customer orders and materials have been focused on and the balance between the three will be continually improved. All three levels use the interaction between human experience and flexibility and the data processing capabilities of computers to produce capacity plans and schedules to meet customer orders.

The project has provided the company with the ability to meet some of its strategic objectives by reducing lead times and improving customer service. The simplified manufacturing infrastructure and the increased understanding of the production process at all levels within the company will allow it to adapt to future changes in the market place.

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A CRITICAL APPRAISAL OF FUNCTIONAL AND FLOW ANALYSIS METHODS USED TO IMPROVE THE MANUFACTURING PROCESS IN A MAKE-TO-ORDER COMPANY

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ABSTRACT

This paper discusses two alternative methods for examining and improving a business process within a make-to-order company. The process considered is producing spares to order. The two alternative methods are flow charting and the functional decomposition of the process using a task model approach. The application of the methods is described within the environment of the process improvement programme. The paper concludes by suggesting a set of criteria to compare methods for modelling processes within a process improvement programme in a small manufacturing company.

Introduction

In today's increasingly competitive environment companies are constantly striving to gain a competitive edge. In many markets the traditional order winning criteria of price, quality and functionality are now becoming market entry criteria. This is certainly true of the capital goods market. In this market where orders can be of a low volume and erratic, business processes within a company need to be robust and capable of meeting the strategic goals of the company.

Hamel & Prahalad [1] include the relationship between a company and its competitive environment and the allocation of resources among competing investment opportunities as elements in the strategy of a company. To compete in the capital goods market improving delivery and customer service must be included in the company's strategic goals [2]. Harrington [3] emphasizes this with the statement;

> "There is a five times greater chance of losing a customer from poor service than from bad products."

The role of a company's core business processes in meeting the strategic goals of the company is an area of increasing interest. Davenport & Short [4], Blaxill & Hout [5] and Harrington [6] all describe the need to improve or redesign the processes within a company as a necessary step to maintain a company's competitive advantage. Recent conferences organised such as BPICS [7] have included presentations by consultants and major multi national companies on redesigning business processes.

Make-to-order companies are distinctive in that there is a high level of freedom for the customer to influence the specification of the product and the processes required to produce it. Also the companies discussed by writers describing business process redesign are frequently large companies, while the company studied in this paper is a relatively small manufacturing company.

The purpose of the paper is to describe how the attributes of a company and the objectives of process redesign influenced the methodology and selection of an analysis tool.

Two alternative modelling tools are described. The first tool analyzes the process by charting the flow of information and physical objects through the process. The second tool describes the possibility of functionally analyzing the process using a generic task model of the type defined by Childe [8]. These are two fundamentally different tools, the flow charting tool is used to develop a model of the current process. The generic task model provides a comparison to the current process to aid the improvement of the process.

The paper is not intended to provide a detailed analysis of the numerous methodologies and tools available for business process improvement and systems analysis and design. Through the discussion of a specific case study, a set of criteria are developed as an aid to support similar companies seeking to analyze and improve their business processes.

Background

The company discussed in this paper is a European subsidiary of a privately owned USA manufacturer. The Plymouth based company sells, designs and manufactures a wide range of custom designed high specification machines to companies worldwide. The company employs three hundred and thirty people and has a turnover which varies between £10m and £20m.

Approximately 35% of the company's annual turnover is gained from spare parts required for machines which are in service worldwide. One of the strategic aims of the company was to improve the after sales spares service to its customers.

The University of Plymouth has been collaborating with the company in a major redesign of the company's manufacturing infrastructure. This collaboration has been coordinated through the Teaching Company Scheme.

The analysis and redesign of the manufacturing infrastructure has taken place during the last three years. Group Technology has been implemented and a new hierarchical production control system using Period Batch Control [9] as the control logic has been developed. These are described in more detail in [10] and [11].

A cell was dedicated to the manufacture of spares. It consisted of a group of manual work centres which provided the flexibility to manufacture a large variety of spare parts in low quantities. It removed spare parts from the main machine shop, reducing the disruption to

the schedules of other orders and concentrating the material movement in a controllable area and removed the requirement to expedite spares.

Implementation of the spares cell had the effect of significantly reducing the manufacturing lead time. Customers were originally quoted a lead time of eight weeks for non-urgent spares by the customer service department. Typically a large order for spares can now be manufactured within one week.

It was identified that there had been a dramatic improvement within manufacturing but this improvement had not been reflected in the time taken for the overall process of taking a customer order for spares to shipping the completed order.

It was decided that the complete process needed to be analyzed and improved to enable maximum benefits of the manufacturing changes to be realised in after sales customer service.

Davenport & Short [12] identify four main objectives of process redesign; cost reduction, time reduction, output quality and quality of working life. Harrington [13] includes a fifth, flexibility to customers' changing needs. The objective of the example company was to reduce the total time for the spares-to-order process within the company, thus addressing the issues of time and cost reduction and flexibility to changing needs.

Process Improvement Programme

This paper is primarily concerned with the two alternative tools used by the improvement team to model the process. The resources available to execute the project and the constraints placed on the team members will have an influence on the tools used during the project.

It was not possible to follow a particular methodology since the company often reacted to changing market conditions in a way in which did not encourage clear project management in an environment of constantly changing priorities.

Five stages could clearly be seen when examining the project in hindsight. These stages can be found in many of the methodologies suggested by various authors (Harrington, etc.).

1. Definition of Objectives and Project
2. Analysis of the Process
3. Redesign of the Process
4. Implementation
5. Evaluate

Definition of the Objectives and Project

The first stage in the process improvement was the definition of the team, its organisation and the statement of the objective which was to reduce the lead time of the spares-to-order process.

A single process improvement team was formed. The team leader was the production manager who was responsible for five of the functional areas involved in the process, while other team members were from the various functions involved in the process. The programme manager was a member of the company's senior management, empowering the team to change the process. The process improvement champion was the managing director.

The team held a meeting every day for two hours over a three week period. This enabled the team to carry out the process improvement with minimal disruption to their normal work. The simultaneous involvement of the team in the project and in their normal work enabled an informal reporting and analysis structure to develop. The team members tended to note events in their normal work which were relevant to the process and its improvement. This could be discussed at the next meeting. Any ideas or comments generated through informal discussion with colleagues could also be included by the team in the improvement process.

Analysis of the process

The second stage was to analyze the current system. A model was developed of the process detailing activities and both material and information flows. There are many tools available to help the team clarify the process through modelling. The tool chosen and developed by the team will be discussed later. Research described by Shapiro et al [14] showed that for progress to be made, an understanding gained through the charting of the whole process is necessary.

The team followed the flow of an order through the process from "birth to death" [15] identifying individual activities and flows at the working level. This was done by temporarily including further members from the functions in the meetings and asking them to describe the activities that they carried out. Each temporary member was introduced to the objectives and the work done so far was summarised. The process was modelled during the meeting and at a later stage each temporary member was recalled to review an interpreted version of their part of the process.

The involvement of other users of the process increased communication of ideas and enabled more people to be part of the improvement process rather than being interviewed in isolation. To establish change Beer et al [16] define the need to "mobilize commitment to change through joint diagnosis of business problems" and then "develop a shared vision of how to organize and manage for competitiveness". The team was able to achieve both a commitment and shared vision through a significant proportion of users being involved in the analysis and improved design.

The final model of the process described the flow of an order for spare parts which involved eight functional areas, eighty-two activities and seventeen physical pieces of documentation. It was displayed around three sides of the team's meeting room. Displaying the complete model enabled people from different functions with different views of part of the process to see and discuss the process as a tangible entity. Problems, opportunities, potential actions and threats could be discussed using the factual representation of the process.

Redesign the Process

The redesigned process must meet the defined objectives. Although the objectives have been defined in stage one, the objectives may require changing as an improved understanding of the process is developed. The process improvement team sought to remove bureaucratic activities, reduce documentation, remove duplication of activities and develop a process which had the minimum number of consecutive activities through core activities happening simultaneously. The redesign process involved an iterative process of identifying areas of improvement, identifying the changes required and discussing the suggested changes. The users in the functions which would have to implement the changes were included in this iteration.

Implementation

The resulting design for the improved process was implemented in a number of stages. An incremental approach to improving process enabled gains to be made as soon as possible.

Evaluation

A staged implementation enabled the users to monitor the changes as they happened. The redesigned process could then be adjusted to maximise the benefits and meet the objectives of the process improvement.

The organization of the process improvement through involving as many people as possible has enabled functional barriers to be broken down through the meetings and discussions during each stage. A shared commitment and vision has been created to provide the momentum to increase the success of the changes. The team was not remote from the process at any stage, thus reducing the possibility of error or failure to consider activities. It has enabled the users to develop a concurrent mental model which will support an understanding of the roles that each user has in the process.

Modelling the process

The flow charting tool

Flow charting is defined in Oakland [17] as the "systematic planning or examination of any process". Harrington [18] discusses the use of four types of flow charting tools to provide an overall model of a process. The four types are :-

1. Block Diagrams to provide a simple overview.
2. American National Standards Institute standard flow charts which detail the activity and flow interrelationships.
3. Functional flow charts depicting process flows between functions or areas.
4. Geographic flow charts showing the flow between locations.

Flow charting is a well established tool used in traditional systems analysis, work study and as a tool in quality improvement programmes. Flow charting can be used in three specific ways, to chart events, to chart activities and to chart the transformations (sub-processes) either in separate charts or in combination.[19]

The process improvement team decided to use flow charting as the tool to analyze the spares-to-order process. All the members of the team were comfortable with the tool and temporary members were also familiar with it. During the meetings simple block diagrams were used to describe the flow and afterwards the block diagrams were translated into a flow chart using an increased number of symbols representing specific types of process elements. The symbols used, a variation of the ANSI standards, are shown in figure 1.

There was no conscious effort by the team to use a particular standard notation system. The symbols used defined the process at the working level. The team adopted a standard of numbering activities which indicated the functional area the activity was performed by. The team had recognised the importance of being able to identify functions and activities to have a complete model of the process. The functions were identified by a numbering convention. Each activity performed by a function was given the same numeric prefix.

The convention of identifying and numbering core activities has reduced the complexity of the flow chart by allowing emphasis to be placed on these activities.

The principal drawbacks of flow charting in its standard form are that flow charting can lead to a model that has a single level of abstraction increasing the complexity of the model, and no indication of who carries out an activity or why the activity is taking place. Harrington reduces the complexity by the use of block diagrams as an overview, the team by developing a numbering convention for activities also reduced the complexity of the flow chart.

In the system-wide redesign the inability of flow charting to provide a means of abstracting detail at a higher level could be seen as a disadvantage. Without the ability to abstract detail it is difficult to analyze the process independent of departments. This reduces the ability of the team to restructure the process and can result in incremental improvements only. However flow charting did enable the process improvement team and other function members involved to work at a "level of detail at which they feel competent" [20] which was the level of the everyday activities they carry out.

The functional modelling tool

Functional modelling tools show activities or tasks performed by a system. The focus on the tasks which are performed by individuals and functions would enable the process improvement team members to work at their level of competence.

Childe [21] developed a generic task model based on the principle that there are a key set of tasks which are consistent throughout manufacturing companies. It allows the tasks that are required in a process to produce the necessary results to be identified. The purpose of this functional model was to provide the users of the tool with a simple framework of tasks without the complication of informational or physical flows. By keeping the modelling technique as simple as possible it was hoped that it could be understood by non experts.

Some tasks appear to be necessary in every manufacturing company, in which case the situation could only affect the way in which the task is performed. These tasks are regarded as "core" tasks. These included for example "Process orders", "Handle goods inward".

The decomposition of a core task could include optional tasks according to the way in which the core task is performed, particularly the decision whether or not to computerise the task. Thus a critical question for a core task is only how it should be done, which is determined by the lower level tasks of which it is constituted.

In the cases where the task requirement is seen to depend upon the situation, the task was regarded as "optional", since there would clearly be cases in which the task was is not required. Examples of these include "Confirm order to customer", "Inspect goods".

"Dependent" tasks are tasks which can be found in the decomposition of optional tasks, but which are not themselves optional. These are necessary in any instance in which the parent task is required.

Initially the task model has the advantage of providing the process improvement team with a focal point. It promotes a more radical approach to redesigning the process. Tasks which occur in the process and do not occur in the task model should lead the process improvement team to question if the task is really necessary. If a task is shown in the task model and does not appear in the process, the process improvement team should review its procedures and identify whether in fact the task is not performed. This provides a checklist for some tasks which may be overlooked. Figure 2 shows a section of Childe's task model. (This only shows the core tasks, a number of optional and dependent tasks are also shown on the full model.)

The use of the task model crosses the boundary between the stages of analysis and redesign as the "fitting" of the process into the task model requires an analysis of the current process and provides a framework for the redesigned process at the same time. The redesign of the process should be explicit and not subject to the influences of individual perceptions within the process improvement team [22]. The task model provides a neutral focal point to aid the redesign.

Tools for modelling tasks and flows

The two alternative tools examined use either a representation of the flows within a process or a representation of the tasks carried out in a process. There are a number of tools described by various methodologies for example actigrams (SADT), Data Flow Diagrams (SSADM [23]) and IDEF0 [24] which combine tasks and flows to provide a complete physical model of the process. IDEF0 and actigrams restrict the number of tasks per diagram which aids the clarity of the model. Both model the process showing for each activity inputs, outputs, controls and the resources required.

IDEF0 is one tool from a set of three tools developed by SOFTECH for the US Air Force's ICAM (Integrated Computer Aided Manufacturing) programme. IDEF0 provides a comprehensive static model of activities and their relationships within a process. The tool provides an effective communication medium which can easily be understood, allows decomposition to the level of detail desired and "has the potential to be used as an industry standard for manufacturing systems design" [25].

Criteria for the identification of suitable tools for process improvement

The above sections have described two analysis tools and their relative advantages and disadvantages with respect to developing a model of the current spares-to-order process within a small manufacturing company. This section will define a set of criteria to facilitate the selection of analysis tools for similar process improvement projects.

The criteria can be categorised under three broad groups as the criteria examine specific attributes of the project, the process to be modelled and the model. Table 1 provides a summary of the groups of criteria.

GROUP	CRITERIA
Project	The ease of use of the tool
	Redesign of the process
	Objectives of the improvement project
	Organisation of the modelling
Process	Elements of the business process modelled
	Representation of constraints
	Modelling exception events
Model	The completeness of the process model
	The level of abstraction represented in the model

Table 1. Criteria Groups

Ease of use of the tool

The two main purposes of the tool are to enable the team to translate the physical process they know into a representative model and communicate to others the attributes of the process.

The first purpose can be influenced by constraints placed on the team by the company environment. If, for example there is a requirement for a rapid improvement to the process, training a team to use the most suitable tool and producing a complete model may be excessive. A more familiar but less suitable tool providing an incomplete model but significantly faster may provide a better alternative.

The second purpose is influenced by the ability of employees at various levels of the company to interpret the model. Each group of employees will have a different skill and experience level and will consider the model from a different perspective.

Ease of use, facilitating better understanding and communication to all those involved in each level, will hasten the analysis and redesign of the process. An understandable physical model is the first step towards a concurrent mental model for all employees.

In the example company, the use of flow charting provided a suitable communication medium as the majority of contributors were familiar with the tool, providing that a standard for the symbols used were defined.

Redesign of the process

The primary objective of the tool is to represent the current process to be improved. The tool can provide additional benefits if it enables the improvement team to focus easily on areas where improvements can be made.

The complex flow chart produced by the process improvement team although indicating that it could be simplified, did not help identify which of the eighty-two activities were needed or which added no value to the product.

Childe's task model identifies the core activities and leads the user to question the need for any further activities. The use of the task model is likely to produce a radical redesign. However the informational or physical flows are excluded from Childe's model. This failure to represent flow could reduce the teams focus on this potential area of redesign.

Objectives of the improvement project

The objective of improving the spares-to-order process was to reduce the lead time of a customer order. The model produced by the team gave the number of activities in the process. It did not give an explicit indication of the time taken to do activities or the delay due to flows of information or physical objects. The team overcame this problem through their knowledge of the actual process and other users' information. Such an in depth working knowledge of the process may not always be available.

To meet the objective of cost reduction a tool which gives a model which includes the entities or mechanisms that perform activities would provide essential information for process redesign. The model of the example process used a numbering convention to identify which function performed an activity. It did not provide sufficient detail for opportunities to reduce cost to identified.

Organisation of the modelling

The process improvement team went through a number of stages of iteration both in the development of the model and the redesign of the process. It was constantly changed and new versions produced. Neither the flow charting tool or the task model provided any formalised means for version control.

The example was a small process and a small improvement team. The size meant one team member could be designated to be responsible for controlling the versions of the model. In a more complex modelling exercise, more rigorous control would have been required.

Elements of the business process modelled

The spares-to-order process included both physical and informational flows with a combination of manual and computerised activities. The model of the process using the flow charting symbols chosen required a compromise between having a limited number of symbols and the strict definition of some of the activities. A predominantly physical process could use flow charting symbols used in traditional work study. A tool designed to model data flows for example those described in SADT or SSADM may be more suitable for modelling a process which predominantly transforms information.

Representation of constraints

Many processes within companies today have developed in an ad hoc manner. Improvements in information technology and the constraints placed on the process at various points in the past have influenced the process.

Typical of the constraints placed on the spares-to-order process within the example company is the lead time for the order to be shipped. A company which keeps a large stock of spare parts or is capable of manufacturing simple spare parts in a minimal time may have a constraint that the order must be shipped within a certain time of receipt.

Constraints placed on the process by its environment are an important factor in determining how the process meets its objectives. Harrington [26] discusses how a non-holistic approach to process improvement can lead to the sub-optimization of the process.

The example company improved the manufacturing lead time of the spares-to-order process, however this sub-process was considered in isolation. The realisation that the improvements to the manufacturing lead time had led to a sub-optimization resulted in the project to improve the complete spares-to-order process.

A tool capable of describing and incorporating internal and external constraints would reduce the risk of sub-optimizing the process. Neither of the tools described provide the user with the ability to represent constraints. IDEF0 does incorporate constraints.

Modelling exception events

To model a complete process it is necessary to model every event however rarely it may happen. To take account of all unusual events the model can become unnecessarily complex. It is difficult for the team to decide if the inclusion of an event will be to the detriment of the completed model and the redesigned process. A strategy at the whole process level is needed to enable a decision to made whether or not the exception event should be included in the model.

The model of the process produced by the team in the company included the major exception events. This added considerably to the complexity of the model. The generic task model does not include exception tasks as exception events are usually specific to the company and occur only at a very detailed level.

The completeness of the process model

Davenport & Short [27] identify three distinct classes of elements in a process; objects, entities and activities. Entities are the mechanisms which perform the activities. The entity is dependent on the level of abstraction of analysis, for example an entity could be a function or a person depending on the level of abstraction. Objects are transformed through the process and can be physical or informational, while activities carry out the transformation of the objects.

This classification is useful when comparing models of different types. If a model is to provide a complete static representation of process it should include all three classes of elements. The flow charting technique enabled the team to identify the objects and the activities of the process. It was difficult to identify the entities of the process apart from the functional area performing the activity. In comparison the task model would have only provided the team with the activities required in the process.

The level of abstraction represented in the model

The level of abstraction required for a model is dependent on the complexity of the process being modelled and hence may need a hierarchical approach. It is also important that the team developing the model are comfortable working at the level of abstraction required.

In the example company the team used a simple block diagram similar to the block diagrams suggested by Harrington [28] to provide an overview of the process to help clarify the model. The task model approach describes the tasks that need to be carried out during the process. The identification of specific tasks, especially the dependent and optional tasks enables the team to identify the tasks they perform, hence the model is working at the correct level of abstraction for the team. The process owner is able to refer to the core tasks which provide a model at a higher level of abstraction.

Conclusion

The purpose of this paper was to develop a set of criteria to facilitate the selection of an analysis tool suitable to model a process as an aid to the analysis and redesign of the business process. The examination of a programme of process improvement within a small manufacturing company and of the tool used to model the process enabled important factors to be identified. The organisation of the process improvement was influenced by the environment of constantly changing priorities within the company.

The two alternative methods examined were chosen partially for their simplicity and their applicability to the organisation and environment of a small manufacturing company. The method should be selected with consideration for the groups of criteria set out above, which are categorised by the attributes examined by the criteria.

The choice of the correct tool to analyze and redesign core business processes is important to enable the objectives of the redesign to be fulfilled. The company in the case study has been able to meet one of its strategic objectives of improving after sales customer service through the application of a process focused approach to improving one of its core business processes.

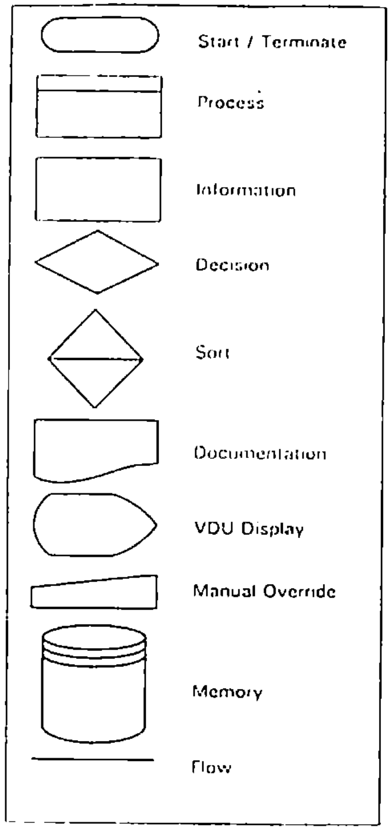

Figure 1. Flow Chart Symbols

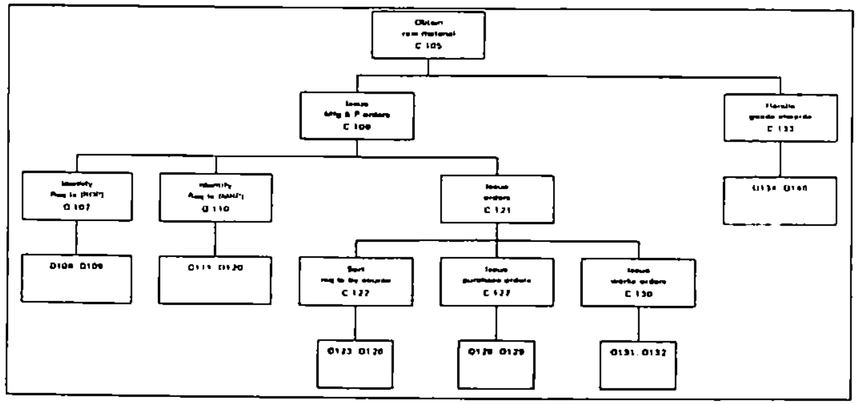

Figure 2. A Section of Childe's Task Model

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Childe S J, Maull R S, Weaver A M

The application of hierarchical control systems to reduce lead times in one-of-a-kind production (OKP)

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The application of hierarchical control systems to reduce lead times in one-of-a-kind production (OKP)

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Abstract

This paper will outline the changes in the manufacturing infrastructure and control system in the transformation of a medium sized one-of-a-kind manufacturing company based in South West England. The changes were based upon Group Technology cells and a dedicated control system designed to deal with uncertainty and lack of data. Initial results indicate reduced manufacturing lead times.

Keywords

Production management, Group Technology, one-of-a-kind production, cell control.

Introduction

One-of-a-kind production (OKP) has been defined by many authors including Kuhlmann (1991), Wortmann (1992), Rolstadas (1991). OKP could be described as a process which produces a product only once (Kuhlmann 1991). Some OKP products may be variations where the basic design remains but the product is customised to the customer's requirements.

Riis et al (1991) classify four different types of one-of-a-kind production. Customer orders may call for:

1. Research and development work before design and production
2. Engineering design before production
3. Process changes in production
4. Configuration and assembly changes

The company described in this paper produces products in all the four types of one-of-a-kind production.

Within the company there was a functional distinction between manufacture and assembly and a finished part stores which acted as a buffer between manufacture and assembly. Senior management's strategic aim was to reduce the overall throughput time of the product. To support this aim it was realised that many functional barriers must be removed. Manufacturing had historically been seen as the major problem area. It was therefore identified as the area to establish momentum for change which would encourage other functional areas in achieving the overall strategic aim.

