UNDERSTANDING THE EFFECTS OF E-BUSINESS ON BUSINESS PROCESSES: A SIMULATION APPROACH

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ABSTRACT

This thesis defines a new approach to the analysis of the effect of e-business on business processes, utilising simulation as evaluation tool. This research was focused on answering five research questions about the suitability of simulation in this context, the role of static modelling and generic business processes, the identification of patterns for e-business activities and how to operationalise these patterns into components in simulation software, as well as how to use these components.

Requirements for modelling of e-business processes were identified and documented. Pilot cases studies proved the potential of simulation for studying e-business processes (Feasibility).

Generic e-business activities were derived and classified from the literature and case studies in order to fill gaps identified in existent process models. Re-usable simulation components are proposed as a result of the unique combination of simulation and e-activities in order to make simulation modelling of e-business easier.

The components were tested in industrial case studies and quasi-experiments with end users for feasibility, usability and usefulness. Results show that the components' approach is feasible, that having re-usable components promotes a better analysis, (usefulness) and that it is easy to build models using the components (usability).

The theoretical novelty of this research resides in bringing together three areas of study: e-business, simulation and business processes to analyse e-business implementations. The research contributes to the knowledge of components and re-use theory in simulation by proposing a new approach to component development, operationalisation and analysis of the degree of granularity required for these components. From a practical point of view, this research provides companies with an easier and more complete way of analysing e-business processes, breaking the barrier for the use of simulation, speeding up model building of e-processes and getting a better understanding of the dynamics of e-processes.

Future work in the area will include extending the component approach to supply chains and inter-company transactions.

EXECUTIVE SUMMARY

E-business brings different ways of doing business. These new ways can be as radical as new business models or as simple as automating an existing process. However, the effects of e-business implementations are not always well understood. This thesis defines a new approach to the analysis of the effect of e-business on business processes, utilising simulation as evaluation tool.

This research was focused on answering five research questions based around the suitability of simulation in this new context, the role of static modelling and generic business processes, the identification of patterns for e-business activities and how to operationalise these patterns into components in simulation software, as well as how to use these components and their limitations. In addition to specifically answering the research questions, the overall aim of this research was to gain new understanding on constructs assisting academics and industrialists to perform e-business analysis.

The requirements for modelling of e-business processes were identified and documented. A review of modelling techniques was carried out and simulation was found to be the one that most closely fulfilled the requirements. Pilot cases studies proved the potential of simulation for studying e-business processes, tested the feasibility of the e-business simulation approach and added insights into the next research questions.

To answer question (2), current business process models were identified and tested to assess how well they represent e-business activities. It was found that existent business process models do not represent e-business activities appropriately. New generic e-business activities were derived and classified from the literature and case studies in order to fill the gaps identified in the process models.

Having established simulation as a suitable tool for e-business analysis and developed generic e-business activities, re-usable simulation components are proposed as a result of the unique combination of simulation and e-activities in order to make simulation modelling of e-business easier. In producing these components, an analysis was required to judge the level of component granularity. Evidence shows that a medium-grained level was appropriate for this type of modelling analysis.

The components were tested in industrial case studies and quasi-experiments with end users for feasibility, usability and usefulness as an aid to building simulation models in order to better understand e-business dynamics. Results show that the components' approach is feasible, that having the re-usable components encourages the use of simulation tools, especially for those users that did not have previous simulation experience -acting as an initial barrier-breaker (usefulness) - and that it is easy to build models using the components as plug-modify-and-play parts of a jigsaw -the model- (usability). The generic e-activities and components increased the model building speed and provide guidelines for modelling.

The theoretical novelty of this research resides in bringing together three areas of study: e-business, simulation and business processes to analyse e-business implementations, proving that simulation provides dynamic analysis capabilities for e-business, faithfully representing the e-process maps. It presents an evaluation of current business process frameworks in the light of e-business and the creation of e-activities to fill the gaps identified in these frameworks. The research contributes to the knowledge of components and re-use theory in simulation by proposing a new approach to component development, operationalisation and analysis of the degree of granularity required for these components.

From a practical point of view, this research provides companies with an easier and more complete way of analysing e-business processes. It gives practitioners guidelines as to what an e-process may look like and the components offer a way of breaking the barrier for the use of simulation, speeding up model building of e-processes and getting a better understanding of the dynamics of e-processes. This in turn could encourage the use of simulation as a day-to-day decision support tool.

Future work in the area will include extending the component approach to supply chains and inter-company transactions. Another specific issue to investigate is that of how to increase the use of simulation in SME's and companies that do not have the expertise or resources to have a simulation expert available.

ACKNOWLEDGEMENTS

I would like to thank my supervisors Dr. Peter Ball and Dr. Jillian MacBryde for their constant support, encouragement, intellectual stimulus and patience. Your trust in me has helped me to develop both personally and professionally in a way in which I did not expect at the outset of this research. Thanks for being more than my supervisors. It has been an honour working with you.

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Special thanks to my family, for always giving me love and encouragement, their constant support and for teaching me to aspire to better things and giving me the confidence to reach those aspirations.

Finally, I would like to thank to CONACyT 'Consejo Nacional de Ciencia y Tecnologia' – Mexico, for their financial support during this research.

GLOSSARY

A limited glossary is provided for the better comprehension of some of the concepts used in this thesis.

Term	Definition
Component	A re-usable, simulation-specific operationalisation of a template. A component can be called from a library and be used a building block for model creation.
e-business	The transformation of key business processes through the use of Internet technologies (Chaffey 2002)
e-commerce	The buying and selling of goods and services via electronic mediums such as the Internet (Bontis and De Castro 2000)
Library	A collection of components in a simulation software. The library can include only the components or the components and a brief description of their function, together with keywords to facilitate searching.
Pattern	Used to denote similar process structures present in more than one case study (e.g. an e-purchasing pattern).
Re-use	All activities aiming at reusing previously constructed artifacts within the process of (software) development (Duskink and van Karwijk 1995)
Simulation	The technique of building a model of a real or proposed system so that the behaviour of the system under specific conditions may be studied (Ball 1996)
Template	A static, non software-specific representation of a pattern. An analogy would be that a template is the conceptual model of a component. Usually represented as a static flowchart.

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Chapter 1 Introduction

The motivation of this research was born from the experience of the researcher during his MSc in Management of Competitive Manufacturing, work experience in Xerox Manufacturing and his BSc in Chemical Engineering. During these stages of development the researcher became involved in different types of simulation projects. It was in this light that a PhD in simulation seemed an attractive opportunity to expand the knowledge of simulation and to look for a new area where simulation could be applied to and to study the benefits of doing so.

At the time of starting this research, the dot-com boom was receding and the attitude of "do it online and you'll be rich" had started to disappear, giving way to a more cautious way of approaching e-business. Gone were the days where you "had" to be doing everything online or else go out of business. Gone were the days of moving towards web presence with little consideration on what processes and infrastructure were needed to respond to this new way of doing business. The need to evaluate the real benefit of investing in e-business applications started to arise. However, there were not many tools available to evaluate this real benefit and how it would affect the back-end operations of businesses.

It was then during discussions with Peter Ball and Jill MacBryde that the idea of evaluating modelling methodologies to study e-business and its effect on business processes emerged. This work is the product of the research that was launched as result of those talks.

This chapter starts analysing the point of the departure of the research. This is followed by discussion on the scope of the thesis and definition of the research aim and research objectives. Finally, the thesis structure is presented.

1.1 Point of departure

The growth of internet-based systems is clearly an increasingly significant factor for businesses (McFarlane et al. 2001). However, the manufacturing sector in the UK has the lowest rate of adoption of advanced e-business applications and also the highest percentage of companies not adopting even the most basic e-business solutions such as e-mail when compared with other sectors(Farish 2001) (See Figure 1.1). A reason could be found in the issues that worry companies when implementing e-business. Apart from security (96%), the main concern for companies when developing an e-business strategy is the re-alignment of business processes (Sweet 2001). Accordingly, the Hurwitz Group (Hurwitz Group 2000) say: "One of the most difficult, yet ultimately most rewarding, parts of an e-Business transformation centres squarely on the enterprise's ability to manage its business processes".

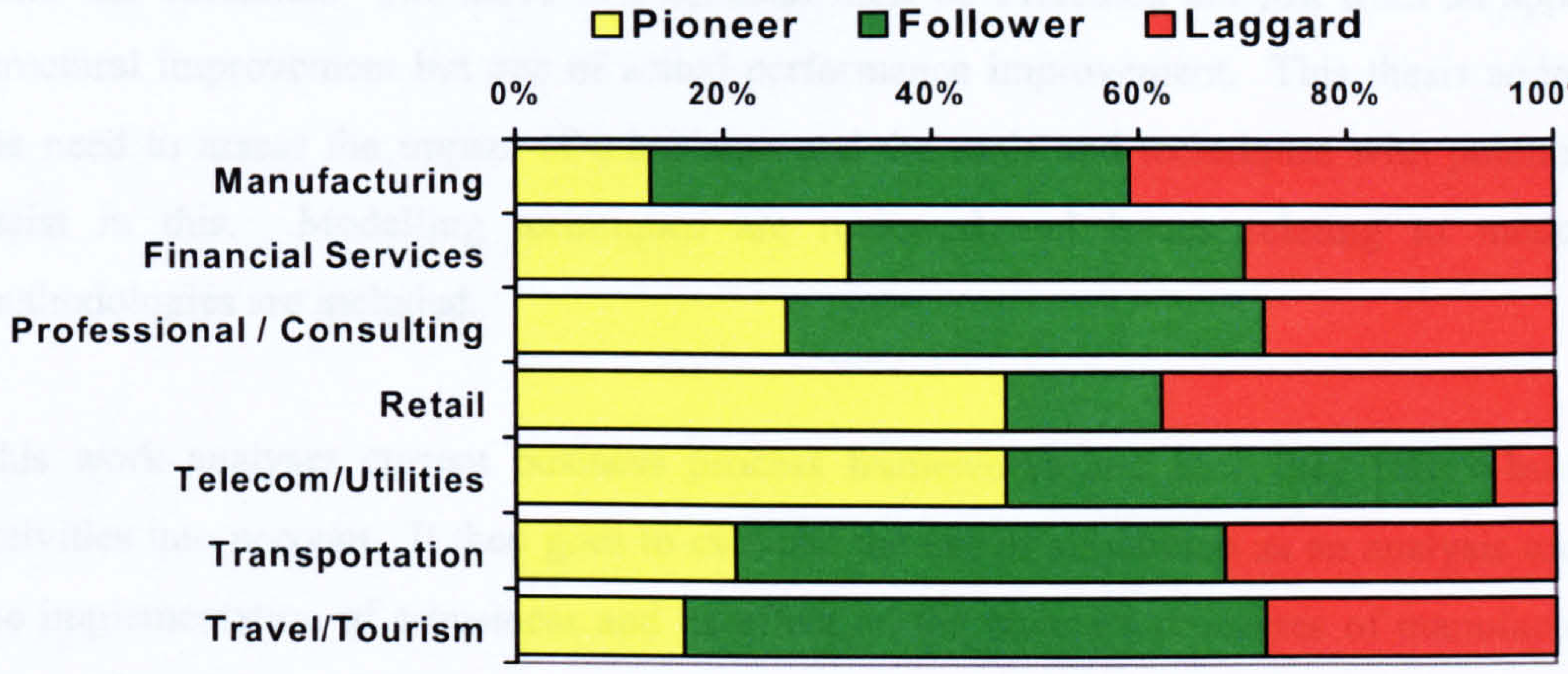


Figure 1.1 Degree of e-business involvement by industry sector in UK (Source Farish, 2001)

For those "brick-and-mortar" companies that want to take that step, guidelines are required for managing the change process and adapt their business processes to e-business process to cope with the change in demand patterns and responsiveness required.

After an extensive search in theory and practice, no evidence was found of the existence of tools that help companies understand the effects of e-business in the dynamics of their business processes. However, looking at the Business Process Modelling (BPM) field, it was found that simulation has been applied as a technique to predict the outcome of changes in the way business processes operate (Hlupic and Robinson 1998; Giaglis and Paul 1996; Greasley 2000; Tumay 1996). Furthermore, efforts were being conducted in the construction sector (Elliman and Orange 2000) to explore e-induced business process re-engineering options using simulation models. It is in the light of these findings that I decided to investigate the suitability of simulation as a tool for the analysis of the implications of e-business in the business processes of manufacturing companies.

The present research intends to analyse the necessary changes in the company's business processes in order to be able to react to an e-commerce environment. A simulation approach is proposed as an analysis technique in business process modelling to evaluate the impact of e-commerce and to select the best re-configuration of current business process to deal with this change effectively and efficiently

It is important that the improvements offered by business process change and e-business are valid and sustained. The move to e-business must be evaluated not just from an apparent structural improvement but one of actual performance improvement. This thesis addresses the need to assess the impact of e-business and the tools and techniques with potential to assist in this. Modelling techniques are reviewed and issues relating to modelling methodologies are included.

This work analyses current business process frameworks and how they take e-business activities into account. It then goes to evaluate the use of simulation as an analysis tool for the implementation of e-business and its effect on the business processes of manufacturing companies.

1.2 Aim and Objectives

The main aim of this work is then to evaluate how modelling methodologies in general and simulation in particular can be used to analyse the impact of e-business on business processes. The general objectives that derive from this aim are:

1. Study how current e-business implementations are carried out.
2. Understand which role (if any) simulation plays in the implementation.
3. Develop a way of integrating modelling and simulation for the analysis of e-business implementations.

1.3 Scope of the thesis

The scope of this work is restricted to the analysis of the effect of e-business on the operate business process (Get Order, Develop Product, Fulfil Order, and Support Product) as classified by Childe et al (1994). The initial intent was to focus on manufacturing companies, although examples of the service sector are included to test the extendibility of the approach. A number of cases are presented, all of them different instances of operate processes (apart from Develop Product, which is less transactional than the other three and hence has different requirements for e-business to support).

1.4 Thesis structure

The objective of this section is to outline the structure of the thesis by highlighting the important issues on each chapter and showing how these are related to other chapters. Figure 1.2 maps the structure of the thesis. It also shows the inputs to the different stages of research, as well as the outputs (in terms of published work) of each phase.

Chapter 1 details the motivations, point of departure, aim and objectives and structure of the thesis. This chapter intends to introduce the reader to the topic and explain why this topic was chosen for the research.

Chapter 2 presents an analysis of the literature in three main areas: e-business, business process management and simulation. The chapter provides an in-depth analysis of current business process simulation applications and derives a set of requirements for modelling e-business. From this review, gaps in current knowledge are identified and research questions formulated.

Chapter 3 deals with methodology and the methodological choices that were made during this work. The chapter includes the selection of an overarching philosophical paradigm, as well a research strategies, methods and techniques for the different stages of the work. The chapter includes the definition of the research quality criteria that will be used to evaluate this research. Chapter 4 presents a pilot case study in which the feasibility of the approach was tested and insights gained to inform the continuation of the research.

Chapter 5 goes on to present the main analysis of current frameworks, identifying the gaps that exist in current models and proposing e-business templates to fill these gaps. The chapter continues by identifying composition in simulation as a possible way of operationalising these templates, as well as the development of e-business simulation components from primary and secondary case studies. This chapter includes a more specific literature analysis in the area of simulation composition and provides the development of a novel methodology for the development of components in e-business.

Chapter 6 presents the testing of the components developed in Chapter 5. This testing is done through application in further case studies (testing for usefulness) and through quasi-experiments with final users (testing for usability).

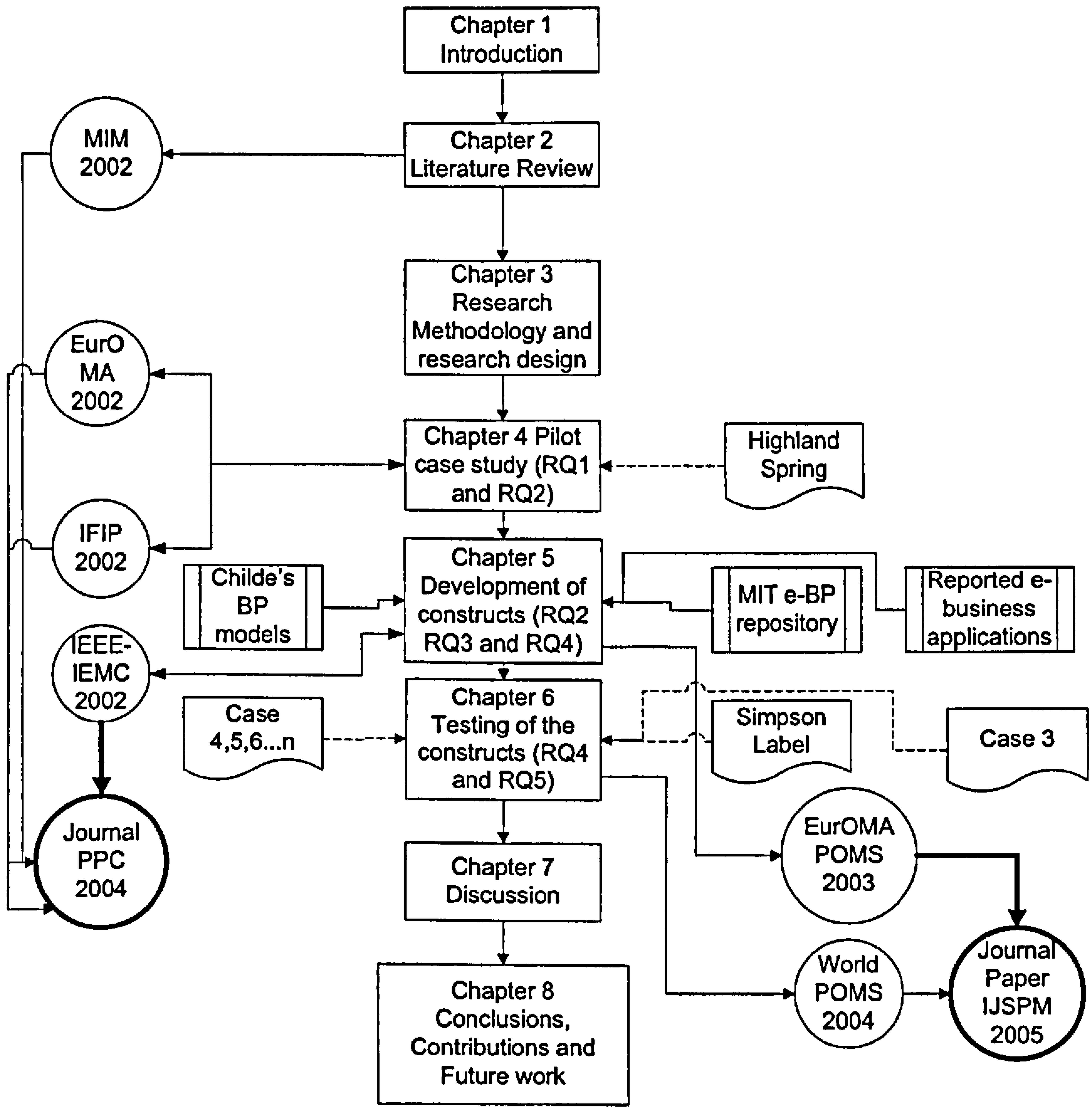


Figure 1.2 Thesis Structure and outputs.

Chapter 7 considers the discussions and lessons learned from the work and describes the evaluation of the research against the predefined research quality evaluation criteria (defined in Chapter 3). Chapter 8 presents the conclusions and summarises the contributions of this work to theory and practice. Further research that emanates from this work is outlined, as well as a retrospective analysis of the research process.

Chapter 2 Literature Review

2.1 Introduction

Undertaking a literature review is an important step in a research project. During the review "the researcher both maps and assesses the relevant intellectual territory in order to specify a research question which will further develop the knowledge base" (Tranfield et al. 2003). The literature review serves not only to give a background to the research, but also to position the research in a wider context and to show how the work relates to others.

Bruce (1994 : 218) describes the literature review process and its different functions:

> Literature reviews in the context of postgraduate study may be defined in terms of process and product. The process involves the researcher in exploring the literature to establish the *status quo*, formulate a problem or research enquiry, to defend the value of pursuing the line of enquiry established and to compare the findings and ideas of others with his or her own work. The product involves the synthesis of the work of others in a form which demonstrates the accomplishment of the exploratory process. (Bruce 1994 : 218 in ; Murray 2002).

In this work the literature review will perform these functions and lead to the development of the research within a theoretical frame.

A literature review has to be both comprehensive and focused. Comprehensive to include all relevant literature, including a wide range of subjects related to the research topic. Once a wide research has been carried out, a more focused selection of topics can be carried out. It is necessary to focus the search and analysis of relevant literature in order to avoid "getting lost" in a sea of information.

2.1.1 Scoping the literature

The literature for this research issue was selected in three broad domain areas: simulation, e-business and business processes. The areas have in themselves overlaps (e.g. business process simulation) and these are also of interest to the research. Figure 2.1 shows the areas in which the main review was carried out.

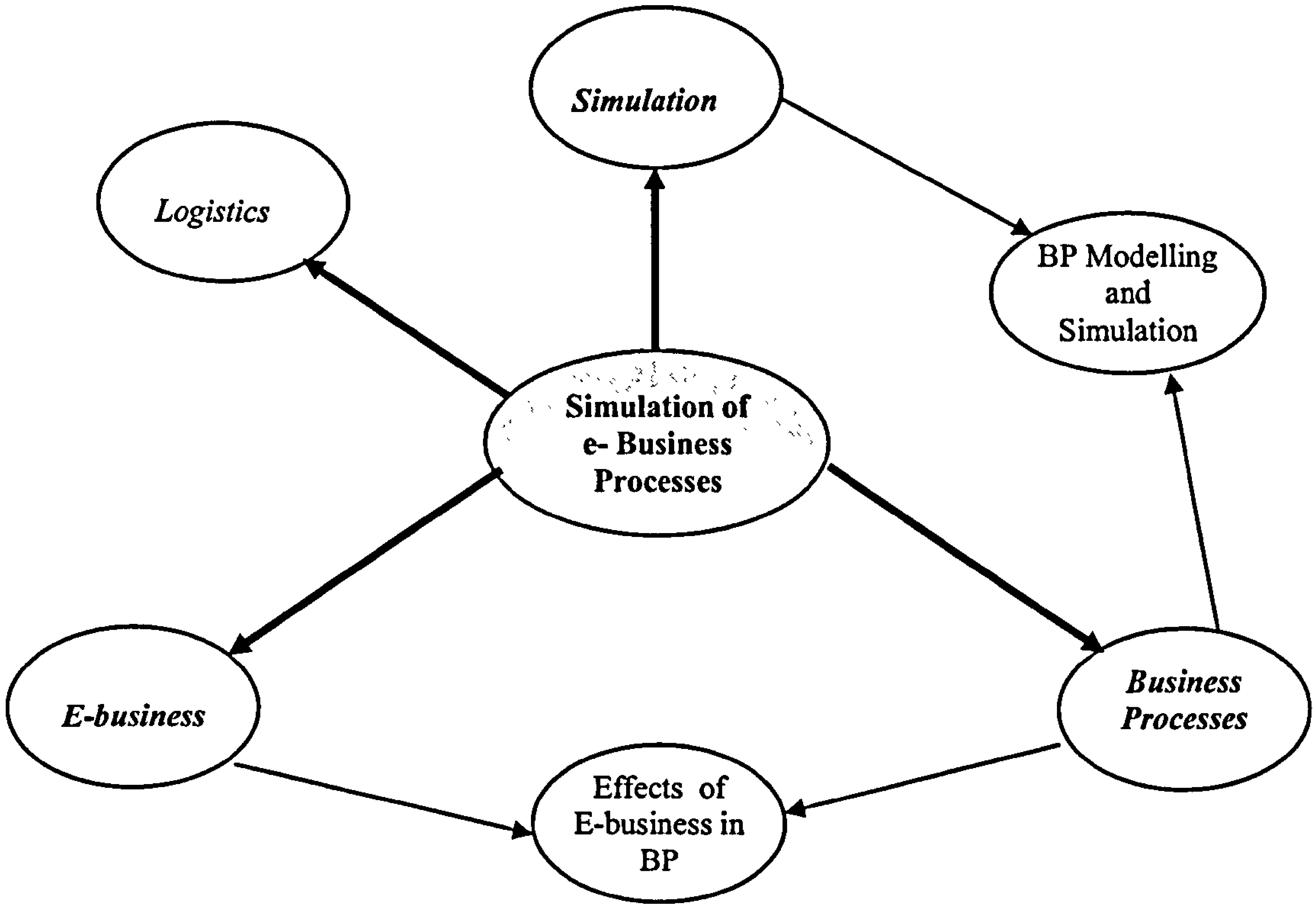
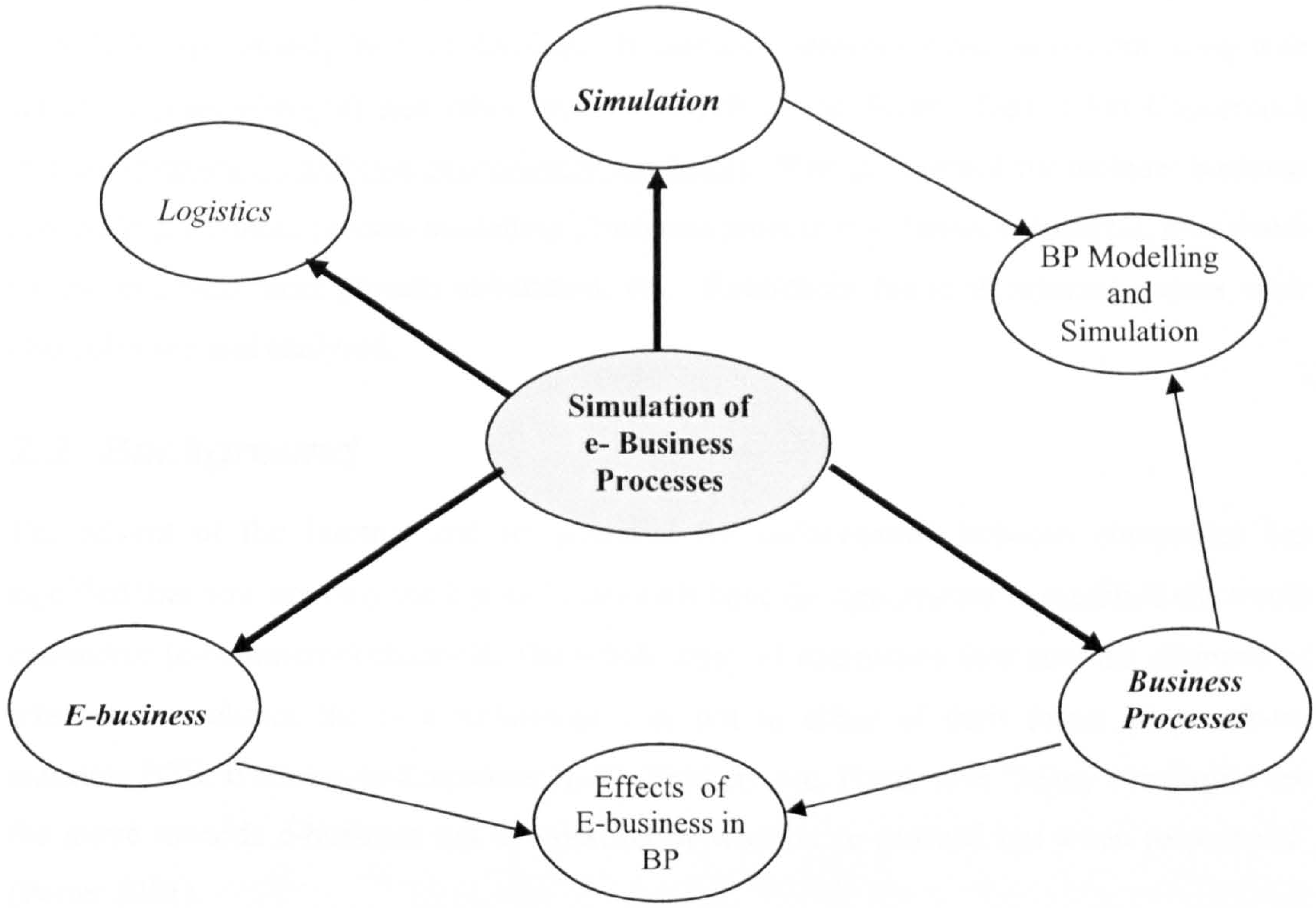


Figure 2.1 Scope of literature review

The literature review is then scoped and structured as shown below:

- Business processes. Including business process re-engineering, characteristics of business processes, business process frameworks and best practices.
- Simulation. Including uses of simulation, characteristics and applications, other modelling techniques. This area excludes approaches such as agent-based simulations, game simulation, business games simulations and military simulations.
- E-business: This area is restricted to the nature of e-business and its impact in business operations. Includes business tools supported by e-business, but not the technical aspects of programming them. Areas such as hardware for e-business, web page usability, browsing technologies, security and encryption technologies and web marketing are not included in this review.
- Logistics: This area includes only use of e-business as a tool to support logistics. Excludes themes like facility location, route optimisation and transportation.