A major manufacturing redesign was instigated, part of which was supported by the University of Plymouth, the aim being to reduce lead times of parts within the manufacturing function.

To understand the reasons for the changes which took place it is important to understand the previous manufacturing system and its environment.

Company background and environment

The company was set up as a European subsidiary of a privately owned United States manufacturer. The Plymouth based company sells, designs and manufactures a wide range of custom designed high specification machines to large international companies. The supply of spare parts, machine updates and service contracts for machines forms a significant part of the business. The market for the goods is typical of most capital goods markets, in that orders can be erratic and of a low volume.

The company employs three hundred and thirty people and has a turnover that varies between £10m and £20m. The production department employs approximately half of the total number of staff of whom two thirds are involved in manufacturing and one third in assembly activities.

Prior to the research project the machine shop was organised into clusters of machines of similar types. The production control system had no master production schedule and no capacity planning. The system established a date for each part through each individual operation required for its manufacture. A back scheduling algorithm was used, allowing one week for each operation, three weeks for each outside (subcontract) process and four weeks were scheduled for inspection. This four week period was also designed as a buffer if the work required subcontracting to meet the "part required" date. High work in progress (WIP) levels were placed on the shop floor in order to attain high machine utilisation.

Long lead times were quickly built up. Due date conformance was difficult to control due to the high WIP levels that produced long and variable queue times at each machine. The production control system was mistrusted by production staff due to most parts requiring expediting at some stage in their manufacture. Costs were inevitably high due to long lead times and the need to subcontract to meet due dates.

The improvement process

The improvements at the company took place in two main stages. Firstly, Group Technology (GT) cells were designed and implemented, and then a dedicated cell-based control system was developed. The approach was based upon the concept of an infrastructure consisting of both computerised and manual functions as described in Maull et al (1990).

Stage 1 Identification and implementation of group technology cells

The first task of the research team was to simplify the complex, functionally organised shopfloor layout. A group technology approach was chosen.

Group technology techniques are based around cells and part families. A cell is a product or skill based unit that is provided with its own group of people, machines and facilities needed to provide the skills and processes required to take a range of parts completely through one or more major stages of production. The cell that takes each part through each major stage is considered to "own" the part throughout that major stage. A major stage may be material preparation (e.g. casting or cutting), component manufacture or product assembly.

Wortmann (1991) discusses the importance of human aspects within OKP and how group technology makes full use of the human aspect. Group technology gives the work force in the cell a sense of ownership and enables a focus to be applied to the workload. Since they work on a part family, it allows decisions to be made to "batch" similar parts together thereby saving setup time.

The identification of the mix of machines to form the cells presented a problem. Most published GTCP (Group Technology Configuration Problem) algorithms found by a literature search were not suitable for use within the company, due to limitations of computing power. The company has over 100,000 parts on an item master file. None of the algorithms claimed to be able to deal with such a large number of parts. Many algorithms required detailed information about each part which was not available within the company.

The method used to identify the configuration of the cells is detailed by Hallihan et al (1992). This method used the routing information which was the only data available for each part.

A pilot scheme was agreed with the company, and the configuration of the pilot cell was developed. The initial design was discussed with a number of people within the company. Using their knowledge of the machine shop and the parts made by the company they agreed that the design appeared feasible. The initial design was based around an easily identifiable family of simple parts, known variously as blocks, brackets, spacers etc. The cell required only manual machines which were easily moved into place. It was set up and ran over a period of three months as a autonomous unit within the machine shop. The results showed a 35% reduction in the lead time. Scrap and rework rates were reduced to zero.

The reduction in lead time was attributed to a number of factors. These factors included a reduction in the number of setups which was allowed by local control of the sequence of work, in-cell based clocking of operations and in-cell storage of frequently used tooling. An allowance must also be made for the possibility of a "Hawthorne" effect.

The success of the pilot scheme led to the general acceptance of Group Technology for the rest of the machine shop.

The next cell to be set up was to manufacture spare parts. Whilst the cell could not produce all parts which could ever be required for spares (which could include any part) a cell design was arrived at which allowed the production of most of the commonly required items. The cell was provided with mainly manual machines and a flexible work team with the aim of reducing the manufacturing lead time for spares. High priority spares could be controlled more easily within a cell and there would be less disruption to the scheduled parts for new machines being manufactured in the other cells.

The spares cell has significantly reduced the lead times for spares. The customer service department previously quoted eight weeks for non-urgent spares. The manufacturing lead time has now been reduced to a week for most spares. Customer services are undergoing a process of reducing their quoted lead times as their confidence in the manufacturing function grows. This has therefore resulted in a real competitive advantage which the company can begin to exploit.

The implementation of further cells is continuing.

Stage 2 Selection of a control system for the cells

To fully exploit the advantages of Group Technology, a cell based control system was required. The next phase of the research was to concentrate on developing a control system specification.

Kuhlmann (1991) points out that existing control system approaches rely upon up-to-date information which is seldom available in OKP. There is thus a high degree of uncertainty about each product and its manufacture. In order to deal with this uncertainty, a hierarchical approach was developed in which decisions are taken at the lowest possible level, where there is the least uncertainty.

The structure used in the analysis of the company's control system and the resulting radically changed system (Table 1) is a development from Browne et al (1988). The framework comprises three levels of control. The strategic level is concerned with decisions about the company's position within its markets especially with respect to its customers. The middle level is the tactical level where orders are scheduled and capacity planning is done. The lowest level is the operational level, which is concerned with the day-to-day operations of the shopfloor.

Strategic level scheduling

For products as complicated as those manufactured by the example company there is very little alternative to the use of MRP logic at the strategic level. This is needed to generate a list of requirements and dates by which they must be met.

There are features of some MRP systems which are not desirable in "one-of-a-kind" manufacturing. The most obvious example is the calculation and ordering of economic batch quantities. This is not suitable because in "OKP" it is often uncertain if or when the components or sub-assemblies will be required again.

The procurement of expensive items can be organised by MRP control systems using a JIT philosophy in order to minimise the expense. This would involve building up long term relationships with a reduced number of suppliers and working to minimise variations in delivery time. As the variation is reduced the safety lead time can be reduced and thus inventory holding costs and the needs for safety stock (De Toni et al 1988) are reduced.

Table 1. Hierarchical structure of control system

Level	Product unit	Decision unit	Resource unit	Data unit	Time unit	Output
Strategic Level	Product (Main machine)	Management level	Factory	Product profile (Section CA Model)	1-3 years	Master Production Schedule
Tactical Level	Components, assemblies or sub-assemblies	Production controller	Cell	Manufacturing route	Weekly or monthly period	Period work list
Operational Level	Manufacturing or assembly operations	Cell leader	Machine, tool, person	Works instructions, layouts or methods	Real time continual updates	Components, assemblies, products

The example company had no form of capacity planning at the strategic level, as capacity was assumed to be infinite and work could be subcontracted as the need arose. A rough cut capacity planning system was developed with the aims of allowing accurate promises to be made to customers and allowing the load on the factory to be smoothed.

One of the major features of the capacity planning system is the use of data from past orders. The company has started to create a load profile model for each type of product section or subassembly. The load generated by an order can be predicted by the "assembly" of these models. This has improved the planning ability and improved the confidence in the quotations given by the sales representatives.

Tactical level scheduling

For shop floor scheduling, MRP and OPT can be eliminated because accurate times do not exist for individual jobs on work centres. Typical "laws" of MRP call for data accuracy levels above 95% as a pre-requisite for successful implementation (Meredith 1981). The existing estimated times for manufacturing operations can be incorrect by as much as 30-100%. Normal finite capacity planning under these circumstances appears impossible.

A generic kanban system (Sandras 1987) would be a possibility, but it would not have the team building advantages of the cells. Also, because of the push-pull links between machines where individual parts have very different flow paths, it would be very complicated to set up. Rather than to simplify the process of planning, a generic kanban system could make it more complex. Generic kanban could be implemented in a cellular environment but this would not give the team the same target of completing a certain amount of work before the end of the cycle. Generic kanban would also make it difficult to gauge what work would be completed by the cells and when the work would be completed.

The best alternative appears to be the use of Period Batch Control (PBC) at the tactical level. PBC does not attempt to control the whole production process but assigns a period's worth of work to a cell for completion by the end of the period. This provides predictability and robustness to inaccurate data as long as the summing of many inaccurate leadtimes averages out the variation to ensure that the period's load is achievable. For this aggregation to occur it is necessary for the load to consist of a large number of different items. Thus the tactical level of scheduling is concerned with aggregated data relating to cells and periods, rather than individual operations.

The decisions for scheduling individual parts would be made at an operational level within the cell hence devolving the decision making process to its lowest level.

PBC is the simplest method of implementing a form of finite capacity planning (Burbidge 1986). More detailed methods of capacity planning would require more accurate times in order to be successful. In the OKP business more accurate information regarding parts that may never be made again is expensive.

Burbidge considers PBC to be "fundamental to the success of Group Technology". The coupling of the two will, at the tactical level, provide the control to integrate the autonomous cells to meet the strategic needs of the company. At the operational level it will increase team work and increase the depth of experience which exists within the cell.

A cell control system based on PBC with multiple (dual) phases has been implemented so far in the spares cell. The overlapping of phases reduces the time a job must wait before entering the cell, while allowing two phases of work to be present at any time. This facilitates the batching of similar parts to reduce the effects of setup times. Since all the work in the period has the same due date, it can be left to the cell to ensure the due date is met, thus providing the predictability that is needed at the tactical level.

The implemented multi-phase PBC system has two phases. This means that in a time period of one week, half a week's work would be inserted into a cell every half a week for completion one week after the date of insertion into the cell (Figure 1). The system is described in more detail by De La Pascua et al (1992).

Figure 1. Operation of the dual phase PBC system

Period Indicator	Week n		Week n + 1		Week n + 2	
Yellow						
Red						
Blue						
Yellow						
Red						
Work indicators in cell	blue (not shown) + yellow	yellow + red	red + blue	blue + yellow	yellow + red	red + blue (not shown)

Operational Level Scheduling

At the start of each period, the cell leader is provided with a list of work required by the end of that period (and for which material is available). The cell leader is responsible for ensuring that the parts for a production period are completed on time by the end of the period. The cell leader has the ability to use his experience to schedule work, decide if work can be batched to reduce set ups, and make optimum use of the skills of the operators. At this low level the cell leader is able to continually assimilate a wide variety of information which may affect the schedule. This reduces the uncertainty and enables him to act on events in real time.

A personal computer based interactive scheduling package is currently under development to aid the cell leader in scheduling task. It will provide the "minor analytical assistance" suggested by Burbidge (1988) to help cell leaders to manipulate the schedule. It is being developed under close consultation with the leaders of the pilot cells to provide a decision support and information management system that meets their requirements. It is hoped that this level of autonomy will provide an opportunity for the members of the cell to continue learning new skills, be engaged in a variety of activities and make a meaningful contribution as they "own" and complete parts.

Conclusion

This paper has outlined the successful application of Group Technology within the highly complex environment of a medium-sized OKP company. The control of the manufacturing system has been improved by a three level hierarchical system. The control system of MRP with a JIT philosophy at the strategic level, Period Batch Control at a tactical level and an internal interactive cell scheduling tool at the operational level, has been employed to reduce the complexity of controlling the manufacturing process. The control system has devolved the decision making process to a point where decisions can be made with the lowest degree of uncertainty.

The company has reduced its leadtimes for components and subsequently improved its due date conformance. The company's sales department have been handed a further competitive advantage in the form of a reduced lead time for spares delivery. This will be extended to main product manufacture. The motivation of the work force has improved and should make a contribution to the productivity of the cells. This has been done through continuous involvement of the work force and autonomy at the cell level.

The momentum to reach the company's strategic aims has been established within manufacturing and from this base, the company can continue to compete in the market place and provide the high customer service standards its customers require.

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An approach to the simplification of production control within a make-to-order company

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An approach to the simplification of production control within a make-to-order company

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ABSTRACT

The make to order industry has to deal with problems of uncertainty which make planning difficult. Capital goods products tend to be "one of a kind" with the effect that most items produced are new and production plans are not tried and tested. This paper describes a project undertaken in a make-to-order company with the aims of reducing product lead times, maintaining delivery to promise and reducing costs. Simplification on the shop floor through Group Technology and a three-level hierarchical control system led to a human based control system in which decisions can be taken at the lowest level and in real time, and where the inaccuracy of planning information is the least.

INTRODUCTION

The make-to-order sector of manufacturing has historically been an area where production has been planned with a high degree of uncertainty (Wortmann 1990) . The capital goods manufacturer discussed in this paper experiences a large and uncertain load on its manufacturing function caused by a small volume of products with a high variety of parts, small batches and diverse manufacturing processes. Customers require contractual commitments to delivery dates even when specifications are incomplete. As in many companies within the make-to-order sector, these pressures create serious problems in the planning of capacity and scheduling the work load.

A simplification exercise was carried out in the company to simplify the manufacturing system and the production control system hence reducing the degree of internal uncertainty (Newman et al 1993).

BACKGROUND

The paper results from a collaboration between the University and a capital goods manufacturer. The company was experiencing increasing competition in a market where most products are unique. The company had identified that to continue to compete it must reduce its product lead times, maintain delivery date conformance and reduce costs. Manufacturing was perceived as the major contributor to the problems. The manufacturing function was selected as the first area to try to improve, both to allow early productivity gains and to give momentum to a company wide improvement process.

Originally the shop floor was arranged in a traditional job shop layout with groups of similar machines together. A complex production control system had developed and capacity planning was minimal and inaccurate. Costs were inevitably high due to the long lead times, the need to subcontract work at moments of excess load, and the use of large buffers to reduce uncertainty.

The production control system was mistrusted by the production staff since most parts required expediting at some stage in their manufacture.

Many of the reasons outlined by Kuhlmann (1991) for failure of production control could be seen within the example company. These include the determination of the schedule in too great detail at an early stage, attempting to control the whole manufacturing hierarchy and not providing sufficient feedback.

THE NEED FOR SIMPLIFICATION

The company's market area is in the production of major plant for process industries. These very large investments only occur when existing facilities are being replaced or when a new manufacturing facility is being established, such as in a newly industrialised country. In existing trading areas, products are sold only when the level of demand in the primary industry increases well beyond existing capacity.

In the case company, orders for new products arrive very randomly, and the amount of work associated with an order is very large. In very approximate terms, five or six major orders would take up the company's entire production facilities for around one year. This explains the great importance of winning each order, since the loss of a contract would be roughly equal to 20% of turnover. Competition on both price and delivery is very intense, since competitor companies have similar circumstances.

At the start of the project it was felt that the company was not sufficiently adept at forecasting completion dates to customers, since factory lead times varied widely due to each new contract being different, and with lead time varying under different conditions of load.

A second aspect of the business was the support of existing products in the field. The nature of the products being fairly complex and their service life being necessarily long, customers require a high degree of service to maintain their operations. Service requires the company to manufacture replacement parts for items which wear out and are regularly replaced, such as bearings, and breakdown replacements to deal with unexpected failure in service. The quality of service offered is very important since customers lose their own productive capacity during a breakdown, and the establishment and maintenance of an excellent reputation for service is a vital element in competing for new business. However, the production of spares, particularly those required urgently, has a very disruptive effect on production schedules in the factory, often causing main machine work to be broken down to allow a spare to be machined immediately. This was found to be causing unpredictability for both major products and spares, making forecasting very difficult.

The simplification and improvement exercise had the aims of reducing manufacturing lead time, and increasing the certainty of delivering on time to satisfy promises made to customers. It was felt that simplification would make the manufacturing process easier to control and more predictable.

THE APPROACH TO SIMPLIFICATION

The company's existing system used a central computer to establish start and due dates for each manufactured item. This was based upon poor load data, since most items were new variants rather than repeat batches of existing designs. It was found that the centralised approach was inappropriate since the manufacturing requirements of each item could not be planned sufficiently well in advance of the material arriving on the shop floor.

The approach to simplification was based on distributing the decision making responsibility to the level where the supporting information existed to control the process and act on any disruptive events. This meant devolving decision making to the lowest possible level. Attention was given to the need for integrating each level into the overall hierarchy to ensure optimisation of the complete system.

Firstly the project addressed the physical process of manufacturing. A group technology (GT) approach was used to design a number of mostly independent production cells to replace the existing functional layout, as suggested by Burbidge (1988, 1975). The reduction in material flow by limiting part manufacture to a cell would reduce the complexity of the system required to control manufacturing. The high variety and low volume of parts presented a problem in identifying the mix of machines to form cells. The method used to identify the configuration of the cells is detailed by Hallihan et al (1992).

A SIMPLIFIED MANUFACTURING INFRASTRUCTURE

Group Technology provides a sense of ownership in the cell since a meaningful family of similar or related components is dealt with. This allows cell personnel to understand the production of whole parts rather than simply performing specialised operations on those parts, which usually had to be transported to other specialists, thus extending lead times and generating queues of work.

The use of cells can be seen as a return to craft skills as opposed to the specialisms of mass production of similar items as introduced by Adam Smith and F W Taylor. It allows the cell personnel to take decisions about the flow of work in the cell and about the way a given item is to be made. They can thus react in real time to changing conditions on the shop floor such as instantaneous capacity problems caused by machine or tool failures. It is an arrangement which makes use of the intelligence of people. The use of the human aspect in GT is discussed by Wortmann (1992).

THE NEW MANUFACTURING CONTROL SYSTEM

The framework used in the analysis and the radically changed control system comprises of three levels of abstraction based on work by Browne et al (1988). The strategic level is concerned with decisions about the company's position within its markets especially with respect to its customers. The middle level is the tactical level where orders are scheduled and capacity planning is done. The lowest level is the operational level, which is concerned with the day-to-day operations of the shop floor.

Strategic level
The complexity of the products leaves little alternative to the use of MRP logic at the strategic level. This is needed to generate a list of requirements and dates by which they must be met. The facility for the calculation and ordering of economic batch quantities which exists in many MRP systems is not needed as it is often uncertain when parts or sub assemblies may be required again.

At the strategic level the master production schedule is produced. A rough cut capacity planning system (RCCP) was developed with the aim of providing accurate promises to customers and allowing the load on the factory to be smoothed.

The RCCP holds an up to date profile of the existing load on the machine shop, the estimated load of orders in the design stage and estimated load profiles for any quotations that have a strong possibility of becoming firm orders.

The most important feature of the RCCP is that it uses data from past orders to estimate loads. The company has created a load profile model for each type of product section or subassembly using the data from actual times taken to complete similar subassemblies in the past. The load generated by an order can be predicted by the "assembly" of these models. The use of this data and human experience makes full use of all the information existing on past orders.

The effects on the machine shop load of a quotation can be seen on a personal computer (PC) within minutes. The PC has the up to date loading of the machine shop transferred to it from the mainframe computing facilities. This has improved the speed and accuracy of quotations given by the sales representatives to customers.

Tactical Level
At a tactical level many methodologies, for example MRP and OPT, make scheduling decisions to produce a schedule of work over a horizon of a number of weeks. This was felt to be too ambitious since the planned times for manufacturing operations are very inaccurate. This is due to various shop floor circumstances which sometimes increase and sometimes reduce the time taken, for example the need to use substitute machines, or the use of new ideas not suggested by planning engineers. A survey comparing estimated and actual times found the estimates to lie in a range from 30 to 200% of actual. More accurate estimates could be obtained, but more accurate information for parts which may be never used again would be expensive. Instead it was decided not to attempt a detailed schedule, which could only be wrong, but to schedule work in aggregate. It was found that despite the wide variation of individual time estimates, the averages over a large sample came close to 100%.

Period Batch Control (PBC) was chosen as the control strategy for the tactical level. It does not attempt to control the whole of the manufacturing process but assigns a period's worth of work to a cell for completion by the end of the period. PBC is the simplest method of implementing finite capacity planning (Burbidge 1986). It provides a schedule at a level of abstraction equal to the accuracy of data available, providing predictability for strategic level planning and robustness to inaccurate data through aggregation of individual manufacturing operations.

Work is initially assigned to a cell for a production period by a "first pass" back scheduling algorithm performed by the company's mainframe, loading the cells assuming infinite capacity. The load for a cell for a production period is then smoothed by the production control department in conjunction with the cell leader. They apply experience and up to date knowledge to ensure commitments to complete parts within the production period can be met. The decision process to smooth the load can take place until the day before the load is allocated to the cell at the start of the production period, thus allowing decisions to be made when the maximum amount of information exists.

Operational level
At the beginning of each production period the cell leader schedules the work by individual manufacturing operations. The cell leader uses his experience and knowledge of the available resources and skills within the cell. Time savings can be made by the cell leader by batching follow-on operations of similar parts to reduce the set up times between operations.

The cell team share responsibility for product quality, machine maintenance, and meeting the schedule. The objectives of the cell and the work load placed on the cell are both focused on the cell's products. Each cell member is aware of the cell's role within the manufacturing system and can work as a team member to meet the objectives.

A personal computer based interactive scheduling tool is used by the cell leader. This provides assistance in visualising the status of the work in the cell and the composition of the work remaining for the period. The package has similar elements to both the Leitstand discussed by Adelsberger and Kanet (1991) and the interactive scheduler by Jackson and Browne (1989). It contains a graphic interface with the ability to edit schedules, a database, a performance monitor and algorithms to schedule work.

The tool uses a simple scheduling algorithm to provide an initial schedule. This schedule is shown on the screen in the form of a Gantt type chart, which can be assessed by the cell leader and either implemented as it is or adjusted and improved. Alterations to the schedule can be made at any time to allow the cell leader to use his knowledge and experience to deal with changing circumstances as the work is completed. A current picture is maintained, and displayed graphically, to allow the best decisions to be taken.

IMPLEMENTATION

The first cell to be implemented was dedicated to the production of a range of spare parts. The cell contains a range of general purpose machines which can manufacture a wide range of part types, rather like a reduced version of the main factory. This has meant that most spares can be dealt with without disrupting the rest of the factory, and the concentration of the parts' entire production on the cell has cut the lead time for the production of most spare parts from eight weeks to one week.

Implementation of further cells is continuing, and development work is continuing on the cell leader's scheduling tool and the strategic level capacity planning tool.

CONCLUSION

This paper has outlined the approach used to simplify the highly complex manufacturing system of a company in the make-to-order sector of the capital goods industry. Group Technology has been applied successfully to a manufacturing system which has to deal with high variety, low volume parts and has only limited often inaccurate data to use in planning its operations.

The control system consists of a hierarchy of three levels using MRP at a strategic level integrating with Period Batch Control at a tactical level and an interactive cell scheduling tool at the operational level. At all three levels human intelligence and experience are used to make decisions. The control system is focused at each level to make the decisions and the resulting plans robust to a changing environment. The hierarchical approach means that no individual has to cope with an impossibly detailed control problem. Planning decisions are devolved to the lowest level where the actions take place and uncertainty can be reduced by real time feedback. The control system utilises human flexibility and experience with data processing power of computers rather than a scheduling algorithm dominated control system.

The company has been provided with the tools to meet its strategic aims and maintain a competitive edge within its market sector through reduced lead times and improved due date conformance. Its simplified and focused manufacturing infrastructure will allow the company to adapt to the changing demands of the market place, and remain oriented towards meeting its customers needs.

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BIOGRAPHICAL NOTES

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Selection criteria for analysis methods used to improve the manufacturing process in a make-to-order company

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ABSTRACT

This paper proposes a set of selection criteria to compare two alternative methods for examining and improving a business process. The process considered is producing spares-to-order within a make-to-order company. The two alternative methods are process flow charting and the functional decomposition of activities using a task model approach. The paper concludes that the correct choice of tool to analyze and redesign business processes is important if the objectives of the redesign are to be fulfilled.

1. INTRODUCTION

In today's market place companies are looking for methods to gain a competitive edge. Davenport & Short (1990), Blaxill & Hout (1991) and Harrington (1991) all describe the need to improve or redesign the processes within a company as a necessary step to maintain a company's competitive advantage. The authors include example case studies that describe radically changed processes within large companies.

Davenport & Short (1990) identify four main objectives of process redesign; cost reduction, time reduction, output quality and quality of working life. Harrington (1991) includes a fifth, flexibility to customers changing needs. The objective of the example company was to reduce the total time for the spares-to-order process within the company, thus addressing the issues of time and cost reduction and flexibility to changing needs.

The purpose of the paper is to describe how the attributes of a company and the objectives of a process redesign influenced the methodology and selection of an analysis tool.

Two alternative modelling tools are described. The first tool analyzes the process by charting the flow of information and physical objects through the process. The second tool describes the possibility of functionally analyzing the process using a generic task model defined by Childe (1991).

2. PROJECT BACKGROUND

The company is a European subsidiary of a privately owned USA manufacturer. The Plymouth based company sells, designs and manufactures a wide range of custom designed high specification machines to companies worldwide. The company employs three hundred and thirty people and has a turnover which varies between £10m and £20m.

A significant proportion of the company's annual turnover is gained from spare parts required for machines which are in service worldwide. One of the strategic aims of the company was to improve the after sales spares service to its customers.

The University has been collaborating with the company in a major redesign of the company's manufacturing infrastructure. Group Technology has been implemented and a new hierarchical production control system using Period Batch Control (Burbidge, 1986) as the control logic has been developed. These are described in more detail in Childe et al (1993).

A cell was dedicated to the manufacture of spares. It consisted of a group of manual work centres which provided the cell with the flexibility to manufacture a large variety of spare parts in low quantities. It removed spare parts from the main machine shop, reducing the disruption to the schedules of other orders and concentrating the material movement in a controllable area and removed the requirement to expedite spares.

Implementation of the spares cell had the effect of significantly reducing the lead time. Customers were originally quoted a lead time of eight weeks for non-urgent spares by the customer service department. Typically a large order for spares can now be manufactured within one week.

It was identified that there had been a dramatic improvement within manufacturing but this improvement had not been reflected in the time taken for the overall process of taking a customer order for spares to shipping the completed order.

It was decided that the complete process needed to be analyzed and improved to enable maximum benefits of the manufacturing changes to be realised in after sales customer service.

3. THE ORGANISATION OF THE PROCESS IMPROVEMENT

A single process improvement team was formed. The team leader was the production manager who was responsible for five of the functional areas which were involved in process, while other team members were from the various functions involved in the process. The production manager was a member of the company's senior management, empowering the team to change the process and the process improvement champion was the managing director.

The team held a meeting every day for a set period of time. This enabled the team to carry out the process improvement with minimal disruption to their normal work. The simultaneous involvement of the team in the project and in their normal work enabled an informal reporting and analysis structure to develop. The team members tended to note events in their normal work which were relevant to the process and its improvement. This could be discussed at the next meeting. Any ideas or comments generated through informal discussion with colleagues could also be included by the team in the improvement process.

The first stage in the process improvement was the definition of the team, its organisation and the statement of the objective which was to reduce the lead time of the spares-to-order process.

The second stage was to analyze the current system. A model was developed of the process detailing activities and both material and information flows. There are many tools available to help the team clarify the process through modelling. The tool chosen and developed by the team will be discussed later.

The team followed the flow of an order through the process from "birth to death" (Blokdijk & Blokdijk, 1987), identifying individual activities and flows at the working level. This was done by temporarily including further members from the functions in the meetings and asking them to describe the activities that they carried out. Each temporary member was introduced to the objectives and the work done so far was summarised. The process was modelled during the meeting and at a later stage each temporary member was recalled to review an interpreted version of their part of the process.

The involvement of other users of the process increased communication of ideas and enabled more people to be part of the improvement process rather than being interviewed in isolation. To establish change Beer et al (1990) define the need to "mobilize commitment to change through joint diagnosis of business problems" and then "develop a shared vision of how to organize and manage for competitiveness". The team was able to achieve both a commitment and shared vision through a significant proportion of users being involved in the analysis and improved design.

The final model of the process described the flow of an order for spare parts which involved eight functional areas, eighty-two activities and seventeen physical pieces of documentation.

The next stage was to redesign the process to meet the defined objective. The process improvement team sought to remove bureaucratic activities, reduce documentation, remove duplication of activities and develop a process which had the minimum number of consecutive activities through core activities happening simultaneously (Harrington, 1991). The redesign process involved an iterative process of identifying areas of improvement, identifying the changes required and discussing the suggested changes. The users in the functions which would have to implement the changes were included in this iteration.

The resulting design for the improved process was implemented in a number of stages. An incremental approach to improving process enabled gains to be made as soon as possible. The stages gave the users chance to monitor the changes as they happened and adjust to the improvements as required.

The organization of the process improvement has enabled functional barriers to be broken down through the meetings and discussions during each stage. A shared commitment and vision has been created to provide the momentum to increase the success of the changes. The team was not remote from the process at any stage, thus reducing the possibility of error or failure to consider activities. It has enabled the users to develop a concurrent mental model (Hamacher, 1991) which will support an understanding of the roles that each user has in the process.

4. MODELLING THE PROCESS

4.1 The flow charting tool

Flow charting is defined in Oakland (1989) as the "systematic planning or examination of any process". Harrington (1991) discusses the use of four types of flow charting tools to provide an overall model of a process. The four types are :-

1. Block Diagrams to provide a simple overview.
2. American National Standards Institute standard flow charts which detail the activity and flow interrelationships.
3. Functional flow charts depicting process flows between functions or areas.
4. Geographic flow charts showing the flow between locations.

Flow charting is a well established tool used in traditional systems analysis, work study and as a tool in quality improvement programmes.

The process improvement team decided to use flow charting as the tool to analyze the spares-to-order process. All the members of the team were comfortable with the tool and any temporary members were also familiar with it. During the meetings simple block diagrams were used to describe the flow and afterwards the block diagrams were translated into a flow chart using an increased number of symbols representing specific types of process elements. The symbols used are shown in figure 1.

There was no conscious effort by the team to use a particular standard notation system. The symbols used defined the process at the working level, Figure 2. shows part of the process model produced by the process improvement team. The team adopted a standard of numbering activities which indicated the functional area the activity was performed by. The team had recognised the importance of being able to identify functions and activities to have a complete model of the process. Figure 3. removes the physical and informational flows and shows only the core activities identified by the numbering convention, giving a functional model of the process as opposed to a flow model.

The convention of identifying and numbering core activities has reduced the complexity of a flow chart by allowing emphasis to be placed on these activities. Figure 4 shows the numbering convention to provide a functional overview of the process.

The principal drawbacks of flow charting in its standard form are that flow charting can lead to a model that has a single level of abstraction increasing the complexity of the model, and no indication of who carries out an activity or why the activity is taking place. Harrington (1991) reduces the complexity by the use of block diagrams as an overview, the team by developing a numbering convention for activities also reduced the complexity of the flow chart.

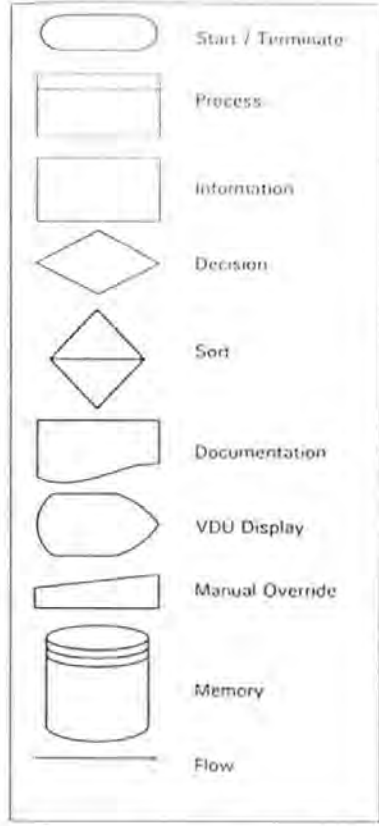

Figure 1. Flowchart Symbols

In the systems wide redesign the inability of flow charting to provide a means of abstracting detail at a higher level could be seen as a disadvantage. Without the ability to abstract detail it is difficult to analyze the process independent of departments. This reduces the ability of the team to restructure the process and can result in incremental improvements only. However flow charting did enable the process improvement team and other function members involved to work at a "level of detail at which they feel competent" Blokdijk & Blokdijk (1987) as this is the level of the everyday activities they carry out.

4.2 The functional modelling tool

Functional modelling tools show activities or tasks performed by a system. The focus on the tasks which are performed by individuals and functions would enable the process improvement team members to work at their level of competence.

Childe (1991) developed a generic task model based on the principle that there are a key set of tasks which are consistent throughout manufacturing companies if they are to succeed in meeting strategic objectives. It allows the tasks that are required in a process to produce the necessary results to be identified. The purpose of this functional model was to provide the users of the tool with a simple framework of tasks without the complication of informational or physical flows. By keeping the modelling technique as simple as possible it was hoped that it could be understood by non experts. The task model is also designed to allow the use information technology (IT) within the redesigned process to be identified.

Some tasks appear to be necessary in every manufacturing company, in which case the situation could only affect the way in which the task is performed. These tasks are regarded as "core" tasks. These included for example "Process orders", "Handle goods inward".

The decomposition of a core task could include optional tasks according to the way in which the core task is performed, particularly the decision whether or not to computerise the task. Thus a critical question for a core task is only how it should be done, which is determined by the lower level tasks of which it is constituted.

In the cases where the task requirement is seen to depend upon the situation, the task was regarded as "optional", since there would clearly be cases in which the task was is not required. Examples of

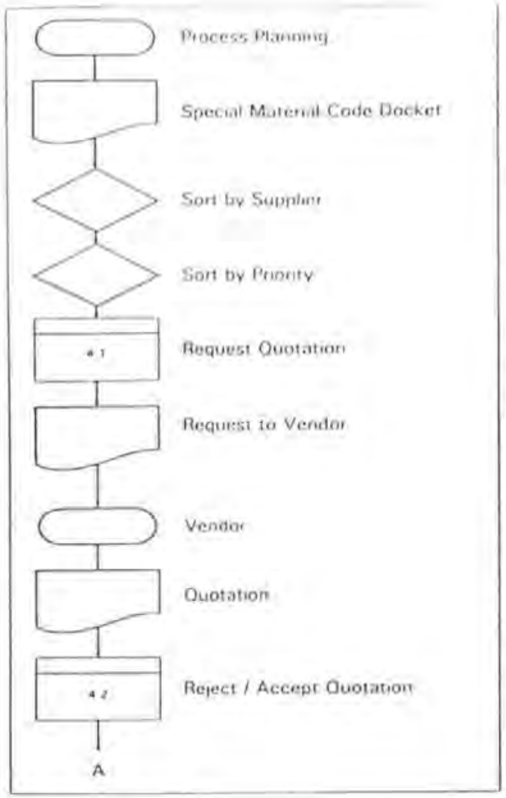

Figure 2. Initial model

these include "Confirm order to customer", "Inspect goods".

"Dependent" tasks are tasks which can be found in the decomposition of optional tasks, but which are not themselves optional. These are necessary in any instance in which the parent task is required, thus depending upon the appearance or non-appearance of an optional task.

Initially the task model has the advantage of providing the process improvement team with a focal point. It promotes a more radical approach to redesigning the process. Tasks which occur in the process and do not occur in the task model should lead the process improvement team to question if the task is really necessary. If a task is shown in task model and is not done in the process, the process improvement team should review its procedures and identify why the task is not performed. Figure 5 shows a section of Childe's task model. (This only shows the core tasks. A number of optional and dependent tasks are also shown on the full model.)

The use of the task model crosses the boundary between the stages of analysis and redesign as the "fitting" of the process into the task model requires an analysis of the current process and provides a frame work for the redesigned process at the same time. The redesign of the process should be explicit and not subject to the influences of individual perceptions (Ravden, Clegg & Corbett, 1987) within the process improvement team. The task model provides a neutral focal point to aid the redesign.

4.3 Tools for modelling tasks and flows

The two alternatives tools examined use either a representation of the flows within a process or a representation of the tasks carried out in a process. There are a number of tools described by various methodologies for example actigrams (SADT), Data Flow Diagrams (SSADM, Downs et al, 1992) and IDEF0 (1981) which combine tasks and flows to provide a complete physical model of the process. IDEF0 and actigrams restrict the number of tasks per diagram which aids the clarity of the model. Both model the process showing for each activity inputs, outputs, controls and the resources required.

IDEF0 is one tool from a set of three tools developed by SOFTECH for the US Air Force's ICAM (Integrated Computer Aided Manufacturing) programme. IDEF0 provides a comprehensive static model of activities and their relationships within a process. The tool provides an effective communication medium which can easily be understood, allows decomposition to the level of detail desired and "has the potential to be used as an industry standard for manufacturing systems design" (Wu, 1992)

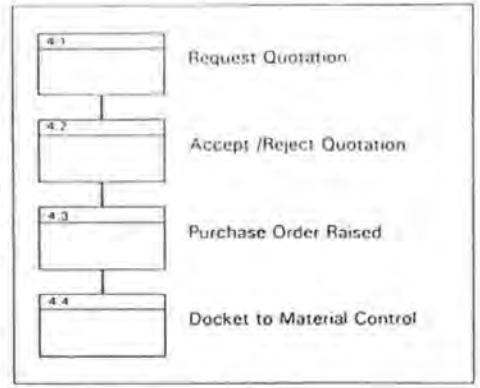

Figure 3. Functional model

5. SELECTION CRITERIA TO IDENTIFY SUITABLE TOOLS FOR PROCESS IMPROVEMENT

Sections 4.1 and 4.2 have described two analysis tools and their relative advantages and disadvantages with respect to developing a model of the current spares-to-order process within a small manufacturing company. This section will define a set of criteria to facilitate the selection of analysis tools for similar process improvement projects.

5.1 Does the tool provide a complete model of the process?

Davenport & Short (1990) identify three distinct classes of elements in a process; objects, entities and activities. Entities are the mechanisms which perform the activities. The entity is dependent on the level of abstraction of analysis, for example an entity could be a function or a person depending on the level of abstraction. Objects are transformed through the process and can be physical or informational, and activities carry out the transformation of the objects.

This classification is useful when comparing models of different types. If a model is to provide a complete static representation of process it should include all three classes of elements. The flow charting technique used by the team enabled the team to identify the objects and the activities of the process. It was difficult to identify the entities of the process apart from the functional area performing the activity. In comparison the task model would have only provided the team with the activities required in the process.

5.2 Is the tool capable of representing the model at the correct level of abstraction?

The level of abstraction required for a model is dependent on the complexity of the process being modelled and hence may need a hierarchical approach suggested by Harrington (1991) or IDEF. It is also important that the team developing the model are comfortable working at the levels of abstraction required. In the example company the team used a simple block diagram similar to the block diagrams suggested by Harrington to provide an overview of the process to help clarify the model.

5.3 Is the tool unfamiliar to the team using it? If yes, will the time and cost spent on training

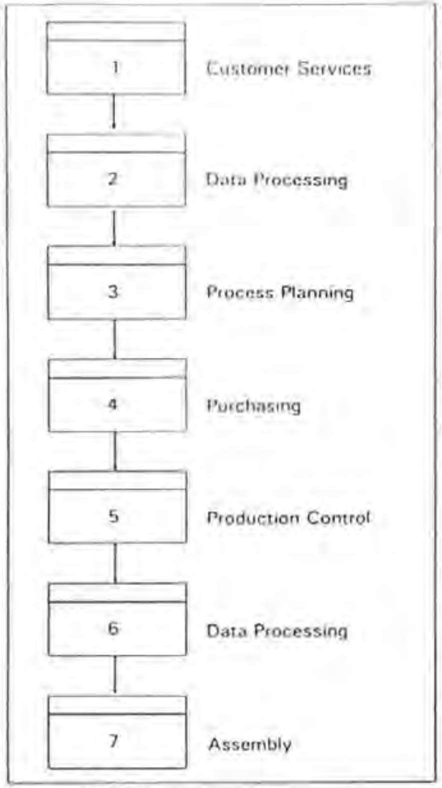

Figure 4. Overview model

outweigh the process improvements achieved with a familiar tool?

The example company required a rapid improvement to the process. Training in an unfamiliar tool would have increased the time taken by the team. It would have also been less familiar to the users who were asked to contribute throughout the process improvement.

5.4 Does the tool facilitate the redesign of the process? Is the design to be an incremental or radical change?

The complex flow chart produced by the process improvement team although indicating that it could be simplified it, did not help identify which of the eighty-two activities were core activities. Childe's task model identifies the core activities and leads the user to question the need for any further activities. The use of the task model is likely to produce a radical redesign. The informational or physical flows are excluded from Childe's model, this failure to represent flow could reduce the teams focus on this potential area of redesign.

5.5 Does the tool enable the objectives of the improvement project to be obtained?

The objective of the improving of the spares-to-order process was to reduce the lead time of a customer order. The model produced by the team gave no explicit indication of the time taken to do activities or the delay due to flows of information or physical objects. The team overcame this problem through their knowledge of the actual process and other users' information, such an in depth working knowledge of the process may not always be available.

To meet the objective of cost reduction a tool which gives a model which includes the entities or mechanisms that perform activities would provide essential information for the process redesign. The model of the example process used a numbering convention to identify which function performed an activity. It did not provide sufficient detail for methods of reducing cost to identified.

5.6 Is the tool capable of describing the elements of the business process to be modelled?

The spares-to-order process included both physical and informational flows with a combination of manual and computerised activities. The model of the process using flow charting symbols chosen

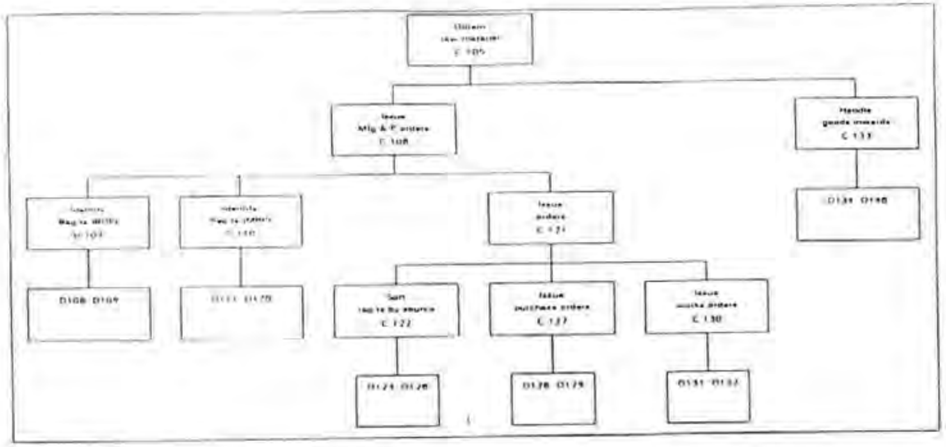

Figure 5 Task model extract

required a compromise between having a limited number of symbols and the strict definition of some of the activities. A predominantly physical process could use flow charting symbols used in traditional work study. A tool designed to model data flows for example those described in SADT or SSADM would be more suitable for modelling a process which predominantly transforms information.

6. CONCLUSION

The purpose of this paper was to develop a set of criteria to facilitate the selection of an analysis tool suitable for business process improvement. The approach has been to examine the organisation of a process improvement within a small manufacturing company and the tool used to model the process to be improved. In critically appraising the project a number of criteria important to the selection of a suitable analysis tool have been identified.

The tool should be selected with consideration for the type of process, the objectives of the project, the task of redesigning the process, its suitability for the users of the tool and the ability of the tool to model the process.

Improving business processes through either incremental or radical redesign is becoming increasingly necessary as companies strive to maintain a competitive edge. The choice of the correct tool to analyze and redesign core business processes is important to enable the objectives of the redesign to be fulfilled.

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The state of the art in Business Process Re-engineering in UK Manufacturing Companies

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THE STATE OF THE ART IN BUSINESS PROCESS RE-ENGINEERING IN UK MANUFACTURING COMPANIES

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Abstract

This paper reports the initial findings from SERC/ACME sponsored research GR/J95010 into Business Process Re-engineering. The paper records the results of the research groups initial visits to a number of large manufacturing organisations currently undertaking BPR projects. The organisations visited include, Lucas, Rank Xerox, IBM, Rover and ABB. The paper concentrates on three areas currently exercising considerable interest ; firstly, a framework for analysing types of BPR intervention based on the nature and scope of the change, the risks involved and the potential benefits to be gained. The second area is an analysis of the use of visioning tools to encourage radical change and the third area is a summary of the standard process descriptions found within three of the organisations.

Introduction

The traditional functional structure of UK manufacturing companies is being re-evaluated as many companies are facing new competitive challenges that require a dramatic improvement in operational performance.

The panacea of the 1990's claimed to enable the dramatic improvements required to meet the new challenges is Business Process Re-engineering (BPR). The current interest in Business Process Re-engineering can be attributed to Hammer and his seminal article entitled "Re-engineering work: Don't Automate, Obliterate " (Hammer, 1990). Business Process Re-engineering seeks to meet the new competitive challenges through the identification of the core business processes within a company and re-engineering these processes to gain radical operational improvements.

What is Business Process Re-engineering?

Many approaches to organisational change are applied in a systematic manner ie "methodical arranged according to a plan" but not are not systemic "of or affecting a whole system" (Hitchins 1992). Systematic approaches do not focus on the whole process and the integration of work between functions. A BPR approach focuses on the whole process and is the key to achieving the substantial benefits many have claimed for BPR. BPR takes a systemic view of a company re-focusing the attention of the company on the emergent properties of business processes such as delivery lead times, service levels and flexibility.

Various authors have described approaches that are based on the principle of re-orientation of a company towards a business process orientated organisational structure. Amongst the most notable of these are Hammer, Harrington and Davenport.

Scope and Rate of Change

Hammer is at one extreme of how the re-orientation should take place. He has referred to as the "neutron bomb" approach to business improvement ("We'll leave the walls standing and we'll nuke everything on the inside").

Hammer states, for example, that firms can only hope to achieve radical performance improvements using Business Process Re-engineering methods which strive to "break away from the old rules about how we organise and conduct business." He states that re-engineering cannot be accomplished in small or cautious steps but must be viewed as an "all-or-nothing proposition.".

Davenport (1993) shares Hammer's view but is more pragmatic and concedes that, in practice, most firms will need to combine incremental and radical improvement activities in an ongoing quality programme.

> *"Ideally (though not necessarily), a company will attempt to stabilise a process and begin continuous improvement, then strive for process innovation"*

Here Davenport echoes the Japanese continuous improvement philosophy, exemplified in Imai, which sees radical and incremental improvement merely as the opposite sides of the same coin.

Alternatively, Harrington (1992) inhabits the more incrementalist and less IT dominated end of the BPR opinion spectrum. He defines the concept of Business Process Improvement as a "systematic methodology developed to help an organisation make significant advances in the way in which its business processes operate".

A more complete representation of the spectrum of process improvement activities has been developed by Childe, Maull and Bennett (1993) and is presented in Figure 1. The axes on Figure 1 differentiates between the radical and incremental types of BPR, the potential benefits and risks to be gained from the change program and the scope of the program.

The scope of change in the bottom left hand corner of Figure 1 is restricted to personal improvement. This type of change, where an individual within a function seeks to improve his or her part of the process. Such improvements are essentially small in scale.

The work undertaken by Quality Improvement Teams (QITs) extends beyond the localised small group improvement activity and into other functional areas of the firm.

Process Simplification (PS) may be regarded as the first real type of process based change. Often a Process Improvement Team (PIT) will have been established whose job is to analyse the whole process for such non value-added activities as storage and inspection, and who will be seeking to remove these activities.

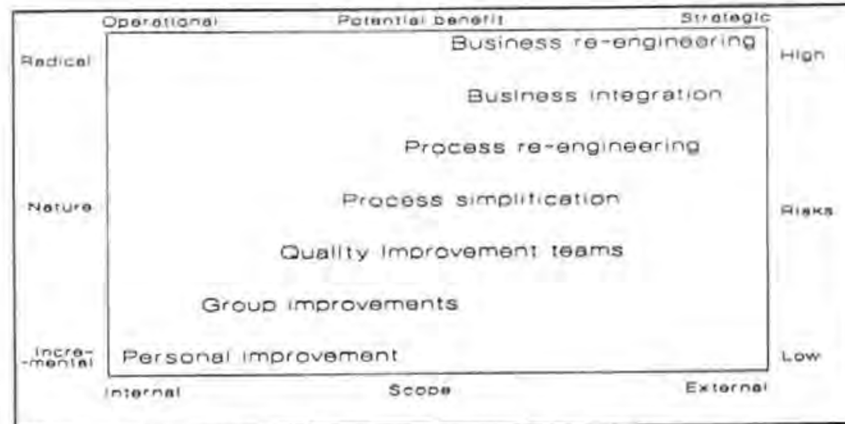

Figure 1 Comparison of various process initiatives

Process Improvement (à la Harrington) and Business Process Re-engineering (à la Hammer) again focus on the whole process but have a wider scope than the removal of waste.