These areas were deemed as the most relevant areas to look at after defining the aims and objectives in Chapter 1. Once the main areas of search are defined, a search was carried out using the following resources from the electronic library services at the University of



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Strathclyde: ABI/Inform, BIDS, EDINA, Elsevier Science, Emerald, Theses and Web of Knowledge (previously Web of Science). In addition, searches were carried out using web search engines (Google) and other resources such as the Winter Simulation Conference website (http://www.informs-cs.org/wscpapers.html). Strings searched for include: business process(es), business process modelling[1], business process simulation, e-business, e-business simulation, e-business process simulation, etc. References found in relevant papers were also collected and analysed.

2.2 Background

The advent of the Internet and its potential for collaboration between companies has signified that now not only the big multinationals have the opportunity to establish electronic commerce (e-commerce) channels. The whole array of enterprises face now the dilemma of whether to embrace the new technologies or not in either of their forms (Business-to-Business B2B, Business-to-Consumer B2C). Furthermore, Porter says "Many companies see the move towards e-business not as question of whether to proceed but when to proceed" (Porter 2001).

Despite the high general awareness of e-business, within the UK the manufacturing sector has the lowest rate of adoption of e-business strategies and the highest rate of "e-laggards" (Farish 2001). Interestingly business process change is seen as a pre-requisite for e-business implementation and yet many businesses have failed to derive the benefits from transformation to a business process viewpoint, in many cases companies being left in a position of competitive disadvantage. Furthermore, Sweet (2001) has identified the realignment of business processes as one of the main worries of companies when implementing e-business.

It is important that the improvements offered by business process change and e-business are valid and sustained. The move to e-business must be evaluated not just from an apparent structural improvement but one of actual performance improvement.

For those "brick-and-mortar" companies that want to take that step, guidelines are required for managing the change process and adapt their business processes to cope with the change in demand patterns and responsiveness required.

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[1] All strings were searched for in both British and American spellings (e.g. Modelling and Modeling)

The present research intends to analyse the necessary changes in the company's business processes in order to be able to react to an e-commerce environment. A simulation approach is proposed as an analysis technique in business process modelling to evaluate the impact of e-commerce and to select the best re-configuration of current business process to deal with this change effectively and efficiently.

2.2.1 The drive to adopt e-business

There are many drivers for adoption of e-business. ICT providers are promoting their systems and solutions. In addition, government-funded organizations (such as Scottish Enterprise in the UK) are promoting the use of e-business as a means to gain competitive advantage.

The growth of internet-based systems is clearly an increasingly significant factor for businesses (McFarlane et al. 2001). However, the manufacturing sector in the UK has the lowest rate of adoption of advanced e-business applications and also the highest percentage of companies not adopting even the most basic e-business solutions such as e-mail when compared with other sectors (Farish 2001). A reason could be found in the issues that worry companies when implementing e-business. Sweet (2001) reports that apart from security (96%), the main concern for companies when developing an e-business strategy is the re-alignment of business processes (Figure 2.2a). Paradoxically, Sweet describes in the same report that the simplification/re-engineering of business processes is one of the main drivers for e-business implementation. (Figure 2.2b)

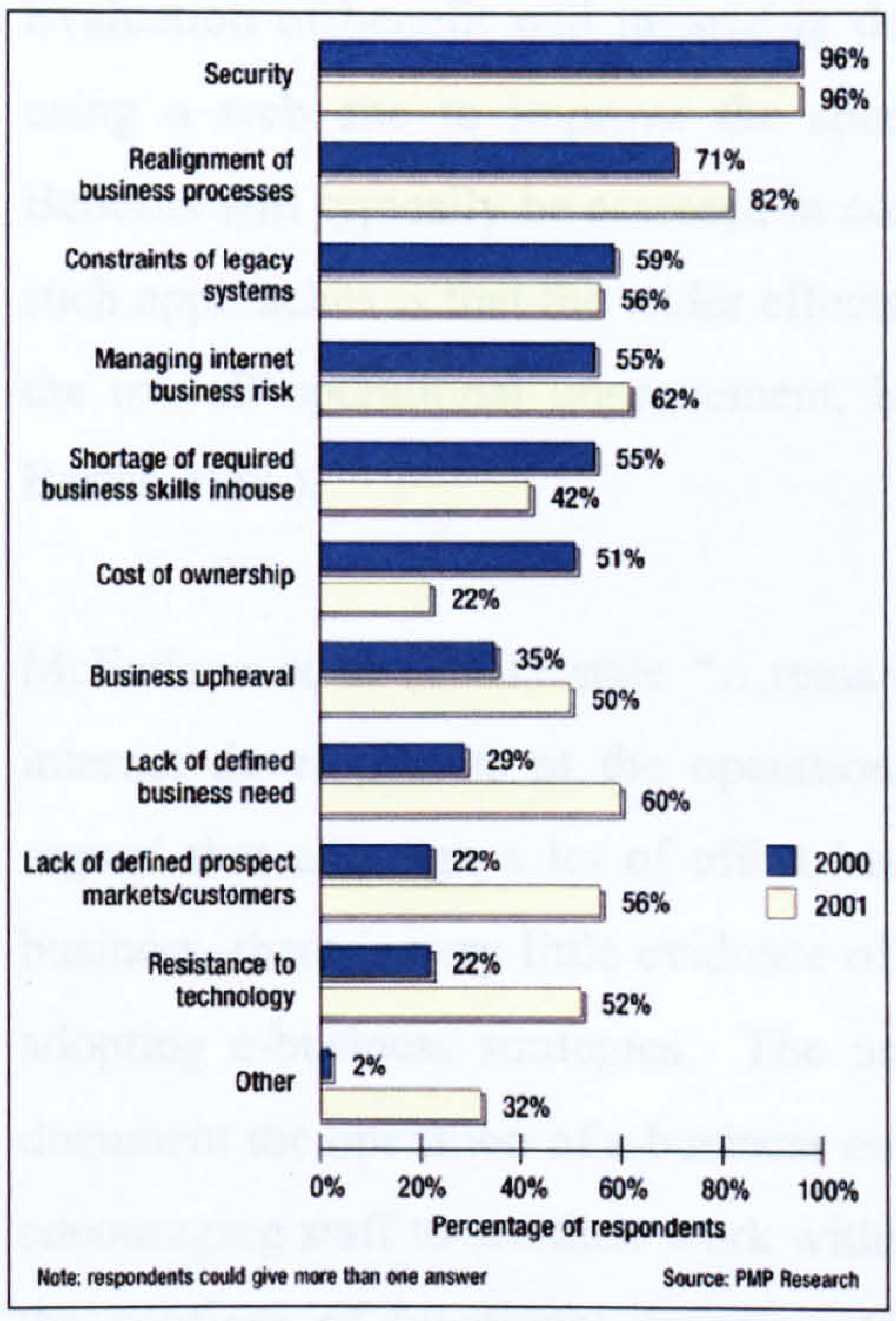


Figure 2.2a . Key Issues in e-business

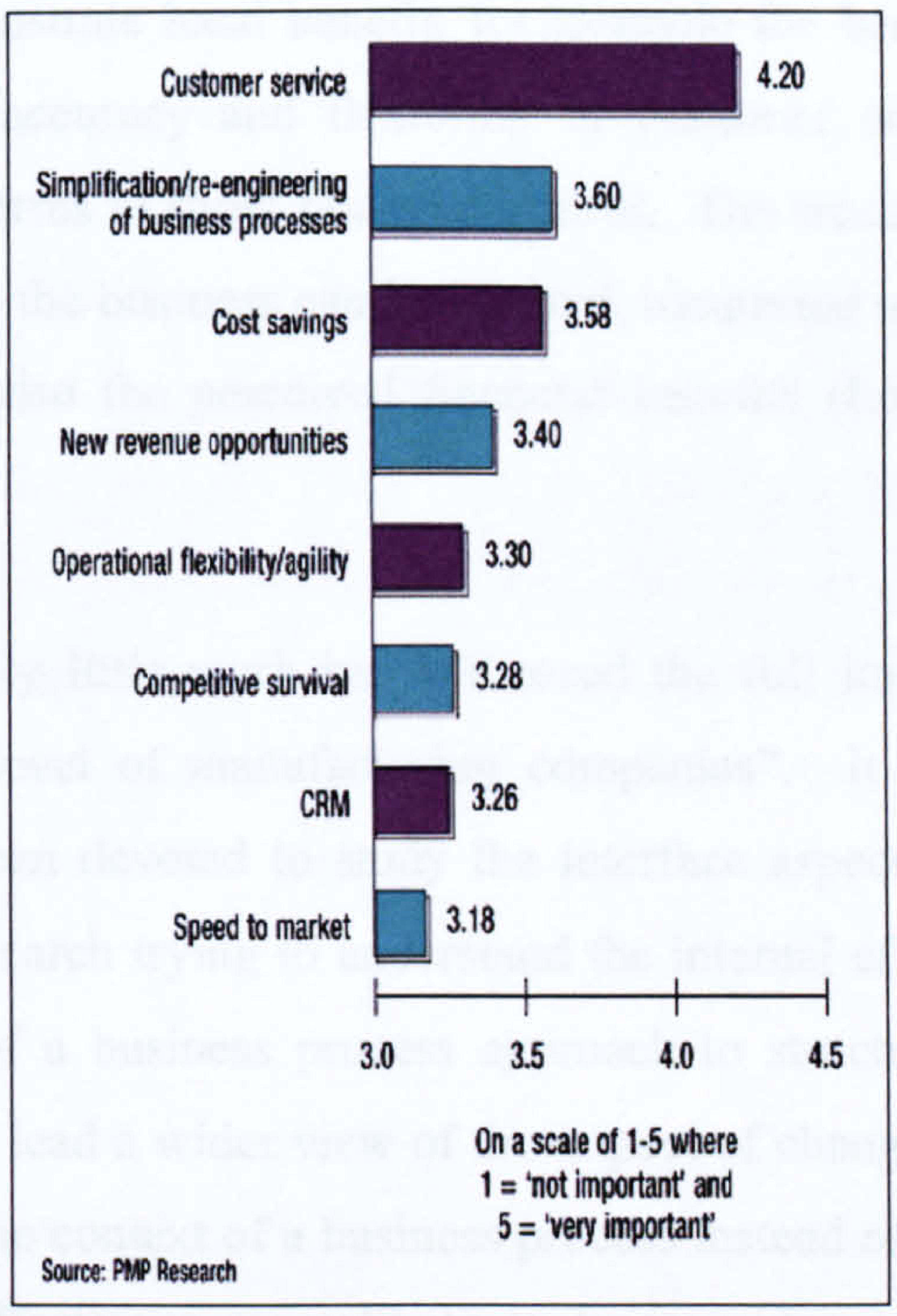


Figure 2.2b E-business Drivers..

It can be argued that one of the main deterrents of e-business adoption is the uncertainty about how this implementation will affect the business processes (internal and external) and how to manage this change. Accordingly, the Hurwitz Group (2000) says: "One of the most difficult, yet ultimately most rewarding, parts of an e-Business transformation centres squarely on the enterprise's ability to manage its business processes".

As it can be seen from the surveys above described, uncertainty of the outcome is one of the main issues when implementing change in any company, particularly when new technologies such as electronic business are integrated to this change.

2.2.2 The need to evaluate business processes.

In the course of improving business processes to improve performance, companies must assess the specific impact the changes will have on them. The temptation to use e-business tools because other businesses are adopting them should be resisted. Adoption should be based on clear operational and business benefit. Additionally, the benefit should be proven to be superior to other changes, possibly including those that do not use ICT.

Evaluation of benefit will invariably demonstrate local benefit, for example the benefit of using a web site to improve the speed, accuracy and flexibility in customer ordering. Benefits will typically be assessed in cost terms to show financial benefit. The weakness in such approaches is that the wider effects on the business can be ignored, tempering not only the overall operational improvement, but also the perceived financial benefits (Love and Barton 1996).

McFarlene et al (2001) state "...remarkably little work has addressed the full impact of internet developments at the operational level of manufacturing companies". It can be argued that although a lot of effort has been devoted to study the interface aspects of e-business, there is very little evidence of research trying to understand the internal effects of adopting e-business strategies. The use of a business process approach to structure and document the operation of a business could lead a wider view of the impact of changes. By encouraging staff to see their work within the context of a business process instead of within the confines of functional departments, effects are more likely to be considered on the upstream and downstream activities. An illustration of this is the use of the web for customer ordering, extending this to view the whole order fulfilment process and assessing whether there are any positive or negative effects on the speed, accuracy and flexibility of delivering the product or service to the customer.

Yen and Ng (2001) argue that transforming a company to take advantage of e-business necessitates business process change. However, examples of assessing the consequential impacts on the support processes and manage processes within a single company are rare. Such evaluation is important as it will illustrate the cost to the business both in terms of the overhead of additional skills, for bringing in and maintaining the new technology, as well as whether direct personnel were subsequently removed from the business or simply displaced to another area.

Several authors (Dennis et al. 2000; Greasley 2000; Giaglis and Paul 1996) have reported the application of simulation for business process redesign. The applications reported range from resource analysis in a Police Custody Suite (Greasley 2000) to a process for providing basic telephone service (Dennis et al. 2000). However, very little literature was found about the use of simulation tools in the re-design of processes to incorporate e-business capabilities to traditional enterprises.

After an extensive search in theory and practice (carried out at the beginning of this project), no evidence was found of the existence of tools that help companies understand the effects of e-business in the dynamics of their business processes. However, looking at the Business Process Modelling (BPM) field, it can be found that simulation has been applied as a technique to predict the outcome of changes in the way business processes operate (Hlupic and Robinson 1998; Giaglis and Paul 1996; Greasley 2000; Tumay 1996). Furthermore, current efforts are being conducted in the construction sector (Elliman and Orange 2000) to explore e-induced business process re-engineering options using simulation models. It is in the light of these findings that I decided to investigate the suitability of simulation as a tool for the analysis of the implications of e-business in the business processes of manufacturing companies.

The present research assesses the use of tools such as modelling and simulation to predict the possible outcome of changes to business processes when e-business (either Business-to Business B2B or Business-to-Consumer B2C) takes part in the new design of the process.

The following sections review the concepts of electronic business, business process modelling and business process simulation. Next, the research need and research questions are described, setting the scene for the research project

2.3 Electronic business (e-business) and electronic commerce (e-commerce)

When Electronic Data Interchange was introduced in the big corporations, it was the start of computer-to-computer, business-to-business transactions (Giaglis 1996). It was found that benefits such as "reduced shipment errors, increased speed and accuracy and other potential benefits" were attained (Strader et al. 1998). However, a problem with EDI technology is the disparity of data transfer protocols and the high investment in proprietary systems. (Strader et al. 1998).

As an alternative to the cumbersome EDI projects, the Internet and its open standards are a suitable (and cheaper) solution for the implementation of electronic interchange. It widens the spectrum to Business-to-Consumer (B2C) and consumer-to-consumer (C2C) interactions in addition of the existent (but not always accessible or affordable for the Small or Medium Enterprises –SMEs-) Business-to-Business (B2B).

2.3.1 Definition of Electronic Commerce and e-business

E-business and e-commerce have been defined in different ways, sometimes conflicting or incomplete. In order to set the context of the research and avoid confusion, some definitions will be presented.

For the purpose of this research, e-commerce has been defined as "the buying and selling of goods and services via electronic mediums such as the Internet" (Bontis and De Castro 2000). Although the definition is rather simplistic, it encompasses the essence of electronic commerce transactions: goods or services being interchanged using an electronic interface E-business, on the other hand, is defined as "the transformation of key business processes through the use of Internet technologies" (Chaffey 2002). There are different levels of application of electronic business, from the internal sharing of information, to the customer interface or a wider supply chain application involving a network of companies. E-business is now usually referred as being comprised of applications such as e-commerce, business intelligence (BI), customer relationship management (CRM), supply chain management (SCM) and enterprise planning (ERP) amongst other (Strauss and Frost 2001).

As can be appreciated from the previous definitions, e-business presents a more complex scenario than solely e-commerce, having the potential of affecting a greater number of internal operations in a business. The complex situations that could derive from the application of e-business must be analysed and understood before going ahead with the project. New technologies have failed because not enough analysis of the effects of such implementations was carried out before starting the project.(Larsen and Myers 1999; Hlupic and Robinson 1998).

2.3.2 Electronic market's characteristics

At the beginning of this research, electronic commerce was in its infancy and complex transaction structures remained relatively unexplored (Elliman and Orange 2000). This is particularly true when trying to define the difference between traditional processes and processes focused on e-commerce.

Fryer (Fryer 2001) identifies the characteristics of the market in an electronic commerce environment: more erratic and difficult to predict demand, last-second orders and expectation of overnight fulfilment, a removal of the slack that traditional processes have between operations and the uncertainty to back-end supply chain members about order fluctuations, reducing their responsiveness. This is particularly apparent in the Order Fulfilment processes and other processes in the operate classification. It has been stated (Porter 2001) that "the internet has created some new industries... however, its greater impact has been to enable the reconfiguration of existing industries that had been constrained by high costs for communicating, gathering information or accomplishing transactions"

One important remark to make here is that with the current problems in the completely electronic-based companies and the discovery that the business models introduced by the dot-com companies are no longer sustainable. "The winners will be those that view the Internet as a complement to, not a cannibal of, traditional ways of competing" (Porter 2001). As a consequence, it is very likely that the growth in electronic commerce will be from traditional companies that have current physical presence and that will embrace Internet as an extra channel to reach customer and suppliers.

2.4 Business Process Management

The business process view of how to deliver value to the customer is transforming the way businesses organize themselves and the way they see themselves aligning to customer needs. Companies have re-oriented from a view of functional areas such as sales and production as distinctly separate units to viewing activities in a series to add value to the customer. One value adding process is that of order fulfilment, containing all the activities to transform a customer order into a delivered product or service which includes order receipt, check availability, credit check, source materials, produce, pick, dispatch and invoice

Business process modelling has been widely researched in the last 10 years. Since Davenport and Short (1990) and Hammer (1990) first formalised the concept of Business Process Re-engineering (BPR), a whole array of studies has been performed in the area. Ranging from supporters (Hammer and Champy 1993) to sceptics (Jones 1994), covering issues such as tools (Kettinger et al. 1997), implementation and success (Grover and Kettinger 1995; Larsen and Myers 1999), people (Hammer and Stanton 1999) and IT (Larsen and Myers 1999), the amount of information is immense.

In order to avoid getting lost in a deep analysis of each one of the aforementioned issues, I will restrict my analysis to defining business processes and business process re-engineering and analysing how the trends have moved in the relatively short life of this concept.

2.4.1 Definition of Business Process

Several definitions of business processes have emerged since the start of BPR. Some of them are given below.

A Business Process is:

- "The creation of value to internal and external customers through collection of tasks and activities that take one or multiple inputs and creates a single/multiple outputs" (Fathee et al. 1998)
- "A set of causal and logical interrelated tasks performed to achieve a determined outcome" (Davenport and Short 1990) (Cited in Mellao & Pidd, 2000)
- "The logical organisation of people, materials, energy, equipment and procedures into work activities designed to produce a specified end result" (Davenport and Short 1990)(cited in Childe, 1994)
- "A set of activities that are structured and measured to produce a specified output for both internal or external customers" (Davenport 1993)
- "A set of activities that, taken together produces a result of value to a customer" (Hammer and Champy 1993)

As can be seen, there are some common elements in the definitions: Process (transformation, flow, activities), inputs, outputs (products or services) and clients (internal or external).

Paul et al (1999) state that "process based organisational analysis implies a 'systemic' view of organisations, characterised by identifiable components with complex relationships between them"

The Business Process Architecture proposed by CIM-OSA, (CIMOSA, 1989) is a useful framework to classify business processes and to analyse each one of the Business processes' different levels. Using the CIM-OSA business architecture, researchers such as Childe et al (1994) have derived generic business process models that can then be used to define the actual processes of a particular company in detail.

In order to understand this complexity, Childe et al (1994) described a set of generic business process models for manufacturing enterprises based on the CIM-OSA business process architecture (Figure 2.3).

In their framework, they identify three main classifications of business processes. ***Operate Processes*** are those which are related directly to satisfy the requirements of external customers, ***Manage Processes*** are those related with strategy and business planning and ***Support Processes*** act in support of the other two types of processes. This framework will be used to analyse the impact of electronic business in the business processes of manufacturing companies, focusing on the Operate processes and specially on the order fulfilment process.

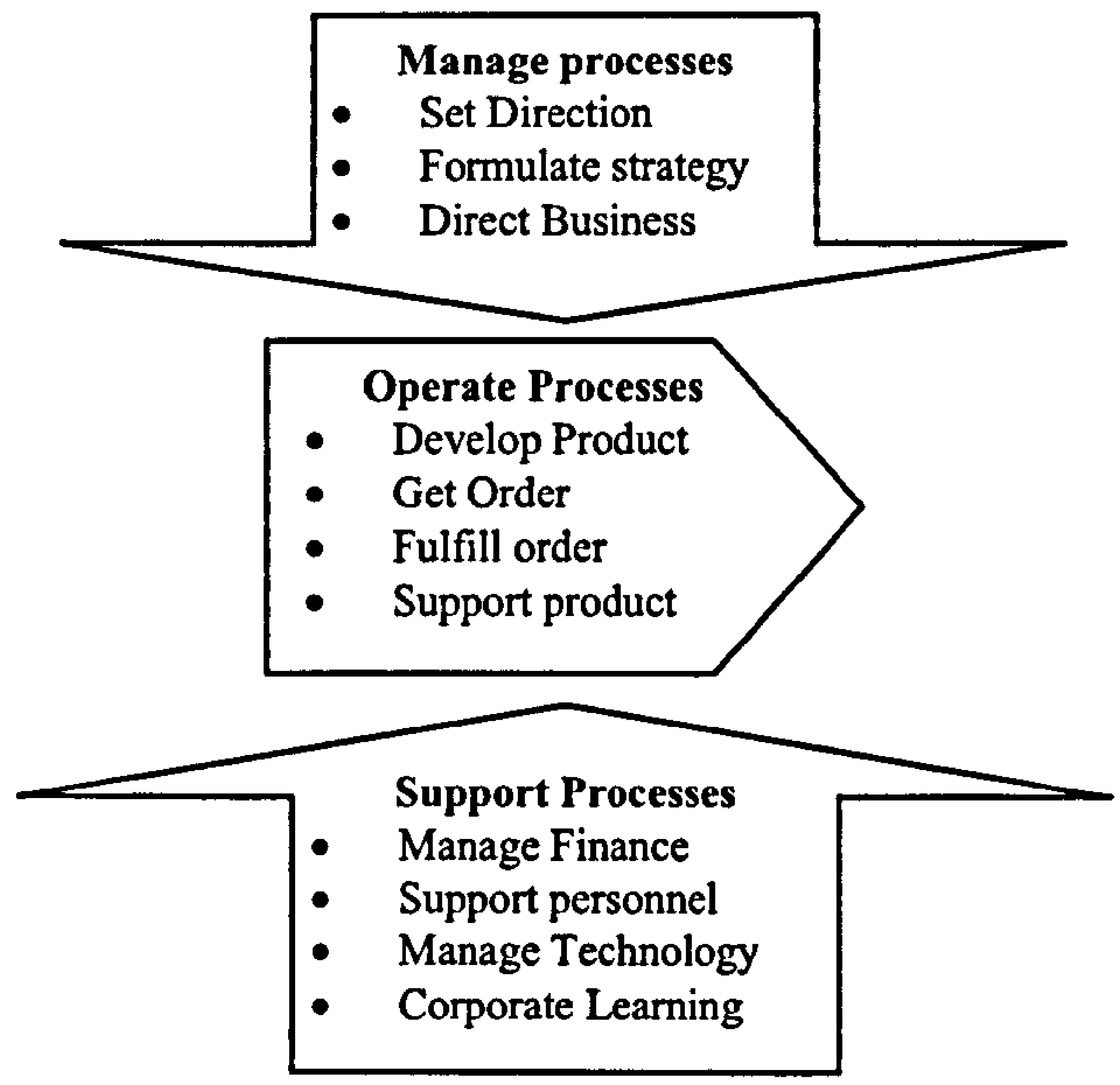


Figure 2.3. CIM-OSA business process architecture (Adapted from: Childe et al. 1996)

2.4.2 Business Process Re-engineering

Business Process Re-engineering has been defined in many ways. In order to make a similar exercise to the previous section, two definitions are presented.

- "The fundamental rethinking and radical design of business processes to achieve dramatic improvement in critical, contemporary measures of performance such as cost, quality, service and speed" (Hammer and Champy 1993)
- "Is concerned with fundamentally rethinking and redesigning business processes to obtain dramatic and sustaining improvements in quality, service, cost, lead-times, outcomes, flexibility and innovation" (Irani et al. 2000)

From the previous definitions, we can find characteristics such as radical, dramatic, fundamental rethinking. This was the way in which the pioneers of BPR considered that the changes should be done. Melao and Pidd (2000) gathered evidence that differentiates the first generation of BPR practitioners (Inspirational, Radical, broad, IT led, hard, etc) from the second (Methodological, continuous improvement, focused, IT enabled, soft, etc). This change is reflecting the consideration of softer aspects (people, strategy) over the traditional, mechanistic approach to re-engineering. As a consequence, new tools are needed to embark on a business process re-engineering project.

Despite the excitement occasioned and the rush to adopt business process approaches to improve performance, a big number of implementations failed and left companies in a position of competitive disadvantage.

According to Paul et al (1999) "many authors argue that one of the major problems that contributes to a high failure rate in many real life business change projects is a lack of tools for evaluating the effect of designed solutions before implementation". Simulation appears to be a tool that can be used to fill this gap

2.5 Business Process Simulation

2.5.1 Modelling and simulation

Modelling of business process has been a pre-requisite for Business Process Re-engineering. The initial modelling approach used was to create a static model of the process, for example flowchart diagrams, IDEF0, DFD, etc. Later, the need for a dynamic representation of the business process and the change in these processes over time was identified. This led to the use of simulation as a tool for analysing and "predicting the outcome of radical change of BPR" (Hlupic and Robinson 1998).

A simulation model is a model that mimics reality (Robinson 1994). Ball (1996) defines simulation in a more complete manner: "simulation is the technique of building a model of a real or proposed system so that the behaviour of the system under specific conditions may be studied. One of the key powers of simulation is the ability to model the behaviour of a system as time progresses".

The main benefits obtained from simulation include (Robinson 1994):

- Risk reduction,
- Greater understanding of the dynamic of the system,
- Low cost compared with real life experimentation,
- Repeatability
- Identification of dynamic and transient effects.

2.5.2 Suitability of Simulation for Business Process Modelling

Taking into account the above-mentioned characteristics, simulation has been identified as a suitable technique to help the implementation of BPR projects. A number of authors (Giaglis and Paul 1996; Paul et al. 1999; Tumay 1996; Fathee et al. 1998; Jones 1995; Irani et al. 2000; Wolsthenholme and Stevenson 1997; Melao and Pidd 2000; Strader et al. 1998;

Hlupic and Robinson 1998; Dennis et al. 2000; Greasley 2000; Kettinger et al. 1997) have reported the application of simulation to the evaluation of these alternatives, and have come to the conclusion that the main characteristics of simulation reported to be useful in business process modelling are:

- Provides quantitative information for decision-making.
- Analyses the dynamic interdependency of activities and entities within the process.
- The conduction of "What if" experiments.
- Enhancement of corporate capabilities to achieve in-depth understanding of internal process performance and correct allocation of resources. (Fathee et al. 1998)
- Simulation can be used to analyse process change or to design completely new processes and test the future behaviour of the real system
- Incorporates the stochastic nature of business processes and the random behaviour of their resources (Irani et al. 2000)
- Allows the participation of non-technical staff on BPR teams since it has a highly visual display of the process and its operation and hence be used as a training tool.
- Detailed analysis before incurring the risk of making major changes to existing processes or implementing new processes (Jones 1995).
- A greater understanding of the key drivers in resource management and increased dependability in terms of the decisions made (Dennis et al. 2000).

2.5.3 Reported applications of simulation of business processes

As can be gathered from these reports, simulation has a great potential for the analysis of business process change and as a decision support tool, increasing the confidence in the decisions taken by analysing multiple scenarios and the effects of such scenarios across the processes.

Different applications have been reported in business processes, and although they claim that it is a business process application, these applications have been mainly restricted to the operational side (i.e. manufacturing). For example, Irani et al (2000) propose a paint shop example where the configuration of the mechanical process was altered to find the best possible solution. It can be argued that this is not a proper "business process simulation" since it lacks of two of the characteristics of business process (Hammer and Champy 1993):

- Cross-functional activities
- Flow of information, not only parts.

The rationale behind this classification is that any manufacturing process could be considered "a business process" when modelling at certain level, however, it may not be interrelated with other functions or be a simulation built to improve the process in a mechanistic way, without considering the external effects of changes.

On the other hand, some authors report applications where the simulation includes the characteristics of an enterprise-wide business process. By way of illustration, Dennis et al (2000) describe the simulation of an installation service for a telecommunications company, where the interactions between customer service, control functions and field engineering are present and the information flow presents a crucial role in the efficiency of the process.

In the next higher level of modelling, Hlupic and Robinson (1998) use simulation to model an automotive company manufacturing operations in order to synchronise the operation of three plants (body, engines and assembly). The model includes order taking and co-ordination between different functions across the company, qualifying as a business process simulation.

Finally, at a higher level, Strader et al (1998) apply simulation to study the impact of information sharing across the supply chain and study the type of Demand Management Policy that best suits specific types of Supply Chains.

From the range of applications reported as business process simulation, five groups have been identified:

- **Conceptual business process simulation.** This group of authors deal mainly with the identification of the requirements for simulating business processes. In this group we find (Hlupic and Robinson 1998; Paul et al. 1999; Fathee et al. 1998; Tumay 1996; Jones 1995). They have identified the importance of hierarchical capabilities within simulation software, the need of a good process model interface (usually linked to standards like IDEF0, IDEF3 or flowcharting) and the need to have flow objects, resources, activities and routings in order to better represent business processes.

- **Manufacturing systems simulations.** This group include applications that are focused on the physical flow of entities through a series of workstations. An example application is (Irani et al. 2000). Although it is presented as a business process simulation, it lacks the flow of information and cross-functional activities that should characterise a business process.

- **Process Specific Simulations.** This group includes those authors that have undertaken the simulation of a specific process (e.g. Service provision process) within an organisation. Examples of this include (Greasley 2000; Dennis et al. 2000).

- **Enterprise-wide simulations.** This type of simulation refers to the interaction between different actors (processes) within an enterprise. Examples of this category are the Whole Business Simulator (Love and Barton 1996) and the application of simulation to understand and improve the co-ordination between three different plants of the same automotive company (Hlupic and Robinson 1998).

- **Supply-chain-wide simulations.** Related to the simulation of co-ordination between companies across the supply chain. An example is the analysis of demand management policies (Make to Stock, Make to Order, etc) and its implications for the members of the supply chain (Strader et al. 1998).

These categories are used to define the focus of the published work. The categories will overlap to a certain extent and earlier categories could be sub-sets of the latter ones. For example, it could be possible, although it has not been reported, to have detailed enterprise-wide simulations linked together to form supply-chain-wide simulations. The categories illustrate the varying capabilities of simulation and the uses to which it has been put.

As can be seen from the wide variety of applications, business process simulation is a well-established tool and can be used at any level of the enterprise with different degree of detail and level of scope. It is a particularly useful tool for the analysis of system change and provides elements of comparison between different alternatives to the design of these changes. Such a technique can be applied to study the impact of new ways of doing things; especially those that have a big impact in the ways business operate, such as e-business.

The ability of such simulation techniques to represent the detail of a business process does not necessarily preclude its use at higher levels. Whilst many discrete simulation tools have their roots in manufacturing system simulation some tools have been designed specifically for business process modelling. For example, Igrafx Process models are built as a diagrammatic business process that can then be simulated over time. The downside of using such techniques is the time, skill and cost of use. Software tools can help enormously in this to reduce the time and skill and costs can be minimized with packages such as Simul8 that retail in the office software price range.

As can be seen, not only different types of processes are analysed, but also different scope and level of detail is incorporated in each one of the reported applications. In order to create a better picture of the current application of simulation in business processes, the reported applications are mapped to each one of the top level operate processes proposed by CIMOSA (Figure 2.4)

As can be seen in this figure, most of the applications have been done in the Fulfil Order process. This is (up to certain extent) an expected outcome, since it is here that most manufacturing activities are included.
From the observation of Figure 2.4, it comes to light the fact that a more detailed mapping is necessary (in the next level of detail) in order to better understand the areas where work has been done. In the mean time, from the analysis carried out, it can be inferred that a great deal

of work has been done in the "Obtain Required Materials" and "Manufacture products" sub-processes.

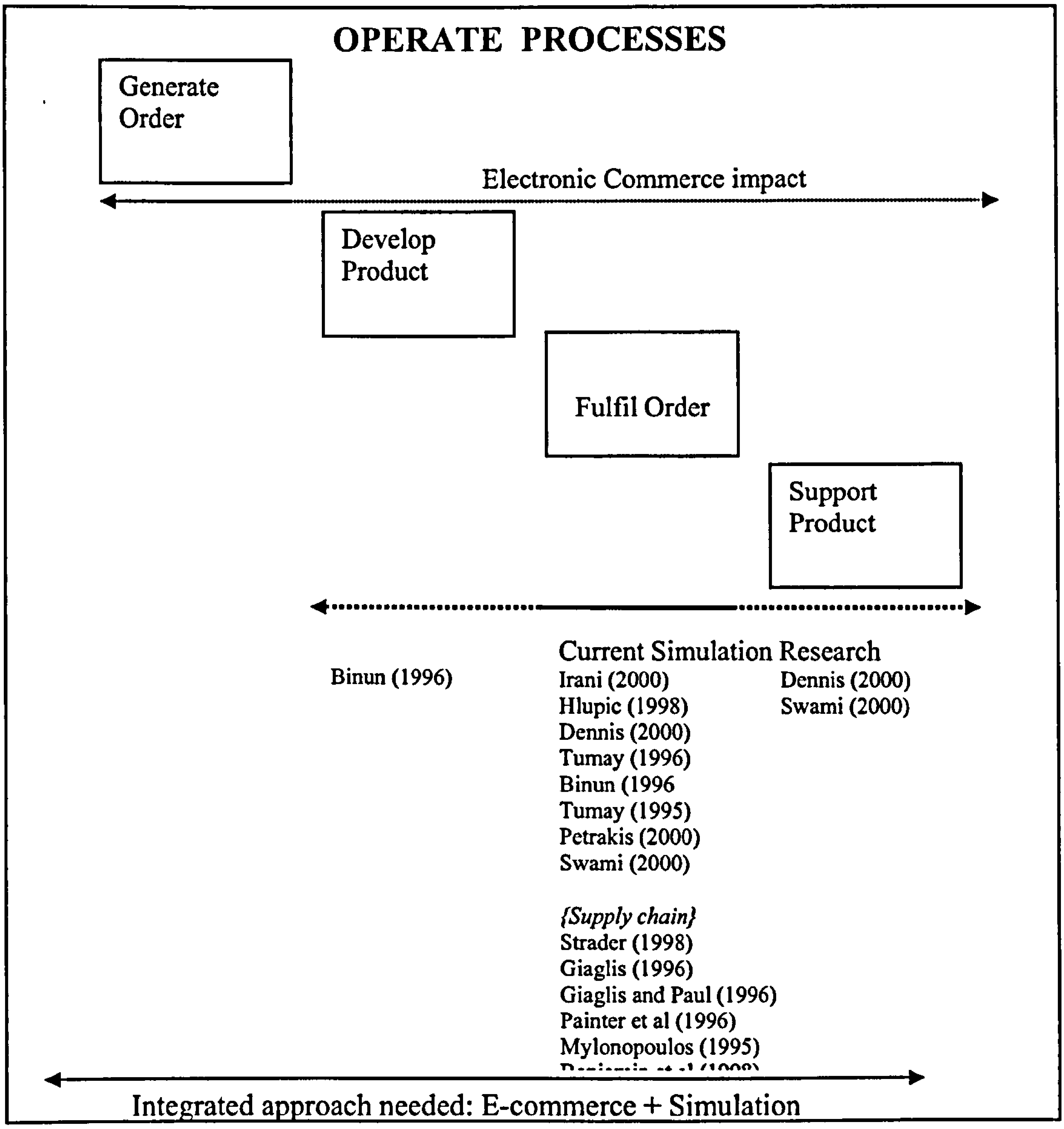


Figure 2.4 Current reported simulation applications.

It is also evident that the trend in simulation is to have a wider scope and to analyse not only the internal business processes, but to include third party companies, such as customers, suppliers and subcontractors in the supply chain.

Another emerging trend (although not mapped in Figure 2.4) is the application of Enterprise Simulation. Datar (2000), Harrol (1998), Mielke (1999) Mastaglio (1999), and Love and Barton (1996), all report on this subject, and the general consensus is that an Enterprise

Simulation is a simulation which is constructed with a top-down view of a business enterprise and which is intended to serve as decision support tool for decision makers, : "determining the impact across all the significant elements of the company's internal systems and even inclusion of necessary external elements like suppliers and customers" (Barton et al. 2001). The concept of enterprise simulation is also being extended to the analysis of supply chain designs (Tang et al. 2004).

2.6 Modelling for e-business

2.6.1 Modelling requirements for e-business

The idea that e-business will impact the dynamics of a business process, rather than its structure has been proposed (Albores et al. 2002). Accordingly, the ability to represent the passage of time, or dynamics, is an important feature of any e-business process modelling. Business processes are naturally stochastic and their resources exhibit random behaviour (Irani et al. 2000). The randomness aspect is especially important when we consider the erratic and difficult to predict nature of e-business (Fryer 2001). For example, the knock-on effects of randomness (such as failure of a quality check preventing a batch to proceed to customer) would be masked by a static analysis in which the output rate is increased to account for the quality losses.

E-business systems are increasingly used in aspects of the planning and control of the whole business. Planning and control activities have significant impact on the dynamics of the business and failure to take account of this during analysis will invariably underestimate the impact on the operation of the business when implemented. Modelling the information flows could be interpreted in its widest sense and include transactions arising from e-business systems. Transactions, such as allocations, stock movements, changes to schedules, etc. make a key contribution to the dynamics of a business. This is particularly important when the dynamic aspect is being altered as radically as in an e-business implementation.

The degree of detail represented is important, as at a high level, it is the behaviour of the activities and not their configuration that will affect performance. Tools should be able to reflect a range of modelling scopes. From the black box modelling approach to very detailed models, the tools should allow different levels of analysis and diversity in the scope to tackle the different simulation levels identified above.

From this, the need for abstract representation is derived, as is the need to represent different levels and types of information, for example: process flow, distinct objects and hierarchies. Information and physical flows should be included in e-business process modelling. One of the determining factors of what represents a true business process are the inclusion of cross-functional activities and the flow of information, not only parts (Hammer and Champy 1993). Accordingly, a modelling approach to e-business processes should be able to represent these two elements.

It is also important that the measures used in the model are the same as those used operationally to enable a true comparison of the wider operational benefits to be made (i.e. quantifying in business measures).

In summary, e-business modelling tools and techniques must capture the activities and interactions present within a business process appropriately. The random and time varying (dynamic) nature of these processes must be represented. Additionally, models must represent both the physical and information flows associated with a business process, including the transactions that arise from the business systems. These requirements are expanded below.

Abstract representation: Business processes consist of collections of activities, connected by flows of information or materials. The type of activities to be modelled may be at a very generic level, e.g. modelling the 'check stock' activity within the order fulfilment process. This could be simply modelled as a 'black box' with inputs, outputs and times associated with the activity but no detail on how it is carried out. More in-depth analysis may break the 'check stock' activity down to progressively greater degrees of detail. Indeed, Bosilj-Vuksic, et al (2001) note that "...from the process map itself not many differences can be observed ... the most important differences are evident in the way of performing these activities". The need for abstract representation draws upon the first category of 'conceptual business process simulation' where process flow, distinct objects and hierarchy are evident. In doing this modelling challenges occur such as representing decision making of employee of whether to, say, de-allocate stock from one customer order to be able to supply stock to a key account customer. Other challenges arise on how to model business systems as new customer orders entered may or may not trigger a recommended change to the manufacturer's production schedule. Whilst this may be seen as very detailed issue it demonstrates the degree to which ICT can have an impact on the dynamics of a business.

Information and physical flows: Two of the determining factors of what represents a true business process are the inclusion of cross-functional activities and the flow of information, not only parts (Hammer and Champy 1993). The modelling of physical as well as information flows therefore represents an important feature for e-business modelling. There is the need to highlight the difference on the simulation categories of 'manufacturing systems simulation', where only physical processes are modelled and 'process specific simulation' where the physical processes and the business processes are integrated. A more complete e-business model would therefore not only include the flow of information, such as orders, but the corresponding flow of product for that order. At a detailed level, this could be the representation of stock records within a business system as well as the physical stock in a warehouse. To model only the stock records within a business system to, say, test the ability of a business process to deliver product on time in full could be flawed. Business metrics commonly include stock record accuracy to monitor and control discrepancies between physical stock and stock records. It could be argued that the management of such discrepancies is an operational matter, however, the opposing view is that e-business processes should be designed from the outset to be robust to such matters and therefore detail should be included in analysis.

Control rules: Modelling the information flows could be interpreted in its widest sense and include transactions arising from e-business systems. Transactions, such as allocations, stock movements, changes to schedules, etc. make a key contribution to the dynamics of a business. How a business system is set up will affect how responsive or sluggish a process responds to change, for example how often schedules are re-planned will affect the responsiveness to changes in demand volume and mix. Therefore, in order to evaluate the performance of the whole system (such as is represented by the 'enterprise-wide simulation' applications), the communication environment cannot be ignored (Wang et al. 2002). This has been taken further to question whether to model the business system using a copy of the real business system instead of an abstract model, including real business systems within the simulation model (Love and Barton 1996). The advantage of this approach is that not only are the transactions modelled faithfully, but also the impact of the dynamic behaviour of the business system on the whole business is captured.

Randomness: Business processes are naturally stochastic and their resources exhibit random behaviour (Irani et al. 2000). Randomness may take the form of failure in resources, failure in the resources to provide output in the appropriate quality, variation in demand, variation in commodity price, etc. Such effects are significant as they critically impact on the efficiency and effectiveness of processes. They limit the performance that would have expected from a deterministic analysis. A deterministic analysis could be factored to account for an average of 5% absenteeism or +/-20% variation in customer demand to negate the need to consider randomness, however, it is when the knock-on effects of randomness are considered over time that the real impact is apparent. The randomness aspect is especially important when considering the erratic and difficult to predict nature of e-business (Fryer 2001).

Time-based effects: The ability to represent the passage of time, or dynamics, is an important feature of any e-business process modelling. Firstly, the knock-on effects of randomness (such as failure of a quality check preventing a batch to proceed to customer) would be masked by a static analysis in which the output rate is simply factored up by a given percentage to account for the quality losses. Secondly, e-business systems are increasingly used in aspects of the planning and control of the business which impact on the dynamics and failure to take account of this during analysis will invariably underestimate the impact on the operational performance when implemented. The degree of detail represented is important as at a generic level it is the behaviour of the activities not their configuration that will affect performance.

Varied scope of evaluation: The scope of modelling naturally reflects the application area being studied. Tools should be able to reflect a range of modelling scopes. With the case of e-business evaluation this can involve interaction with other companies, perhaps along a supply chain. Drawing from the 'enterprise-wide' and 'supply-chain-wide' applications reported, properties of e-business simulation may need to include: ability to build models from "process-specific" simulations to "supply-chain-wide" models, and the ability to analyse them individually as well as a whole. Examples of activities to be included are: activities and systems in the order fulfilment process, the communication and logistics between companies, a number of suppliers and customers and finally the performance measures used in all these areas.

Quantifying in business measures: In carrying out evaluation of options, various measures can be used for comparison. It is important that some of the measures used are the same as those used operationally to enable a true comparison of the wider operational benefits to be made.

In summary, e-business modelling tools and techniques must capture the activities and interactions present within a business process appropriately. The random and time varying (dynamic) nature of these processes must be represented. Additionally, models must represent both the physical and information flows associated with a business process, including the transactions that arise from the business systems.
Having identified the modelling requirements for e-business processes, an analysis of different modelling techniques was carried out. The next section will look at how specific tools and techniques are able to meet these requirements.

2.6.2 Modelling techniques for e-business

Modelling techniques enable an abstract representation of a system, in this case a business process, to be built up. A wealth of modelling tools and techniques have potential to assist in evaluating the impact of change in organisations. Modelling tools vary in the way a process can be represented and the degree to which they can assist in quantitative analysis. This section briefly introduces the generic properties of the techniques.
Some modelling techniques are static in nature and provide a diagrammatic representation of the process (for example IDEF models). Other techniques allow quantitative analysis (e.g. implemented using spreadsheets). Other modelling techniques are truly dynamic (e.g. Simulation). I will now look at these three types of approaches in turn, before discussing their appropriateness for use in planning e-business change.

2.6.2.1 Overview of modelling approaches

Static Models. Process mapping is one approach which is often used to structure and document the operation of a business and can help to provide a wider view of the impact of changes. Building a detailed process map can be very valuable as a starting point for any change activity. However, building process maps can be time consuming. To try to get over this problem, a number of generic process models have been developed. Some of these are discussed later in the thesis.

Quantitative modelling. The advantage of these tools is that they can be used for "what if?" type analysis whereby a model is repeatedly run under different conditions and using different parameters (e.g. Montecarlo analysis in a spreadsheet). Quantitative modelling techniques can be easily supported through the use of spreadsheets, however, they typically ignore the passage of time necessitating more sophisticated dynamic software described next.

Dynamic models. These techniques can capture and replicate real world effects over time such as variation of customer orders, the level of inventory in the supply chain, unexpected failure of an activity, occasional poor quality output, etc. This extends analysis from a static, stable view of a business process to a real-life fluctuating performance. This is an important aspect of analysis as it could be argued that companies never settle into steady state and it is the dynamic, random aspects that have a critical impact on performance. Furthermore, I suggest that in modelling the differences between 'traditional' business processes and e-business processes, the most significant differences will appear in how each activity performs rather than their sequence or structure. Such dynamic and random behaviour therefore is more topical. Inevitably, techniques able to represent dynamic and random behaviour will require more time, skill and expense to use and these will have an impact on their adoption.

2.6.2.2 Analysis of modelling tools for e-business

One of the key strengths of modelling techniques is to enable an abstract representation of a system, in this case a business process, to be built up. The abstract representation captures key information at a certain level of detail. Although there is no predetermined level of detail for a particular technique (interestingly simulation is often assumed to only be applicable at a detailed level), some tools and techniques (e.g. Bridge 1990) offer hierarchical capabilities to allow multiple levels of detail to be built up. For example, for the order fulfilment process (receive order, check availability, credit check, produce, pick, dispatch and invoice), the check availability stage could be further broken down into check stock, check production plan, allocate, etc.

Some modelling techniques are static in nature and provide a diagrammatic representation of a process. The use of such techniques for communicating the structure of a business process makes them an obvious candidate for assessing the impact of e-business processes. Techniques range from providing simple *flow charting* and process flow to more formalized methods such as Data Flow Diagrams (DFD), IDEF modelling and using GRAI grids. All these techniques have the ability to capture the activities and interactions present but lack the ability to model the dynamic and random aspects. IDEF3 and GRAI grids inherently represent the time phasing but these are static in nature and would require links with simulation to execute the dynamic behaviour.

Other techniques allow *quantitative analysis*. Such techniques may be implemented using bespoke spreadsheets. The advantage of these tools is that they can be used for "what if?" type analysis whereby a model is repeatedly run under different conditions and using different parameters. For example, what if the demand varied, what if an activity was more responsive or, more significantly, what if the process was reconfigured in a different way? With spreadsheets it is also possible to incorporate randomness; however, the limited or non-existent representation of dynamic behaviour is severely limiting. Whilst in practice such analysis is often quick to carry out, there are difficulties in conveying the process flow and interaction for communication and validation purposes.

A more select group of techniques is able to look at the dynamic and random behaviour of a process. These techniques can capture and replicate real world effects such as variation of customer orders over time, the level of inventory in the supply chain over time, unexpected failure of an activity, variation in quality, etc. This extends analysis from a static, stable view of a business process to a real-life fluctuating performance over time. This is an important aspect of analysis as it has been argued that companies never settle into steady state and it is the dynamic, random aspects that have a critical impact on performance. Furthermore, Albores et al (2002) suggest that in modelling the differences between 'traditional' business processes and e-business processes the most significant differences will appear in how each activity performs rather than their sequence or configuration.

Queuing theory uses mathematical techniques to calculate the typical queues that could build up in front of a process due to its variability. The underlying structure makes queuing theory models inherently fast to evaluate and in turn the associated software tools have been branded rapid modelling techniques (Suri 1988). Whilst software is able to shield the user from the underlying mathematical construction, the technique lacks the ability to represent detailed interaction over time (e.g. to model individual transactions or batches) and is therefore limited to more abstract analysis. The lack of equivalence between an abstract model and the real world in turn will make validation and implementation more difficult.

Simulation techniques are more powerful and are able to represent the passage of time. The degree to which they can represent interaction varies. Techniques include system dynamics and discrete event simulation. *System dynamics* is not a commonly deployed technique (Melao and Pidd 2000). The technique, using software such as Ithink (e.g. Michaelides et al., 2002), is typically deployed at the supply chain level rather than detailed business process level. Building more detailed models of processes and in particular representing individual transactions is extremely difficult and this technique is therefore appropriate to more abstract analysis.

Discrete event simulation is able to represent detailed transactions, information and physical flows over a period of time as well as incorporating randomness. Applications range from e-commerce (Giaglis et al. 1999b) to supply chain management (Chan et al. 2002) to business process redesign (Greasley 2000). The ability of such simulation techniques to represent the detail of a business process does not necessarily preclude its use at higher levels. Representing processes at different levels of abstraction is typically down to the software user's skill although some software, such as Arena, does ease this with the use of templates and hierarchical approaches to hide lower levels of detail. Also business process simulators such as Simprocess and Igrafx Process models are built up as a diagrammatic business process that can then be simulated over time.

2.6.3 E-business modelling: reported applications

With the introduction of e-business, companies were trying to catch up with the new ways of doing business and jumped on the "e" bandwagon without much analysis of what the implications of this technology would really have on their performance and the implications for the running of their business processes. The analysis of the impact of e-business on business processes had not been taken into account until very recently. Giaglis et al (1999a; 1999b) pioneered the application of modelling tools to assess the impact of e-commerce (EDI in this case) on business performance. Their analysis is the only one of its type in the pre-dotcom-bubble-burst. They presented a case study of a pharmaceutical company, which was looking into applying EDI to their Order Fulfilment process. Their findings are encouraging in that simulation gave insights into the benefits that could really be attained by implementing EDI as opposed to the results that were expected.

After the dotcom bubble burst, having the interest drawn away from the dotcoms, the number of reported studies of the effect of e-business on traditional companies increased.

Initially, the focus of these studies was e-commerce. For example, Eatock et al (2001) presented an analysis of the impact of IT on business processes through the ASSESS-IT project and applied it to the same case study presented by Giaglis et al (1999a). Tatsiopoulos et al (2002b) presented an application of e-commerce modelling using GRAI Grid, IDEF-0 and IDEF-3 modelling tools combined with activity based costing (ABC) and gave some guidelines as to what the assumptions in populating e-business activities were. Finally, Gunasekaran et al (2002) identified potential areas of operations management that could be affected by e-commerce; however, they do not go into detail to evaluate quantitatively what the impact will be.

More recent publications show a wider scope, not restricted to e-commerce, incorporating other areas of e-business. Barnes et al (2002) present an analysis of e-business processes in the service sector. Greasley (2003) applies simulation to a workflow management systems and Ngai et al (2003) presents the analysis of the development of a web-based system for sales in a water manufacturing company. Finally Bosilj Vuksic et al (2001) presented an analysis of a virtual company in which the procurement process is analysed and Albores et al (2002) have applied simulation to the analysis of e-purchasing and workflow in two manufacturing companies.

Table 2.1 presents a summary of the reported e-business modelling application described above. The modelling approach, type of case study (industry), e-business application under study and the business processes affected by the application is described, as well as the objective (performance measures) in carrying the implementation. As can be seen, most of the applications of e-business have as ultimate objective the improvement of the dynamics of the business (reduction of lead-time and/or cost), which confirms the usefulness of evaluating dynamic behaviour in e-business implementation.

Table 2.1 Modelling of e-business applications.

Author	Modelling Approach	Case Study	E-business application analysed.	Business Processes affected	Performance measures
Giaglis et al (1999a)	Discrete event Simulation (DES) (Process Charter)	Pharmaceutical industry	e-commerce (EDI)	Order fulfilment (OF)	On time in full Lead time
Tatsiopoulos et al (2002a)	GRAI Grid, IDEF-0/ IDEF-3 ABC costing	Garment manufacturer	e-commerce	Order receiving (manage customer order)	Lead time Cost
Gunasekaran et	---	---	A variety of	A Variety of	--

Author	Modelling Approach	Case Study	E-business application analysed.	Business Processes affected	Performance measures
al (2002)			applications.	processes	
Eatock et al (2001)	DES/ Computer Network simulation	Pharmaceutical industry (Same case as (Giaglis et al. 1999a)	E-commerce	OF/ Information systems	Lead time Inventory
Ngai et al (2003)	Flowcharting	Mineral water manufacturer	Web-based workflow	OF (Sales management)	Efficiency Cost
Greasley (2003)	DES implemented in spreadsheet.	Real estate agency	Workflow management systems	Sales	Leadtime
Barnes et al (2002)	Flowchart	Financial Institutions	Online trading	O.F. (Quote Management)	Lead time Cost
Bosilj Vuksic et al (2001)	DES (Igrafx Process)	Virtual company	e-procurement	Procurement	Lead time Cost
Albores et al (2002)	DES (Simprocess / Simul8)	Water and Label manufacturers	e-procurement / workflow	O.F. (Sales and sourcing/ Full OF)	Lead time Cost Labour Utilisation

From Table 2.1, reported applications can be grouped in terms of the business process affected by e-business. For example, Tatsiopulous et al (2002b), Barnes et al (2002) and Ngai et al (2003) deal with sales management. An analysis of commonalities in the processes can lead to the discovery of patterns (i.e. similar structures present in more than one case) in the sales process. These patterns can then be re-used within simulation to facilitate the analysis of sales processes in other case studies. The advantages are to have guidelines of how processes change when e-business is involved and to have pre-built sales processes that can then be customised for the specific needs of the case under study.

2.7 Use of Generic business processes and simulation in e-business

The interrelations inherent to business process modelling and the different levels at which they can be analysed make business process modelling a complex task. In order to facilitate the comprehension of this complexity, generic business processes have been developed (Childe et al. 1994). The idea of this generic business processes is that a company could use them to guide the identification and formalisation of a business process approach (it must be remembered that most of these processes already exist in a company, albeit in a tacit way). Once the processes are identified, strategies can be developed and resources assigned to ensure that the company operates within these business processes, rather than in the traditional departmental view.