Business integration focuses primarily on growth outside the organisation most obviously through horizontal integration along the supply chain.

Business re-engineering (rather than Business Process Re-engineering) looks at the improvement of the (already process focused) organisation to exploit its capabilities in a way which leads to the growth of business in new and different areas.

BPR Methodologies

The authors have identified over 20 approaches to BPR from visits to practioner companies and through analysis of the current BPR literature. In summary, the methodologies tend to have the following five phases:

Phase 1	Create/Identify corporate, manufacturing and IT strategies
Phase 2	Identify key process(es) and performance measures
Phase 3	Analyse existing process(es)
Phase 4	Redesign process(es)
Phase 5	Monitor and continuously improve new process(es)

The methodologies are systematic ie step by step and focus strongly on project management. In terms of the framework developed above most fall into the category of Process Simplification as there is little evidence that effort is made to encourage visioning to deliver "out of the box thinking".

Visioning

The are however a small number of organisations that are currently attempting a more radical approach to BPR through the use of up front visioning tools. Such methods invert phases four and three of the traditional approach and encourage the development of conceptual models as a vision for the re-designed process. This visioning process develops a conceptual boundary which prescribes the process to be analysed. This prevents an excessively time consuming analysis phase which often only produces copious models of the existing process. Whilst this is useful for analysing for simplification it can act as a barrier to re-engineering, because it tends to limit thought patterns to modifications to what we already have. Out of the box thinking is encouraged by placing the visioning "up front".

Tools and methods that enable the visioning are relatively rare. The authors have seen excellent use made of TOP Mapping (Moyes 1993) a technique which may be used to support visioning. TOP Mapping employs a large variety of pictures (for example, islands, motorways, tunnels, and road traffic symbols) to enable users to create a picture of organisational processes. In the authors' view this technique is extremely useful in generating high level conceptual models for redesign.

Another creative problem-solving technique which the authors believe may usefully be applied during the process redesign phase is Synectics (Gitter, Gordon and Prince), an approach which, more than some others, emphasises the more non-logical activities of the mind. Synectics aims to achieve:

- freedom from constraints imposed by the problem as stated
- elimination of negative responses
- deferred judgement
- escape from the boundaries imposed by orthodox thought patterns.

Standard Processes

Just as the functions within businesses have become standardised (although functionally organised businesses employ variations on the standard) it can be expected that the growing number of BPR implementations will ultimately develop a standard set of business processes.

Generic standards such as the CIM-OSA grouping of Manage, Operate and Support appear to have general approval in companies but do not provide specific help for companies wishing to structure their own processes, which requires a more detailed analysis. This is acknowledged by Parnaby (1993) who provides the three core processes identified in Table 1 and who states that these must be carefully subdivided using considerable skill and experience into logical subsidiary processes.

Table 1

Top Level Processes from Parnaby
1. Development and product introduction process functions
2. Manufacturing operations and materials flow management process functions
3. Operations support process functions

An adaptation of the CIM-OSA structure, based upon markets is presented by Childe Maull and Bennett (1994) which consists of *Direction Setting Process, Order Flow Processes, Supply Process, Investment Process, Technology Processes* and *Personnel Process*.

Several sets of lower level or more detailed processes are offered by Parnaby, Xerox (Davenport 1993) and Rover Group (Bower 1993). These are illustrated in Table 2.

Conclusions

This paper has attempted to apply some frameworks and structures to some of the current issues in Business Process Re-engineering. The field is one which has yet to develop a common language as various companies experience the changes involved. Research work in the areas identified in this paper is proceeding at Plymouth.

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A SOFT SYSTEMS PERSPECTIVE OF BUSINESS PROCESS RE-ENGINEERING

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The paper uses a systems perspective to examine the concept of a "business process" and then contrasts current BPR methodologies with the "soft" systems methodology (Checkland)[1]. The application of current BPR methodologies and the Checkland "soft" systems methodology (SSM) in industry is considered and the requirement for a methodology that combines the attributes of both types of methodology is defined. The paper concludes with a proposal for a hybrid BPR methodology that combines both "hard" and "soft" systems methodologies and uses generic process models as an intervention tool.

INTRODUCTION

In today's global market place many multi-national organisations are now looking towards Business Process Re-engineering (BPR) to keep ahead of their competitors.

What differentiates BPR from other approaches to business improvement is the fact that it acknowledges that many business activities cut across both internal and external organisational boundaries. Hammer[2] states that BPR methods, which strive to "break away from the old rules about how we organise and conduct business" offer organisations the only hope of achieving radical performance improvements. He states that re-engineering cannot be accomplished in small or cautious steps but must be viewed as an "all-or-nothing proposition."

To achieve the scale of change advocated by Hammer, BPR methodologies need to facilitate the search for opportunities to achieve radical change. The authors believe that current BPR methodologies which use a systematic approach and view a business process from a positivist perspective are not able to meet Hammer's requirements for a BPR methodology.

THE CONCEPT OF A "BUSINESS PROCESS"

In the authors' view a certain confusion surrounds the meaning of the word "process". When used in a business context, the word can have two meanings and it is therefore important to establish the meaning to be used in this paper. Checkland[3] describes a similar confusion in the use of the word "system".

Paraphrasing Checkland, this confusion arises from the use of the word "process" or "system" to describe two different entities. In everyday language a "system" or "process" is used to describe parts of the real world as a complex whole (for example "the education system", "the manufacturing process"). In systems thinking terms a "system" or "process" is used to describe a structured model of reality to improve understanding of the real world. In this paper the word "process" describes a model of reality which assists in understanding the real world.

Checkland[4] defines a system as,

> "a model of a whole entity; when applied to human activity, the model is characterized fundamentally in terms of hierarchical structure, emergent properties, communication and control."

To Checkland a system is an abstract concept that may be used to organise our thoughts about "a problem situation". It only exists because we have defined the boundaries of the system by stating what is part of the system and what is part of the environment or outside the system. Within the boundaries there are a set of entities that interact with each other and the environment (an "open" system). These entities exist in a hierarchical structure and their interaction results "in properties which are properties of the whole, rather than properties of its component parts" (Checkland[5]).

Davenport[6] defines a business process as;

> "a structured, measured set of activities designed to produce a specified output for a particular customer or market"

In our view, however, a "business process" does not exist in reality. It only exists because we have defined the boundaries of the business process by stating what is part of the "business process" and what is part of the environment. If we consider a human carrying out the activity of "entering data into a computer" as part of a "business process", are the activities of "purchasing the computer" and "hiring the human" part of the "business process"? If not, why not? These are two of the many activities that are required to produce the specified output. Most observers would only include the activity of "entering data into a computer" as being part of the business process. The observer makes a judgement to decide what is to be included and what is not to be included. There are no boundaries in reality, the boundaries are conceptual and are being used by the observer to construct a model of a set of activities performed in a company to meet its objectives. Each observer may use different boundaries depending on the observer's "world view" and thus the activities included may be different.

In attempting to re-engineer aspects of their businesses, many companies adopt the positivist perspective which assumes that a business process exists in the real world as a complex whole which is independent of the observer.

Considering a business process from a positivist perspective constrains the ability of those re-engineering the business process to identify a radically new approach. A methodology that encourages the development of as many different views of a business process as possible is more likely to generate the radical new approach.

CONTRASTING CURRENT BPR METHODOLOGIES WITH THE "SOFT" SYSTEMS METHODOLOGY

Jackson[7] describes a methodology as;

> "an organized set of methods an analyst employs to intervene in and change real-world problem situations"

Business Process Re-engineering methodologies seek to provide an organized set of methods to enable groups of people or individuals to intervene in and change the real-world problem situation to meet the objectives of the business.

The key attribute which differentiates Business Process Re-engineering methodologies from other methodologies is that the concept used to provide an abstraction of reality is a business process. The reason for using a concept such as a business process is to help us simplify the real world so that we can understand it and make judgements to intervene and change it. In systems methodologies the concept used to provide an abstraction of reality to help us understand the complexities of the real world problem situations is a "system".

A methodology that uses the concept of a "system" and was designed specifically to intervene and change real-world problem situations where human activity systems are involved is the "Soft" systems methodology developed by Checkland[8] at Lancaster University.

To intervene in and change real-world situations there is a need to understand the interactions and interests of the entities that are under investigation and that may be changed by the intervention. Since the set of entities within a company's systems or processes are dominated by human activities or controlled by human activities, social theory can provide important guidance in the use of methodologies.

According to Habermas[9], human beings have three cognitive interests in gaining knowledge, these are as follows;

Technical interest - It is the interest in gaining knowledge to enable manipulation and control of the physical world.

Practical interest - It is the interest in gaining knowledge by communication and understanding other people leading to mutual understanding.

Emancipatory interest - It is the interest in gaining knowledge to help the individual in learning and controlling their own destiny.

Jackson[10] believes that methodologies that are seek to intervene and change the real-world should be "grounded on all three cognitive interests".

Many current BPR methodologies (Harrington[11], Harrison & Platt[12], Ulis[13], Furey et al[14]) are designed to enable organisations to:

Define business processes and their internal or external customers;

Model and analyze the processes that support these products and services;

Highlight opportunities for both radical and incremental business improvements through the identification and removal of waste and inefficiency;

Implement improvements through a combination of IT and good working practices;

Establish mechanisms to ensure continuous improvement of the redesigned processes.

These methodologies have been designed to fulfil the "technical interest" of company managers to manipulate and control the physical world. The methodologies described by the above authors are all systematic in their approach.

In fact these BPR methodologies and many other BPR methodologies currently being used follow what is referred to by Checkland as "Hard" systems thinking. The reasons for the current BPR methodologies being described as "Hard" systems thinking are that they are used by companies that use a positivist perspective of a business process and consider the company to be made up of business processes (systems) and study it systematically. Woodburn[15] paraphrases Checkland and describes "Hard" systems thinking as considering "the world to be systemic (made up of systems) and it is studied systematically".

Wilson[16] divides human activity systems into two sub-systems, a system of activities and the social system. Using "Hard" systems thinking there is a tendency to concentrate on the entities within the business process that can easily be identified and controlled. In a business process (human activity system) it is the system of activities that is easy to identify and control as this system can be measured explicitly in terms of time and cost to the business. The social system is more difficult to identify and control and hence many companies only consider the social system during the implementation of a re-engineered business process.

In comparison to current BPR methodologies the "Soft" systems methodology (SSM) views systems (processes) from the interpretive paradigm which reflects the view that processes only exist as the creative construction of human beings. The methodology views the real-world as problematic and impossible to define and uses a systemic approach to attempt to intervene and change real-world problem situations. To encourage the understanding of others points of view and intentions, the SSM positively encourages debate, information gathering, re-evaluation and obtaining consensus and discourages assumptions and single solutions.

The products of the SSM are not solutions but desirable and feasible changes to the problem situation agreed on by consensus of the participants who are involved in the every day problem situation. Figure 1 is adapted from the classic SSM methodology diagram.

Woodburn[17] paraphrases Checkland and describes "Soft" systems thinking as considering "the world to be problematic and ill-defined and it is studied systemically". Mingers[18] describes the SSM as being designed to fulfil the "practical interest" of human beings to communicate and understand.

We have identified that although both current BPR methodologies and the SSM have been designed to intervene and change real-world problem situations involving human activity systems they are considerable different in structure and approach.

THE APPLICATION OF CURRENT BPR METHODOLOGIES AND THE "SOFT" SYSTEMS METHODOLOGY

There are many case studies in current literature describing the success of BPR methodologies. The systematic approach of current BPR methodologies and fulfilment of company managers' "technical interest" in controlling and manipulating the physical world meets the needs of a "management by objectives" culture which can be found in many companies.

Although there are success stories, Hall et al[19] believe that many companies may fail to reap the benefits from BPR by not considering sufficiently the "breadth" (number of activities consider at any one time) and the "depth" (number of dimensions considered simultaneously e.g structure, skills, IT, roles, measurements, shared values) of a BPR project. Hall et al suggest that there needs to be more consideration to not just to "measurements" and "structures" which fulfils Habermas's "technical interest" but also to "shared values", "roles" and "skills" which fulfil the "practical interest".

In contrast to current BPR methodologies the SSM methodology fulfils the Habermas's "practical interest", but it is difficult to apply in industry. In the conclusions from a survey in 1992 by Mingers & Taylor[20] which included the views of industrial, public and academic sector practitioners, Mingers and Taylor believed the problems in using SSM to be as follows;

Gaining acceptance for the use of SSM.

It is perceived as time consuming by managers

Inability to deal with situations of power and resistance to change.

There were some positive findings;

It was being used by respondents to bring about understanding more than to bring about change.

It had been successfully combined with other techniques to suit the requirements of the users.

It can be started or stopped at any point in the 7 stages.

Rhodes[21] also agrees that gaining initial acceptance of the SSM is difficult and in his paper advocates the use of a single root definition for a manufacturing company and two conceptual models as an initial starting point for the SSM.

In conclusion after examining both current BPR methodologies and the SSM, none provide all of the features required to provide the scale of improvements to business processes described by Hammer. Current BPR methodologies have a systematic approach that has a constraining positivist perspective which lacks the ability to fulfil the "practical" interests. The SSM although meeting the "practical interest" does not fulfil the "technical interest" and is difficult to apply in industry.

A BPR methodology that uses the concept of a "business process" from interpretative perspective and that allows participants to fulfil both "technical" and "practical" interests is required.

PROPOSED HYBRID BPR METHODOLOGY

It has been demonstrated in previous sections that neither current "hard" BPR methodologies or "soft" system methodologies can provide a complete methodology to enable companies to meet their objectives through the application of a business process focus. A methodology is required to fulfil both "technical" and "practical" interests and thus needs to be able to combine both "hard" and "soft" systems methodologies.

Miles[22] suggests two possible approaches for combining "hard" (HSM) and "soft" systems methodologies (SSM) in the context of information systems development. The HSM that Miles refers to is the Systems Life Cycle[23] which is a linear framework similar in format to the BPR methodologies currently being used. The two approaches used are "grafting" and "embedding" to combine the SSM and the HSM.

In the proposed hybrid BPR methodology we will use the "embedding" approach since the "grafting" approach does not result in a change from a systematic to systemic methodological approach.

The "embedding" approach is described by Miles[24] as;

> "two interrelated levels of methodological operations; 'hard' methods are deployed at one level, but in a subordinate manner to the operations at a meta-level at which iterations of SSM take place"

The SSM iterates at a meta-level and can be stopped and started according to the wishes of the participants. The meta-level identifies desirable and culturally feasible changes to the real world and agrees on them. The 'hard' methods can be used at any stage for example if the participants agree that using a modelling technique or a quantitative analysis needs to take place or changes need to be made to the relevant systems. The important feature of "embedding" is that at any time the participants can move to the meta-level and debate the problem situation, root definitions and conceptual models as the problem situation changes through a richer picture or changes being made using the SSM structure.

The "embedding" uses the flexibility of the SSM which can be combined with other techniques and is not systematic but systemic and can be thus started from any stage with any amount of information.

The advantages of "embedding" are listed by Miles[25]:

It enables the SSM to be operated whenever and for as long as the participants deem it is useful to do so.

It engenders the collaborative relationship between participants and specialists

It enables changes in the problem situation to be consider whenever appropriate

It does have the disadvantage that it is a complex methodology and the complexity may negate its advantages. An "embedding" approach does not answer the problem of initial acceptance of the SSM to a "management by objectives" culture.

Rhodes[26] used a root definition and conceptual model of a manufacturing company to gain initial acceptance for the SSM. Instead of introducing the SSM to a manufacturing company by attempting to identify and express the problem situation Rhodes assumes that one of the relevant systems within the company is "the manufacturing company system". Using the root definition developed from his perspective of a manufacturing company system a conceptual model has been developed to be used as the initial intervention tool.

The conceptual model used by Rhodes was a high level conceptual model of resources, procedures and products. To enable a business process focus to be established conceptual process models of the generic business processes within a company in a particular product sector (for example manufacturing, banking) could be used.

A generic process such as the "order-flow process" could be presented to a company as the intervention tool. The participants of the methodology would be asked to compare it with their perceived reality of the specific company process. This could result in one of a number of paths;

The company participants can say from their own perspective of reality (knowledge of their specific company process) that the model requires changes. (Performing stages 3 and 4 of SSM)

The company participants can say they believe there are missing activities or sub-process that are relevant. (Performing stages 2, 3 and 4 of SSM)

The company participants may be able to identify immediate desirable and feasible changes to the specific company process and decide to implement those. (Performing stages 5, 6 and 7 of the SSM)

Once the generic process has been established as a focus and altered by the participants to be specific to their company the richness of the problem situation or immediate benefits can be seen and the participants can be encouraged to iterate around the SSM cycle or use a HSM at the subordinate level when required. It is also less likely to be perceived by managers as time-consuming as it does not require managers starting from a "blank sheet of paper".

The BPR methodology proposed will use an "embedding" approach to combine the SSM at a meta-level and the "hard" systems methods at a subordinate level. To encourage the use of SSM in a task-oriented company culture, generic process models (conceptual models) for the relevant business sector will be used as initial intervention tools. Figure 2 gives an overall outline of the proposed hybrid BPR methodology adapted from a diagram published by Miles.

The proposed hybrid BPR methodology is only a conceptual model at present and further research is required in the linking of the meta-level to the subordinate level and the development of generic process models.

CONCLUSION

The paper has explained the importance of using the concept of a "business process" to create a structured model of reality that can be used to understand the real world which is ill-defined.

It has been identified that current BPR methodologies have a systematic approach using a constraining positivist perspective which lacks the ability to fulfil the "practical" interests of human beings. Also the SSM although meeting the "practical interest" does not fulfil the "technical interest" and is difficult to apply in industry. Both types of methodologies do not provide all of the features required to provide the scale of improvements described by Hammer.

A hybrid BPR methodology has been proposed which is systemic in approach. It will use "embedding" to combine the SSM at a meta-level and the "hard" systems methods at a subordinate level. To encourage the use of SSM in a task-oriented company culture, generic process models (conceptual models) for the relevant business sector will be used as initial intervention tools.

The hybrid BPR methodology is at present only a conceptual model and there may be problems with complexity of the methodology and application of it within industry, hence further research work is required.

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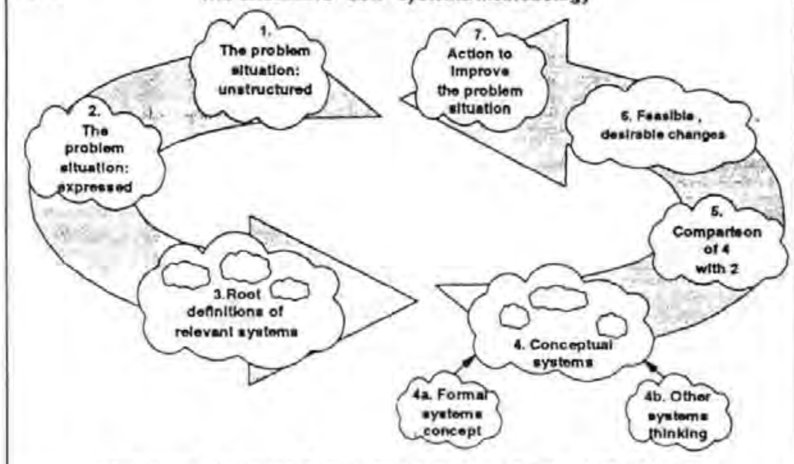
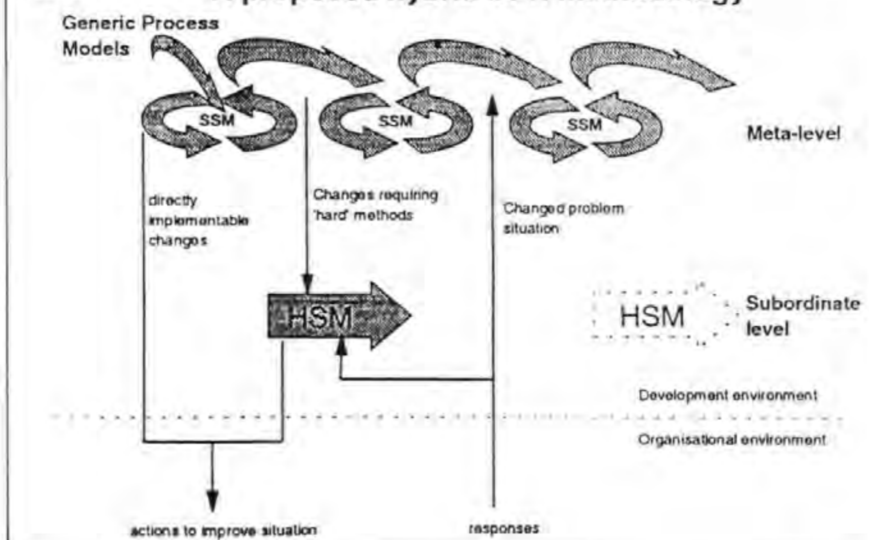
Figure 1 The Checkland "Soft" systems methodology



Adapted from Checkland P, Systems Thinking, Systems Practice, J Wiley 1981

Figure 2 A proposed hybrid BPR methodology



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A SOFT SYSTEMS APPROACH TO MANUFACTURING REDESIGN

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The aim of this paper is to examine whether a "hard" systems model-based approach to the redesign of manufacturing companies will produce the radical improvements required to compete in today's global market place.

A working definition of a model is established and the theoretical preconceptions that are employed to create models of processes are discussed. The paper then proceeds to describe the deficiencies in both "hard" and "soft" systems approaches and how BPR methodology that integrates both "hard" and "soft" model-based approaches will encourage more radically improved business processes.

Introduction

In today's global market place many multi-national organisations have implemented successful Total Quality Management programmes resulting in a set of incremental improvements and a change in organisational culture. These organisations are now looking towards the more radical approaches of Business Process Re-engineering (BPR) and Business Redesign (Johansonn, 1993) to keep ahead of their competitors.

BPR differs from other approaches to business regeneration by explicitly recognising that many business activities cut across both internal and external organisational boundaries. Hammer (1990) states that BPR methods, which strive to "break away from the old rules about how we organise and conduct business," offer organisations the only hope of achieving radical performance improvements. He states that re-engineering cannot be accomplished in small or cautious steps but must be viewed as an "all-or-nothing proposition."

Kaplan and Murdock (1991) have identified several benefits to thinking of an organisation in terms of its core processes. They maintain that the adoption of such a viewpoint helps a firm to link its strategic goals to its key processes. These include the complete chain of organisational activities independent of departments, geography,

cultures. Most importantly they also embrace suppliers and customers.

The process-oriented viewpoint emphasises cross functional performance rather than encouraging departmental optimisation and the consequent system-wide sub-optimisation. It also encourages the firm to focus on business results, particularly where total lead times are an issue. Process focus also offers an organisation the opportunity to re-engineer the process or radically reduce the number of activities it takes to carry out a process, often through the application of IT. This in turn provides opportunities to reduce the cost base and/or improve service levels.

The process focused approach concentrates first on identifying the business processes, then analyzing and re-engineering each process. Many current BPR methodologies (Harrington(1992), Harrison & Platt(1993)) are designed to enable organisations to:

- Define business processes and their internal or external customers;
- Model and analyze the processes that support these products and services;
- Highlight opportunities for both radical and incremental business improvements through the identification and removal of waste and inefficiency;
- Implement improvements through a combination of IT and good working practices;
- Establish mechanisms to ensure continuous improvement of the redesigned processes.

The model-based tools advocated by these authors to facilitate the analysis and redesign of the business processes are used in what could be described in as a "hard systems approach" (Checkland, 1981). The "hard systems approach" is frequently used by most organisations, systems analysts and engineers since they are all "analytical and detail oriented in their problem solving" (Hammer, 1993).

This paper examines whether the hard systems approach which is reductionistic in nature and assumes a well-defined problem situation and objective is the most appropriate approach to be used when attempting a radical improvement through the use of a BPR methodology.

Initially a number of theoretical issues concerning the use of models as part of any approach are discussed. The deficiencies with both hard and soft systems approaches with respect to the objectives of a BPR methodology are examined and finally it is proposed that a "softer" approach is required to enable the organisations to gain radical improvements from the application of a BPR methodology.

Models and their application within a BPR methodology

> "The way forward lies in gaining an increased understanding of theory and of its relationship to practice. We need to be more aware of our theoretical preconceptions and the way these affect attempts to change the real world."
> Jackson(1982)

In the modelling of any system or process there is always a tendency for the analyst to forget the theoretical preconceptions that exist when the initial decision is made to produce a model. These preconceptions need to be taken into account when analyzing and designing a process by a model-based approach. To examine the preconceptions it is worthwhile establishing a definition of a model that will be used throughout the paper.

The definition that will be used in this paper to describe what a model is, its objective and how it models a subject and combines the simplicity a definition used by Meredith (1993) and Dubin's (1969) emphasis on boundaries and two goals of science which are to "predict and understand" Dubin(1969).

> "A model is a bounded representation or abstraction of reality. It describes, replicates, or reflects a real event, object or system, with the objective of understanding or predicting."

The term "process" and "system" are assumed to be interchangeable within this paper since both a "process" and a "system" are;

> "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" Checkland (1981)

The important element of the definition is that a model is a bounded representation or abstraction of a system. It is therefore an enabler or aid to understanding and prediction, but with limitations. The importance of the limitations are emphasised by Meredith (1993) thus;

> "The primary difficulty in using models to analyze situations is obtaining adequate simplification, while maintaining sufficient realism."

The limitations are a result of the subjective decisions that are made by the modeller or in as Ashby (1965) describes a "list of variables nominated by an observer".

Not only must the analyst be aware of the limitations of the model but also their preconceptions as Cleland and King(1983) state;

> "The kind of model used depends on the knowledge, experience, profession and life-world an individual is embedded in; it is not necessarily determined by the subject to be modelled"

The use of models within a BPR methodology whether to gain an understanding of the existing processes or to redesign or to predict performance of a process must be done with the knowledge that the models are an analyst's abstraction of reality. The analyst must also recognise that the models are influenced by their experience and perspective and may constrain a radical approach which could exist external to the analysts perspective. According to Askin & Standridge (1993), the value of a model "lies in its substitutability for the real system for achieving its intended purpose". A process model used within a BPR methodology should therefore encourage the possibility of radical redesign otherwise it does not give maximum value.

Deficiencies in Hard and soft systems approaches

The objective of a BPR methodology is a radical improvement in the performance of the business processes within an organisation. To gain this radical improvement Hammer (1990) tells us that we need to "break away from the old rules". The problem situation that the BPR methodology must address is that the existing processes within the organisation are not producing the desired performance.

A business process is a complex socio-technical system, the elements within the process that interact can be divided into physical designed systems such as machine tools in the case of a manufacturing element in a business process and human activity systems such as the managers and operators within a business process. The emergent properties of a business process can be essential to the strategic aims of the business.

The "order-flow" process within a manufacturing company has a starting point is the customer's order and its end point is the delivery of goods to the customer is a socio-technical system that can have problems that are ill-defined and stochastic in nature. BPR methodologies are used to provide a radical improvement in the emergent properties of business processes. In the case of the "order-flow" process these could include the time taken from receipt of order to delivery and cost of processing the order.

A hard systems approach to BPR used by so many organisations would start from the perspective that the problem situation or process was well-defined and deterministic in nature. It would then proceed to reduce the process into components, the components could then analyzed and modelled by using accurate data, and a solution could be constructed from the improved components. Hard systems approaches are based on rationality described in Trought (1993) as a type of rationality that;

> "... assumes that within the system there is access to all the relevant data which is also accurate, and that all alternatives of choice and consequences are unambiguous."

In comparison a soft systems approach to BPR would start from the perspective that the problem situation or process is ill-defined and the process is stochastic in nature. It would then attempt to create "rich" picture of the problem situation and the systems involved. Conceptual models would be developed and compared with reality. Feasible and democratic changes would be agreed upon through debate and the changes implemented. By using the soft systems approach, the properties that are only a result of interactions between all elements in a process (emergent properties) can be considered more easily.

Considering the objective of radical improvement in the emergent properties of the business processes within an organisation a soft systems approach provides a holistic approach that encourages open debate and creative thought to break down the old rules. The soft systems approach also develops a set of conceptual models of the relevant systems for the problem situation which;

> "is envisaged ... will lead to improved conceptualisation of user requirements." Dooner (1991)

Although hard systems approaches may assume incorrectly at times that a business process is a well defined problem, accurate data is available and it is deterministic in nature, it has been successfully used for many years in addressing the problems of physical designed systems.

At the higher levels of abstraction the problem situation or process is less well-defined it is therefore suggested that a BPR methodology should initially use a soft systems approach for analysis and design of processes. A soft systems approach would consider the emergent properties of the whole process and where a single change could result in a more radical change of the emergent properties of the process.

At the lower levels of abstraction where the problem situation is less ambiguous and more accurate data is available (Trought, 1993) a hard systems approach should be used.

The output from the soft systems phase applied to the higher levels of a process is used as the input to the hard systems phase at the lower levels of detail. The two approaches can therefore be regard as "complementary" and form part of a single BPR methodology.

Conclusion

The paper has described the increasing interest in Business Process Re-engineering and its objectives of radically improving an organisation's performance using a process perspective. It has been identified that a model-based approach is dependent on the analysts experience and preconceptions and could therefore reduce the possible number of radical alternatives considered in the analysis and redesign.

A structure for a BPR methodology has been proposed to facilitate radical improvements in the performance of process. It should use a soft systems approach at the higher level process analysis and redesign. To complement the soft systems approach, a hard systems approach at the lower levels of process abstraction is required especially where the process being analyzed has sub systems that are physical designed system at the lower levels such as the "order-flow" process within a manufacturing organisation.

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THE ROLE OF $IDEF_0$ IN PROCESS RE-ENGINEERING

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This paper will review the role of $IDEF_0$ as part of a re-engineering programme. It will concentrate on the key analysis phase of a BPR methodology and suggest that $IDEF_0$ is particularly suited to modelling within this phase. The features and attributes of $IDEF_0$ are described and the paper will conclude by detailing an example of an $IDEF_0$ model used by the authors' in a re-engineering project in a small engineering company addressing the problem of engineering change.

Introduction

Business Process Re-engineering (BPR) is becoming a key enabler of the 1990's for companies seeking to achieve competitive advantage. BPR offers the opportunity for sustained competitive advantage through radical reductions in lead time and cost and substantial service level improvements. Increasing attention is being paid to BPR by many manufacturing companies including Lucas, IBM, ABB, BAe, HP and Rank Xerox.

Despite the widespread interest there is a lack of conceptual models and operating tools to support any process re-engineering (Bartezzaghi, Spina and Verganti 1993). Similarly, Heynes (1993) cautions that, in the absence of any agreed, correct modelling techniques and languages for describing business processes, IS departments increasingly appear to be using their "mechanistic" systems development models to model business processes.

Consequently, despite the widespread interest in BPR there is evidence,that some companies are not obtaining the benefits from BPR that were initially envisaged (Hammer 1991). The authors believe that without a clearly defined methodology and guide to good practice there is a danger that failure to achieve envisaged benefits will become increasingly common.

BPR Methodology

A number of authors (Davenport and Short 1990, Kaplan and Murdock 1991) and companies for example, IBM (Snowden 1991) have proposed, in very general terms, the stages of a BPR methodology. The authors have distilled from these what they believe to be a good composite BPR methodology consisting of five phases. These are:

Phase 1	Create/Identify corporate, manufacturing and IT strategies
Phase 2	Identify key process(es) and performance measures
Phase 3	Analyse existing process(es)
Phase 4	Re-design process(es)
Phase 5	Monitor and continuously improve new process(es)

For those wishing to read an excellent overview of the entire BPR process, the authors have produced a working paper defining each stage in considerable detail. This paper will continue by focusing upon the development of methods for what the authors regard as the key phase of the methodology - phase three.

Phase 3 Analyse Existing Processes

This phase defines key business processes and identifies possible opportunities for re-engineering by comparing corporate objectives and business drivers within the defined processes.

The first activity is to carry out a key process profile. This profile attempts to understand process flow in terms of activities/tasks/steps performed, cycle times for products/services produced, individual task timings, redundant tasks or steps, delays and work volumes

In our view, in order to provide a basis for incremental and radical change it is necessary that some comprehensive effort be made to analyse existing processes. This may best be achieved through the development of a process model. A number of possible modelling tools exist which could be used at this stage. The most widely used techniques include flow charting (Oakland 1989) Role Activity Diagrams (Ould 1993) and $IDEF_0$ (Le Clair 1982). There is insufficient space to provide an analysis of each of these methods, this paper will now concentrate on describing the most widely used technique - $IDEF_0$ and its application to analyse a process in a manufacturing company.

ICAM Definition Method

$IDEF_0$ consists of three to six boxes. Three is felt to be a reasonable minimum (a diagram of two can usually be incorporated into a higher level diagram) and six a maximum because of individual cognitive limitations. The graphical language of $IDEF_0$ uses boxes and arrows coupled together in a simple syntax. Boxes on a diagram represent activities. The arrows that connect to a box represent real objects or information needed or produced by the activity. The side of the box at which an arrow enters or leaves shows the arrow's role as an input, a control or an output.

The strength of $IDEF_0$ is that it is a tool designed for modelling processes and in our view it is relatively easy to use (though more difficult than flow charting). It uses a structured set of guidelines based around hierarchical decomposition, with excellent guidance on abstraction at higher levels, if used well this ensures good communication and a systems perspective. It is also becoming the defacto standard modelling tool for business process modelling.

The main weaknesses in using $IDEF_0$ are that some users claim it is too complex to use and that it is not possible to produce a detailed software specification directly from the $IDEF_0$ diagrams, thus its use in linking stages three and four is very limited.

Case study

The application of $IDEF_0$ is illustrated in Figure 1. Here we can see an example of $IDEF_0$ applied in a small engineering company based in Plymouth. The sub-process that the authors analysed was engineering change. There are six key activities A11..A16. The first activity is to filter the engineering change proposal, the key control on the filtering process are the company policies on acceptable engineering change requests. The marked drawings are then used to input a hypothetical effectivity date into the CAPM system. At this stage the effectivity date is always 1999 ie some future date. The drawing and engineering notices are then used by the draughtsman to produce the changed drawings which are then evaluated by supply for a true effectivity date. Supply will assess their stock levels and if, for example, they have a large stock of material affected by the drawing change they will request that the effectivity date be pushed out as far as possible. The feedback loop is to the product engineer who has to interface with the customer to identify whether the proposed effectivity date is acceptable. This activity produces an effectivity in date for the new part and also an effectivity out date for the existing part which is entered on the Bill of Materials. The final activity is where the drawing and engineering notices are appraised and signed off for implementation by the product engineer.

Discussion and Conclusions

The $IDEF_0$ models are useful in identifying areas for improvement in three main ways. Firstly, they act as a means of understanding the process. The $IDEF_0$ models developed of the process were the first time that the process had been modelled in such detailed manner. Secondly, because of the hierarchical nature of $IDEF_0$ the models are useful in communicating this understanding of the process to senior executives. In essence, because $IDEF_0$ insists on consistency amongst levels yet allows for abstraction of terms, the models can be shown to strategic meetings where radical re-engineering decisions are made. Thirdly, the models allow an analysis of the process to take place. The team are currently engaged on developing a specification of a methodology for BPR which will take the $IDEF_0$ models and indicate areas for radical and incremental improvement.

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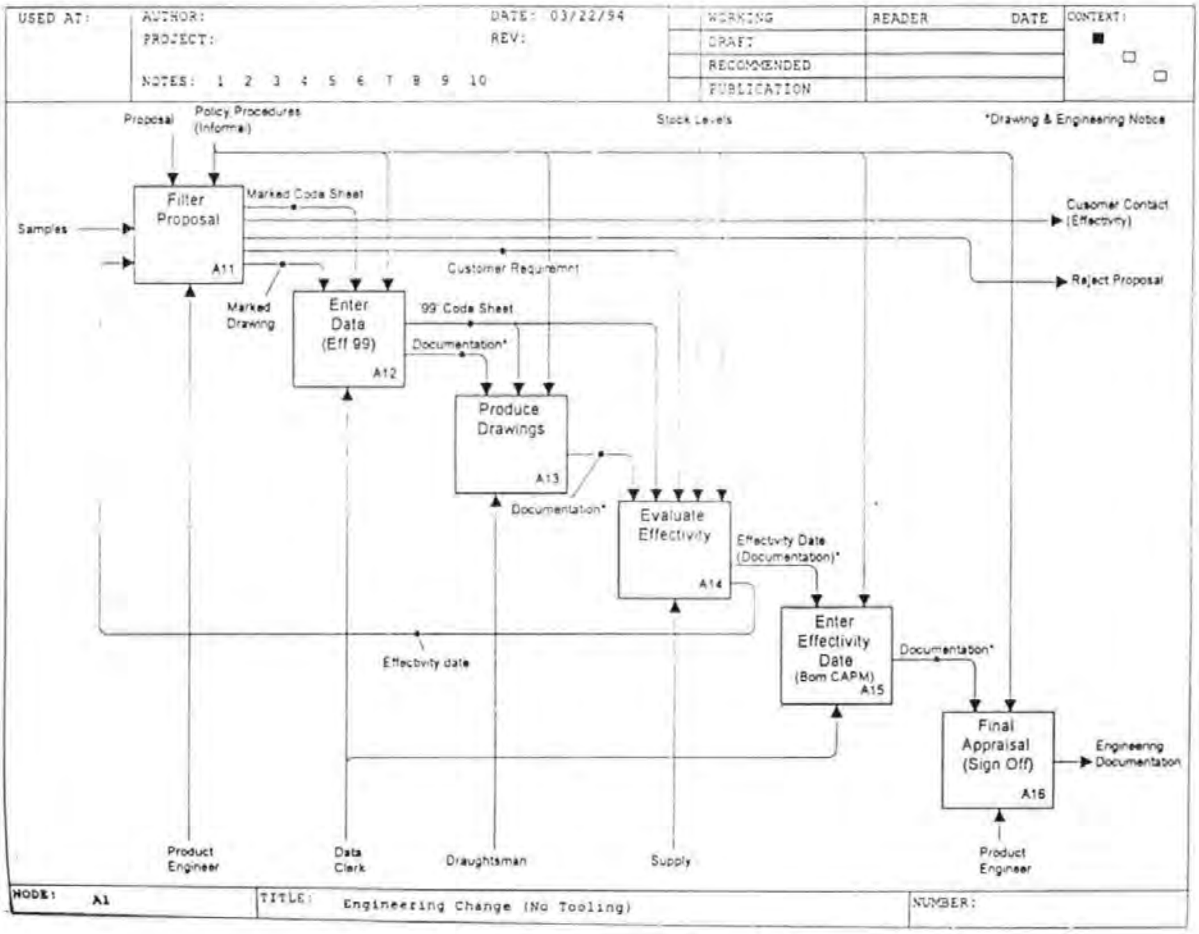
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TITLE: Engineering Change (No Tooling)
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The application of generic process models in Business Process Re-engineering

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The application of generic process models in Business Process Re-engineering

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Abstract

Research work is proceeding on the development of a framework that will help manufacturing businesses identify business processes, process components and links between the processes to form a company-wide view. This paper describes the supporting theory of systems and the structure, development and validation of a model of standard business processes.

Keywords

Business Process Re-engineering; process model; manufacturing; SME; $IDEF_0$

1 INTRODUCTION

The objective of this paper is to describe the development of generic process models for Business Process Re-engineering (BPR) that will encourage companies and participants carrying out BPR projects to take a business process perspective. It will address specifically the application of BPR within Small and Medium Sized Enterprises.

The authors believe that the issue of how to encourage individuals at all levels within a company to think in terms of business processes is critical to the success of a BPR project. This is pointed out by Rummler and Brache (1990) who have found that;

> *"When we ask a manager to draw a picture of his or her business (be it an entire company, a business unit or department), we typically get something that looks like the traditional organisation chart."*

A number of multi-national companies have successfully used generic process models to intervene and change processes within business units, for example Xerox and Shell. The purpose of these generic process models is to encourage individuals within the business units to think in terms of business processes and to provide a starting point for process redesign. The business process view gives the individuals a holistic view of the activities that are carried out within the business units. The authors believe that the use of generic process models could be applied just as successfully by Small and Medium Sized Manufacturing Enterprises (SMEs) to provide a process framework and intervention tool for BPR projects.

2 SME's

The initial problem is to identify which SMEs may benefit from undertaking a BPR project. SMEs have very different characteristics compared to large organisations especially in the area of innovation (Lefebvre et al 1990, Meredith 1987).

Mount et al (1993) provide a framework to deal with this issue which consists of five typical phases of small business development.

1 Owner Operated The owner manages the business and also performs many of the day-to-day productive activities with a small workforce.

2 Transition to owner-managed The owner's role is changing to a state in which the owner is engaged in managing the business full-time, yet the business is small enough not to require a middle level of management.

3 Owner-managed The owner is engaged full-time in the management activities within the business. Supervisory roles may exist but there are no formal functional boundaries.

4 Transition to emergent functional The company is becoming too big to be managed by the owner. Functional boundaries become defined and hence a middle layer of management is required. The addition of specialist middle managers demands substantially more delegation of decision making. In this case the owner is often obliged to screen the viewpoints of senior functional managers and to arbitrate some consensus on a final course of action.

5 Emergent functional organisation A company in which defined functions and managers and a clear organisation structure exists. Middle management is established and functions have frequently established their own objectives, mission statements etc. There may be a conflict of interest between functions, and political manoeuvring may be widespread.

We believe that companies where such conflicts and complexity are emerging are those who may benefit from BPR programmes. The generic models have therefore been developed with emergent functional organisations in mind.

3 GENERIC PROCESSES

In the majority of documented BPR methodologies, including those developed by Coopers & Lybrand, IBM, British Telecom, Xerox and Lucas, one of the initial activities is to identify the core business processes. In identifying the core processes the participants in the BPR project are defining boundaries within their organisation using a process perspective.

By comparing the sets of core processes produced by companies that have undertaken BPR projects, a hierarchy of common processes that are generic across the companies becomes evident. This suggests that a set of standard processes may evolve in process oriented organisations, in the same way that a roughly standardised set of functional divisions (manufacturing, design, sales and marketing, finance, personnel, etc.) developed.

4 AN ARCHITECTURE OF BUSINESS PROCESSES

A manufacturing company can be represented at the most abstract level as a process which transforms inputs into outputs to satisfy the objectives of the various organisational stakeholders. The organisation can be sub-divided into a number of sub-processes that

interact to meet these overall objectives. An overall structure or architecture allows each process to be considered without losing the context of its purpose within the whole organisation. The process view of an organisation ensures a strong emphasis on how work gets done and is a "revolutionary change of perspective" from the traditional functional based view of an organisation (Davenport 1993).

There are many examples of organisations identifying a hierarchy of business processes. It is one of the initial activities in the majority of documented BPR including those developed by Coopers & Lybrand (Johansson et al 1993), IBM (Kane 1986), British Telecom (Harvey 1994), Xerox and Lucas (Parnaby 1993). The number of business processes identified at the various levels within the hierarchy varies considerably from organisation to organisation. Davenport (1993) gives a number of reasons for this variation:

- *Processes within organisations are almost infinitely divisible.*
- *The identification of processes can be exploratory and iterative.*
- *An organisation seeking to carry out incremental changes is likely to focus on improvements in sub-divisions of processes whereas for radical changes an organisation should attempt to define processes as broadly as possible.*

Examples of process identification by organisations can be found in Davenport (1993) and the Business Intelligence report on BPR (Harvey 1994) and many case studies in journal articles, for example Shapiro et al (1992), Davenport and Short (1990).

Two activity types "primary" and "support" activities are identified by Porter in his "value chain" concept (1985). The "primary activities" are those activities that interface with the external customer and add value to a product either by designing, manufacturing or by selling the product. The "support activities" are those activities that enable the primary activities to function.

"Management" activities represent a third type of process, including activities which do not directly add value to the customer, the direction setting, enabling change or managing performance activities. For example Veasey (1994) refers to "Management, Support and Value Adding" processes; Royal Mail have "External Customer, Support and Management" processes; Lucas have "Development, Delivery Operations and Support" processes; Pagoda (1993) have "Manage, Operate and Support" processes. The CIM-OSA standard (AMICE ESPRIT 1989) also groups processes into "Manage, Operate and Support".

The grouping of the processes under "Manage, Operate and Support" emphasises some of the general characteristics of the processes and the approaches to redesigning the different types of processes may be different. For example, the concept of value-added must be applied differently in the Operate and Manage areas. Paradoxically, the grouping of processes is a functionally based analysis rather than a process analysis and must be seen as less important than the analysis of the processes themselves.

4.1 The "Operate" processes

The "Operate" processes are those processes which directly produce value for customers. Value is added if activities lead directly to the fulfilment of a customer's requirements. The core operational processes identified by Champy (1995) and Meyer (1993) for a business are "customer service", "product development", and "order fulfilment". The "customer service" process transforms knowledge of customer requirements and the market into customer orders. The "product development" process transforms the actual or perceived requirements of a customer into a design that can be manufactured. The "order fulfilment" process takes the order, manufactures and delivers the product to the customer.

The focus of the work in developing a set of generic processes has been on the "Operate" processes because these are the processes where greatest gains in competitive advantage can be made (Hammer and Champy 1993, Meyer 1993, Johannson et al 1993). Analysis of these processes will also

illuminate the most important support process impediments and do so within the context of meeting customer needs (Meyer 1993)

A recent survey (Harvey 1994) also showed that the most commonly cited processes that organisations were targeting for re-engineering included customer service, logistics and new product development.

From our discussions with companies and our comparison of the lists of core processes developed by a number of organisations including Xerox, IBM and Rover, many companies further divide the "customer service" process into two parts. The two parts are the process of getting an order from a customer and the process of providing support to the customer after the order has been fulfilled. We have called these processes the "Get Order" process and the "Support Product" process.

We have thus identified a set of four "Operate" processes within a manufacturing company. We have named each one with an imperative verb so that the process names are consistent with the $IDEF_0$ models. The four "Operate" processes are

- Get Order
- Develop Product
- Fulfil Order
- Support Product

4.2 Process definition

There are many different views of what should be included or excluded within the boundaries of each process. Each organisation is likely to have a different view. To describe a consensus view of the "Operate" processes we are developing a precise description using a *root definition* and an $IDEF_0$ model of each of the processes showing activities and flows in each process and between the four processes. These are intended to provide what Wilson (1984) terms a "Consensus Primary Task Model".

To develop a rigorous definition of each process, a "root definition" of the process was defined. The concept of a "root definition" is part of the Soft Systems Methodology (SSM) described by Checkland (1981). A root definition should be a "concise description of a human activity system which captures a particular view of it" (Checkland 1981). Checkland also developed a mnemonic CATWOE by which the six elements that should be covered in a root definition can be remembered. The six elements paraphrased from Checkland are:

- *Customers* of the process, beneficiaries or victims affected by the processes activities.
- *Actors* or agents who carry out or cause to be carried out the main activities of the process.
- *Transformation*, the means by which defined inputs are transformed into defined outputs.
- *Weltanschauung*, the outlook or framework that makes the root definition meaningful.
- *Ownership*, the agency having a prime concern for the system and the ultimate power to cause the system to cease to exist.
- *Environment*, features of the environment of the process that must be taken as given.