For the purpose of this thesis, I will focus on the Operate Processes from the CIM-OSA business process architecture (Childe et al. 1994). These processes include Generate Order, Develop Product, Fulfil Order and Support Product (Figure 2.5)

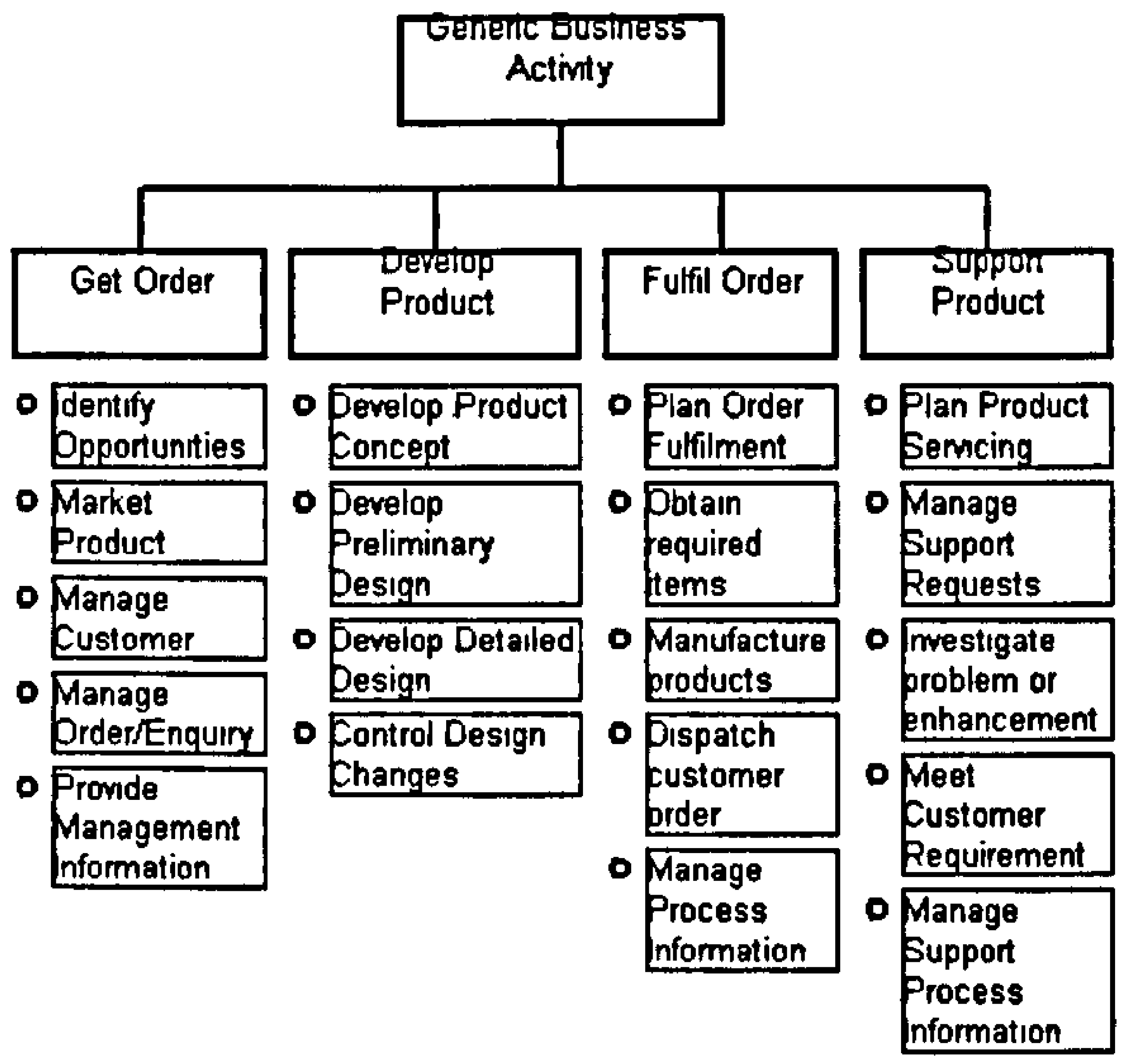


Figure 2.5 Generic operate business processes (Childe et al. 1994)

These processes were developed for traditional manufacturing companies and, as can be seen, are at a level high enough to be applicable to the majority of companies. Figure 2.5 presents the model down to the third hierarchical level. Even if these processes are decomposed, (e.g. sub-processes of Plan Order Fulfilment are: Process Enquiries, Process Orders and Maintain Manufacturing Schedule) the processes are still generic enough to be applied across a range of manufacturing companies. It is important to highlight here that the models are not prescriptive and that need to be customised to fit the individual needs of specific companies.

One of the disadvantages of this model (at least at this level of detail) is that it shows what to do, not how to do it. If we were to search for differences between business processes in a manufacturing company before and after an e-business implementation, it is very likely that we would not be able to find a significant differentiation between processes. The argument for this assertion is that a manufacturing company will require planning the order fulfilment, obtaining the required items to manufacture, make the products, deliver them and measure the performance of the process regardless of the use of e-business. My thesis is that it is how fast, efficiently and resource-intensive they perform these processes where the difference will arise.

Being the difference one of system behaviour rather than one of system configuration puts a limit on the usefulness of static models for the analysis of these differences. It is here where simulation comes to play, allowing further analysis of the dynamics of these processes, and acting as a tool to analyse the interaction of the different activities in a process. For example, changing the way of receiving orders (e.g. via a website) will affect not only the order-planning horizon, but also the purchasing activity and delivery logistics. Even if this change is not on the structure of the process, it will definitively affect the speed and hence the dynamics of the process.

Efforts have been conducted in the use of simulation for the analysis of technologies such as EDI in the business value of electronic commerce (Giaglis et al. 1999b). These efforts are focused on the analysis of the intangible benefits of e-commerce and identified the problems that would be faced by two companies when collaborating through EDI. Another example of application of simulation to the analysis of e-business implementation is reported in (Bosilj Vuksic et al. 2001). This application is focused on the analysis of the business model selected by the company. Although these reported applications deal with some aspects of e-business simulation, the use of generic business processes has not been explored.

Another set of standard processes is the Supply Chain Operations Reference (SCOR) Model proposed by the Supply Chain Council (2002). The model describes standard supply chain activities (Plan, Source, Make, Deliver and Return), and related performance measures and best practices.

There has also been work to develop generic business processes for e-business. Examples of this are the MIT e-Business repository in the US (Malone et al. 1999) and the work conducted by Barnes et al at the Open University in the UK (Barnes et al. 2001). The idea behind the e-business repository (Malone et al. 1999; MIT 2000) is that in order to build an e-business application, one selects from an arrangement of predetermined business process models for each activity and then fits them together to form the business model. The repository was built drawing from experience gained in work like that of Childe et al (1994) and the International Benchmarking Clearinghouse model (American Productivity & Quality Center 1992). Such work can guide analysts to focus on the area of e-business change, e.g.

the whole of the order fulfilment process, but it should be noted that the changes observed will be static, structural changes without any evaluation of change in operational or financial performance.

These process models offer an opportunity to act as templates for simulation analysis of e-business process change. It is my proposition that by creating re-usable simulation templates (also known as components in some simulation packages) the analysis of e-business processes can be facilitated and made faster. The generic business process models can act as a starting point to create these templates.

With work underway on building e-business process models (Barnes et al. 2001; MIT 2000) there is a lack of e-process templates to assist in the development of simulation models. Whilst the inherent properties of discrete event simulation techniques have the potential to assist in helping to model the impact of e-business processes, issues of how to represent the business systems and their dynamic influence on the whole process remain. The next section will look in more detail at these gaps and the research need that arises to fill them.

2.8 Gap analysis and Research need

Although electronic commerce is having an impact in the way companies make business, its penetration is not equally distributed along the different business sectors. As described before, Farish (2001) reports that manufacturing in the UK is the sector with the lowest rate (13%) of e-pioneers (i.e. those using Internet technology to support the most crucial business activities) and the highest rate (41%) of e-laggards (i.e. those business that have yet to evolve beyond the most basic Internet-enabled applications such as e-mail), an indication of a big number of manufacturing companies not ready to make the transition to leading-edge status. (See Figure 1.1).

Farish's study suggests that there is a need for manufacturing companies to speed up the adoption of e-commerce and to understand what is the reason behind this lagging. Some of the possible reasons are the difficulty of integration with the current systems and processes, and the lack of a framework in which analyse the changes required in these systems and processes, hence minimising the risk involved in the transition. Such framework would need to reduce uncertainty, make explicit the dynamic interactions of different business processes across the enterprise, have the power of analysing whether an e-business strategy is really beneficial and as result, provide the required information for a faster e-business adoption

With business process change seen as a pre-requisite for e-business there are two notable gaps. Firstly, there is a lack of detailed but generic e-business process models for specific implementations of e-business. If such detailed models can be created for generic e-business processes they will aid more rapid analysis of the potential impact of change. Secondly, there is a lack of simulation tools that can directly use such generic business processes as templates to create simulation models. This could be attributed to the functional deficiencies of tools to represent e-processes or illustrate the difficulties in creating generic process models at a level useful for simulation modelling. As e-business systems are used more and more for the planning and control of the business they will be more responsible for the dampening or otherwise of the dynamics of the business. Guidance is required on how to capture the dynamic impact of e-business systems in simulation models.

By extending the assessment of change from the area of focus to the wider effects on the business process, a more complete assessment of the true business benefit can be made. Subjective and qualitative assessment is a valuable, if not essential, activity to ensure the cultural and political aspects are accounted for. Such assessment alone is insufficient and must be supported by more quantitative techniques to provide insight to the operational and business impacts.

Such quantitative assessment of change should make use of the same metrics as used to measure the business on a day to day basis; the measures are well understood within the business, can be easily translated into operational performance and necessarily give a more complete view of the changes. For example, analysing the effects of the introduction of e-procurement should include assessment not only of the procurement activity cost but also of the effects on supplier performance, supply chain costs and inventory.

Some tools such as benchmarking used to assess the changes a company should consider would typically contain a significant element of quantitative assessment. Benchmarking ranges from informal comparison with local companies to formal models. One such formal benchmark is the Supply Chain Operations Reference (SCOR) model (Supply Chain Council 2002). The SCOR model contains a standard process reference model and common metrics that can then be benchmarked. By carrying out an audit of a company, a comparison against best practice can be made, thus indicating the areas that the company should focus on. The gap identified against the benchmark data is quantitative and will indicate the extent of improvement necessary.

Some benchmark schemes, such as SCOR, contain suggestions for specific applications that can be used to close gaps with those best in class. Such schemes are extremely useful in suggesting overall change and positioning it in comparison to best in class companies, not for assessing the impact of making e-business change at a local level. Typically any improvement therefore would be judged using static cost analysis that lacks insight to the operational performance over time at a local and company-wide level.

Whether the analysis into e-business change is driven by an informal investigation or more structured approaches using benchmarking, a business case will be made. As a minimum the case would show the cost of the investment and a payback period. The business case is unlikely to show the impact on the operational performance either in business process terms or for the whole business. Such omissions could be addressed through the use of modelling techniques that are able to capture the on-going operational characteristics associated with the change.

2.8.1 Potential for innovation

It is in the light of the aforementioned gap that the current research is focusing. Since simulation is a technique that permits the analysis of different scenarios and hence the reduction of risk, it is deemed suitable to analyse the impact of electronic business in manufacturing business processes and serve as a design tool for this change.

From the initial gap analysis, I have selected the operate processes as a starting point for the research since these are the processes that are directly involved in producing value for the customer (Childe et al. 1994) and are more likely to be impacted by e-business.
The scope of the present research will be focused on "bricks-and-mortar" manufacturing companies that want to adopt e-commerce and will explore the modalities of internal, external and inter-organisational issues.

2.8.2 Research Questions

It is at this stage where the different aspects of the agenda are set. The research questions to be answered are:

1. Is simulation suitable as a tool to analyse the effect of e-business implementation in the business processes of manufacturing companies.
2. What is the role of static modelling in understanding change brought about by e-business, and can generic business process maps be a useful starting point?
3. Can patterns be identified that characterise the e-business processes of manufacturing companies?
4. Can re-usable simulation templates be derived from these patterns?
5. What are the limitations, scope and range of applicability of these templates? and what methodology must be followed when using simulation in this context?

The next chapter will present the methodological options available to answers these questions and the choices made regarding these options.

Chapter 3 Research methodology

Research in the Operations Management field presents a number of difficulties usually not associated with the more "scientific" approaches used by natural sciences and engineering. One of these difficulties is

> "the notion that 'research' implies a search for 'facts' which are in some sense precisely observable under replicable circumstances, or, at least, are subject to some statistically measurable experimental error which has been established by multiple experiments by the researcher. It is both difficult to 'experiment' with human beings and difficult to replicate many experiments". (Elder 1992)

This is particularly true when dealing with "management" type research, where each situation is context-bound and hence, difficult to replicate in an exact manner. Research methodology takes an especially important part on this type of research since an appropriate research design will constrain the number of uncontrolled factors and lead to a better replicability of the research. As Karlsson (2002) states: "Methodology is there to make it credible to the reader that you have planned and carried through your study as well as analysed and drawn conclusions in a way that we can rely on what you write... the idea is quality assurance in research". (Karlsson 2002)

The present chapter will deal with the selection of an appropriate research paradigm and research design to tackle the problem in hand. The chapter will start by briefly reviewing the different research paradigms, explaining the differences and similarities, as well as some of the issues debated around the selection of a paradigm.

Next, the chapter will analyse the research project in the light of the analysed paradigms and justify the selection of one of them for the specific project. Then, the detail of the research design is presented, presenting the specific research stages and the methods, techniques and tools used in each one of them.

Finally, the chapter will close with a summary of the selected methods.

3.1 Methodology: what is it and what is for.

If you asked ten researchers to define methodology, most probably you would end up with ten different answers. The term methodology is usually used loosely and according to the idiosyncrasies or schools of thought of the individual researchers It is important then to define what methodology is from the point of view of this study (although it will not claim to have THE definition of methodology at the end of it). Lehaney and Vinten (1994) have identified that the term 'methodology' has six different definitions. They argue that "methodology" has been used by different authors to signify the following different concepts (Lehaney and Vintem 1994):

1. The way in which hypotheses become theories –scientific methodology.
2. The ways in which methods and techniques are chosen to address a particular problem.
3. The ways in which problems are chosen (as well as their level of detail, scope).
4. Methods and techniques
5. The modelling process,
6. The chronological planning of events, i.e. the research programme

As can be seen, the use of the term methodology encompasses a wide variety of meanings, some of which are not only complementary, but also some of the concepts may be part of other concepts (for example, the first definition could include all the other definitions as steps of the process).

For the purposes of this work, the term methodology will a combination of the above in term of describing the process in which the research questions are converted into theory and the selection of the methods and techniques that help this process.

3.1.1 Methodological process

A number of processes have been defined as to what are the steps to follow when developing a methodology. Martinez and Albores present a proposed path for research, starting from the identification of the research issue, through to the finalisation of the research work. (Martinez and Albores 2003a).

The process presented in Figure 3.1 depicts the more common activities of the research process and adds the steps of definition of the research quality evaluation criteria and the actual evaluation of the research against these criteria, a step not usually present in the research processes existent to date. (NOTE: One important point to make here is that this process is iterative and not strictly sequential).

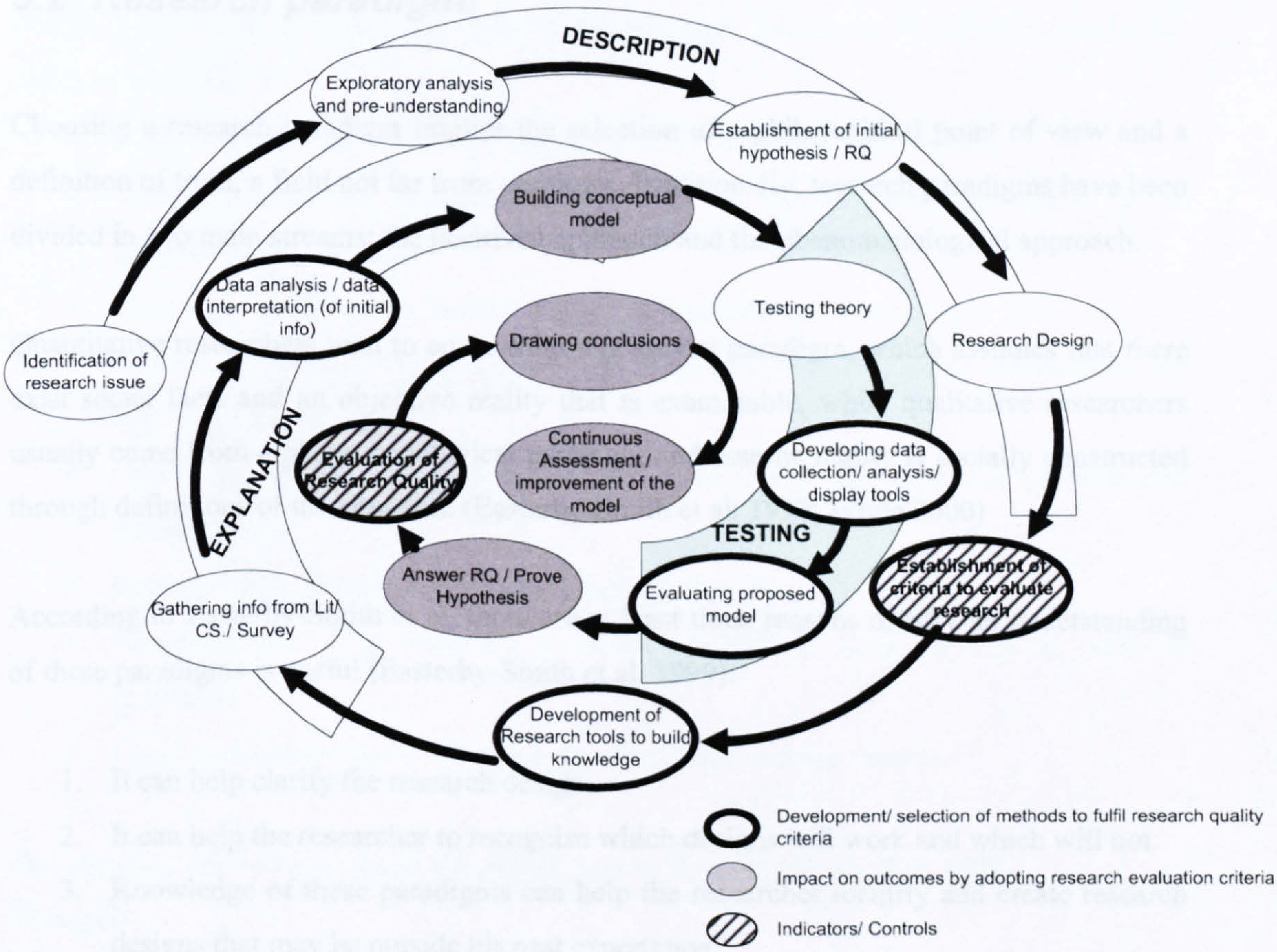


Figure 3.1. Research methodology process (Martinez and Albores 2003a)

This process was used as a guide during the project and will serve as reference point in this chapter. Steps 1 to 3 (Identification of research issue, exploratory analysis and pre-understanding and establishment of initial research questions/hypothesis) were dealt with in Chapter 2. The research design will be described in section 3.3, with section 3.4 describing the selection of research quality evaluation criteria.

Before going to the detail of the research design, it is important to select a philosophical paradigm within which the research will be framed. Such decision it is important because it has an impact in the selection of methods and techniques to be used in the research design and in the view of what constitutes good research outcome. Section 3.2 describes this selection process.

3.2 Research paradigm.

Choosing a research paradigm implies the selection of a philosophical point of view and a definition of truth, a field not far from ontology. Traditionally, research paradigms have been divided in two main streams: the positivist approach and the phenomenological approach.

Quantitative researchers tend to come from a positivist paradigm, which assumes that there exist social facts and an objective reality that is examinable, while qualitative researchers usually come from a phenomenological paradigm and assume reality is socially constructed through definitions of the situation. (Easterby-Smith et al. 1999; White 2000)

According to Easterby-Smith et al, there are at least three reasons of why an understanding of these paradigms is useful (Easterby-Smith et al. 1999):

1. It can help clarify the research design.
2. It can help the researcher to recognise which designs will work and which will not.
3. Knowledge of these paradigms can help the researcher identify and create research designs that may be outside his past experience.

Numerous debates have taken place and continue taking place about the validity of each research paradigm and their application to different contexts.

I will now briefly review both paradigms and describe their characteristics, comparing and contrasting them.

3.2.1 Positivist paradigm

According to Easterby-Smith et al (1999), "the key idea of positivism is that the social world exists externally, and that its properties should be measured through objective methods, rather than being inferred subjectively through sensation, reflection or intuition". Positivism sees the world as objective and value-free. This characteristic makes positivism look at the world from a detached distance and assert that the phenomena would be perceived equally despite being observed by two researchers with different sets of pre-conceptions and values. It aims to generalise by having samples of sufficient size. Positivism then implies (Easterby-Smith et al. 1999):

- Independence. The observer is independent of what is being observed.
- Value-freedom. The researcher's values do not interfere with the results or the interpretation of results.
- Causality. The aim is to identify causal explanations and fundamental laws.
- Hypothetico-deductive. Proposing hypotheses and deducting what observations are required to prove them.
- Operationalisation. Needs to operationalise in a way that facts can be measured quantitatively.
- Reductionism. Reduce a problem to its simplest parts.
- Generalisation. It is necessary to select samples of sufficient size in order to generalise.
- Cross-sectional analysis. Comparison of variations across samples

The strengths and weaknesses of this paradigm are (Easterby-Smith et al. 1999):

Strengths:

- can provide a wide coverage of different situations
- can be fast and economic
- can provide relevance to decision, especially when statistics of large examples are involved.

Weaknesses:

- tend to be inflexible and artificial
- not effective to understand the process or significance of people (actors)
- Not very helpful in generating theories because it is focused on what is now, by inferring that changes and actions should take place in the future, but not in their research time.

3.2.2 Phenomenological paradigm

Phillips and Pugh (2000) state that the starting point of induction is an impossible one; that it is a myth that out of a disorderly array of sensory data an orderly theory will emerge. According to them, there is no such thing as an unbiased observation. This last sentence captures the ethos of the phenomenological paradigm, which views the world not as objective an external, but as "socially constructed and given meaning by people" (Easterby-Smith et al. 2002). The task of the researcher should not be to gather facts and measure patterns, but to "appreciate the different constructions and meanings that people place upon their experience".

The identified strengths and weaknesses of the phenomenological paradigm are (Easterby-Smith et al. 1999):

Strengths:

- Ability to look at change processes over time,
- Ability to understand people's meanings
- Ability to adjust to new issues and ideas as they emerge and
- To contribute to the evolution of new theories.

Weaknesses:

- Data collection can take a lot of time and resources,
- Analysis and interpretation may be difficult.
- It is harder to control the pace, progress and end-points of the project.

Selecting a paradigm is relevant because it will influence the research design. The researcher must be aware of the research paradigm when choosing research strategies, methods techniques and tools, in order to have consistency between the research elements. Morgan identified three levels of use of the word paradigm: the *philosophical level*, which reflects basic beliefs about the world; the *social level* which provides guidelines about how the researcher should conduct his or her endeavour; and the *technical level*, which involves specifying the methods and techniques which should be ideally adopted in conducting research (Morgan 1979). Easterby-Smith et al present the main characteristics of the two competing paradigms mapped against Morgan's classification in order to illustrate the differences between the paradigms (Easterby-Smith et al. 1999) (Table 3.1).

	Positivist paradigm	Phenomenological paradigm
Basic Beliefs	The world is external and objective Observer is independent Science is value-free	The world is socially constructed and subjective Observer is part of what is observed Science is driven by human interest
Researcher should	Focus on facts Look for causality and fundamental laws Reduce phenomena to simplest elements Formulate hypothesis and then test tem	Focus on meanings Try to understand what is happening Look at the totality of each situation Develop ideas through induction from data
Preferred methods include	Operationalising concepts so that they can be measured Taking large samples	Using multiple methods to establish different views of the phenomena. Small samples investigated in depth over time

Table 3.1 Key features of positivist and phenomenological paradigms (Easterby-Smith et al. 1999)

3.2.3 The debate

As can be expected from having two different and somehow conflicting philosophical views of research, a continuous debate have been taking place about the appropriateness and applicability of each one of the approaches to different problems. The debate has signalled a dismissal of the opposite paradigm (depending on which side of the argument the author is) as an invalid approach for the creation of science.

From a quantitative point of view, there are several criticisms made to the qualitative approach. As Saludadez and Garcia (2001) report from a roundtable where quantitative researchers were asked to give their impression of qualitative research

> ... one central theme that related to the participants' view of qualitative research vis-à-vis quantitative research emerged: qualitative approach is subordinate to the quantitative approach. This central theme is made up of three sub-themes which are presented below ....
>
> Sub-theme 1: Qualitative method cannot approximate the precision and objectivity of the quantitative method.
> Sub-theme 2: Qualitative method is used only when quantitative method cannot do the job.
> Sub-theme 3: Qualitative method must aim for prediction, not just understanding, to be legitimately called a science

... all these sub-themes make qualitative research inferior to quantitative research by putting a lower premium on what qualitative research considers important, namely, description, meaning and understanding. Sub-theme 1 gives the impression that qualitative description is of a lower standing than quantitative measurement, sub-theme 2 that qualitative data (words) are of lower value than quantified data (numbers) and sub-theme 3 that understanding as an aim of science is of lower value than prediction.... (Saludadez and Garcia 2001)

Similar comments have being made from the qualitative corner about the quantitative approach. The main arguments are:

- The unsuitability of quantitative research to grasp the complexity that social systems present.
- The fact that a quantitative approach cannot appreciate the "different constructions and meanings that people put on their experience" (Easterby-Smith et al. 1999), hence loosing insight into what may be the cause or solution to a problem and that cannot be measured using quantitative tools.
- The assumption of value-freedom is difficult to sustain, especially in the social sciences and management research.

Despite all the arguments and theoretical debates, it has been recognised that in practice the two approaches mix and are even complementary in some situations (Fielding and Schreier 2001). The view that quantitative research is always "objective" and on the other side of the coin, that qualitative methods always lead to more meaningful analyses, is open to question (Laurie and Sullivan 1991).

Cupchick argues that the "competition between qualitative and quantitative research is resolved into complementarity" (Cupchik 2001). He sees both approaches as essentially inter-related, with quantitative research contributing towards the precise identification of relevant processes, and qualitative research providing the basis for their "thick description".

Hammersley has argued that the distinction between qualitative and quantitative is of limited use and "indeed, carries some danger" (Hammersley 1992). For one thing, dichotomisation may narrow the arena for complementarity and I must be aware of the possibility of combining research methods, keeping always in mind the selected predominant paradigm.

Fielding and Schreier (Fielding and Schreier 2001) also show that, because of the way in which research has been done historically and the weight that quantitative methods have had in the development of science, qualitative researchers are more prone (or are forced) to use quantitative methods than quantitative researchers to use qualitative methods. As Laurie and Sullivan state: "we believe that if an attempt is to be made at understanding which is not entirely relativist then some way must be found to accommodate the findings of both quantitative and qualitative research" (Laurie and Sullivan 1991)

3.2.4 Paradigm selection for this research

Being trained as an engineer and having a strong quantitative background, the natural choice for a research paradigm is the positivist, quantitative research strategy. However, having studied the different paradigms and the debate surrounding the suitability of the different paradigms to different situations, it was decided that the research paradigm that would be used for this research would be predominantly phenomenological/qualitative. Nonetheless, some of the techniques and tools used in the positivistic/quantitative approach would be required. This selection is in line with those authors that argue the complementarity of both approaches to have a better understanding of the phenomena under study.

The reason for selecting a predominantly phenomenological approach is that this research aims to explore the use of tools and techniques and their implementation process for the study of e-business implementations. Of interest in this research is the perception of potential users about the value of using simulation and re-usable components for the analysis of e-business processes. In order to do this, a small number of studies was carried out in which the context was studied and the researcher involved in the process and not completely independent. Table 3.2 presents a summary of what the project outcomes would be from using different paradigms.

	Positivist	**Phenomenological**
Success of the project	Degree of representation of real business processes (specific measure?)	Degree of usability perceived by the client.
Role of researcher	Analyst	Facilitator in understanding change and analysing options
Focus of the research	Develop Constructs and test the "appropriateness" of these constructs.	Constructs and tools to evaluate the response to these constructs
Proposed number of Samples	>30 for statistic validity	~ 6 theoretically sampled

Table 3.2 A comparison of the project in the light of the two different approaches

Having selected the main philosophical paradigm, the next section will deal with the specific detail of the research methodology in every step of the research: the research design.

3.3 Research Design

Research design has been defined as " the logical sequence that connects the empirical data to a study's initial research questions and, ultimately, to its conclusions" (Yin 1994). Yin advocates that research designs should have five components:

1. a study's question
2. its propositions
3. its units of analysis
4. the logic linking the data to the propositions, and
5. the criteria for interpreting the findings.

However, Yin's is only of many research frameworks. From the definitions proposed by different authors (Lehaney and Vintem 1994; Yin 1994; Easterby-Smith et al. 1999; Voss et al. 2002), a summary can be presented as to what (in this author's view) a research design should include:

- Research Paradigm (as a pre-requisite and affecting the research design issues)
- Research Design
    - Problem definition (Limits, level of detail) (What and why)
    - Choosing/developing methods and techniques (How, where)
        - Research methods/strategies.
        - Data collection (Sources, instruments)
        - Data analysis
        - Modelling techniques
        - Selection of tools
    - Researcher role (Who and in which quality)
    - Time scales for the above. (When)
    - Research quality evaluation criteria.

Every one of these steps will be described in the remainder of this section

3.3.1 Problem definition

The problem definition was described in Chapter 2 and the research questions can be summarised as:

1. Is simulation suitable as a tool to analyse the effect of e-business implementation in the business processes of manufacturing companies.
2. What is the role of static modelling in understanding change brought about by e-business, and can generic business process maps be a useful starting point?
3. Can patterns be identified that characterise the e-business processes of manufacturing companies?
4. Can re-usable simulation templates be derived from these patterns?
5. What are the limitations, scope and range of applicability of these templates? and what methodology must be followed when using simulation in this context?

The study will be focused in the order fulfilment process of manufacturing companies.