Since the generic process models stem form the same work, the Actors, Weltanschauung and Ownership for each are the same. The Actors in each process are the people and machines within the manufacturing company under consideration. These cannot be defined more precisely, as the model has to preserve its generic nature. The Weltanschauung for each model is the same, that is to say they are all intended to be more helpful than a neutral model which would be acceptable to *all* manufacturing companies, but which in its theoretically wide application would lose all meaning. Rather it is intended to produce a consensus model which will accommodate the Weltanschauung of the majority of manufacturing companies. Ownership can only be expressed as the owner of the manufacturing company. In some specific cases, process owners may be created which provide the owner role for a particular process, but this can not be seen as a general concept until the process architecture is generally accepted, thus, it can not be part of it.

The root definitions that capture the view of the authors with respect to the "Operate" processes of any manufacturing company is as follows;

The "get order" process contains activities performed by humans and machines. Its principal transformations are to transform a product or concept of a product into a customer order, to translate customer requirements into a form meaningful to the other processes and to use market data to identify potential requirements for new products. It includes the flow of information that is required to satisfy a customer by providing information to the customer and to the other "Operate" processes. The process constantly seeks to ensure that customers' requirements are met and that there are sufficient orders to meet the stakeholder requirements.

The "develop product" process contains activities performed by humans and machines. Its principal transformation is from knowledge into the specification of a product that can be produced to meet customer requirements. It includes the flow of information to enable development of the specification of a product that can be manufactured and the development of product concepts that may fulfil future customer requirements. The process constantly seeks to provide specifications for products that will meet the requirements of customers whilst balancing stakeholder requirements.

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 result in the fulfilment of the external customer order or enquiry. The process constantly seeks to fulfil customer requirements whilst balancing stakeholder requirements.

The "support product" process contains activities performed by humans and machines. Its principal transformation is a need for support into a product that continues to meet the requirements of a customer. It includes the flow of the resources and information that are required to meet the customer's support requirements. The process constantly seeks to fulfil the customer's support requirements whilst balancing stakeholder requirements.

In the tradition of Checkland's Soft Systems Methodology, the root definitions are being revised as more knowledge about the processes is gained.

5 DEVELOPMENT AND VALIDATION OF THE PROCESS MODELS

5.1 Modelling technique

The model of the "Operate" processes has been developed using $IDEF_0$ (CAM-I 1980). $IDEF_0$ is widely used in the manufacturing sector for modelling processes. $IDEF_0$ comprises:

- A set of methods that assist in understanding a complex subject;
- A graphical language for communicating that understanding;
- A set of management and human-factor considerations for guiding and controlling the use of the technique.

$IDEF_0$ uses top-down decomposition to break-up complex topics into small pieces which can be more readily understood and which are set in their proper context with respect to other system elements. An $IDEF_0$ model is an ordered collection of diagrams, related in a precise manner to form a coherent model of the subject. The number of diagrams in a model is determined by the breadth and depth of analysis required for the purpose of that particular model. At all times the relationship of any part to the rest of the whole remains visible.

In summary $IDEF_0$ provides the ability to show what is being done within a process, what connects the activities and what constrains activities. It uses a structured set of guidelines based around hierarchical decomposition, with excellent guidance on abstraction at higher levels. If used well this ensures good communication and a systemic perspective.

5.2 Level of analysis

The level of analysis is critical when developing a generic model. For the generic model to be of any use it must contain elements which are at a level of detail that allows meaningful discussion within a particular company. Conversely, too much detail would restrict its application. A very detailed model would become specific to a particular company. Thus an attempt is being made to judge the appropriate level of detail.

Using $IDEF_0$ as a modelling technique ensures that the context for any part of a process model under analysis in relation to the whole of the process model is always known. Therefore a company can focus on the part of a process model it is particularly interested in and develop a further levels of detail without losing its context within the whole process.

5.3 Information sources

The models have been developed with the involvement of a number of manufacturing companies varying in size from Times 1000 companies to Small and Medium Manufacturing Enterprises (SMEs) with under 500 employees.

The information used to develop the process models has been extracted and assimilated from a number of sources including literature (especially Harrington 1984, CAM-I 1984, Porter 1985), previous work (Childe 1991), generic models described in other modelling methods and individual models of company processes.

The $IDEF_0$ models of the "Operate" processes will cover all four types of manufacturing companies defined by Wortmann (1990): Make-to-stock, Assemble-to-order, Make to order and Engineer-to-order.

5.4 $IDEF_0$ standard process models

The "Operate" processes are represented in a single $IDEF_0$ model that shows the interactions between each of the processes and external customers, suppliers and other parts of the

organisation that are outside the boundaries of the model. $IDEF_0$ has allowed us to develop a model of each process separately and then combine the $IDEF_0$ models into an integrated model of the "Operate" processes. The complete model includes a set of $IDEF_0$ diagrams and a glossary of terms.

5.5 Validation

The validation of the process models is currently being carried out. Validation methods include criticism and comment by academic colleagues and industrial practitioners experienced in BPR and manufacturing management and a comparison by third parties to their own process models.

6 APPLICATION

In the introduction the critical issue of getting employees to think in terms of business processes was identified. The generic process models are intended to be used as an intervention tool to encourage the participants of a BPR project within a manufacturing company to take a business process perspective. The participants in a BPR project would generally be individuals from the functions who currently perform activities within the process, guided by objectives set by senior management.

In the initial stages of the BPR project, following the identification of a core process to be redesigned, the participants would be presented with the generic process model and glossary of terms and asked to compare the generic process model against the activities within the company. These activities would be carried out under the guidance of an internal or external facilitator.

In carrying out a comparison the model encourages the participants to;

- Take a business process perspective as the generic model provides an existing process framework.
- Develop a consensus view of their own company's process by debating the differences between the generic model and each participants perceived view of the company's process.
- Identify and change the generic model to represent their company's process.
- Identify immediate changes that could be made to the company's process as differences between the model and reality are found.
- Consider the systemic relationship of all parts of the process as model provides a structured medium where inconsistencies in the changed model can be identified easily.

In comparison with current BPR approaches where the participants are encouraged to develop a process model of the existing business process, the use of generic models reduce the danger of participants reverting to tradition functional thinking by providing a process focused framework. It also provides greater momentum to the project than a "blank sheet of paper" and the generic process model is non-political having being produced externally. The non-political nature of the generic process model should enable participants to more freely criticise the model and in doing so generate debate and understanding amongst the group.

7 CONCLUSION

This paper has described the development of a set of generic process models for business process re-engineering in small and medium sized manufacturing companies. Initial validation of the models has supported the view that generic models would be useful in the re-engineering of SME's and the models have raised considerable interest. Further development and validation of the models is proceeding.

Acknowledgements
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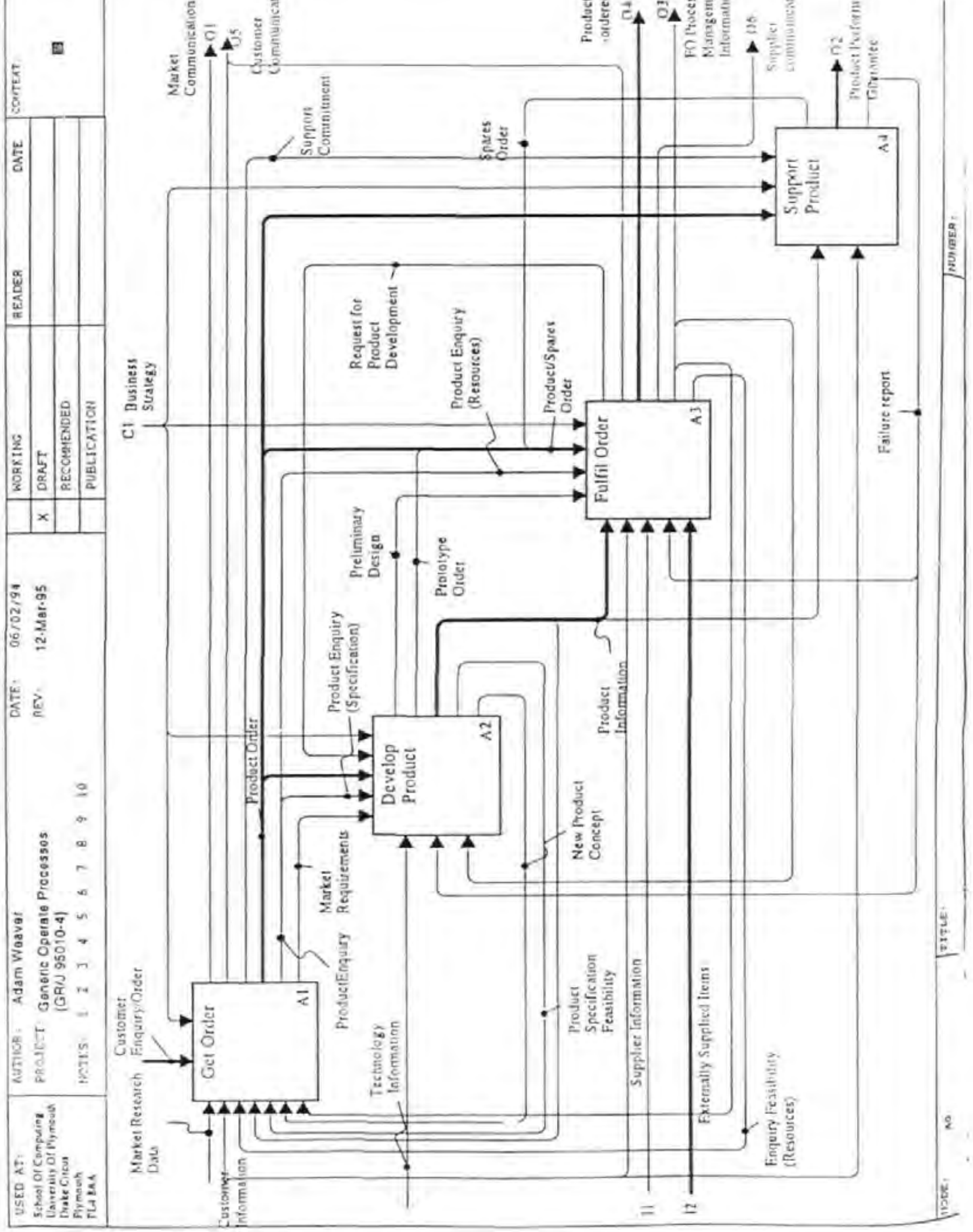

The authors are members of a research team at the University of Plymouth engaged upon various research projects in the field of systems modelling and design in manufacturing and service industries. Current projects are in the areas of business process re-engineering in SME's, production management, concurrent engineering and manufacturing strategy. Current collaborators include manufacturing companies, software companies, financial institutions and hospitals.

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The application of BPR to SME's

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THE APPLICATION OF BPR TO SMEs

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This paper will provide a framework in which organisations can focus on processes through the adoption of a generic process architecture. The research team at the University of Plymouth have identified three 'sets' of processes; manage, operate and support and have further sub-divided the operate processes into; get order, product development, order flow and after-sales service. Using a Soft Systems approach we describe a root definition and a conceptual model for the order flow process. The paper presents this model.

Although there is significant evidence of the use of generic models in large companies e.g. Xerox Nordic and Shell International, there is little evidence of their application in Small and Medium Sized Enterprises (SMEs). The paper concludes by providing a framework which may be used to establish the suitability of BPR for SMEs.

INTRODUCTION

The latest fad and fashion to arouse the interest of practising operations managers is Business Process Re-engineering (BPR). Interestingly, its take-up has been widespread in both the manufacturing and service sectors with significant success stories being reported by Rover, TSB, ICL, Royal Mail etc. Rummler and Brache [1] have found that managers traditionally have a functional perspective of a business. They state that;

"When we ask a manager to draw a picture of his or her business, we typically get something that looks like the traditional organisation chart."

This view reduces the organisation into component parts e.g. sales, marketing, manufacturing and attention is focused on the effectiveness of each functional specialisation. A process perspective enables managers to visualise the connectivity between each specialisation which is required to meet the requirements of the external customer.

The importance of encouraging individuals at all levels within a company to think in terms of business processes is therefore critical to the success of a BPR project. To achieve this shift in perspective a template based on a hierarchy of generic processes may be utilised to aid the identification of processes within the organisation.

A number of Multi-national companies have successfully used generic process models as a means to help focus on processes as opposed to functions, for example Xerox and Shell. However, there is little research into how Small and Medium Sized Enterprises (SMEs) can use BPR to bring about competitive advantage. The authors are part of a research team based at the University of Plymouth which has been contracted by the EPSRC (UK Research Council) to specify a BPR methodology based around a series of business processes specifically for SMEs.

As a major part of our research project a series of generic process models have been developed. These models may be used to encourage individuals within the business units to think in terms of business processes, and may provide a starting point for process redesign.

RESEARCH METHODOLOGY

The research team have followed a research methodology based on the approach outlined by Meredith [2]. This has three main phases:

Description - reporting and chronicling events and elements of situations. The result is a well documented characterisation of the subject of interest. More detailed descriptive research is known as exploratory research. The result of exploratory research is greater insight and understanding;
Explanation - producing a description of a situation which includes some initial concepts about a situation. If a complex, relatively closed set of relationships is operating then a framework may be constructed. The integration of frameworks helps develop a theory. Theory must improve our understanding of a non-unique phenomenon and must be a non-trivial issue;
Testing (through prediction) - predictions may be postulated and then checked against observation.

The team began the research process by identifying a number of exemplar organisations from those which have been presenting the findings of their BPR work at conferences or which are undertaking BPR projects either in-house or as consultancy operations. These include Lucas Engineering and Systems, Coopers and Lybrand, Rank Xerox and IBM. The purpose of the research within these organisations is descriptive and exploratory, in that an attempt is being made to produce greater insight and understanding by defining, specifying and codifying the field of process identification. To accomplish these aims, semi-structured interviews have been conducted around a general agenda which focuses on:

- Definition of processes;
- Types of change - radical vs incremental;
- Role of IT in BPR;
- Performance measures and BPR;
- Human factor issues in BPR.

The results of this phase of the research were presented at The First European Operations Management Association conference in 1994 [3]. A more detailed working paper is now available from the authors.

DEVELOPMENT OF A GENERIC PROCESS ARCHITECTURE

In the second, explanatory phase of the research, the team have concentrated on what may be regarded as the key first stage in any BPR methodology - the definition of the process. This is very much in accord with documented BPR methodologies such as those developed by Coopers & Lybrand, IBM, British Telecom, Xerox and Lucas. The identification of core processes requires boundaries to be drawn by the participants.

By comparing the core processes produced by companies that have undertaken BPR projects, a set of generic processes becomes evident. This suggests that a set of standard processes may evolve in process oriented organisations, in the same way that a roughly standardised set of functional divisions (manufacturing, design, sales and marketing, finance, personnel, etc.) developed.

Examples of breaking down businesses into varying numbers of processes include Arthur Andersen (200) and Xerox Nordic (48). The difference in numbers of processes can be explained by the level of analysis, the lower number being more abstract. IBM are currently organising their world-wide operations around ten generic internal and external customer facing processes. Lucas Engineering and Systems Ltd have developed a model

containing 16 generic processes. There are further examples of core process definition by companies in both Davenport [4] and the Business Intelligence report [5] on BPR and many case studies in journal articles [6],[7].

The definition of core processes has required extensive investment by the organisations discussed above. The purpose of developing the generic process models described in this paper is to provide small and medium-sized manufacturing enterprises with a similar framework without requiring a disproportionate use of their limited resources.

First level model - manage operate and support

A useful structure established by the CIM-OSA standards committee[8] sub-divides processes into three main areas: Manage, Operate and Support. The CIM-OSA framework regards *manage processes* as those which are concerned with strategy and direction setting as well as with business planning and control. *Operate processes* are viewed as those which are directly related to satisfying the requirements of the external customer, for example the logistics supply chain from order to delivery. These are sometimes referred to as "core processes". *Support processes* typically act in support of the Manage and Operate processes. They include the financial, personnel, facilities management and Information Systems provision (IS) activities.

The initial focus of the authors' work in developing a set of generic processes has been on the operate processes because these are the processes that add value and where greatest gains in competitive advantage can be made [9], [10], [11].

The authors have defined the core operational processes which include, Get Order, Product Development and Order Fulfilment. This is similar to the framework proposed by Champy [12] and Meyer [13]. The "get order" process transforms knowledge of customer requirements and the market into customer orders. The product development process transforms the actual or perceived requirements of a customer into a design that can be manufactured. The order fulfilment process transforms the order by manufacturing and delivering the product to the customer.

The get order process adds value by translating the customer requirements for a product into a form which may be used as a basis for further value adding by the other three operate processes. The product development process adds value for the end customer by using knowledge to design a product to the customer's requirements. The order fulfilment process adds value by manufacturing the product and delivering it to a customer.

The order fulfilment process

The research team have developed a process model of each of the operate processes and have documented the inter-relationships between these core processes. For many companies the most complex of the operate processes is the order fulfilment process.

To develop a rigorous definition of the order fulfilment process, a "root definition" of the process was defined. The concept of a "root definition" is part of the Soft Systems Methodology (SSM) described by Checkland [14]. A root definition should be a "concise description of a human activity system which captures a particular view of it"[15]. Checkland also developed a mnemonic CATWOE by which the six elements that should be covered in a root definition can be remembered. The six elements paraphrased from Checkland are;
Customers of the process, beneficiaries or victims affected by the process' activities.
Actors or agents who carry out or cause to be carried out the main activities of the process.
Transformation, the means by which defined inputs are transformed into defined outputs.
Weltanschauung, the outlook or framework that makes the root definition meaningful.
Ownership, the agency having a prime concern for the system and the ultimate power to cause the system to cease to exist.
Environment, features of the environment of the process that must be taken as given.

The root definition that captures the view of the authors with respect to the order fulfilment process of any manufacturing company is as follows;

The order fulfilment 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 result in the fulfilment of the external customer order or enquiry. The process constantly seeks to fulfil customer requirements whilst balancing stakeholder requirements.

The order fulfilment process is best described through the use of a pictorial model which relates together all these aspects of the root definition (Figure 1.). A description of the model is provided in the section "order fulfilment model".

It is from the root definition in the SSM that a conceptual (pictorial) model is developed. The modelling technique IDEF$_0$[16] was used to create a conceptual model which represented the root definition. IDEF$_0$ enables diagrams to be created which explicitly focus on the activities and their connections that collectively represent a process.

IDEF$_0$ is widely used in the manufacturing and service sectors for modelling processes, it comprises:

- A set of methods that assist in understanding a complex subject;
- A graphical language for communicating that understanding;
- A set of management and human-factor considerations for guiding and controlling the use of the technique.

A comprehensive description of IDEF$_0$ can be found in the IDEF$_0$ user manual [17].

The types of flows that are modelled in the generic process model can be divided into physical and information flows. The information flows can be further divided into seven categories of information described by Jorysz and Vernadat [18]. These seven categories of information are

1) *Product information* describes what to produce e.g. drawings, part lists
2) *Process Information* describes how the product should be produced e.g. process plans
3) *Production Information* describes the quantities to be produced and shop floor progress
4) *Planning Information* describes the schedules, inventories and plans
5) *Resource Information* describes the facilities that produce the products
6) *Administrative information* describes management information e.g. customer orders
7) *Organisation information* describes responsibilities

The generic process model includes potential flows between activities representing the first six types of information. Information regarding responsibilities in organisations differ widely thus constraining their inclusion in the generic model. Only in a specific company implementation of the generic can responsibilities be assigned.

Generic flows were identified from IDEF$_0$ models of manufacturing companies that had been produced by the authors in the course of their research work. Information was also distilled from other models produced in a number of different modelling techniques presented in the literature [19].

Order Fulfilment model

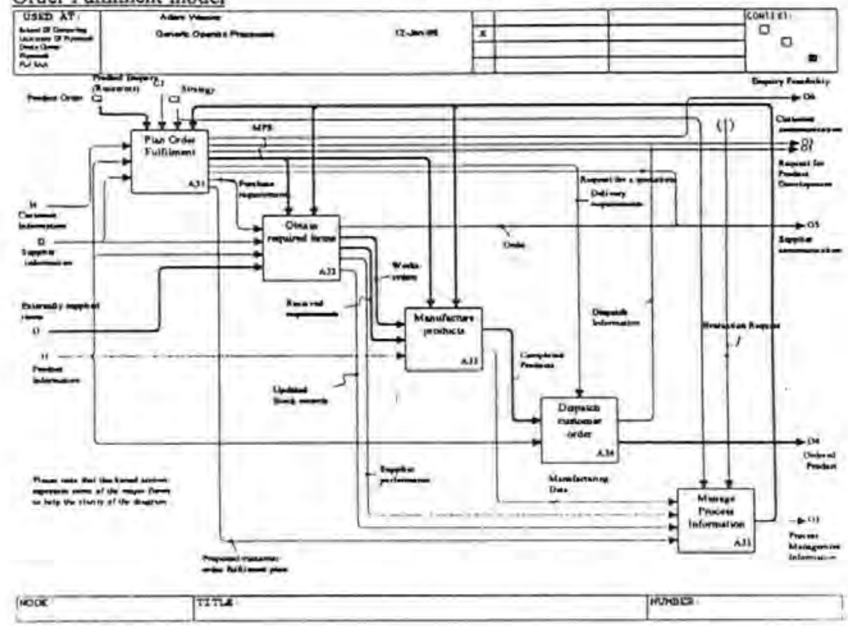

Figure 1

The generic order fulfilment model includes over 110 activities integrated by both physical and information flows. Figure 1. shows the order fulfilment process from the second of five levels of abstraction. The complete model also includes a glossary of terms.

The information that triggers the process is either a product enquiry or a product order (C3, strategy, is the overall controlling factor for the process). An order (C2) is transformed by the sub-processes until it is dispatched as ordered product (O4). An enquiry enters the process (C1) which results in customer communication (O3) or a request for product development (O1).

The terms used in the model are as generic as possible, for example an "enquiry feasibility report" could represent a verbal "yes" from the Production Manager to the Salesman or a detailed analysis of the capacity requirements, delivery date feasibility and additional capital costs for investment in new tooling presented at a board-level meeting.

The five primary activities represented by the generic model are as follows:

Plan Order Fulfilment

This activity establishes how the company is going to fulfil the customer's requirements. To accomplish this activity Product information (Engineering Drawings and Process Plans), Process Management Information (Resource and Capacity information), Customer Information and Business strategies are all required. The output of the activity is Planning Information and Purchase Requirements.

Obtain Required Items

This activity represents all activities that are involved in acquiring goods and services internally and externally to fulfil a customer's order. Planning Information controls this activity and Product, Supplier and Process Management Information are used. In addition to information flows, the physical items which are required by the activity are also illustrated. The outputs from this activity are orders to suppliers, together with works orders and externally obtained items which form the input to the next activity.

Manufacture Products

This activity represents the production activities together with the low-level scheduling on the shop floor, the progressing of work through the factory and the monitoring of performance. This activity is controlled by schedules and works orders. It uses Product and Process Management Information (Resources and Capacities) and transforms physical flows of materials into finished products.

Dispatch Customer Order

This activity delivers the finished products to the customer. This activity is controlled by delivery requirements and transforms physical flows of completed products to meet a customers requirements.

Manage Process Information

This activity gathers supplier performance, manufacturing data, and proposed plans from other activities to give information on process performance and up to date planning and capacity information to ensure the process meets the objectives of the company.

The validation of the generic process model is proceeding as more knowledge is gained through using the model within manufacturing companies. The principal means of validation has been the dissemination of the model to 30 industrialists who have critically evaluated the model.

Application of the generic process models

In the introduction the critical issue of getting employees to think in terms of business processes was identified. The generic process models are intended to be used as an intervention tool to encourage the widespread ownership of a business process framework.

In the stages of the BPR project following the identification of a core process to be redesigned, the participants would be presented with the generic process model and a glossary of terms and asked to compare the generic process model against the company's processes. These activities would be carried out under the guidance of an internal or external facilitator.

In carrying out a comparison the participants would be encouraged to;

1. Think about the business in terms of process flows.
2. Develop a consensus view of their own company's process by debating the differences between the generic model and each participant's perceived view of the company's process.
3. Tailor the generic model to represent their company's process.
4. Identify immediate changes that could be made to the company's process.
5. Consider the effect of any changes on the whole of the process.