3.3.2 Choosing methods and techniques

Case studies were selected as research methods, using interviews, questionnaires and non-participant observation as data collecting tools. A quasi-experiment was set-up to test the perceived "usability" of simulation components for the analysis of e-business. Simulation will be at the heart of the project, hence, some degree of quantitative techniques and tools will be used. However, it must be emphasised that the findings of this project will be restricted by the limitations imposed by qualitative projects. A full justification of the above selections is given next.

3.3.3 Method selection: Case studies

A case study may be defined as "an extensive study of a single situation such as individual, family or organisation" (White 2000)

Voss et al (Voss et al. 2002) cite three strengths of case research, put forward first by Bebensat et al (1987):

1. The phenomenon can be studied in its natural setting and meaningful relevant theory generated from the understanding gained through actual practice

2. The case method allows the questions of why, what and how, to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon.
3. The case method lends itself to early, exploratory investigations where the variables are still unknown and the phenomenon not at all understood

Yin (1994) states that case studies should be used when "a why or how question is being asked about a contemporary set of events over which the investigator has little or no control". Additionally, Voss et al (2002) specify that case studies in operations management should pay attention to what processes (manufacturing and services) and systems are to be studied, the methods for studying them and the operating data to be collected from them.

The research questions for this project are of a "how" nature. How do traditional and e-business process differ and how do we go about analysing these differences using a specific technique (simulation) are the main questions this research aims to answer. The nature of e-business as a contemporary (i.e. occurring at the moment as opposed to a historical fact) phenomenon is irrefutable. Finally, there is little degree of control from the researcher over the implementation of a particular e-business application in an industrial setting. Such decisions can be affected by other technological implementations, changes in strategy or simply internal politics and changes in priority. It was then thought that case studies would be a good strategy to follow in this research. The researcher is aware of the fact that the case study method is not the only option for this project. A brief description of how the research design would have been different if other research strategies would have been chosen is presented at the end of this section.

It is very important at this stage to clarify some of the characteristics of case-based research and highlight its differences with the more traditional (i.e. quantitative) way of doing research. According to Yin, one of the most common criticisms of case studies is that they provide little basis for scientific generalisation (Yin 1994). The mistake here is "to try to generalise to a population or universe, instead of trying to generalise to theoretical propositions". It is very important to stress that a case study does not represent a "sample" and that the aim of the researcher is to achieve analytical, rather than statistical generalisation.

In statistical generalisation, an inference is made about a population on the basis of empirical data collected about a sample. Analytical generalisation is achieved when a previously developed theory is used as a template with which to compare the empirical results of the case study (Yin 1994). In analytical generalisation, the researcher aims to generalise a particular set of results to some broader theory. Yin, however, warns about trying to make this generalisation automatically. A theory must be tested through replications of the findings in a second or third case (replication logic). If similar results are obtained from all the cases, replication is said to have taken place. Each case must be selected so that it either predicts similar results (literal replication) or produces contrasting results, but for predictable reasons (theoretical replications).

3.3.3.1 Case study design

Yin presents a case study method in which "each individual case study consists of a 'whole' study, in which convergence is sought regarding the facts and conclusions for the case. Each case's conclusions are then considered to be the information needing replication by other individual cases. Figure 3.2 shows this method

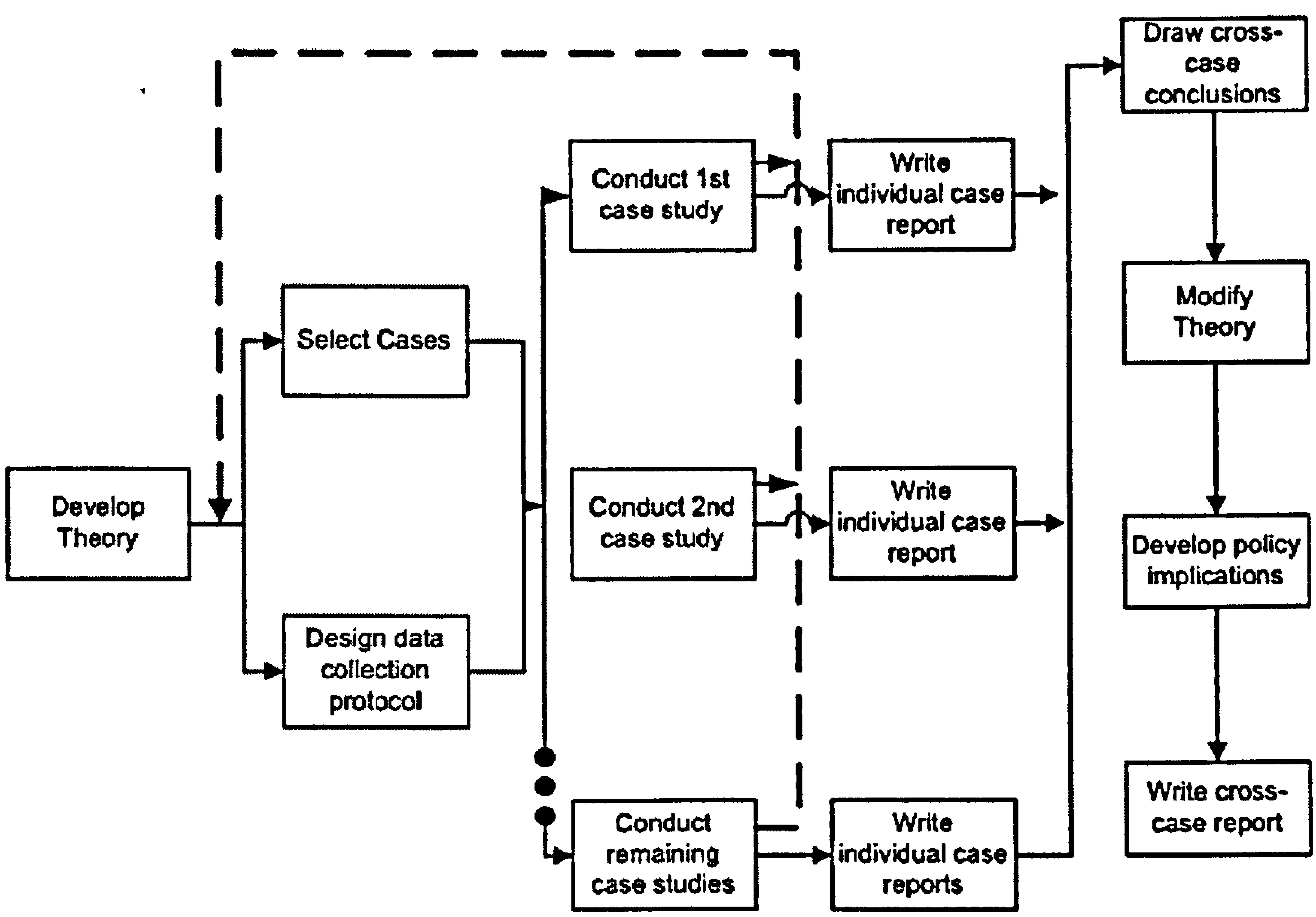


Figure 3.2 Case study method (Yin 1994):49

Different case study designs have been proposed. Yin presents a matrix in which the axes represent different case study design situations (single and multiple-case designs) and the units of analysis within these design situations (holistic –single unit of analysis- and embedded –multiple units of analysis-)

This research uses a combination of these case study designs. Initial case studies (both reported and empirical) are used to generate the initial e-business process models (theoretical) and test the feasibility of the approach. Each case study will be described later in this thesis. An analysis of the type of case study used in each case is presented in Table 3.3

Case	Case type	Design situation	Unit of analysis	Processes
WaterCo.	Primary (D)	Single	Embedded	POH and order taking
LabelCo	Primary (D)	Multiple	Holistic	Order management process
MotorCo	Primary (D)	Multiple	Embedded	Ordering and Planning.
PharmaCo	Secondary (D)	Multiple	Embedded	Ordering and Shipping
VirtualCo	Secondary (D)	Multiple	Holistic	
BottlingCo	Secondary (D)	Multiple	Holistic	
CopierCo	Primary (T)	Multiple	Embedded	Lab order taking and Result delivery
UtilityCo	Primary (T)	Multiple e	Holistic	
ERPCo	Primary (T)	Multiple	Embedded	

D= Development case T=Testing Case

Table 3.3 Case types and units of analysis

The approach ensued during this research was as follows: An initial pilot case study was set-up to investigate the feasibility of the project and analyse how relevant the research questions were to the industry. From this case study, confirmation of the validity of the approach was obtained, as well as a number of initial e-business templates. These templates were then validated against reported case studies.

In order to validate the templates, a pattern-matching logic approach was followed, in which "such logic compares an empirically based pattern with a predicted one (or several alternative predictions)" (Trochim 1989). The approach followed for the development and validation of the templates was as follows:

- Potential templates would be identified in a case study (source case study). For example, order taking via Internet.
- These potential templates would then be tested applying them in the next case study (test case study). For example, did the activities depicted in the order-taking-via-internet-template from the source case replicate in the test case?
- Modifications to the potential templates would occur to make them generic to both the source and test case study. At this stage, sometimes the specific characteristics of a case would need to be sacrificed in order to obtain a more generic template.
- Additional potential templates would be identified in the test case, hence converting the test case in a new source case.
- A new case would then become the test case where the potential templates from the previous source cases would be tested.
- The process is repeated until theoretical saturation is reached.

This approach will be denominated "sequential-case-studies design" during this thesis. The advantages of such an approach are that the templates/components are evaluated as they are being developed, allowing for modifications to occur while the initial testing of a potential template. These modifications were then tested against the new cases, building internal validity into the constructs. This is in line with what Einsenhardt says about constructs in case studies: "...the construct, its definition, and measurement often emerge from the analysis process itself, rather than being specified a priori" (Eisenhardt 1989)

Another advantage of this approach is that a lower number of case studies would be required in order to obtain validity and reliability in the study. The alternative approach would have been to take a set of case studies as source cases and another set of case studies as test cases. This would have been more time consuming, and would have probably required a third set of case studies in order to re-test the modifications arising from the test case studies.

Referring back to Figure 3.2, the approach proposed for this thesis would have an extra line coming from case study 1 to case study 2, from case study 2 to case study 3 and so on, hence having the case studies not only as an input to the overall cross-case analysis, but also as an input to the next case studies.

An analogy can be made with Meredith's cycle (Meredith 1993) to illustrate the research process that is going to be followed in this project. Figure 3.3 shows a mapping of the process in which each cycle would be the input for the next case, repeating it until satisfactory results are obtained. The iterative nature of the approach must be highlighted. During the research, I went through this loop a number of times, creating new processes, refining them and testing them.

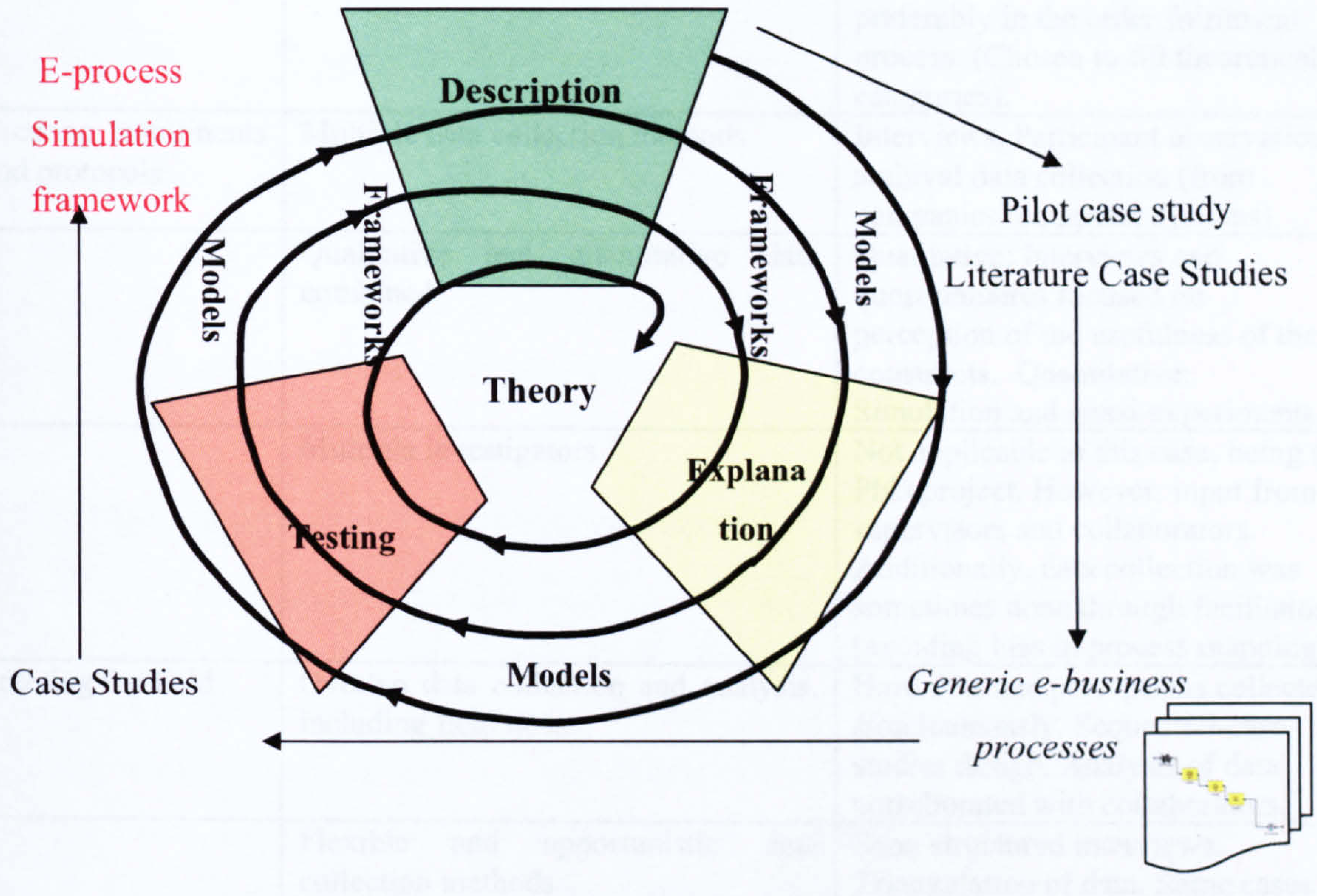


Figure 3.3. Iterative "sequential-case-design" mapped against Meredith's theory creation cycle

3.3.3.2 Case study protocol

In order to have a reliable outcome of research, especially when using case studies it is necessary to have a case study protocol (Yin 1994). Eisenhardt (Eisenhardt 1989) proposes a case study process that can be used as starting point for the design of a case study protocol. This process, depicted in Table 3.4, presents the different steps (column 1) and activities (column 2) that are suggested when developing theory from case studies. Column 3 presents how this steps and activities are tackled in this research project.

Step	Activity	How is tackled in this research
Getting Started	Definition of Research Questions	Personal interests and literature review.
	Possibly a priori constructs	Questions posed and construct

		development from literature (simulation components)
	Neither theory nor hypothesis	Open research questions. Exploratory analysis to begin with.
Selecting Cases	Specified Population	Manufacturing related companies.
	Theoretical, not random sampling	Companies that are implementing/ have implemented e-business, preferably in the order fulfilment process. (Chosen to fill theoretical categories).
Creating instruments and protocols	Multiple data collection methods	Interviews, Participant observation, archival data collection (from companies' computer systems)
	Qualitative and quantitative data combined	Qualitative: Interviews and questionnaires focused on perception of the usefulness of the constructs. Quantitative: Simulation and quasi-experiments
	Multiple investigators	Not applicable in this case, being a PhD project. However, input from supervisors and collaborators. Additionally, data collection was sometimes done through facilitators (avoiding bias in process mapping)
Entering the field	Overlap data collection and analysis, including field notes	Hard data and perceptions collected simultaneously. Sequential-case-studies design. Analysis of data corroborated with collaborators.
	Flexible and opportunistic data collection methods	Semi structured interviews. Triangulation of data. Some cases conducted through email due to distance.
Analysing data	Within-case analysis	Detailed case study write-up. Data reduction and data display techniques
	Cross-case pattern search using divergent techniques	Pattern searching between cases for generic e-business activities. Pattern-matching logic. Creation of categories (e.g. type of e-activities) for with-in group similarities. Juxtaposition of pairs of cases (e.g. Albores et al IFIP 2001).
Shaping hypothesis	Iterative tabulation of evidence for each construct	Refining the constructs via the "sequential-case-studies" design. Tables used as comparative tools for different case studies.
	Replication, not sampling, logic across cases	Manufacturing companies that have implemented or are about implement e-business in order fulfilment process. Constructs derived from one case study are tested in the next. New constructs

		developed if required and tested in further new case.
	Search evidence of "why" behind relationships	Qualitative data collected
Enfolding literature	Comparison with conflicting literature	Comparison with Melao and Pidd. (Albores et al. 2005)
	Comparison with similar literature	Comparison with authors like Giaglis, Tatsioupolous, etc
Reaching closure	Theoretical saturation when possible	Proof of concept sought.

Table 3.4 Case study building theory process (Adapted from Eisenhardt 1989)

Having studied the different stages of a case study project, the next step is to make explicit the case study protocol. Two case study protocols were defined for this project, one for the pilot case study and other for the multiple case studies. The details of the protocols are presented in the relevant chapters (Chapters 4 and 6).

3.3.4 Method selection: Quasi-experiments

Experiments investigate the relationships between cause and effect. They determine whether a change in one factor causes and produces an effect in other factor. (White 2000). Usually experiments require complete control over the variables, both endogenous and exogenous. However, in the management field, it is difficult to have complete control over all variables. Hence the term quasi-experiment has been proposed to signify situations in which the concept of control and experimental groups is present, but not chosen at random fashion (White 2000). The idea of a quasi-experiment is to get a before and after effect and relate this to the variable under study.

Once the components were developed (partially developed in one case) two quasi-experiments were set up. The experimental design used was that of "pre-test, post-test control group design". According to White (2000), "this form of design is particularly robust. Both groups are tested at the start, one group receives the treatment, the control does not, and both groups are post-tested at the end". The first test involved thirty learners of simulation and the second test involved eight researchers not specialising in simulation. The idea behind the quasi-experiments was to evaluate the usefulness of the proposed templates/components when actually building e-business simulations. Detail of the experiment design is given in Chapter 6

3.3.5 Techniques selection

Using case studies and quasi-experiments as research methods implies using a number of techniques and tool to collect and analyse data within these methods. In this research different techniques were used at different stages. Simulation methodologies and simulation results, being the main point of interest in the project are embedded throughout the project Semi-structured interviews, standard data collection sheets, and non-participant observation were used during the case studies, while questionnaires and observation were used during the quasi-experiments. Within the mentioned research methods, the following techniques will be used:

3.3.5.1 Simulation

The characteristics of simulation have been analysed in Chapter 2. In this section, an analysis of simulation in a methodological context will be conducted.

It could be argued that since simulation is primarily a tool for quantification, its use within a more quantitative approach would seem sensible. However, simulation is not only a tool for quantification (although it is one of its main strengths), but also of understanding and this characteristic makes it a suitable tool to be used in a phenomenological research.

This is further supported by a recent discussion on the SIMSOC mailing list (SIMSOC mailing list 2003), in which the nature of the use of simulation as theory building and theory testing tool was debated. Some of the arguments are:

For:

- "All simulations, including those that are numerical in nature, are done to capture both qualitative and quantitative elements of processes. The point here being that to get qualitative feedback, one is not required to employ a qualitative model". (Fishwick, Paul). This illustrates the view that simulation can be used to gain understanding and hence qualitative insights.
- "I should have thought that simulation is a way of exploring different kinds of (social) dynamics, and then using the findings to inform further (social) research". [Green, Nick] (brackets added by this researcher)
- It seems to me that simulations (at their best) are built on top of pre-existing explanatory theory, they may act as tests of those theories, but in a true Popperian sense, can do little to confirm only perhaps help falsify them. There is a third role for simulation which is in generating the phenomena about which we go on to theorise. This seems to me to be particularly important ... because it allows us to be experimental, to control our parameters

and to focus on the dynamics of emergent systems in a way that may help us to develop explanatory theory (Penn, Allan)

- It is in the model that we find roots of explanatory functions. But also to the extent that we simulate the model, this surely also contributes to an explanation. (Fishwick, Paul)
- Sometimes we observe phenomena specifically to test our theories (as Popper would have it). Sometimes we create phenomena to give us something to theorise about (as Hacking would have it). Simulations let us create, control and repeat the production of phenomena about which to theorise (Penn, Allan)
- the simulation results are used to uncover or observe the processes - but the simulation model is a formal description of the process. (Carley, Kathleen)

Against

- Invariably, you are forced to make numerous judgments and choices along the way in order to make the simulation run, especially in regard to which factors mentioned by the theory are needed and which are not, and the functional forms that will relate those factors to one another in the simulations. Moreover, writing the simulation almost certainly will reveal logical gaps in the theory that must be filled in order to make the simulation work. The simulation introduces functional relationships that the theory does not specify, and usually specifies gap-filling assumptions that the theory never made. The simulation or simulations represent improvements over the original theory, and if there are multiple simulations with mutually contradictory derivations, they are all improved versions of the theory (at least from a logical standpoint) and may be adjudicated by empirical testing. (Markovsky, Barry)

- The problem with the view that simulations are tests of theories is that there is no way other than argument to 'prove' that a simulation represents a theory. Once we accept that problem, then simulation becomes yet another mode of discursive argument, one surrounded with complex and 'cool' techie stuff, but nevertheless, just another mode of argumentation.(O'Sullivan, David)

- Jules Henri Poincare said it best: "Science is built with facts just as a house is built with bricks, but a collection of facts cannot be called science any more than a pile of bricks can be called a house." Theories don't accumulate from observations, instead theories may help us to integrate observations (Johnson, Paul)

- A theory embodies our best knowledge regarding the nature and workings of a particular class of phenomena. A theory-building tool would serve a theory, but not contain it (Markovsky, Barry)

As can be seen from this discussion, the use of simulation to create theory has a good number of advocates, although it is hotly contested whether the simulation can be a theory or just a vehicle to test the theory. This is particularly relevant to this research since the idea is to create theory about simulation and how to use it in the particular context of e-business process analysis. Care had to be taken to conduct the simulation in a rigorous, methodological manner (mainly following the approach proposed by Robinson (Robinson 1994), but at the same time analysing the non-modelling aspects of the simulation and its perceived use.

3.3.5.2 Simulation Software selection

Different simulation software tools were evaluated to be used in this research. The evaluation was carried out by modelling e-business case studies and was done in parallel to the pilot case study (See Chapter 4) and the initial cases (Chapter 5). A summary describing the capabilities of the different software against an established set of criteria is presented in Table 3.5.

Feature	**Simul8**	**Simprocess**	**Witness**	**Arena**	**Process charter**
Operational					
Machines (or activities)	✓	✓	✓	✓	✓
People (resources)	✓	✓	✓		
Conveyors			✓	✓	
Buffers (queue)	✓	✓	✓	✓	✓
Parts (entities)	✓	✓	✓	✓	✓
Vehicles			✓	✓	
Paths			✓	✓	
Control					
Schedules			✓	✓	
Shifts	✓				
Batch	✓	✓	✓	✓	✓
Split	✓	✓	✓	✓	
Merge (join) with any					
Merge (Match) with original partner	✓				
Prioritisation	✓		✓		
Load / Unload					
Financial					
Operation Cost (activity)	✓			✓	
Product cost	✓		✓		
Departmental cost	✓	✓			✓

Table 3.5 Simulation software evaluation

Simul8 was selected to develop the components in this research. This tool has the technical capabilities for the creation of components and is easy to use and relatively inexpensive. This is of paramount importance since one of the driving forces behind this research is to increment the use of simulation in organisational contexts. Choosing a software that is more powerful, but difficult to learn or too expensive would hinder the applicability of the constructs developed during this research. Simul8 was seen as a good compromise between capability, ease of use and accessibility.

3.3.5.3 Semi-structured interviews

Semi-structured interviews were used to define the project in each of the case studies and to gain a better understanding of the e-business application and context of the project. Semi-structured interviews were selected because of their flexibility to explore issues that may emerge when doing the interview, but at the same time keeping focus on the issue under study. An example of the interview preparation notes is presented in Appendix 1.

3.3.5.4 Non-participant observation

This was used as a technique to map processes, studying the activities carried out in the case study companies. The idea was "to remain detached from the situation, but record what is happening" (White 2000). This usually involved observing the process and documenting flows, routings, timings and resource utilisation.

3.3.5.5 Questionnaires

Questionnaires were used for the pre-test and post-test phases of the quasi-experiments. The structured nature of questionnaires allowed comparing before and after perceptions. Detailed questionnaire creation and analysis is presented in Chapter 6

3.3.6 Alternative approaches

The research approach has been established, describing the research methods and techniques used during this research. However, the final selection was not evident from the beginning and a number of alternative approaches had to be considered. A brief description of these alternatives is given next, as well as the researcher thoughts on how the research would have been affected if following such alternatives.

3.3.6.1 Action research

Action research (AR) has been defined as a type of research that is conducted in-situ and that "achieves improvement in the company while building up the body of knowledge."(Coughland and Coghland 2002)

The same authors identify some of the characteristics of action research:

- Research in action, rather than research about action
- Participative (Teamwork)
- Concurrent with action
- A sequence of events and an approach to problem solving

and propose a process to follow when implementing action research projects.

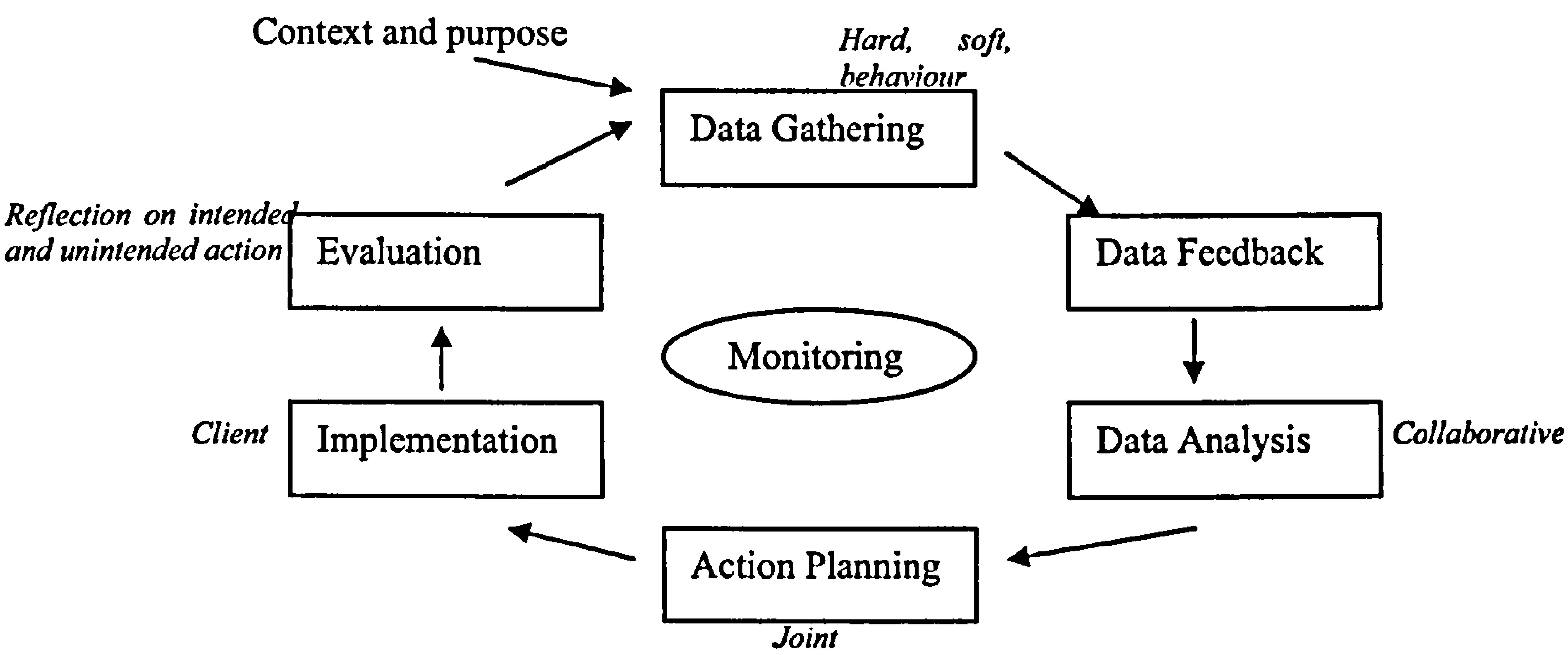


Figure 3.4. Action Research Cycle (Source Coughland and Coghland 2002)

According to Coughland and Coghland (2002), in order to avoid confusion between action research and consultancy, certain criteria must be followed in the development of action research:

- Must be explicit in the relationships between the researchers and the members of the organisation
- Must have reflective concern for practical outcomes
- It is important to ensure Conceptual-theoretical integrity and methodology appropriateness
- The work must have significance, not only for the organisation, but also for knowledge in the academic sense.

- Finally, sustainable change must be achieved as a result of AR. This implies significance of the work and the fact that the changes introduced will continue in place after the researcher leaves the organisation and that the changes made were not only a temporary experiment or fad in the view of the internal stakeholders. This point rises some concern about the mechanism to ensure or monitor that the changes are still in place once the researcher has finished its participation.

If action research had been included in the project, then the testing of the constructs derived from initial case studies and literature case studies would have been done via action research projects in companies. This approach was not feasible because the access gained to companies did not allow getting involved to such degree as to be part of the implementation team of the e-business strategies.

On the plus side, the path of initial case studies to build the research constructs from previous theory and empiric evidence and then test them using action research would have helped the general validity of the project, since action research "demands an explicit concern with theory that is formed from the conceptualisation of the particular experience..." (Coughland and Coghland 2002)

3.3.6.2 Surveys

A survey for this project would have been particularly difficult to implement and most likely it would have failed to answer the research questions. The reason for this is that the type of companies that were required for this project have special characteristics (implementing e-business in the order fulfilment process, using simulation as analysis tool) and it is unlikely that a relevant sample would have been obtained. If a survey had been carried out, it would have been on a narrow issue and the results would have been without much depth. At one point in the research process the idea of a survey was considered to analyse real changes in the structure of e-business process. However, a lack of a defined potential universe from where to sample, the means of getting the survey to companies and the feeling that the outcome of the survey would not bring great new insights discouraged us.

3.3.6.3 *Experiments*

Experiments were not used since there is difficulty in having control over all variables in an industrial setting. Quasi-experiments were used in an academic setting (see above).

3.4 Research quality evaluation criteria.

As described in Figure 3.1, after the research design step, the definition of the research quality evaluation criteria must be done. In this thesis, a number of research quality evaluation criteria as proposed by Martinez (2003) and Martinez and Albores (2003b) will be used to evaluate the rigour of the research process and outcomes. Table 3.6 shows a summary of these criteria.

	Generic Criteria of Evaluation 'controls'	TB	TT	TB-TT
1	The construct allows predictions or increases understanding	✓	*	✓
2	The construct is non-trivial	✓	*	✓
3	The construct includes attributes, variables, etc.	✓	*	✓
4	The construct does not include undefined variables	✓	*	✓
5	Provides research boundary 'scope of the construct'	✓	*	✓
6	Rigour of the research methodology process a) shows proof of logical research methodology design b) Internal validity c) Construct validity d) External validity e) Reliability	✓	✓	✓
7	Contains evidence to support the construct a) Select relevant samples and cases b) Provide sufficient evidence to substantiate the conclusions that have been drawn	*	✓	✓
8	Contribution to knowledge	✓	*	✓
9	Contribution to practice a) practical relevance b) practical functionality	*	✓	✓
10	Linking existing theory with theoretical novelty of the construct	✓	*	✓
11	Application of the construct on other environments	*	*	✓

TB: Theory Building
TT: Theory Testing

Table 3.6 Generic Research Quality Evaluation Criteria

These are explained below(Source: Martinez and Albores 2003b):

The construct increases understanding. The proposed constructs should enhance the comprehension of existing knowledge and/or new knowledge by providing a logic and reasonable explanation of the phenomena.

The construct allows predictions. Based on certain inputs, constructs should estimate or model different scenarios.

The construct is non-trivial. It refers that constructs should avoid the obviousness and bareness, although, this does not imply that constructs should be complicated.

The construct does not include undefined variables. Technically, every variable used should explicitly state how and why it is related or unrelated to each and every variable in the model (Wacker 1998).

Provides research boundary (scope of the construct) Constructs should define their area of applicability by establishing the environment where it can make accurate predictions. The use of different surveys, interviews and/or case studies on different fields are some methods suggested to defined the boundary of the research (Dubin 1969).

Rigour of the research methodology process. The rigour of the research process is demonstrated through:

a) A proof of logical research methodology design. It is concerned with the evidences that show a mastery research process, research protocol and a rational selection of research methods tools and techniques, which address the research issue (Sekaran 1992). Croom (2002) proposes a set of questions to explore the research processes (Croom 2002).

b) Internal validity is the extent to which the researcher can establish a causal relationship; whereby certain conditions are shown to lead to other conditions as distinguished from spurious relationships ((Easterby-Smith et al. 1999; Yin 1994). Some techniques used to ensure the internal validity are: methodological triangulation (action research, case study, interviews, surveys, etc.), use of different respondents, cross case analysis, pattern matching logic, explanation building and use a systematic process in building theory (decomposing, composing and interpreting) amongst others.

c) Construct validity is concerned with the idea that the research design fully addresses the research questions and the research objectives (Thomas and Tymon 1982; White 2000). The common techniques used to ensure construct validity are: triangulation of data, use of different source of evidence, selection of multiple data collection techniques, use of codes, standard data reduction tools and enfolding theory.

d) External validity establishes the domain to which a study's findings can be generalised (Yin 1994):33). Replication logic and use of multiple case studies are two techniques widely used to support external validity.

e) Reliability is the extent to which a study's operations can be repeated. It is also about consistency of research, and whether another researcher could use the same research design and obtain similar findings. The common techniques used to build reliability on the research are: implementation of controls to evaluate the research outcomes, use of case study protocol, pilot cases and use of standard databases (White 2000):25; (Kekäle 2001; Easterby-Smith et al. 1999):41; (Thomas and Tymon 1982; Sekaran 1992).

Contains evidence to support the construct. It is concerned with the support data or proof that fully address the research issue 'construct' (Kekäle 2001). This is achieved by:

a) Selecting relevant samples and cases. It is concerned with the quality of samples. Examples should rigorously test the features of the propose construct.

   In building theory from case studies, Voss et al (2002) recommend case selection by using replication logic. i.e. cases should be selected to predict similar results (literal replication) or produce contrary results but predictable reasons (theoretical replication).

   In theory testing, Miles and Huberman (Miles and Huberman 1994) suggest sample selection by finding typical samples, or negative/disconfirming samples or polar samples that contrast the characteristics being studied.

b) Providing sufficient evidence to substantiate the conclusions. This is concerned with the quantity of evidence to support the construct.

   This issue not just addresses the sample size e.g. number of case studies, survey samples, etc. but also, the different methods used to test a construct within the same sample e.g. interviews, documentation, observation, etc. (Forza 2002; Stake 1995)

Contributions to knowledge. The final objective in doing research is to make a contribution either to theory or practice or both by proposing something new, not known before the research. The contribution to knowledge underpins the development of constructs to simplify the understanding of the world and /or make predictions.

Contribution to practice. The aim is to provide:

a) Practical relevance. i.e. provide important information.
b) Practical functionality. i.e. provide something useful such as a tool, framework or process to simplify the understanding, or efficiently arrive to conclusions by saving time, making it easier, etc.

Linking existing theory with the theoretical novelty of the construct. It strengthens the research findings by supporting them with previous theories, and potentially it increases the importance of the research (Kasanen, 1993; Voss et. al, 2002).

Application of the construct in other environments. As Albert Einstein (1879-1955) estates 'a theory is more impressive the greater the simplicity of its premises is and the more extended is its area of applicability'. It is concerned with the generalisability of the research and the applicability of the research in others fields (Forza, 2002; Wacker,1998; Thomas and Tymon, 1982).

These criteria will be used to evaluate the research (Chapter7) and to guide the research during the conduction of the project.

3.5 Summary and conclusions

Research methodology is of growing importance, especially in OM, where traditionally a quantitative approach has been prevalent. The different research paradigms were explored and a research design selected for this research. A mainly qualitative approach was selected as the most appropriate for the type of research that this project is undertaking. Case studies were selected as research methods, using interviews, questionnaires and non-participant observation as data collecting tools. Simulation will be at the heart of the project, hence, some degree of quantitative techniques and tools will be used. However, it must be emphasised that the findings of this project will be restricted by the limitations imposed by qualitative projects.

A summary of the methodological choices of this research is outlined below.

Philosophical choice	Phenomenological
Research strategy	Qualitative
Research methods	Case Study,
	Quasi-experiments
Techniques	Simulation
	Interviews (semi-structured and un-structured)
	Observation
Tools	Simul8
	Witness
	Simprocess

Table 3.7 Summary of methodological choices

The next chapter will describe the pilot case study, the protocol used and the findings that allowed the modification of research questions and initial development of the constructs.

Chapter 4 Pilot Case Study (RQ1)

4.1 Introduction

Once the research questions and research need (Chapter 2) and the methodology to tackle the research (Chapter 3) have been established, a pilot case study was carried out in order to test the feasibility of the research and to inform and enrich the formulation of the research issues.

The pilot case study is used here as an exploratory tool to further develop the research ideas and questions. Here a pilot case will be used to test the feasibility of the research and to explore what other issues may be missing from the other research questions. Voss et al (2002) state "many doctoral thesis begin with one or more case studies in order to generate a list of research questions that are worth pursuing further". Additionally, Tellis (1997) states: "Pilot projects are very useful in determining the final protocols that will be used ". Accordingly, another use of the pilot in this research is to test the case study protocol to be used throughout this research.

Another use of pilot case studies is to test the feasibility and give early indication of the worthiness of pursuing a project (in my project that translates as answering RQ1). For example, Baines and Kay (2002) state of a pilot case carried during their investigation:

> "the objective of this evaluation has been to establish whether the methodology 'can work', rather than critique 'how well' it works in a variety of applications. If the approach is valid, then future work can build from this and explore the limitations of the approach, whereas a failure to produce a single working model suggests that the whole modelling methodology is invalid. On this basis, evaluation has been based on a single and relatively straightforward experiment." (Baines and Kay 2002)

As can be seen, the Popperian approach followed by these authors is a reflection of the usefulness of a pilot case study to test feasibility and to inform and enrich future research. One of the main reasons to carry out the case study is to test the applicability of the research idea in an industrial context. In Chapters 2 and 3, the idea of using simulation for the analysis of e-business process was considered theoretically feasible and the potential benefits were identified at that stage. However, the challenges of implementing this concept in a real application were not known and hence a pilot case was considered as the next step in the research.

The case study was selected to be a small company in which the change brought about by e-business was focused on a specific application. This selection has a threefold objective:

- To study a process that is focused on the order fulfilment process and in which the e-business application was focused on a specific activity of the process.
- To have a small number of outside variables that can affect the results of the pilot case and hence have more control over the results of the initial testing.
- To test different modelling tools and analyse their capabilities for the simulation of e-business processes.

The chapter will start with a description of the company and the context of the study, followed by the model building and experimentation phases and concluding with lessons learnt and new research insights gained from the pilot.

4.2 Company Description

WaterCo. was established in 1979 and has become the largest employer in Blackford, Perthshire with some 150 staff.

Since 1979, the company has invested over £30 million establishing one of the most modern natural mineral water plants in Europe. Today, WaterCo is the UK's most popular bottled water (Target Group Index) and is exported to over 50 countries around the world.

WaterCo has been involved in many projects and training courses in order to improve the performance of the whole organisation and improve the way the people work. Management skills development courses, problem solving courses, teamworking activities, etc, have resulted in more suitable ways of working for the current business needs. In many cases, these projects have involved the input and guidance of a third party such as a consultancy or university.

4.2.1 Water source

The Ochil Hills in Perthshire, Scotland is an area of outstanding natural beauty. Layers of red sandstone and basalt formed these ancient hills around 400 million years ago and they provide a natural filter for the fresh rainwater, which falls on the undulating heather clad slopes. This same rainwater takes up to 30 years to reach the point deep below the hills from which WaterCo derives its source. On its way, the water passes through thousands of intricate fissures, absorbing wholesome minerals on its way.

In the light of current awareness of polluted water supplies caused by increasing use of chemical pesticides and fertilisers, WaterCo. has made sure it has total control of its catchment's area, -an extensive 3,000 acre area surrounding it's boreholes in the Ochil Hills- where no farming, agricultural spraying or building is permitted to prevent pesticides, fertilisers and animals from polluting the rainfall as it approaches the mineral-rich rock strata.

The WaterCo. plant is one of the most modern of its kind in Europe. Total quality procedures ensure a premium product, which has been recognised with Gold, and Silver awards by the British Bottlers Institute.

4.2.2 Bottled Water Market

The UK bottled water market is one of the fastest-growing sectors in the soft drinks category with retail sales worth more than £500 million per year. Since 1991, the market has grown by 9% per year.

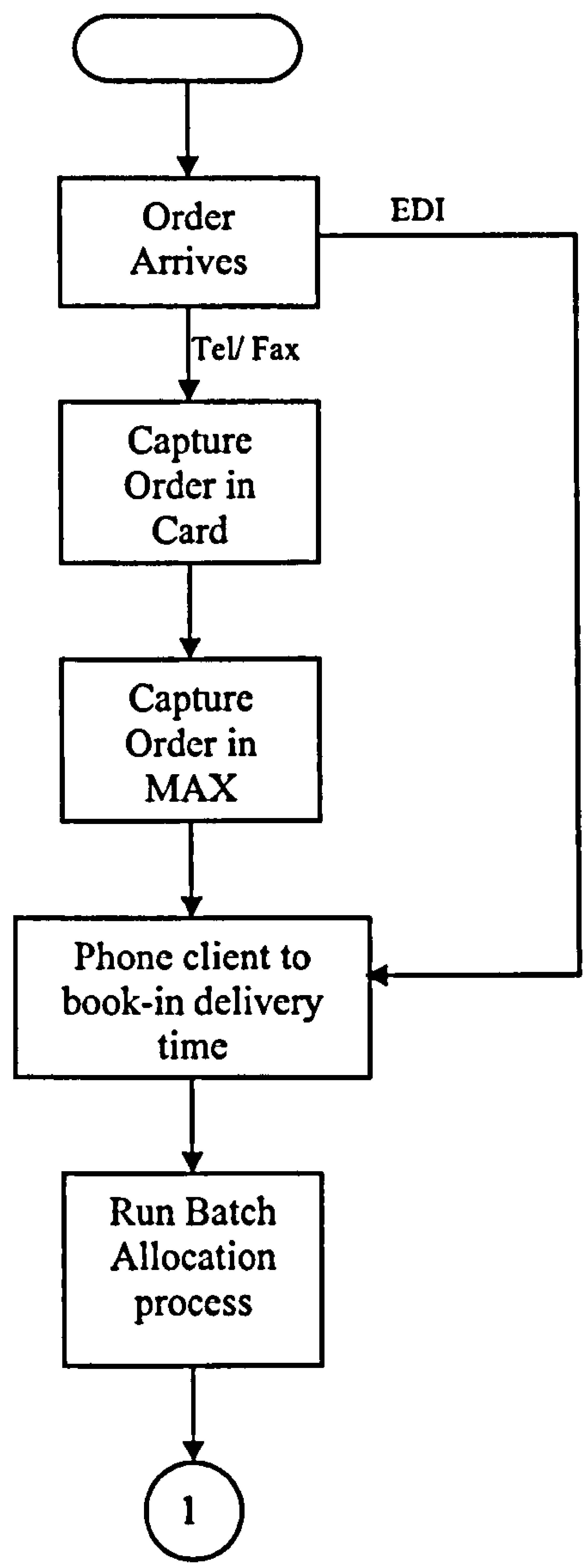
There are many factors that have influenced the growth of the bottled water sector, including rising concern about the quality and taste of tap water, an increase in health-consciousness and foreign travel where bottled water consumption is considerably higher. Despite intense competition, the 1998 Target Group Index figures from the British Market Research Bureau show that WaterCo retained the No 1 slot in the UK for the fifth consecutive year as the UK's favourite bottled water.

Recently, WaterCo has won a contract for the manufacture of an own label for one of the biggest retail stores in the UK, a move that will double the production in the plant. This will lead to an increase in warehouse capacity, currently under development, and an increase in production capacity in order to cope with this demand.

4.3 Process Description

Having worked in the past with simulation tools, WaterCo saw the opportunity of applying this tool to the analysis of changes in the way the business processes of the company would be affected by the introduction of electronic handling of the orders sent to the company's transport suppliers (Hauliers).

The process of interest for the company is the order handling process, specifically the Purchase Order for Haulier (POH) process. The process is illustrated in Figure 4.1



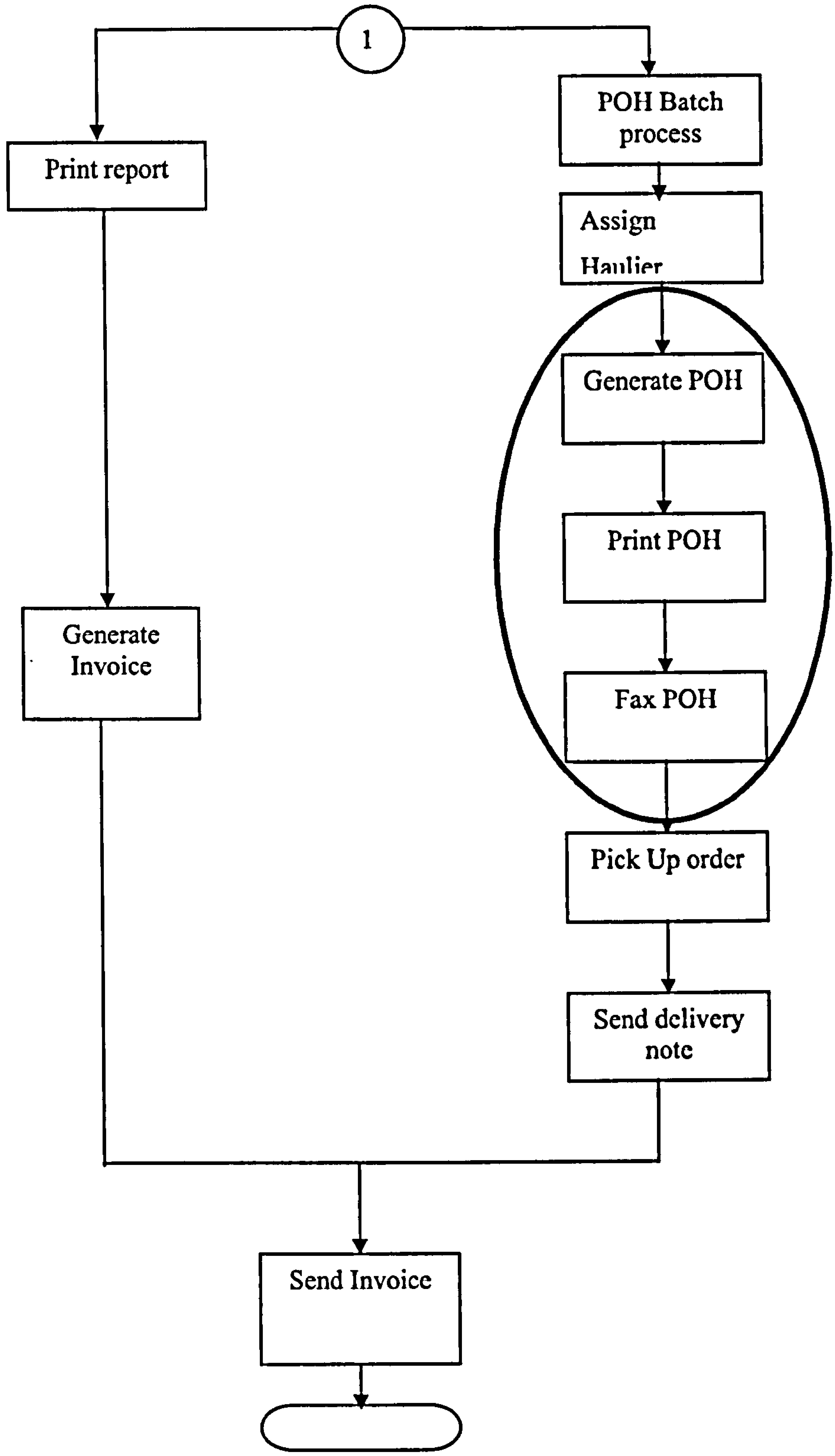


Figure 4.1. Order processing in WaterCo.

The process starts when an order arrives. There are three types of order arrivals. Telephone, Fax and EDI. Telephone and Fax orders are captured in a card and then logged into the ERP system (MAX). EDI orders are automatically logged into the system when they are "pulled" from the EDI server. A sales agent then calls the customer to book a delivery time and adds this information to the order file. Approximately each two hours, the batch allocation process is run. This automated process assigns a specific pallet/group of pallets to the order, accordingly to the required quantity and type of product. The process allocates about 20 orders (hence the "batch" name) each time it is run and takes about 20 minutes to complete.

After the batch allocation process, the order is split. One part goes to the finance department and waits until conditions are fulfilled to send out the invoice. Meanwhile, the warehouse department receives its copy of the order, runs a batch process similar to that described above, but with the purpose of finding which orders are "cleared" for delivery (i.e. they don't have a credit problem or similar issues). Once having the valid orders, the warehouse department assigns the haulier that will handle the shipment (based on heuristic rules) and generate a Purchase Order for Haulier (POH) in the system. The POH is then printed and accumulated on a tray. Once a number of orders (20-25) are stored in the tray, they are faxed to the Hauliers, so they can make the necessary planning for the trucks to come on the specified day, pick the orders and deliver to the customer. Once the orders have been delivered, the haulier sends a delivery note to WaterCo.. This delivery note is tied to the customer order and the invoice is sent out to the customer.

4.4 Project Scope

The scope of the project is the exploration of changes in the way the POHs are sent to the haulier. Alternatives such as e-mail, e-fax and XML are to be explored as technical solutions for this end. From the point of view of the process modelling, these transactions are going to be considered equivalent in the model. The transactions to be simplified are circled in Figure 4.1

In addition, an exploration of the future possibilities of reception of orders via electronic means (XML) is going to be carried out. Different scenarios (order mixtures) are going to be analysed, as well as the mixed effect of e-order taking and e-POH.

4.5 Model building

In order to build the model, the physical process was followed, interviews with the persons in charge of each part of the process were carried out and historical data was retrieved from the ERP system.

4.5.1 Assumptions

Some assumptions had to be considered at the time of modelling. These assumptions are intended to simplify the modelling task although without diminishing the validity of the model. The main assumptions are:

- Equally distributed arrival of orders across the week.
- 20 % of current orders are made by EDI means.
- Book-in takes place after receiving the order and cannot be processed if it is not booked.
- 3 persons receiving orders
- 1 person generating POHs
- Batch allocation process is run each 2 hours.

4.5.2 Model Building

The model was built in sequential stages. Three main sub-processes were identified within the whole process and using the capabilities of the selected simulation software (Simprocess V2.2.2), were created as high-level processes within which specific activities would be detailed. The high-level representation of these sub-processes can be seen in Figure 4.2.

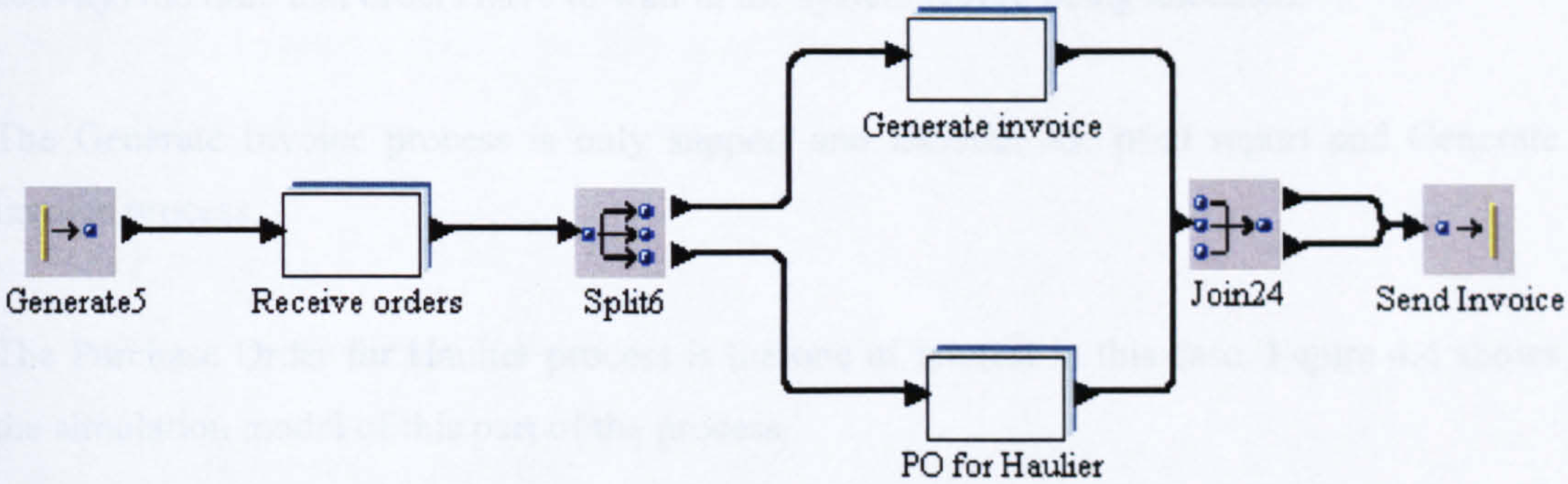


Figure 4.2. High-level Model of the Business Process

The Receive order sub-process deals with the reception of orders, distinguishing between EDI and Fax/Telephone, taking into consideration the three persons involved in this part of the process, the capture of orders into the system and the allocation of specific pallets to the order. See Figure 4.3

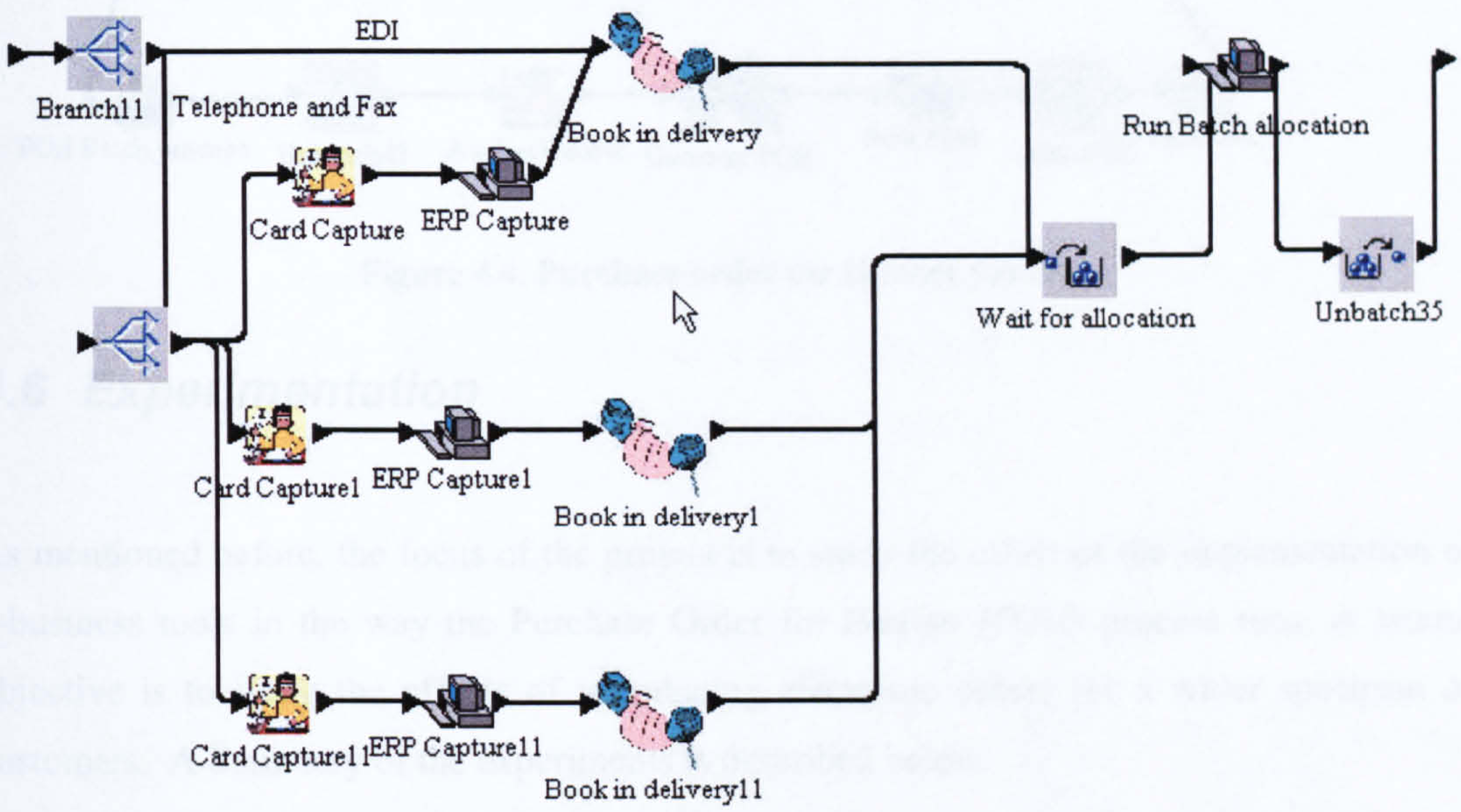


Figure 4.3 Receive Order Sub-process

From the point of view of simulation, there are two elements to be described in this part of the process. First, the use of the Branch element to route the types of orders (Branch11) and to distribute the workload between the three sales people (second Branch). Second, the use of batch and unbatch elements to simulate (together with the Run Batch allocation activity) the time that orders have to wait in the system before being allocated.