The use of generic models enforces a process focus via the application of a process framework. It also provides greater momentum to a project than a "blank sheet of paper" approach[20]. The generic process model is essentially non-political having being produced externally to the company. The non-political nature of the generic process model enables participants to criticise the generic model and in doing so generate debate and understanding amongst the group.

SUITABILITY FOR SME

The third phase of the research has only just begun. This phase concentrates on testing the generic framework in live manufacturing companies - specifically SMEs. A useful summary of the literature for analysing SMEs has been proposed by Mount et al [21]. They describe five typical phases of small business development.

Owner Operated. The owner manages the business and also performs many of the day-to-day productive activities with a small workforce.

Transition to owner-managed. The owner's role is changing to a state in which the owner is engaged in managing the business full-time, yet the business is small enough not to require a middle level of management.

Owner-managed. The owner is engaged full-time in the management activities within the business. Supervisory roles may exist but there are no formal functional boundaries.

Transition to emergent functional The company is becoming too big to be managed by the owner. Functional boundaries become defined and hence a middle layer of management is required. The addition of specialist middle managers demands substantially more delegation of decision making. In this case the owner is often obliged to screen the viewpoints of senior functional managers and to arbitrate some consensus on a final course of action.

Functional organisation A company in which defined functions and managers and a clear organisation structure exists. Middle management is established and functions have established their own objectives, mission statements etc. There may be a conflict of interest between functions, and political manoeuvring may be widespread.

The research team have made research visits to twelve SMEs which have been classified in the Mount framework. Early results indicate that in organisations in phases one, two and three the owner exhibited control by being intimately involved in customer requirements and orders and consequently had a thorough understanding of the whole customer supply chain. However, in those organisations which were moving into, or had established, an emergent functional organisational form, it was much more difficult for owners (or CEOs) to have a clear picture of the whole organisation and its constituent processes. It would appear to be in these organisations, which have lost sight of the processes and which manage and measure performance by function, that a process focus may provide real benefits.

For example, in two companies, both employing 250 staff, two different organisational types have emerged. Company A had a problem with the speed of order entry and the speed with which an order was released to the shop floor. The MD was able to convene a meeting of all the staff involved, establish stretch goals and facilitate a genuine holistic approach to process analysis. This company was still essentially owner managed, and functional sub-division was not culturally embedded.

In Company B with a similar planning problem, functions had emerged, were established and indeed encouraged. The MD had way of identifying cross functional problems, he was unable to identify order entry/works order release issues. In this type of organisation a generic model is invaluable. It provides the MD with a tool around which he can analyse his problems as a "whole", and concentrate on areas for change. He can then convene cross functional teams and look for bureaucracy, inspection/exception routines etc.

The essential difference between the two cases is that in Company A the MD was always taking a "whole" process perspective, whereas in Company B the organisation's structure was configured to make this almost impossible.

CONCLUSION

The objective of the paper was to describe the development of a generic process model and its application within SMEs. The definition of core processes depends upon the level of abstraction that the organisation finds meaningful. In this paper a generic set of activities has been provided in abstract form which every manufacturing company performs in fulfilling an order. A process architecture for manufacturing companies provides a framework to encourage a process perspective. The generic process model is to be used as an intervention tool for companies which are less able to invest resources in the definition of core processes themselves.

The real challenge with SMEs is to change mindsets - to begin to convince their opinion formers of "knowing what they don't know". A process perspective provides a real opportunity for SMEs to change, based on processes and external customers rather than functional division. The test of the process model is how successful it will be in changing minds and re-focusing SMEs not just on efficiency and cost reduction but also upon enhancing service to the customer.

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The development and application of a generic "order fulfilment" process model

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THE DEVELOPMENT AND APPLICATION OF A GENERIC "ORDER FULFILMENT" PROCESS MODEL.

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Abstract

The objective of this paper is to describe how generic process models can be used as a technique within an approach to Business Process Re-engineering that will encourage companies and participants carrying out BPR projects to take a business process perspective. The definition of core processes within organisations is identified as common practice in BPR projects. The paper proposes the development and validation of a set of generic process models to provide a process framework and intervention tool for BPR projects within Small and Medium Sized Manufacturing enterprises.

The development and validation of a generic process model representing the "order fulfilment" process of a manufacturing company is used as an example. IDEFo is used to develop the model. A method of using the generic process models as intervention tools is outlined and its advantages are described.

1. Introduction

> "If you want to understand the way work gets done, to improve the way work gets done, and to manage the way work gets done, processes should be the focus of your attention and actions. Viewing issues from a process perspective often reveals a need to make radical changes in goals, in the design of business systems and the management practices." Rummler & Brache (1990)

Rummler and Brache describe the essence of Business Process Re-engineering (BPR) i.e. viewing the issues in an organisation from a business process perspective and changing the design of business systems and management practices.

In recent surveys between 65% and 77% of respondents were carrying out or considering Business Process Re-engineering (BPR) projects. The popularity of BPR suggested by these figures is backed up by an abundance of literature, seminars, conferences and software tools that have emerged over the past few years.

In their survey (Skinner and Pearson 1993), Highams Systems Services Group Ltd , found that the respondents to the survey were implementing BPR projects for a number of reasons. The list of reasons given included "the need for continuous improvement", "increased customer expectations", "increased competition" and "changing market needs". The benefits that these companies hoped to achieve were again various, "increased customer focus", "improved profitability" and "improved corporate flexibility" all featured high on the list of benefits.

A Business Intelligence survey found that their respondents had mixed experiences of using BPR, in fact, "few have succeeded in transforming their total operations" (Harvey 1994). Business Intelligence refer to a number of possible reasons for the mixed experiences including weaknesses at any stage of the methodology resulting in partial or complete failure, corporate cultural barriers and lack of a sound business strategy.

The objective of this paper is to describe how generic process models can be used as a technique within an approach to BPR that will encourage companies and participants carrying out BPR projects to take a business process perspective. The authors believe that the issue of how to encourage individuals at all levels within a company to think in terms of business processes is critical to the success of a BPR project. This is reinforced by Rummler and Brache who have found that;

> "When we ask a manager to draw a picture of his or her business (be it an entire company, a business unit or department), we typically get something that looks like the traditional organisation chart." (Rummler and Brache 1990)

2. Definition of Business Processes

In the majority of documented BPR methodologies, including those developed by Coopers & Lybrand (Johansson et al 1993), IBM (Kane 1986), British Telecom (Harvey 1994), Xerox and Lucas (Parnaby 1993), one of the initial activities is to identify the core business processes. In identifying the core processes the participants in the BPR project are defining boundaries within their organisation using a process perspective.

It is useful to compare a business process to a system. A system embodies four basic ideas; which paraphrased from Checkland (1981) are emergent properties, a hierarchical structure, communication between entities within the system and a process of control. A business process embodies the same four basic ideas. For example products and information are emergent properties of a business process since they are a result of the overall interaction of the entities within the process; a business process can be decomposed into a hierarchy of sub-processes; there are flows of information and physical entities within a business process connecting the entities and the process is managed.

The basic idea of a hierarchy of processes is important when considering generic processes for an industry type and the core processes within a company. The hierarchy of processes provides the framework within which the analysis and redesign will take place. The number of core processes within a company is very much dependent on the level of abstraction at which the organisation decides the core process definition will be meaningful. Business Intelligence's report (Harvey 1994) provides a table of the core process taxonomies of a number of consultants, the numbers ranging from 7 to 20 core processes.

Examples of breaking down businesses into varying numbers of processes include Arthur Andersen (200) and Xerox Nordic (48). The difference in numbers of processes can be explained by the level of analysis, the lower number being more abstract. Other companies where the definition of core processes was evident and was being used at senior management level in the initial stages of a BPR project include IBM which is currently organising its world-wide operations around ten generic internal and external customer facing processes and Lucas Engineering and Systems Ltd. who have developed a model containing 16 generic processes. There are further examples of core process definition by companies in both Davenport (1993) and the Business Intelligence report (Harvey 1994) on BPR and many case studies in journal articles (Shapiro et al 1992, Davenport and Snort 1990).

The prospect of managing businesses in a process organisation may lead to the evolution of standard processes, in the same way that a roughly standardised set of functional divisions (manufacturing, design, sales and marketing, finance, personnel, etc.) developed.

The definition of core processes has required extensive investment by the multi-national organisations discussed above. The purpose of developing the generic process models described in this paper is to provide small and medium-sized manufacturing enterprises with a similar framework without requiring the use of their limited resources. The generic process models described provide a framework and the detail of the generic process models provides the ability for the models to be used as an intervention tools in a BPR approach .

3. The development and validation of the generic "order fulfilment" process model

3.1. The level of analysis

The first objective is to establish the level of analysis or "bound" the model. For the generic model to be of any use it must contain elements which are at a level of abstraction that allows meaningful discussion. Breaking a major business process into 5-10 generic activities and flows would not provide a catalyst for comparison with a company's existing process. Conversely the generic model should not be at a level of abstraction where much of the model is irrelevant to any particular company.

For a generic model to act as an intervention tool to encourage participants in a BPR project to take a process perspective and work with the model as a framework for improvement, it must model a process that is key to the success of the business. The generic process model described in this paper is a model of the "order fulfilment" process within a manufacturing company. The model has been developed in discussions with a number of manufacturing companies varying in size from Times 1000 companies to Small and Medium Manufacturing Enterprises (SMEs) with under 500 employees.

The generic process model of the "order fulfilment" process will cover all four types of manufacturing companies defined by Wortmann (1990); Make-to-stock, Assemble-to-order, Make-to-order and Engineer-to-order. During discussions with companies it was evident that different companies place different emphasis on parts of the "order fulfilment" process. For example a local company that can be classified as engineer-to-order places considerable emphasis on the preliminary stages of the order fulfilment process where the company works closely with the customer to specify the product and plan the manufacture of the product. Another local company that can be classified as make-to-stock considers the activities immediately before shipping to be of particular importance.

3.2. The Modelling Technique

The generic model of the "order fulfilment" process has been developed using IDEFo (CAM-I 1980). IDEFo is widely used in the manufacturing sector for modelling processes. IDEFo comprises:

- •A set of methods that assist in understanding a complex subject;
- •A graphical language for communicating that understanding;
- •A set of management and human-factor considerations for guiding and controlling the use of the technique.

IDEFo uses top-down decomposition to break-up complex topics into small pieces which can be more readily understood. An IDEFo model is an ordered collection of diagrams. The diagrams are related in a precise manner to form a coherent model of the subject. The number of diagrams in a model is determined by the breadth and depth of analysis required for the purpose of that particular model. At all times the relationship of any part of the whole remains graphically visible.

In summary IDEFo provides the ability to show what is being done within a process, what connects the activities and what constrains activities. It uses a structured set of guidelines based around hierarchical decomposition, with excellent guidance on abstraction at higher levels. If used well this ensures good communication and a systemic perspective.

3.3. Information used to develop the generic model

The information used to develop the generic process model has been extracted and assimilated from a number of sources. The activities that are carried out within the "order fulfilment" process were adapted from a generic task model developed by Childe (1991). Childe's task model was based on the proposition that there are a key set of tasks or activities which are consistent throughout manufacturing companies (all manufacturing companies order materials, take orders from customers etc.). The task model does not show any information or physical flows and hence it does not show how the activities within a manufacturing company may be integrated horizontally to produce an output. However it did provide a validated model of activities from which to develop a generic process model of the "order fulfilment" process.

The physical and information flows that integrate the activities to form the "order fulfilment" process were identified by using IDEFo models of manufacturing companies that had been produced by the authors in the course of their research work. Information was also distilled from other models produced in a number of different modelling techniques, from literature and from the experiences of the authors while working with manufacturing companies.

3.4. Validation of the generic process model

The validation of the generic process model is on-going as more knowledge is gained through using the model within manufacturing companies. Validation includes the criticism and comment by academic colleagues, a comparison by third parties to their own generic models of the "order fulfilment" process and experience gained by applying the generic process model as an intervention tool within manufacturing companies interested in BPR.

The generic process model of the "order fulfilment" process currently includes over 110 activities integrated by the flows of physical and information entities. Fig 1. shows the second highest level of abstraction of the "order fulfilment" process. The model extends to 5 lower levels of activities and flows. The complete model also includes a glossary of terms.

4. The application of generic process models

In the introduction the critical issue of getting employees to think in terms of business processes was identified. The generic process models are intended to be used as an intervention tool to encourage the participants of a BPR project within a manufacturing company to take a business process perspective. The participants in a BPR project would generally be individuals from the functions who currently perform activities within the process guided the objectives set by senior management.

In the initial stages of the BPR project following the identification of a core process to be redesigned, the participants would be presented with the generic process model and glossary of terms and asked to compare the generic process model against the process within the company that the model is intended to represent. In carrying out a comparison it encourages the participants to;

1.Take a business process perspective as the generic model provides an existing process framework.

2.Develop a consensus view of their own company's process by debating the differences between the generic model and each participants perceive view of the company's process.

3.Identify and change the generic model to represent their company's process.

4.Identify immediate changes that could be made to the company's process as differences between the model and reality are found.

5.Consider the systemic relationship of all parts of the process as IDEF0 provides a structured medium where inconsistencies in the changed model can be identified easily.

In comparison with current BPR approaches where the participants are encouraged to develop a process model of the existing business process, it reduces the danger of participants reverting to tradition functional thinking by providing a process focused framework. It also provides greater momentum to the project than a "blank sheet of paper" and the generic process model is non-political having being produced externally. The non-political nature of the generic process model should enable participants to more freely criticise the generic model and in doing so generate debate and understanding amongst the group.

5. Conclusion

The objective of the paper was to describe the development of generic process models and their application within small and medium sized manufacturing enterprises. A generic process model of the "order fulfilment" process was chosen as an example following considerable interest expressed by companies visited during the research project.

The definition of core processes is dependent on the level of abstraction that the organisation finds meaningful. There has been substantial investment by many multi-nationals in defining core processes within their organisations. The identification of an "order fulfilment" process is a commonly defined across many different sectors of industry. A set of generic process models of core processes within manufacturing companies would provide a framework to encourage a process perspective in companies less able to invest resources in the definition of core processes and could be used as an intervention tool.

The generic process model was developed using IDEF0. IDEF0 provided structured approach, hierarchical decomposition and medium to enable easy of communication of the model.

The application of generic process models in SMEs as part of a BPR project encourages a process perspective to be taken by participants, provides an additional momentum to the project and encourages debate and understanding of the existing process within the company.

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The generic process model was developed using DESIGN/IDEF supplied by IDEFine Ltd.

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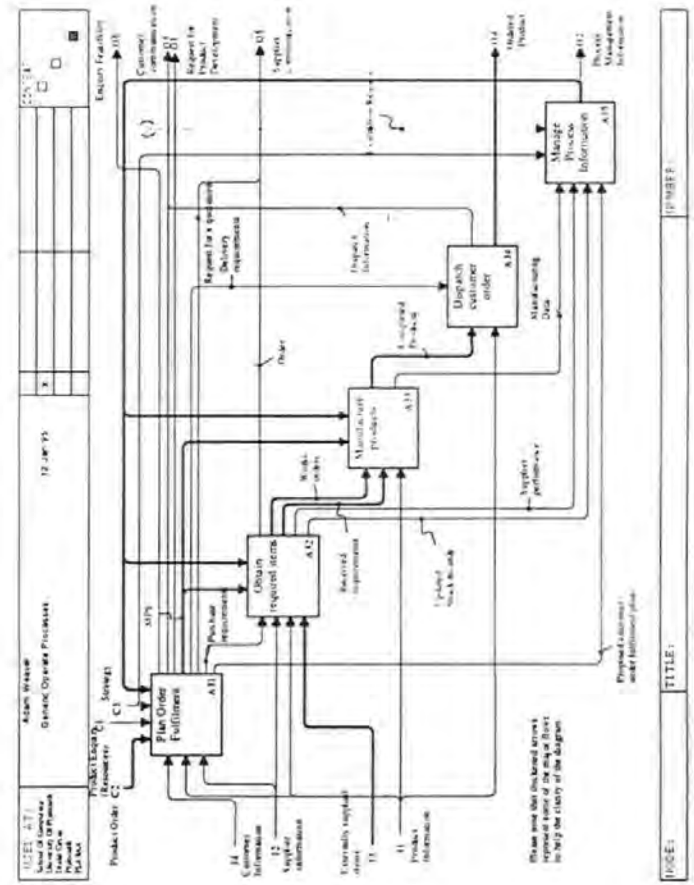

Figure 1. IDEFo Diagram of the 2nd Level of abstraction of the Generic "Order Fulfilment" Process

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A MODEL OF THE ORDER FLOW PROCESS FOR IMPLEMENTING BUSINESS PROCESS RE-ENGINEERING

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Abstract
The objective of this paper is to describe how generic process models can be used within an approach to Business Process Re-engineering (BPR) that will encourage companies and participants carrying out BPR projects to take a business process perspective.

Business Process Model
The first requirement for the development of standard business process models was the establishment of a high level framework which would allow processes identified within manufacturing companies to be grouped. It has previously been established that the CIM-OSA standards committee's sub-division of processes into "Manage", "Operate" and "Support" processes provides a useful framework[1] for categorising and analysing processes.

The work has initially focused upon the development of a set of generic "Operate" processes. Such "core" processes add value by acting directly to satisfy a customer's requirements and it is here that the greatest gains in competitiveness can be achieved[2 3 4].

The authors' have defined the core operational processes for a manufacturing business as ;

- Get Order;
- Develop Product;
- Fulfil Order;
- Support Product.

Linking the "Operate" processes
In order to develop a set of generic "Operate" processes for a manufacturing company which designs and manufactures products, it is important to understand how such processes interact. The extent of interaction between the four "Operate" processes is related amongst other factors to the amount of new knowledge the company must absorb in order to fulfil a customer's requirements.

Culverhouse[5] proposes a model for assessing the amount of new knowledge involved in a product development project. He defines four "design paths" which may be followed by a company between the arrival of a customer order and the manufacture of the product. These are: Repeat Design, Variant Design, Innovative Design and Strategic Design. Culverhouse's model categorises designs according to the amount of change required in the production processes and according to the amount of new technical knowledge design engineers must assimilate.

For example, a Repeat Design requires the assimilation of little or no new knowledge either of component or of manufacturing process technology and there is therefore no value added by the "Develop Product" process. In this case, the interaction between the four "Operate" processes will tend to be confined to the "Get Order" and "Fulfil Order" processes.

Fulfil Order
The fulfil order process is a complex business process containing many elements we have defined it as follows;
*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 result in the fulfilment of the external customer order or enquiry. The process constantly seeks to fulfil customer requirements whilst balancing stakeholder requirements.*
The authors' have developed a generic model which includes over 110 activities integrated by the flows of physical and information entities. The model extends to 5 lower levels of activities and flows each showing the detail of the activities of the level above. (It is available from the authors' by e-mail at *ADAMW@soc.plym.ac.uk)*. A copy of the model will be presented at the conference.

The information that triggers the process is either a product enquiry or a product order (C3, strategy, is the overall controlling factor for the process). An order (C2) proceeds through the sub-processes until it is dispatched as ordered product (O4). An enquiry enters the process (C1) and leaves the sub-processes as either customer communication (O3) or a request for product development (O1).

The terms used in the model are as generic as possible, for example an "enquiry feasibility report" could represent a verbal "yes" from the Production Manager to the Salesman or a detailed analysis of the capacity requirements, delivery date feasibility and additional capital costs for investment in new tooling presented at a board-level meeting

The five primary activities represented by the generic model are as follows
Plan Order Fulfilment .
This activity establishes how the company is going to fulfil the customer's requirements. To accomplish this activity Product information (Engineering Drawings and Process Plans), Process Management Information (Resource and Capacity information), Customer Information and Business strategies are all required and the output of the activity is Planning information and Purchase requirements.

Obtain Required Items

This activity represents all activities that are involved in acquiring goods and services internally and externally to fulfil a customer's order. Planning information controls this activity and Product, Supplier, Process Management Information are used. There is also the flow of physical items from suppliers into this activity. The outputs of this activity are orders to suppliers, and to the next activity, works orders and physical flows of externally obtained items.

Manufacture Products

This activity represents the production activities together with the low-level scheduling on the shop floor, progressing of work through the factory and monitoring performance. This activity is controlled by schedules and works orders. It uses Product, Process Management Information (Resources and capacities) and transforms physical flows of materials into finished products.

Dispatch Customer Order

This activity delivers the finished products to the customer. This activity is controlled by delivery requirements and transforms physicals flows of completed products into collections of products to meet a customers requirements.

Manage Process Information

This activity evaluates supplier performance, manufacturing data, proposed plans from other activities to give information on process performance and up to date planning and capacity information to ensure the process meets the objectives of the company.

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CURRENT ISSUES IN
BUSINESS PROCESS RE-ENGINEERING

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ABSTRACT
This paper presents the results of empirical research into issues faced by 25 companies undertaking Business Process Re-engineering (BPR) programmes. The research team sought to understand the BPR phenomenon through visits to 21 leading practitioners and four in-depth case studies. The research indicated that six key issues affect the way in which BPR programmes are carried out, namely the *nature of the change* proposed (radical or incremental), the *performance measures* applied during the programme, the impact of *Information Technology*, the impact of *human factors*, the presence or absence of a *process architecture* and the link between *BPR and strategy*.

The outcome of this research has implications both for practitioners and researchers. Where practitioners are concerned, we believe that the conventional, step-by-step BPR methodology should be amended to more fully take into account these six issues. For researchers we believe that there is a need for substantial research into good practice in BPR in each of the six areas.

INTRODUCTION
Over the past five years, BPR has emerged as a popular approach used by organisations seeking improvements in their business performance. Interest in BPR was sparked by Hammer who wrote a seminal article entitled "Re-engineering work: Don't Automate, Obliterate" [1]. While there have been numerous BPR projects undertaken since then, relatively little empirical research has been undertaken in this field. Surveys such as those conducted by the Highams Group [2] and Business Intelligence [3], for example, focus only on the levels of interest in, the motivation for and the benefits to be gained from BPR. They provide no guidance regarding the key factors which need to be considered in any BPR programme.

Hall *et al* [4] have attempted to remedy this deficiency by proposing three critical determinants of successful BPR projects. These are:

- **Breadth** - whether the project is set up to improve performance across the whole business unit;
- **Depth** - the change to six fundamental organisational elements, namely organisational structure, roles and responsibilities, measurements and incentives, information technology, shared values and skills;
- **Leadership** - the extent of top management commitment.

The work reported here is similar to that undertaken by Hall *et al* in so far as it sought to identify the key issues underpinning a BPR programme. However, our work differs from their earlier research in two major ways. Firstly, in their sample of 20 projects Hall and his colleagues have concentrated on large companies, mainly located in the USA. Our results have been achieved through research undertaken in a range of companies, both large and

small, located solely within the UK. Secondly, the primary focus of the Hall paper rests with the re-engineering or change issues in BPR. Our work recognised the importance of re-engineering but was also concerned with investigating the nature of the business process itself.

IN-DEPTH STUDY OF FOUR COMPANIES
The research team has been actively involved in BPR studies for a number of years and has recently undertaken four in-depth BPR studies using the action research approach. There is strong support for the use of action research in the field of Production and Operations Management, for example by Warmington [5], Platts [6], Meredith [7] and Susman and Evered [8]. Outline descriptions of each project will now be presented.

Company A (Capital Goods Manufacturer)
Company A is a manufacturing subsidiary of a larger multi-national organisation. It has less than 500 employees on the site where the process redesign project was undertaken. The company had a traditional functional culture with a large number of middle managers. The market in which the company sells its products has dramatically changed and the company has rapidly been losing its market share. The products are made-to-order and have long lead times.

Members of the Plymouth research team were involved in a six month project to redesign the process of fulfilling spares orders. The Managing Director sought to achieve an 80% reduction in non-urgent spares lead-time quoted to customers. However, the lack of power to change areas outside the control of the Production Director hindered the redesign and ultimately limited the scale of improvement the company could have obtained. As a result, the redesign effort focused on detailed activities, all of which were under the control of the Production Director. A number of models of the redesigned process were created on paper using a large flowchart that extended around the room in which the team held its meetings.