The Generate Invoice process is only support and includes the print report and Generate invoice process.

The Purchase Order for Haulier process is the one of interest in this case. Figure 4.4 shows the simulation model of this part of the process.

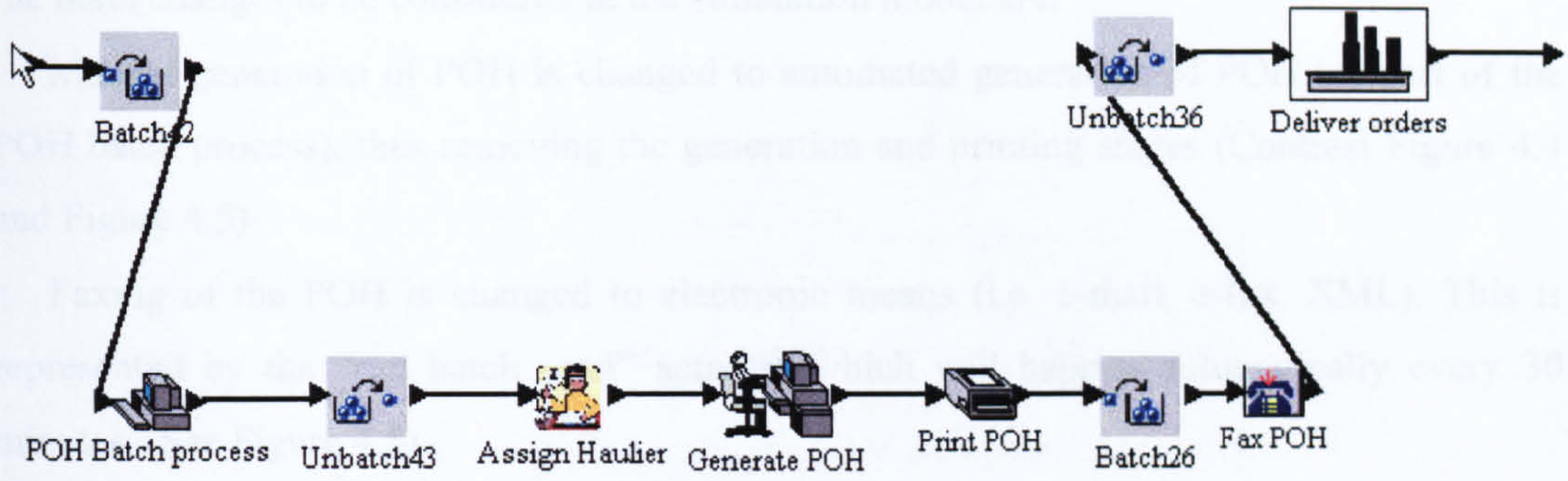


Figure 4.4. Purchase order for Haulier process

4.6 Experimentation

As mentioned before, the focus of the project is to study the effect of the implementation of e-business tools in the way the Purchase Order for Haulier (POH) process runs. A lateral objective is to study the effects of introducing electronic orders for a wider spectrum of customers. A Summary of the experiments is described below:

Purchase order for haulier

Comparison between traditional (Fax) and electronic processing (Auto Fax, email, XML).

Receive Order

Comparison between different ratios electronic vs. traditional order

20% E-orders, 80% traditional orders (Current)

50% E-orders, 50% traditional orders

80% E-orders, 20% traditional orders

The selected metrics for the comparison of results are:

- Processing time
- Throughput
- Staff utilisation
- Cost (informative purpose only)

4.6.1 POH experimentation

4.6.1.1 Changes to the process

The main changes to be considered in the simulation model are:

- Manual generation of POH is changed to automated generation of POH (as part of the POH batch process), thus removing the generation and printing stages (Contrast Figure 4.4 and Figure 4.5)
- Faxing of the POH is changed to electronic means (i.e. e-mail, e-fax, XML). This is represented by the "run batch send" activity, which will happen automatically every 30 minutes. (See Figure 4.5)

In addition to the general assumptions, the following specific assumptions are considered:

- Current demand pattern is sustained (~ 2080 orders/month)
- Manual input is still required to select the specific Haulier

The modified model is illustrated in Figure 4.5 (Note: Contrast with Figure 4.4)

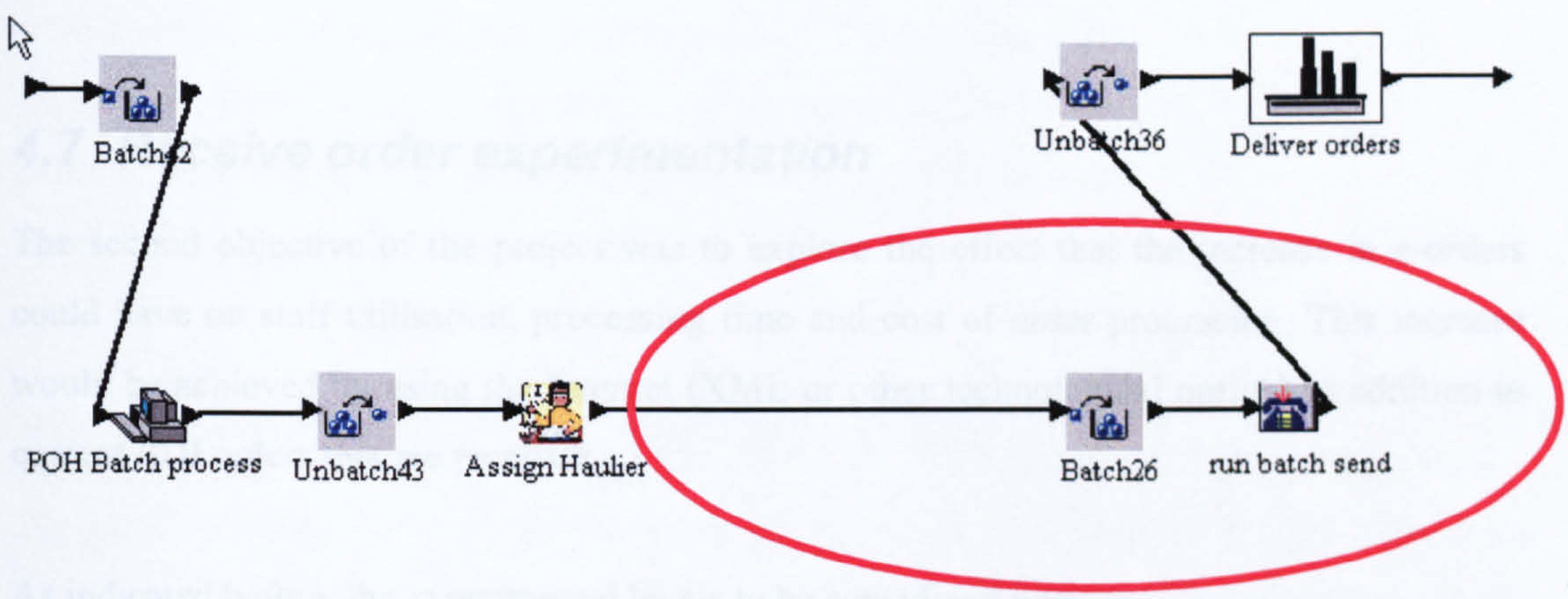


Figure 4.5. Modified POH for Haulier.

4.6.2 Experiment Results

After modifying the model, the experiment was conducted. The results presented in Table 4.1 are the average of 10 iterations of 1 month, considering 8 hours shifts.

	Current	e-process
Units processed	2052	2052
Units remaining in system	54.4	36
Processing time /unit	272 min	215 min
Staff Utilisation (POH)	77.66%	17.90%
Cost/unit	£ 4.58	£ 2.9
Cost/month	£ 8755	£ 5650

Table 4.1 Experimentation of purchasing process (POH)

4.6.3 Discussion of POH process

By simply utilising the existent capabilities in the ERP system (e-ordering), the simulation show that staff utilisation in this part of the process can be reduce from 77% to less than 20%

As a result of less human intervention, cost of processing can be reduced by 35%

Order residence time is reduced by using an electronic POH process

A larger number of orders can be processed (quantity to be defined by further experiments)

4.7 Receive order experimentation

The second objective of the project was to explore the effect that the increase in e-orders could have on staff utilisation, processing time and cost of order processing. This increase would be achieved by using the Internet (XML or other technological option) in addition to current EDI orders that are received.

As indicated before, the experimental levels to be considered are:

Comparison between different ratios electronic vs. traditional order

- 20% E-orders, 80% traditional orders (Current)
- 50% E-orders, 50% traditional orders
- 80% E-orders, 20% traditional orders

The number of orders received in a month will be maintained constant in order to have a comparison base. The ratio of orders will be changed in the order generation module. For this part of the experiment, no change will be considered in the POH process.

The results are described in Table 4.2.

	Current 20 e-80% T	50 e –50 T	80 e -20 T
Units processed	2052	2064	2064
Units remaining in system	54	54	61
Processing time /unit	286 min	296	308
Staff Utilisation (POH)	77.66%	78.46%	77.57%
Cost/unit	£ 4.58	£3.815	£ 3.352
Cost/month	£ 8755	7863.75	£ 6934.62

Table 4.2 Experimentation results for receiving e-orders

4.8 Conclusions from simulation

By simply utilising the existent capabilities in the ERP system (e-ordering), we can reduce staff utilisation in this part of the process from 77% to less than 20%
As a result of less human intervention, cost of processing can be reduced by 35%
Order residence time is reduced by using an electronic POH process
A larger number of orders can be processed.

4.9 Lessons learnt from the Case Study

The pilot case study showed the feasibility of the use of simulation to analyse e-business processes. The analysis carried out using simulation gave a better understanding of the issues that were likely to emerge when implementing e-business in the company.
Additionally, it can be considered that the pilot case was successful in that it allowed the enhancement of the research questions, illustrated some deficiencies in the initial assumptions about the work and created new lines of enquiry.
The findings from the case study, some of which challenged the initial assumptions are:

- Change in behaviour, rather than change in structure. The e-business literature suggested that one of the initial steps of an e-business implementation is the re-design of business processes (e.g. Chaffey 2002). However, from the case study it was noticed that the main change was not on the structure of the business processes, but rather in their behaviour (dynamics) (see section 4.6.1). This point was further investigated in the literature and evidence was found that reinforce this finding (Quayle and Christiansen 2002; Barnes et al. 2002; Bosilj Vuksic et al. 2001). There seems to be a drive to use e-business, paraphrasing Hammer (1990), to automate rather than obliterate. This issue remarks the need for a tool to better understand the change that e-business will have. If the changes are merely in the behaviour, rather than in the structure, the need for tools to evaluate the changes in the dynamics of the processes is highlighted. From this finding I can be encouraged for the usefulness of simulation to carry out his evaluation.

- Degree of detail of e-business analysis. At this point in time the question of level of detail (degree of granularity) of the future analyses comes to light. If re-usable components will be developed to facilitate the model-building process, at what level should this components be developed. The initial idea at the start of the research project was to develop generic processes at high level, similar to those proposed by Childe et al (1996). Chapter 5 deals with the analysis of the level of detail and the comparison of different established business process models and process models from industry.
- The need to assign cycle times to electronic transactions. How much does an electronic transaction last? Is this value something that is worth considering when modelling?. The view from this researcher is that what is important here is not what is there (i.e. how long it takes a task to complete, assuming we are talking about seconds or milliseconds), but how much of the time "is not there". This time savings is what will affect the dynamics of the process. This is an issue that requires further investigation and will be studied in Chapter 5.

4.10 Conclusion of the Chapter

As a result of the pilot case, it was concluded that the project is feasible and that some other issues were needed to be taken into account when developing the research further. Some of the initial assumptions were challenged, such as the level of detail in which to analyse e-business implementations and the fact that e-business is being used as a means of automation, rather than of re-design of business processes.

In carrying out this work, it was noted that the generic business process models are only sufficient to show what is done, but not the interactions between activities in complex processes. The development of such process models to a greater degree of detail would assist in operationalising the process models (showing the how, as well as the what; the how being more detail on the what). This in turn would enable simulation models to be used to help businesses more easily assess the fundamental impact of e-business transformation by taking into account the complexity, dynamic nature and interrelations between actitivies

The results from the case study were encouraging and justified continuing with the research. Chapter 5 will deal with some of the issues raised during the pilot case and will describe the development of the main constructs of this research: the re-usable simulation components for e-business analysis.

Chapter 5 Development of Constructs

5.1 Introduction

Chapter 4 confirmed the suitability of using simulation for the analysis of e-business. At the same time, a number of new research issues emerged from the analysis of the pilot case study. This chapter will deal with the analysis of some of the research issues emerged during the pilot, such as the level of detail for the generalisability of e-business process patterns.

Further into the research, it was found that the answer to the original second research question is not what was expected. The researcher concurs with Childe et al (1996) in believing that process models can be very useful in facilitating an understanding of "how" an organisation operates and "what" activities it undertakes. However process modelling can be a resource intensive activity. Childe et al (1996) suggest that this problem may be overcome by utilising a set of generic models which may be adapted to fit specific company scenarios.

At the outset it was expected to be able to develop high-level e-business generic models of business processes, in the same way that earlier work by Childe et al (1996) produced IDEF0 models of traditional operate processes. I had hoped that by developing such generic process models I would simplify the analysis process for companies – giving them a starting point for analysing the effects on their business processes.

However the results of my case study work suggests static process-mapping techniques uncover very little difference at this level. This finding is supported by Bosilj-Vuksic et al (2001), who say "...from the process map itself not many differences can be observed between the AS-IS and TO-BE model. However, the most important differences are evident in the way of performing these activities". It is then proposed that in practice, the changes brought about by e-business on business processes are not in the structure, but rather in the dynamics of the process. This assertion conflicts with what is generally accepted as one of the steps of e-business implementation, namely re-engineer the process. It also suggests that what companies are using e-business for is to automate, rather than to completely rethink how they conduct their business. Other research into the degree of change on business processes when implementing e-business supports this result (eg.Quayle and Christiansen 2002; Scottish Enterprise 2002).

In order to explore this issue further, the chapter will deal with an evaluation of current business process models by comparing and contrasting real business processes with the proposed generic processes in order to see if they can represent e-business activities and can capture the difference between traditional and e-enabled processes. The chapter then continues with the identification of a number of generic e-business activities from primary and secondary case studies. Next, the procedure for operationalisation in simulation software is described and an initial testing on two manufacturing environments (Make to Order and Make to Stock) is presented. Finally, conclusions are drawn on the development process of the components and the scene is set for the testing of the components.

5.2 Generic business process models

Different business process models exist at the moment. These process models have the aim of serving as guide of what a process should look like according to its final purpose. For example, the order fulfilment process will include activities such as plan order fulfilment, obtain required items, manufacture product, deliver product, etc. An initial exploration was carried out in order to assess the suitability of these generic process models for the static modelling of business process and to test their ability to differentiate traditional and e-enabled activities.

From the analysis (reported below in Table 5.1 and Table 5.2) it emerged that the interrelations inherent to business process modelling and the different levels at which they can be analysed make business process modelling a complex task. As previously mentioned, there is a number of generic business process models existent in the literature. Childe et al (1994) proposed a set of generic business processes for manufacturing companies. They divide the processes in three types: Manage, Operate and Support processes. The focus of this work is in the analysis of the Operate Processes as proposed by Childe et al, especially the order fulfilment process.

Another set of standard processes is the Supply Chain Operations Reference (SCOR) Model proposed by the Supply Chain Council (Supply Chain Council 2002). The model describes standard supply chain activities (Plan, Source, Make, Deliver and Return), and related performance measures and best practices.

There has also been work to develop generic business processes for e-business. Examples of this are the MIT e-Business repository in the US (Malone et al. 1999) and the work being conducted by the Barnes et al at the Open University in the UK (Barnes et al. 2001). The idea behind the e-business repository (Malone et al. 1999; MIT 2000) is that in order to build an e-business application, one selects from an arrangement of predetermined business process models for each activity and then fits them together to form the business model. The repository was built drawing from experience gained in work like that of Childe et al (Childe et al. 1994) and the International Benchmarking Clearinghouse model (American Productivity & Quality Center 1992).

These process models offer an opportunity to act as templates for simulation analysis of e-business process change. It is my proposition that by creating re-usable simulation templates (also known as components in some simulation packages) the analysis of e-business processes can be facilitated and made faster. The generic business process models can act as a starting point to create these templates.

With work underway on building e-business process models (Barnes et al. 2001; MIT 2000) there is a lack of e-process templates to assist in the development of simulation models. Whilst the inherent properties of discrete event simulation techniques have the potential to assist in helping to model the impact of e-business processes, issues of how to represent the business systems and their dynamic influence on the whole process remain. The next section will look in more detail at the case studies and discuss the value found from using both static and dynamic modelling techniques.

5.2.1 Method of Analysis

An exploration was carried out in order to assess the suitability of the generic process models mentioned above for the static modelling of business process and to test their ability to differentiate traditional and e-enabled activities. The results of this analysis will tell whether existing models are applicable to e-business and will help to identify areas where they are not able to represent the specificities of e-business process, hence giving guidelines about how to fill these gaps.

It was decided to adopt a case based approach in order to ask a " 'how' question about a contemporary set of events over which the investigator has little or no control" (Yin 1994). The analysis of e-business processes fulfils these characteristics: it is a contemporary issue, we need to understand how to use modelling tools to better understand e-business and there is little degree of control from the researcher over the implementation of a particular e-business application in an industrial setting.

In order to make the comparison, process maps (gathered from case studies carried out by the researchers and from the literature) were mapped against the generic business process models under consideration (Childe et al. 1994; MIT 2000; Supply Chain Council 2002). Five cases were analysed. The cases were selected to provide theoretical replication (Yin 1994; Eisenhardt 1989): companies that are implementing or have implemented e-business, preferably in the order fulfilment process were selected as cases. Two of these case studies are presented in this section to illustrate the method of analysis, the rest are presented in Appendix 2.

In order to avoid bias in the existing process maps, the cases were selected to include process maps created by the authors in their case studies, process maps created by companies supported by the authors, and finally, process maps reported in the literature (Bosilj Vuksic et al. 2001; Ngai et al. 2003).

Once the process maps were selected, they were tabulated. For each activity in the real process, an equivalent was sought from the generic business process models and mapped against the corresponding activity in the case. For this task, a keyword search was carried out, using the activity name and synonyms for the activity. Additionally, a hierarchical analysis was carried out in the business process models, in which potential branches for an activity were identified and all the sub-activities and their description for these branches were analysed.

5.2.2 Results from case studies

The first case is that of the pilot case presented in Chapter 4 (make-to-stock company). The predicted increase in the number of transactions has led to the company to search areas of improvement in their order processing time. The researcher used process mapping and simulation to help the company foresee the effect of moving to an e-procurement model. Figure 5.1 presents the process map for this case.

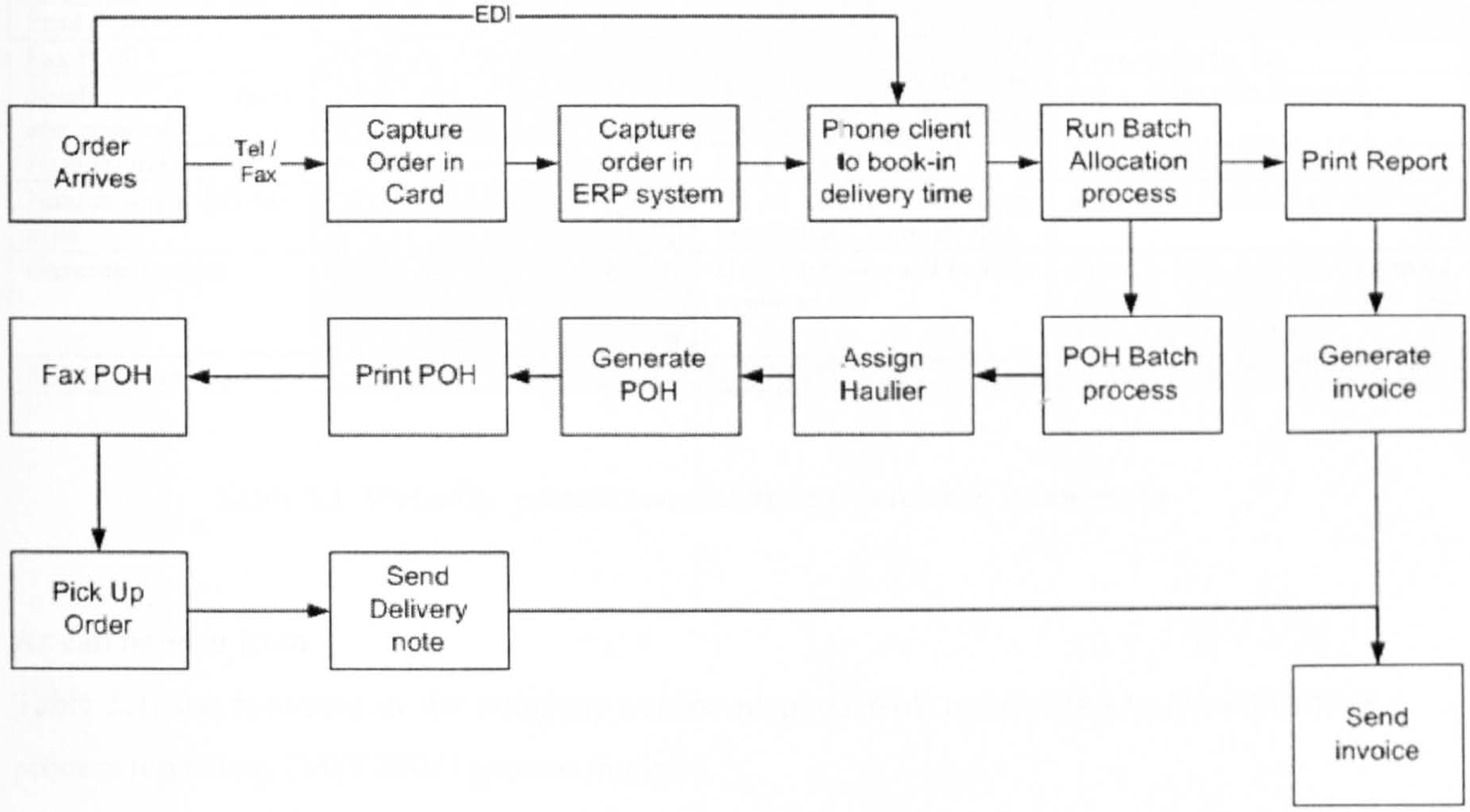


Figure 5.1 Water Co. process map.

Table 5.1 shows the process activities and the corresponding mapping to each one of the generic process models. The activities in italics are those new activities that deal with the e-business alternatives. (Note: although the MIT activities are not numbered, the source of the activity has been included when available.)

Co. Activity	Childe et al (Childe et al. 1996)(Smart et al. 1999)	SCOR	MIT (MIT 2000)
Order Arrives	A141 Manage customer query	M1.1 Receive, Enter & Validate Order	Obtain order
Order Arrives Fax/Tel			Receive order by tel
Order Arrives EDI			Obtain order via EDI
Capture order in Card			
Capture order in ERP system			Enter orders into production and delivery {PCF 4.2.2}
Phone client to book-in delivery time	A343 Schedule delivery	D1.3 Determine Delivery Date & Reserve Inventory	Schedule delivery activities
Run batch allocation process	A31223 Compare requirements to existing schedule + A31234 Add order to main schedule		Enter order, commit resources and launch program {SCOR D3.3}
POH batch allocation process (check which orders are ready to be dispatched)	A143 Accept / release order	Mx.6 Release product to deliver	Release product to deliver {SCOR Mx.6}
Assign haulier	A3221 Identify sources for each item	D1.7 Select Carriers & Rate Shipments	Select supplier
Generate POH in system	A32222 Generate PO for bought-out items	Procurement Signal (Supplier) ? (output of S2.1)	Place order using own application

Print POH			
Fax POX			Place order by fax
Send POH electronically			Place order over internet
Haulier picks order	Dispatch customer order	D1.9 Pick Product	Pick product {SCOR D1a.9}
Haulier sends delivery note		D1.11 Receive & Verify Product at Customer Site	Document delivery of service
Generate invoice		Dx.13 Invoice and receive payment	Invoice and receive payment {SCOR Dx.13}/ Invoice the customer {PCF 7.1.2}
Send invoice			

Table 5.1. WaterCo. process mapped against reference frameworks

As can be seen from

Table 5.1, the activities in the company can be mapped with more detail to the e-business process repository (MIT 2000) generic model.

The second case study refers to a label printer that operates a make-to-order policy. Again, process mapping and simulation were used to analyse the effect of introducing new e-business strategies, specifically geared towards customer interaction and involvement along the design and production process. Having currently order-processing lead times of up to 14 days, they plan to reduce this to less than 5 days introducing e-business. The process mapped starts with dealing with enquiries through to delivering the product. Figure 5.2 shows the process map for the activities under study.

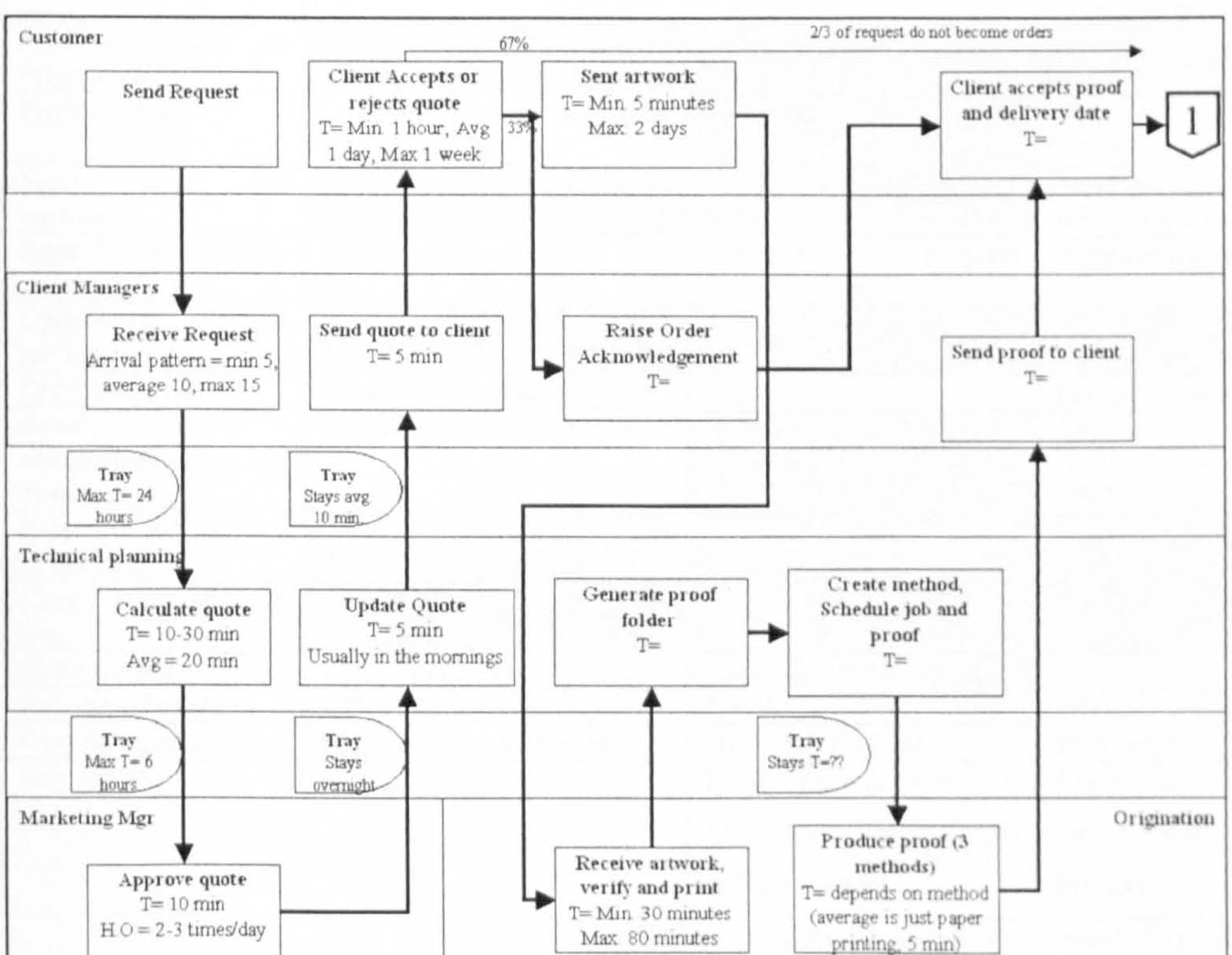


Figure 5.2 LabelCo Process map.