Company B (Small Manufacturer)
Company B is a functionally organised manufacturing subsidiary of a large multi-national organisation and employs just under 200 staff. At the time of the research team's intervention, its products were predominantly made-to-stock and produced in large batches. Furthermore, it was seeking to reduce its order fulfilment lead times and to increase its customer base by selling direct to retailers as opposed to selling products mainly to wholesalers.

The focus of the project was the order fulfilment process. The Managing Director of the company initiated the project to reduce the lead time for an order by 50%, however he stressed the lack of resources to undertake any extensive investment. The redesign team was composed of the Production and Logistics Director, a representative from the University research team and representatives from other functional areas which were part of the process. The project lasted three months and the composition of the team remained constant throughout this period.

The $IDEF_0$ modelling technique was used to represent and analyse the existing process and to create the redesigned process.

Company C (Large Service Company)

Company C is a large service sector organisation and employs over 20,000 staff throughout the UK. Both the UK recession in the early 1990s and major changes to customer requirements were forcing the company to reduce costs, to offer new products and services and to focus on its core business. In response to these pressures the company has undertaken a company-wide BPR activity that began in 1993. This activity is on-going with an overall budget in excess of £20m and involves over 50 staff. Various members of the research team have acted in a support role to this project for over two years.

The redesign of Company C's business processes was undertaken by a series of full-time teams under the guidance of process owners who were senior managers of the functional units to be affected by the change. Each redesign team was composed of key personnel from within those functions which had extensive knowledge of the business process in question. The redesign teams were responsible both for analysing and redesigning the business processes.

The original objective of the project was to investigate all the business processes in turn and incrementally to improve them by removing non value-adding activities. It was later decided to adopt a more radical approach to redesigning business processes and to aim for significant lead time and cost reductions. More recently, the focus of Company C's BPR activities has changed again and is now concerned with improving service through the re-deployment of resources.

Company D (Large Manufacturer)

For the last 18 months, the research team has been undertaking a BPR project in Company D, a manufacturing subsidiary of a large multi-national organisation. The project is ongoing. The company designs and manufactures complex electro-mechanical products on a make-to-order basis and employs over 1000 staff. Recent international and national political events have significantly influenced the markets in which the company competes. The board of the company is under pressure from the main board of the parent organisation to reduce costs while improving overall performance. The redesign project was undertaken in the manufacturing part of the company under the direction of the Manufacturing Director. The project addressed the Fulfil Order process.

The redesign team is comprised of senior staff from different functional areas involved in the process and members of a manufacturing systems group within the organisation whose role is to facilitate change. The composition of the redesign team remained constant throughout the analysis and redesign stages although additional personnel were required to facilitate the implementation stage. The redesign team was not empowered to make any changes. Its brief was only to make recommendations to be presented to the process owner (Manufacturing Director) and his management team.

The company was not aiming for a radical improvement in performance. A set of performance requirements was established which addressed the areas of delivery, quality and cost. The company claimed to be willing to listen to recommendations for radical change, but since the project was strictly confined to the manufacturing area (notably excluding product design and engineering) the project inevitably assumed a more incremental character.

INTERVIEWS WITH LEADING PRACTITIONERS

In addition to these in-depth case studies, the Plymouth BPR team undertook a survey of leading commercial conferences in order to identify companies presenting case experiences of BPR. Four organisations which had undertaken successful BPR projects were selected as exemplars and asked to share their experiences. These were:

- IBM;
- Rank Xerox;
- Lucas Engineering and Systems;
- Coopers and Lybrand (BPR consultancy team).

Unstructured interviews were employed in each organisation in order to elicit a rich picture of the history of their BPR projects.

INITIAL EXPLANATORY FRAMEWORK

Analysis of the accumulated experiences of the eight companies so far described showed that, despite the variations in size (from multinationals to SMEs), complexity (Make-to-Stock to Engineer-to-order) and sectors, a set of fundamental issues was emerging which each company was having to address at some point in the life cycle of its BPR project. These issues were grouped together under five main headings, namely scope of change, performance measures, information technology, human factors and business process architecture. Each issue will now briefly be described.

1. **Scope of change** - The level of change which the company is seeking to achieve.

   In both the exemplar and case study companies, different views of the scope of change were uncovered. Each company had its own perspective on the level of change it was aiming for. For example, Companies A, B and D took an incremental approach to change, reflecting the internal scope of the change required. Company C originally took an incremental view and later realised that to make competitive gains it needed to take a much more radical look at the process objectives.

   In the exemplar companies, IBM has identified three levels of BPR: Continuous improvement, Process re-engineering and Transformation. Lucas takes a pragmatic view of change within the context of BPR. They define BPR as an act of fundamental redesign whereby every activity within the process is oriented to satisfy customer needs. Coopers and Lybrand approach BPR from the radical perspective. Their methodology looks for "Break Points" or opportunities for achieving dramatic increases in competitive advantage.

2. **Performance Measures** - The definition of the operating metrics of the process and the integration of the metrics into an overall set of company performance measures.

   Through its concentration on the customer supply chain, Xerox provides an excellent example of the way in which performance measures can be used. Xerox proposes a generic process model for manufacturing organisations which has three core processes at the highest level. At the next level these are sub-divided into a further ten processes. From a BPR perspective, however, Xerox is not concerned with anything happening at these levels since they are extremely abstract and liable to change when any company wide re-organisation takes place.

Instead, the company focuses its attention on the third level in the hierarchy where there are 48 sub-processes each of which has been agreed throughout the company. Activity Based Costing and other performance measures can be applied to each sub-process. A sophisticated computer tool is used to show the input-output chains through the existing management structure, the aim of which is to allow the management of the processes to be independent of the current divisional / country / business / strategic unit configuration.

It was clear from the information obtained from Xerox that the company regards the manner in which the 48 processes are grouped as less important than the need to identify, measure and manage the input-output relationships between them. The measures on each of these relationships are then used to benchmark across countries.

The research revealed that IBM is involved in a similar exercise. The company has a complex business process architecture of ten processes, each of which is broken down into a number of sub-processes. All sub-processes have identified process measures.

3. **Information Technology** - The role of IT in the BPR project.

None of the BPR projects in the companies investigated was driven by IT considerations. However, it was clear that consideration of IT was a major factor. For example, as a service sector organisation Company C realised from the outset the key importance of IT and that any improved processes must provide a migration path for their existing "legacy" systems. Company D was in a similar situation, having realised that its existing mainframe applications do not support its process requirements and that substantial IT development will be required. The two smaller companies, A and B, were almost totally unconcerned about the Information Technology implications of their redesign activities. Of the exemplar companies, both IBM and Lucas recognised the importance of establishing a coherent IT strategy during the initial stages of a BPR project.

4. **Human Factors** - The involvement of employees in the change programme and the implications of their involvement for the redesigned business processes.

This was an important issue for all the exemplar companies, especially in the area of teams. For example, IBM stressed the importance of changing employee behaviour in an effort to change the company's organisational culture. The company's ultimate goal was to integrate the BPR teams into the organisation. Of the case study companies, only companies C and D (and they only latterly) have begun to address the issue of changing organisation values.

5. **Business Process Architecture** - The definition of an integrated set of business processes.

Xerox, Lucas, IBM and Coopers and Lybrand had all developed extensive business process architectures comprising between 10 and 60 processes. Companies C and D had also developed their own process architectures, of which Company C's was the most comprehensive, covering all customer facing products.

WIDENING THE RESEARCH

The issues listed above emerged from an analysis of the BPR experiences of only a limited number of companies. The next task for the research team was to broaden the coverage of the research to include a larger sample of companies in an attempt to confirm our understanding of the key issues within BPR.

The companies researched were again chosen from companies presenting their BPR experiences in commercial conferences or which had appeared in the literature as the subjects of case studies. They were drawn both from the service and the manufacturing sectors and varied in size from the Western Provident Association with 500 employees to the Royal Mail with over 170,000. Additionally, an explicit attempt was made to target firms at different stages in the BPR cycle. For example, Milliken indicated that it has undertaken a series of change programmes for 15 years, whilst Nuclear Electric and British Alcan were at a much earlier stage of their BPR programmes. The companies visited during this phase were:

British Alcan	Milliken
Oracle	Rover
Royal Mail	Woolwich Building Society
Barclays	Triplex
Western Provident Association (WPA)	National and Provincial (N&P)
Nuclear Electric	Leicester Royal Infirmary
Lloyds Bank	IBM Customer Service Division
D2D (previously ICL Kidsgrove)	IBM Research and Development
Nat West Bank	

The research was conducted through a series of interviews either with an individual or, more commonly, with a team which had overall responsibility for the BPR project within the organisation. The BPR team was asked to describe their project in terms of a time line beginning with an explanation of why they began the project and outlining the major stages within the project. If any of the five key issues had not been covered, the company was then asked whether those issues had been considered.

This stage of the research was conducted over a nine month period, in parallel with a wide ranging literature search. The combination of the data gathered during the initial and extended set of interviews, the four in-depth case studies and the literature search provided the research team with a valuable data set for analysis and for consideration of the usefulness of the initial explanatory framework.

RESULTS

By drawing together all of the work carried out during the extended phase of the research and with reference to the appropriate literature, more detailed evidence underlining the importance of the five key issues will now be presented. The initial issues proposed were: scope of change, performance measures, information technology, human factors and business process architecture. A sixth issue affecting the way in which BPR programmes are carried out, namely **strategy**, was also identified during this phase of the research and will be discussed here.

Scope of Change

By its very nature, BPR is about making changes to an organisation. The types of change being undertaken by companies may be placed on a continuum which has incremental change, epitomised by the Japanese continuous improvement approach, at one extreme and the radical business redesign, or "neutron bomb" approach advocated by Hammer [9], at the other. Dale [10] and Childe *et al* [11] are amongst other authors who have presented similar interpretations of such a continuum.

Our research indicates that many financial services organisations take a conservative view of the extent to which they are able to effect major change and that they tend to look for incremental improvements in such service processes as mortgage delivery and current account opening. Conversely, Oracle clearly takes a radical view and has succeeded in reducing the time taken to fulfil an order from 70 days to 10 days. Similarly, Western Provident Association is now able to change a customer's insurance details in a matter of minutes where before the same process had taken up to 6 weeks.

Many of the case studies discussed in the literature describe reductions in cost and process cycle times only where small sub-processes are concerned. It would appear from this that there is a commonly held view that a narrow scope of change helps to minimise risks. In recent literature, however, an increased emphasis has been placed upon widening the scope of change in order to improve the success of the BPR programmes. Hall *et al* [4], Watts [12], Cypress [13], Jeans [14] and Champy [15] all suggest that future BPR programmes should attempt to bring about change on a much broader front.

Our research indicates that those organisations which took a radical view of the scope of change were taking much greater risks with their profitability and even survival. However, having gained substantial benefits in terms of lead time and cost reduction, they appear to have increased the likelihood of their long-term survival.

Performance Measures

Another important part of any BPR programme is the definition of relevant operating metrics for the processes. By applying such metrics to an existing process and, afterwards, to the implemented redesigned process, organisations will be in a better position both to assess the success of the BPR project and to monitor and continuously improve the way in which the process is carried out.

The development of an integrated set of performance measures encompassing all the business processes within the organisation has been proposed by Guha *et al* [16], Jones [17], Rummler and Brache [18] and Kaplan and Murdock [19]. Without such a performance measurement regime there exists the potential for optimising one sub-process while, at the same time, sub-optimising the overall process. For example, the research indicated that Milliken used to measure order fulfilment time only from order receipt to despatch. They now recognise, however, that the customer is far more interested in the total time it takes to receive their order and Milliken has changed its order fulfilment process measure to reflect this. They now measure the entire process from the time the customer places an order to the time that order arrives at the customer's premises. In addition, far more attention is being devoted to shipping time than to in house processing time because a considerable proportion of Milliken's products are shipped by sea.

Information Technology

IT has a key role to play in BPR programmes. Davenport and Short [20], Grover *et al* [21] and Dennis *et al* [22] have all approached BPR from an IT perspective. Earl [23] suggests that the IT industry and, in particular, IT management consultants have played a significant role in promoting the technological side of BPR. However, only one of the companies we investigated had allowed its BPR efforts to be driven by IT considerations. This was a financial services company where technology is a key enabler.

Evidence was obtained from the companies visited that IT influences BPR programmes in three main areas. These are:

1. **IT as enabler:** Many of the larger companies visited had invested heavily in information technology to enable their BPR programmes. For example IBM, Xerox, D2D, and Oracle had all developed in-house software to model business processes;

2. **IT used to underpin business processes:** Most of the companies visited took the view that IT underpins their business processes and can enable the redesigned processes to meet performance objectives. Western Provident Association has moved from an extensive paper based system to one based around Document Image Processing and fourth generation languages (4GL). They are currently investing heavily in an object-oriented information system while National and Provincial (N&P) already makes extensive use of such software to support their processes. Cole *et al* [24], Housel *et al* [25] and Short and Venkatraman [26] describe successful applications of IT underpinning the business processes in Milacron, Pacific Bell and Baxter's Healthcare respectively.

3. **IT as a constraint:** The view was expressed during a number of visits that so-called "legacy" IT systems were constraining the redesign activities. Most of the financial services companies visited faced extensive problems with their legacy systems which, from a historical perspective, have been designed to support products. Such systems require customer details to be replicated across each database associated with a product (credit cards, mortgages, current accounts and insurance, for example). To re-engineer the architecture of these systems in line with a process focus would be a huge task, and many of these firms expressed an unwillingness even to consider attempting it.

Human factors

The research visits highlighted the overwhelming importance of people in any BPR programme. As one Rover manager put it: "95% of BPR is about the human factor".

The involvement of people in any change programme is usually brought about by the formation of cross functional teams which are composed of staff drawn from throughout the organisation. The re-designed business processes will almost certainly require staff to undergo role and activity changes [27].

Involvement in the change programme

The view was often expressed to the Plymouth research team that BPR projects have gained a reputation for causing large reductions in the work force and such projects are often treated with suspicion as a result. In many organisations it was recognised that, for an employee to belong to a project team would often lead to the removal of that person's previous job role.

As a consequence, many firms have found it difficult to encourage membership of BPR teams.

Nevertheless, many of the companies visited had expended considerable resources on activities aimed at establishing a culture which was open to change before undertaking the BPR programme. Rover stated, for example, that their quality improvement culture was the bedrock of their BPR efforts and indicated that a major BPR project was one of the outcomes of having spent seven years working on the quality "theme". For their part, N&P has spent six years changing organisational values and "mindset" [28] and is now concentrating on building a set of core competences. Milliken has a 20 year history of change projects aimed at gaining organisational commitments and ICL has invested the last ten years in building a quality-oriented culture. All of these major initiatives have prepared these organisations for change and for adapting to change.

However, there was also considerable evidence of what we view as less enlightened practice. While all the companies visited took a team and participatory view, there was often little evidence of anything other than a short term perspective with a number of companies having little or no concept of culture change and few (other than Rover, Milliken, Western Provident Association and N&P) seeing it as part of their remit. Few were paying serious attention to changing attitudes and values.

There have been many suggestions by various writers regarding the management of human factors within the context of a BPR programme. They include:

- Leadership from the top [4];
- Education [23];
- Communication [19];
- Middle management "buy-in" [29];
- Clear focus [30];
- Empowerment [31].

There has also a notable shift in emphasis towards human factors by Champy [15] with respect to his earlier book on BPR which was co-authored by Hammer [9].

Implications for future work processes

Many authors have pointed out implications for the role of people within the re-designed processes [16, 23, 32]. The concept of the "triage", as applied by Leicester Royal Infirmary to their patient treatment, would appear to be relevant in this context, particularly since it has helped the hospital successfully to re-engineer its arthritis clinic. The "triage" approach was developed after research conducted at the hospital indicated that 80% of arthritis patients typically suffer from a standard variant of the disease. A further 15% suffer complications that are relatively common while the final 5% have substantial complications that require extensive expertise to diagnose and treat.

Prior to the change, a patient would first have seen a consultant, blood tests would then have been made, a urine sample taken and analysed and finally X-rays would have been carried out - each of which would have been undertaken by a separate member of staff. The patient would have had to wait for the results of all these tests and then taken them back to the consultant. The consultant would then have diagnosed and prescribed a course of treatment.

The problem was that patients could have been spending three to four hours in the hospital before diagnosis and the number of patients seen at each clinic was quite small. There was substantial pressure to reduce overall waiting lists.

As a result, Leicester Royal Infirmary has created a new process for the typical patient. The patient is first dealt with by a individual staff member who has all the skills needed to take and analyse blood tests, analyse urine samples and then carry out X-rays. The patient then takes all this information to the consultant who now has all the data to hand and can quickly carry out a diagnosis. The end result is that a typical patient now spends less than one hour in the hospital. This leaves the consultant much more time to spend with non-standard cases requiring greater expertise.

One of the financial services companies which participated in the research has adopted a similar approach by automating its insurance underwriting activity so that the 80% of standard cases are dealt with by a rule based IT system. This leaves specialist actuaries free to deal with complex cases requiring specialist underwriting skills.

Business Process Architecture

While traditional approaches to organisational improvement such as Organisation and Methods (O&M) studies or Industrial Engineering (IE) may well be systematic, that is, "methodically arranged according to a plan", they are not usually systemic, that is, "of or affecting a whole system" [36] and do not focus on the whole process and the integration of work between functions. In contrast, BPR explicitly acknowledges that many business activities cut across both internal and external organisational boundaries, a view supported by Earl [23] who suggests a research agenda which might extend knowledge about the concept of a business process.

The research revealed that Lucas, IBM, Rank Xerox, Triplex, TSB and N&P had all invested considerable resources in defining a business process architecture for their organisations. This ensured that the whole of the organisation could be viewed systemically and that the BPR projects to improve the processes selected for re-engineering could be integrated. Rhodes [37] highlights the importance of integration in his generic business process model of an enterprise. Other authors who have recognised the importance of defining a business process architecture include Meyer [38], Kaplan and Murdock [19], Davenport [39] and Harvey [3].

Such use of a business process architecture to achieve a systemic approach is not always reflected in BPR programmes. For example, Company A focused only on spares orders while Company B focused on the whole of the order fulfilment process.

Strategy

As indicated earlier, the extended research identified a sixth issue which plays a key role in determining how BPR programmes are carried out, namely strategy. Strategy is concerned with the degree of alignment between the BPR project and the overall strategy of the company.

During the initial research, which resulted in the identification of five key issues, alignment between the BPR programme and the overall strategy of the company had been taken for granted. However, data gathered during visits to the wider population of companies revealed that, while alignment between the strategy and BPR programme was important, it could not be assumed to exist. Indeed, some companies were having considerable difficulty achieving such alignment. For example, the research uncovered how one company had made four attempts at a BPR programme, using different consultants, and had still not achieved senior management approval. Conversely, companies such as Rover, D2D, Milliken and N&P all have well established strategy making processes, based around policy deployment (*hoshin kanri*), which ensures alignment of process improvements with strategic need.

Policy deployment typically takes around five critical success factors and decomposes these for each set of activities, group and individual within the organisation. Performance measures are established which link up appraisals with overall strategic direction. The success of the process is often enhanced by "360° individual performance appraisal", where subordinates report on the degree to which staff have "lived organisational values" throughout the year. This process helps to ensure both the strategic alignment of major projects and a culture where values can be promulgated throughout the organisation.

The issue of alignment between the organisation's strategy and the BPR programme is one which should be addressed either before or at the start of a BPR programme. Establishing such alignment forms part of the initial stage of many BPR methodologies, including those described by such authors as Guha *et al* [16], Kaplan and Murdock [19], Harrison and Pratt [33] and Parnaby [34]. This alignment relates to the other key issues which have already been discussed in as much as it may significantly affect the scope of the change being undertaken [35], the performance measures employed [18] and the choice of process to redesign [19].

Companies A and B are good examples of the application of BPR as a non-strategic, local intervention and the improvements, whilst substantial in themselves, have made no real difference to the overall performance of either company. Other companies identified processes on the "not working requires a quick fix" principle. Processes were mapped, analysed and improved incrementally on a project by project basis. Little or no attention was paid to the overall strategic direction of the business and how this would affect the BPR project. Consequently, whilst improvements were undoubtedly made, very little substantial change to the company's cost base or level of service was achieved.

DISCUSSION AND CONCLUSIONS

The findings from this research have implications for both practitioners and the research community.

Implications for practitioners

This paper has discussed six of the main issues associated with successful implementation of BPR. These issues have been distilled from an analysis of 21 company visits and four in-depth BPR case studies. It is interesting to reflect that in an earlier analysis [41], the authors were principally concerned with published methodologies for BPR. In that previous work we had investigated methodologies from a wide range of companies including:

Coopers & Lybrand	BP	Lucas Industries plc	Baxter's Healthcare
Glaxo	BT	Digital Equipment	British Aerospace
Wang	Aetna	TSB	Kodak
James Martin & Co.	Xerox	A T Kearney	Pilkington Optronics
IBM	KPMG Peat Marwick	British Airways	Pagoda Associates

and derived from these a composite methodology which consists of five phases:

Phase 1	Identify or create corporate, manufacturing and IT strategies
Phase 2	Identify key process(es) and performance measures
Phase 3	Analyse existing process(es)
Phase 4	Redesign and implement process(es)
Phase 5	Monitor and continuously improve new process(es)

After eighteen months of further research we now believe that strict adherence to such a step-by-step approach is inappropriate and may be misleading for BPR practitioners. Even though a company may go through each phase assiduously, there remains no guarantee that it will fully consider the six issues we have now identified. Where each issue is concerned, however, conscious choices must be made which will affect the way in which the methodology is implemented. For example, the application of a process architecture acts as a structure for the identification of processes in Phase 2 of the above methodology. It also assists the analysis of these processes and acts as a catalyst in Phase 3. Thus the existence of a process architecture will profoundly affect the way the BPR project is carried out.

Similarly, an organisation planning a radical rather than an incremental change programme may focus its attention on Phase 4 (Redesign), and may not carry out any analysis of existing processes. Some organisations which participated in our research focused their BPR efforts almost exclusively on making incremental changes to product-based processes and omitted any strategic considerations. Others, such as N&P, focused on developing an infrastructure for change based around flexible working.

Implications for Researchers

In the authors' view the six issues provide a useful framework by which BPR can be researched. Five of these, namely strategy, the scope of change, performance measures, information technology and human factors are clearly enormous topics in their own right and substantial research is currently underway in each area. However, despite the considerable amount of work published about information technologies for BPR [39, 21, 22] and scope of change within BPR [1], less has been published regarding other issues within BPR. There is therefore considerable scope for further research in the following areas:

- **Strategy**: Given the current interest in capability led strategy, do processes represent a means of bringing together technological and individual routines [40] in ways which offer competitive advantage? How do we build innovation (and possibly redundancy) rather than mere efficiency into process designs?

- **Human factors**: What makes a good BPR team? How should Business Processes be managed? What are the implications for Organisational Design in a Business Process environment? How do we develop processes for organisational learning?

- **Performance Measures**: What are appropriate performance measures for processes? If we move towards Activity Based Costing what are the cost drivers associated with non value-adding support processes?

The sixth issue, namely that of process architecture for BPR, may be the most important of all and the authors believe that the solution to this problem will be found within the domain of systems theory. Work is beginning to emerge on ways to identify business processes, for example through the UK Innovative Manufacturing Initiative (IMI) research framework [42].

Some work has been undertaken to develop high level generic process models from previous research in the areas of Computer Integrated Manufacturing [43] and Enterprise Modelling [44]. A set of more detailed generic manufacturing process models [45] is currently being validated. However, development of such models has often focused on the relatively straightforward processes where activities and flows can easily be identified, and work needs to be carried out on processes such as strategy development and personnel management. Evidence from Rover suggests that processes can even be established for organisational learning. Clearly, much basic research is required in these areas. More importantly, such models need to be applied. Here, the work of the soft systems thinkers such as Checkland [46] might offer a substantial insight. Research findings in this area are sparse.

At a more mundane level, there is a substantial debate as to the merits of various process analysis techniques. This is a complex subject covering techniques such as flow charting, which can be used quickly but the results of which are difficult to turn into IT specifications, and CASE tools which are very difficult to use yet produce an excellent basis for software design and development. In all these areas we have found substantial industrial interest and a growing community of researchers. The result in the UK has been the establishment by the government of the IMI and we look forward with interest to its findings.

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