Table 5.2 describes the process and shows a mapping against the generic business process frameworks. The whole workflow will be transferred to electronic form. Activities in italics show where the biggest impact of e-business is thought to be.

Co. Activity	Childe et al (Childe et al. 1996)(Smart et al. 1999)	SCOR	MIT (MIT 2000)
Receive enquiry	Receive enquiry from customer	Process enquiry and quote	Process enquiry
Produce estimate	Estimate process times/apply standard cost rates		Calculate product/process requirement
Commercial review of quote	A141 Manage customer query		Review/oversee
Update quote			
Send quote to customer			Send quote
Wait for customer to decide			Wait on customer
Receive order	A141 Accept/ release order	M1.1 Receive, Enter & Validate Order	Obtain order
Pass Artwork to origination	Develop preliminary design		Customer provides specifications
Check artwork/ highlight issues & print	A3123211 Check Drawing issue		Conduct initial technical review
Log order & create order spec	Identify process required		Enter orders into production and delivery {PCF 4.2.2
Create method	Generate process instructions	Finalize Engineering	Develop product and process design
Schedule delivery date –proof & job	Compare requirement to existing schedule	Schedule manufacturing activities {SCOR M3.2}	Schedule manufacturing activities {SCOR M3.2} / Schedule prototype build
Proof bag sent to origination			
Produce proof	Develop product to meet specifications		Develop prototypes {PCF 3.2.5}
Send proof to customer			Send physical object/ send information externally
Approve proof & date	Confirm with customer	Approve Request Authorization	Approve transaction
Update order, produce job bag, print spec			
Order materials	Obtain required items	Source	Buy raw materials
Send acknowledgement to customer	Confirm order to customer		Confirm specific service requirements for customer {PCF 5.3.4}
Pass updated job bag to planning			
Check specs and job bag			
Order tooling	Issue work orders		
Run manufacture	*****	*****	****
Despatch goods	Dispatch customer order	D1.9 Pick Product	Pick product {SCOR D1a.9}
Ship goods.	Deliver product	Load Vehicle Generate Ship Docs. Verify Credit & Ship Product	Load Vehicle Generate Ship Docs. Verify Credit & Ship Product

**** not mapped because it is too specific to manufacturing.

Table 5.2. LabelCo process mapped against reference frameworks

5.2.3 Lessons from the case studies

As can be seen from mapping the different processes against established frameworks, the amount of detail available in such frameworks is not enough to represent some of the activities that the specific processes require. From the three frameworks analysed, the one that seems to have the most detail is the business process repository from the MIT. However, it is evident from the case studies that the use of static frameworks cannot fully capture the impact that e-business brings to the business processes of manufacturing companies.

It must be said that the emphasis of the work developed by Childe et al (Smart et al. 1999; Childe et al. 1994) was on manufacturing companies and that their work was developed before the widespread use of e-business. It is then no surprise to find that this framework fails to identify the differences introduced by e-business in the case studies. This is especially applicable since the frameworks were developed as a guide to "what" a manufacturing company most commonly do, not to "how" to do it. It is in the "how" that e-business is having the greatest impact.

On the other hand, the SCOR model is intended as a high level model of supply chain related activities. As such, the guidelines it gives are not very detailed, and although there are specific suggestions about performance metrics and best practices (including some e-business applications) in the written description of each activity, they are difficult to see from the structural/graphical representation advocated by SCOR.

The MIT e-business process repository was better at finding these changes. One of the main reasons for this is that the business process repository has the concept of "specialisations", that is, the ability to "differentiate process into its different types" (Malone et al. 1999). For example, the process "receive order" can have specialisations like "receive order by fax" and "receive EDI order". This will obviously have an impact on the amount of variations that can be accounted for when analysing e-business. Despite this, the researcher does not believe that the business process repository per se can describe the real dynamic aspects of business processes.

Static models have value to help building the initial picture of the process, serve as a communication tool in the initial stages of the analysis and can be used to organise the data collection phase of the dynamic analysis by prompting the asking of the right questions in a structured manner. The use of generic frameworks can help identify relationships or activities that could have been overlooked in the initial mapping of the process. For example, in Table 1 mapping the activity "Phone client to book-in delivery time" against the different frameworks can flag other activities that may be related to this activity. Activity A343 "Schedule delivery" in Childe's (Childe et al. 1994) map is preceded by "A342 Generate Shipping documentation" and followed by "A344 Load order". If any of these activities are not in the current process map, it must be asked why and if necessary include them.

Finally, although the business process activities of the case study companies were mapped against corresponding activities in the generic processes, the processes as a whole did not follow the ordered hierarchies and sequences proposed by the frameworks. For example, from an initial analysis of the WaterCo process (Table 5.1), it was thought that two distinct phases were found in the process: Manage Order/Enquiry and Obtain Required Items/Dispatch Order. One would expect to find all the activities hierarchically accommodated below these high level processes. In reality, in order to faithfully map the companies' activities, generic activities from a wide range of processes were used (e.g. activities from Plan Order Fulfilment and Support Product).

It can be inferred that: first, the generic processes, although a good guide, do not capture the full complexity of business processes. Second, that the concept of what a process comprises is intimately related to the specific perception that the company has of its business. What for a company are completely separate processes, for another are an integrated and inseparable entity.

5.3 Reuse and Component Theory

5.3.1 Reuse in systems engineering

The reuse concept has been proposed in the software engineering arena as a way to make the software creation process speedier. A number of authors have described what reuse entails: for example, Duskink and van Karwijk (1995) define reuse as "all activities aiming at reusing previously constructed artifacts within the process of (software) development". On the other hand, Reese and Wyatt (2005) define reuse as "the isolation, selection, maintenance and utilisation of existing software artifacts in the development of new systems". These authors identify McIlroy as the one who originally coined the term more than thirty years ago. Since then, the reuse concept has been extended to other disciplines such as design (e.g. Smith 2002) knowledge management (Oussalah 2002), modelling and design of manufacturing systems (Chandra et al. 2005) and simulation in general (Pidd 2002; Aronson and Bose 1999; Mclean and Shao 2003). Most of the arguments for reuse are based on the premise that

> "...building models of all types is an expensive process as it takes a considerable amount of time and effort to analyse and understand the systems and processes that form an essential part of the operation of an enterprise" (Chandra et al. 2005).

Accordingly, some of the arguments for reuse are:

- Reusing an existing design in a new application as an obvious way of reducing effort and risk. (Chandra et al. 2005)
- If in building new models, existent solutions can be reused, the construction of this new system will be more likely to be in time. (Dusink and van Katwijk 1995)
- If a single existent solution is used more often, it is likely that the quality of the solution will improve.
- Each new simulation case study performed today probably repeats at least some work previously done by others... hence, the development of standard templates for different types of case studies would be a step in the right direction to minimise the duplication of work. (Mclean and Shao 2003).
- Individual case studies should be able to be used as modular building blocks and templates to solve more complex manufacturing problems (Mclean and Shao 2003).
- Reusability provides not only software productivity and quality, but also provides flexibility to meet changing simulation requirements (Aronson and Bose 1999). The demand for such flexibility can be met by developing simulation applications by composing reusable pieces accessed from a reuse repository.
- Simulation systems are excellent candidates for component reuse since model development, validation and verification costs are high. Composition offers opportunities for large savings in simulation development. (Aronson and Bose 1999)

In summary, it can be argued that reuse takes advantage of existing structured knowledge and applies it to new problems, making in the way the problem solving process faster, more productive, more flexible and (theoretically) of better quality.

5.3.2 Component-based reuse in simulation

Although the reuse concept has been applied to software engineering for almost thirty years, its application to simulation is somewhat more recent.

Pidd (2002) describes a "very non-linear" spectrum for software reuse. It presents four types of software reuse: Code scavenging, Function reuse, Component reuse and Full model reuse. It additionally presents two different horizontal axes: Frequency and Complexity. It is argued that reuse is more likely to occur in code scavenging than on full models, while complexity runs in the opposite direction, making reuse of full models a far more complex task than that of code or function reuse.

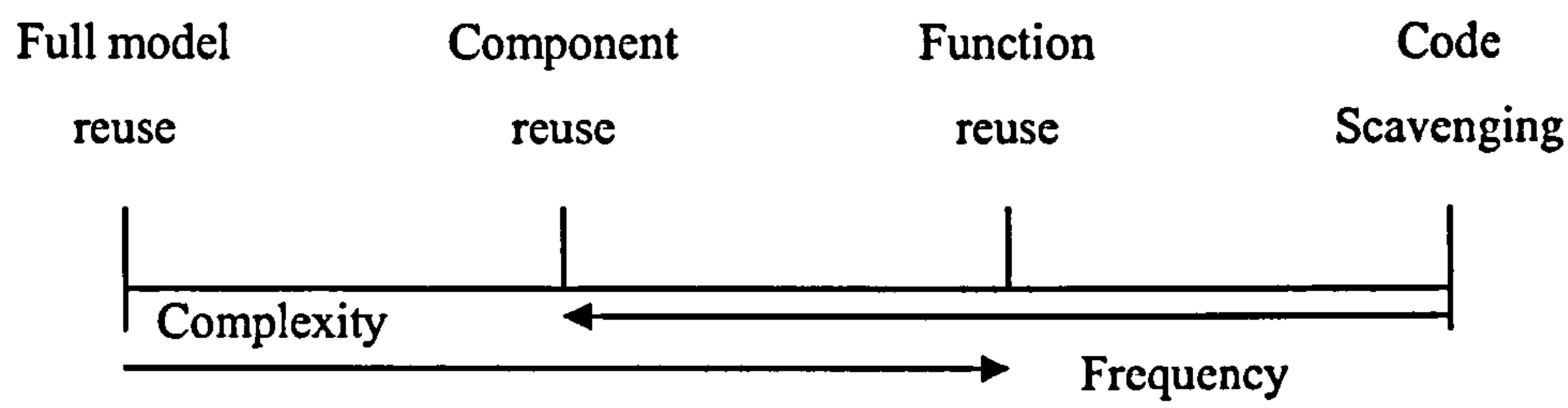


Figure 5.3 Reuse spectrum (Source: Pidd 2002)

Pidd describes the four types of reuse as:

- Code scavenging. Reuse of basic code, as long as we trust the person that wrote the code. This reuse is fine grained and uncontroversial.
- Function reuse: The reuse of built-in functions in particular languages or systems. The functions are very specific in their functionality.
- Component reuse. Components are defined as "encapsulated modules with a defined interface, providing limited functionality and able to be used within a defined architecture" (Pidd 2002). Based on the definition of reuse presented in the previous section, a component would be the artifact in question i.e. a piece of formalised knowledge that can contribute to the (software) engineering process.
- Full model reuse. This is the holy grail of reuse. Full model reuse is extremely difficult and as a result, it is not very common.

The characteristics of the different types of reuse can be summarised in Table 5.3

Type of reuse	Complexity	Frequency	Granularity
Code scavenging	Low	High	Fine Grained
Function reuse	Low	High	Fine Grained

Component reuse	Medium	Medium	Fine to large
Full model reuse	High	Rare	Large grained

Table 5.3 Reuse types and their characteristics (Adapted from (Pidd 2002))

Using Pidd's classification, it can be argued that the area for exploring reuse that has not been completely exploited and that has potential to inform knowledge and contribute to practice is that of component reuse. Code scavenging and function reuse have been extensively used in the past, while full model reuse is rare and it is very difficult to find two contextual setting in which a whole model could be reused. It is then in the area of components that the potential for reuse can be realised. Using components as modules, a simulation model can then be assembled as if it was a jigsaw. A number of conditions must be present for this assembly to take place: a defined set of rules, an interface specification, documentation, processes for reuse.

Different analyses of potential applications of the use of components in simulation have been presented for general simulations (Pidd 2002; Pidd et al. 1999) and for military applications (Kasputis and Ng 2000; Davis et al. 2000). However, as can be seen, the number of reported applications is not extensive, an indication of the developing nature of the field.

It is then in the light of generating a better understanding of how component re-use can be applied to computer simulation that a number of e-business simulation components are developed and their application studied. The next section will describe the developing process for these components.

5.4 Generic e-Business Components

The use of generic static frameworks for mapping the differences between traditional and e-enabled business processes does not capture the full extent of the differences, since these differences are usually perceived in the behaviour, rather than in the structure of the processes. It has also been argued that dynamic analysis, such as simulation, is necessary if such changes in behaviour are to be fully understood. However, one of the problems with dynamic modelling is that is usually more time consuming than static analysis tools.

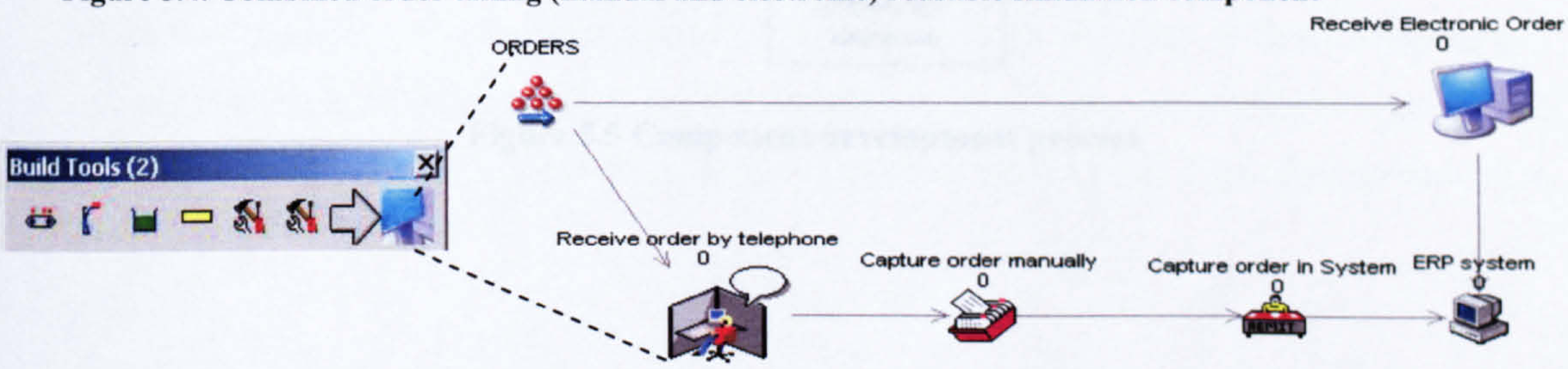
This brings us to the question of how to improve the effectiveness of simulation modelling of e-business and its effect on business processes. As explained in section 5.3, one proposed approach is that of using pre-built simulation elements (templates or components) that encompass a number of entities that represent e-business activities. These components provide a unique set of functionalities that can be used as building blocks in creating multiple simulation models, thereby allowing new models to be assembled, rather than being built from scratch. The questions that arise are: *Are there any benefits in using traditional generic process maps as a starting point for building more dynamic models? Can patterns be identified that characterise the e-business processes of manufacturing companies?*

The initial thought behind these questions was to build complete processes (e.g. Generate order) that then could be "called" from a simulation library and that could "generate" the whole simulation model or at least the corresponding part, e.g. Generate Order with all its activities and sub-activities (22 in total in Childe's model). This approach was in line with the Full Model reuse type proposed by Pidd (2002). However, as explained before, generic process maps have difficulty in capturing the differences between traditional and e-enabled processes. Additionally, it was demonstrated that actual business processes do not conform rigidly to the structure and hierarchies imposed by these generic process maps. Hence, the approach of having such wide process components would bring little aid in building models faster, since the amount of customisation (time and skill) required could exceed that required to build a model from scratch.

5.5 Component development and testing

It has been established that building all-encompassing e-business process models to aid building simulation models is unsuitable. An alternative for the full model reuse approach is that of component reuse as explained in section 5.3. The approach followed to address this was to identify groups of activities that are generic enough to be used in a wide range of applications but at a sufficiently low level (medium grained) to avoid imposing pre-determined hierarchies on processes. The idea is similar to concepts of modularity. Such components can be then be "plugged" to simulation models as required (e.g. instead of having the Generate Order process with all its sub-activities, one would be able to choose from "Order arrives by telephone" or "Order arrives via the Internet" or a combination of both, See Figure 1). The researchers based the development of these components on the observations from the case studies and the generic process maps proposed by the MIT and other frameworks.

Figure 5.4. Combined order taking (manual and electronic) reusable simulation component



The procedure for developing the components was as follows:

- Identify common activities/sub-processes from primary and secondary case studies.
- Operationalise the sub-processes in the simulation tool, subject to the following criteria:
    - In order to be considered a "generic" component, it must be present in more than one case study.
    - There should be consistency in the hierarchical deployment of the elements.
    - In order to keep the degree of modularity intended, a limit in the number of activities present in a component must be observed (8 at the moment).
- Test the components in new case studies.
- Create a component knowledge database, describing the purpose of each component.

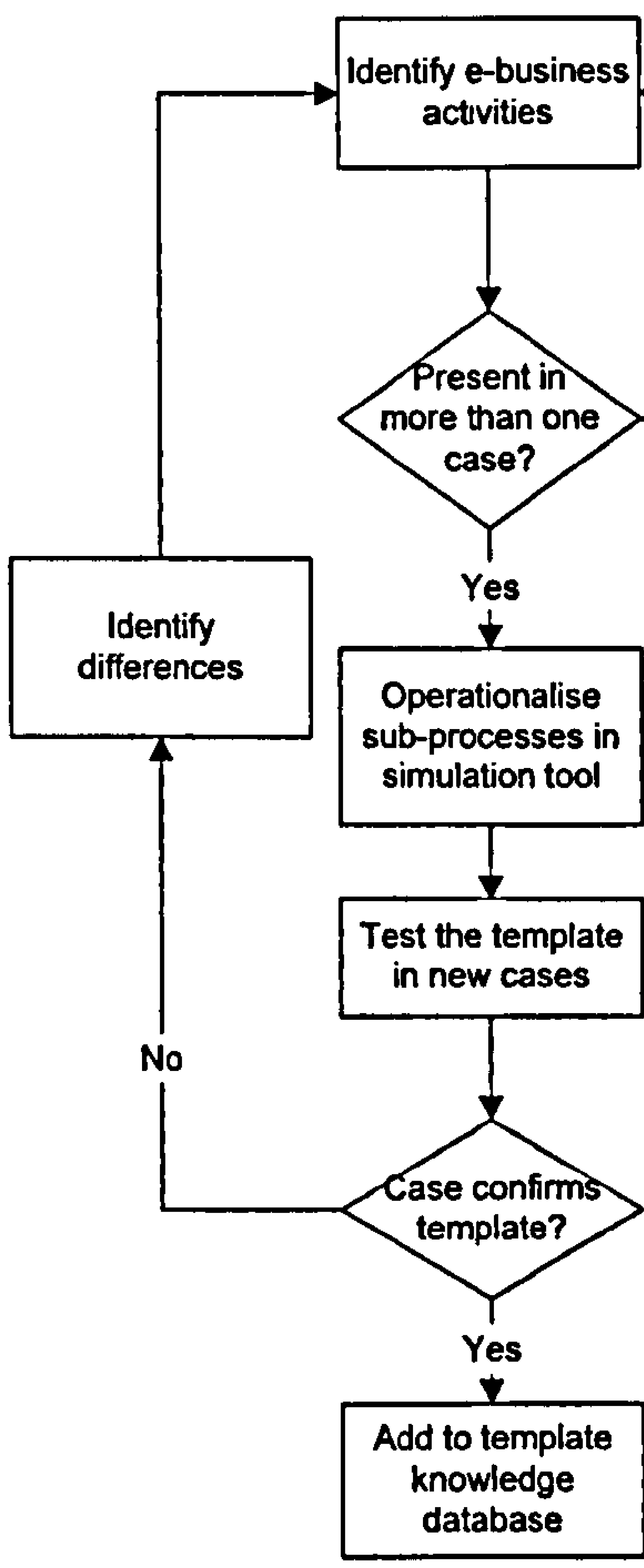


Figure 5.5 Component development process

The development process followed a sampling strategy best described as that of "iterative approach" (Royer and Zarlowsky 2001) in which "the scope of generalisation for the results is not defined at the outset, but rather at the end of the process" (Figure 5.6) . Another important difference with the traditional (i.e. statistical) sampling approach lies in the "progressive constitution of the sample by successive iterations. Each element of the sample is selected by judgement. The data are then collected and analysed before the next element is selected." Glaser and Strauss (1967) suggest first studying similar units in order to enable the emergence of a substantive theory before enlarging the collection to include units with different characteristics. With this in mind, the sample cases were focused on applications of e-business to the order fulfilment process, although giving room to incorporate both make to order and make to stock manufacturing policies.

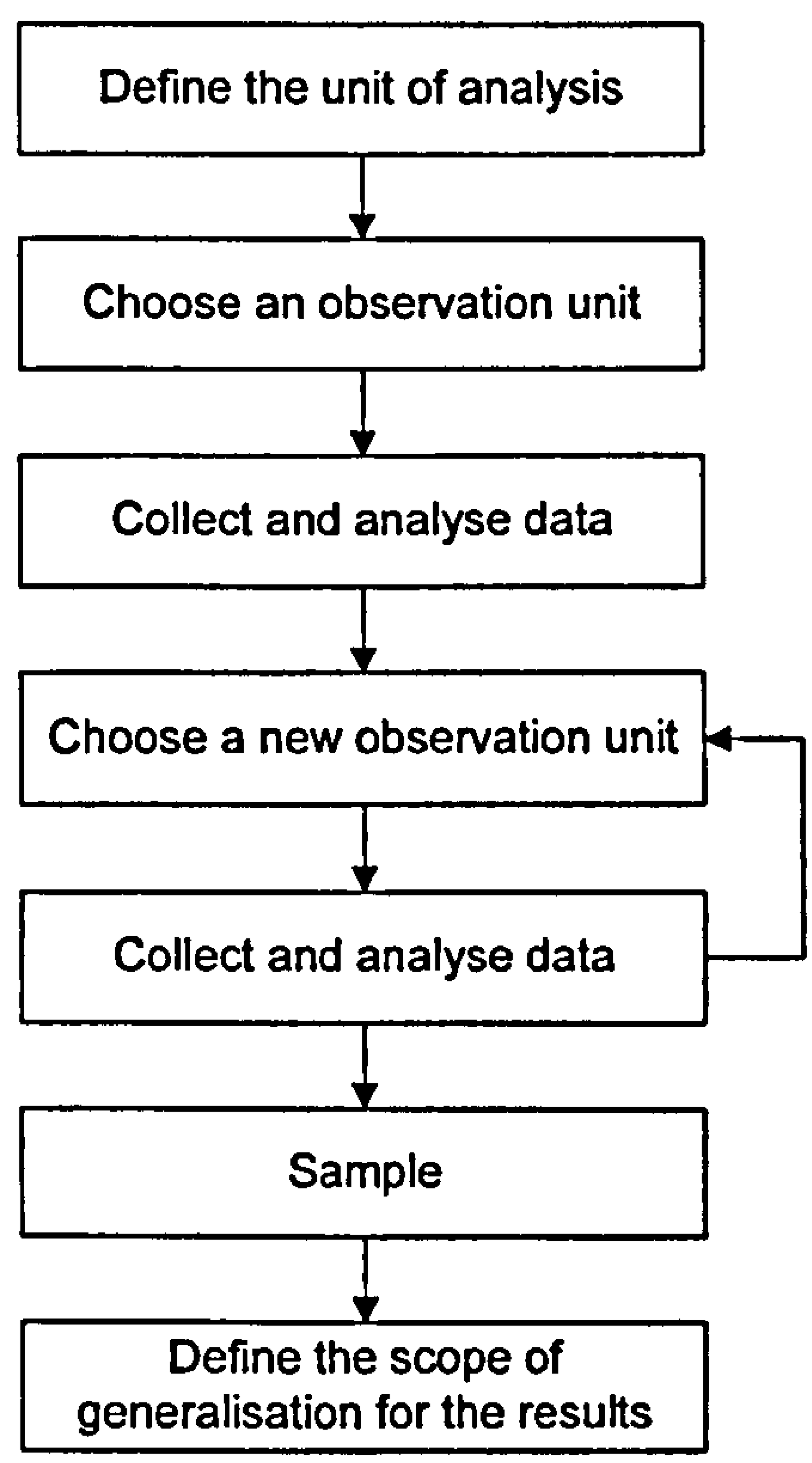


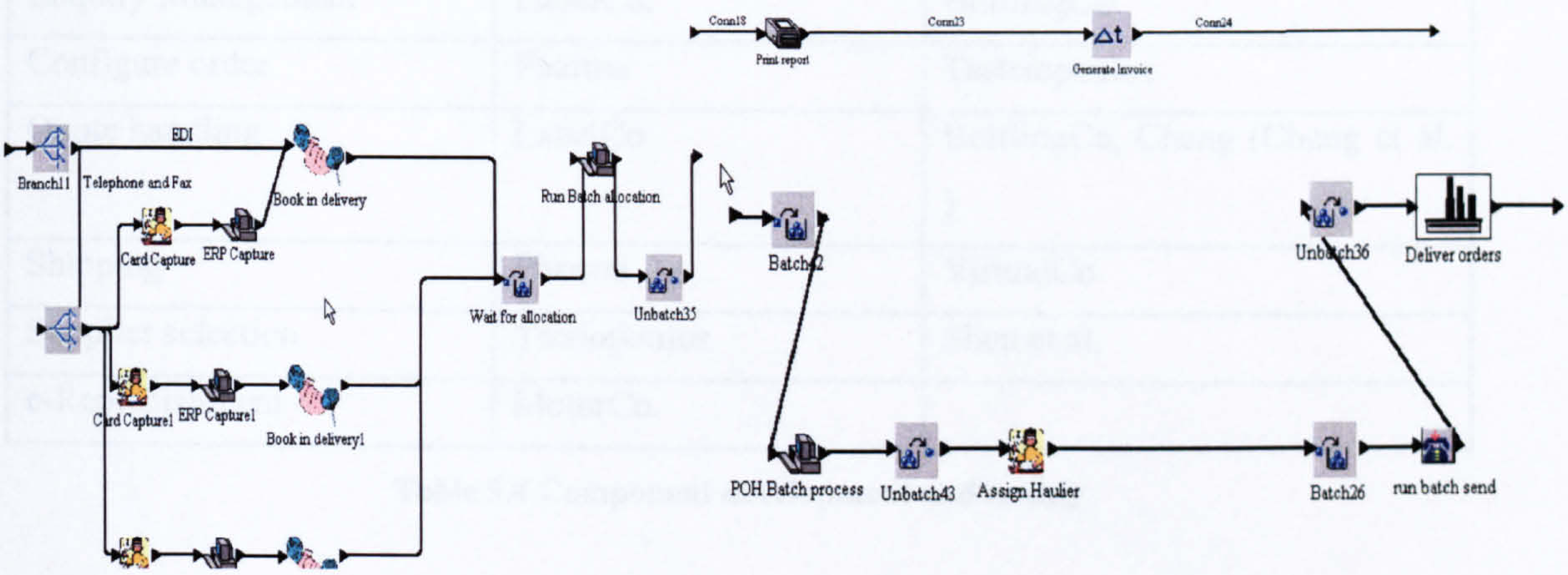
Figure 5.6 Iterative approach to sampling

In order to validate the components, a pattern-matching logic approach was followed, in which "such logic compares an empirically based pattern with a predicted one (or several alternative predictions)" (Trochim 1989). In order to test the usability of these components, a number of tests are conducted. First, the building of simulation models from current case studies. Figure 5.7 shows a comparison between (a) a model built from scratch and (b) a model built with the components (the model is presented without further customisation). As can be seen, the models are similar, although some modifications are needed in order to reflect the actual process (for example, increasing the number of operators receiving order from one to three).

As mentioned before, the components are "progressively tested". That is, they are built from initial case studies and tested in later cases, each case validating the pertinent components and serving as source for the development of new components, which in turn are validated in the next case.

A further test was to make the components available to a group of simulation users. The analysis of this deployment is presented in Chapter 6, but initial comments confirm the usefulness of such components, although care must be taken to explain what each component includes and what is the function of each activity within the component, in order to make the most of the components.

a)



b)

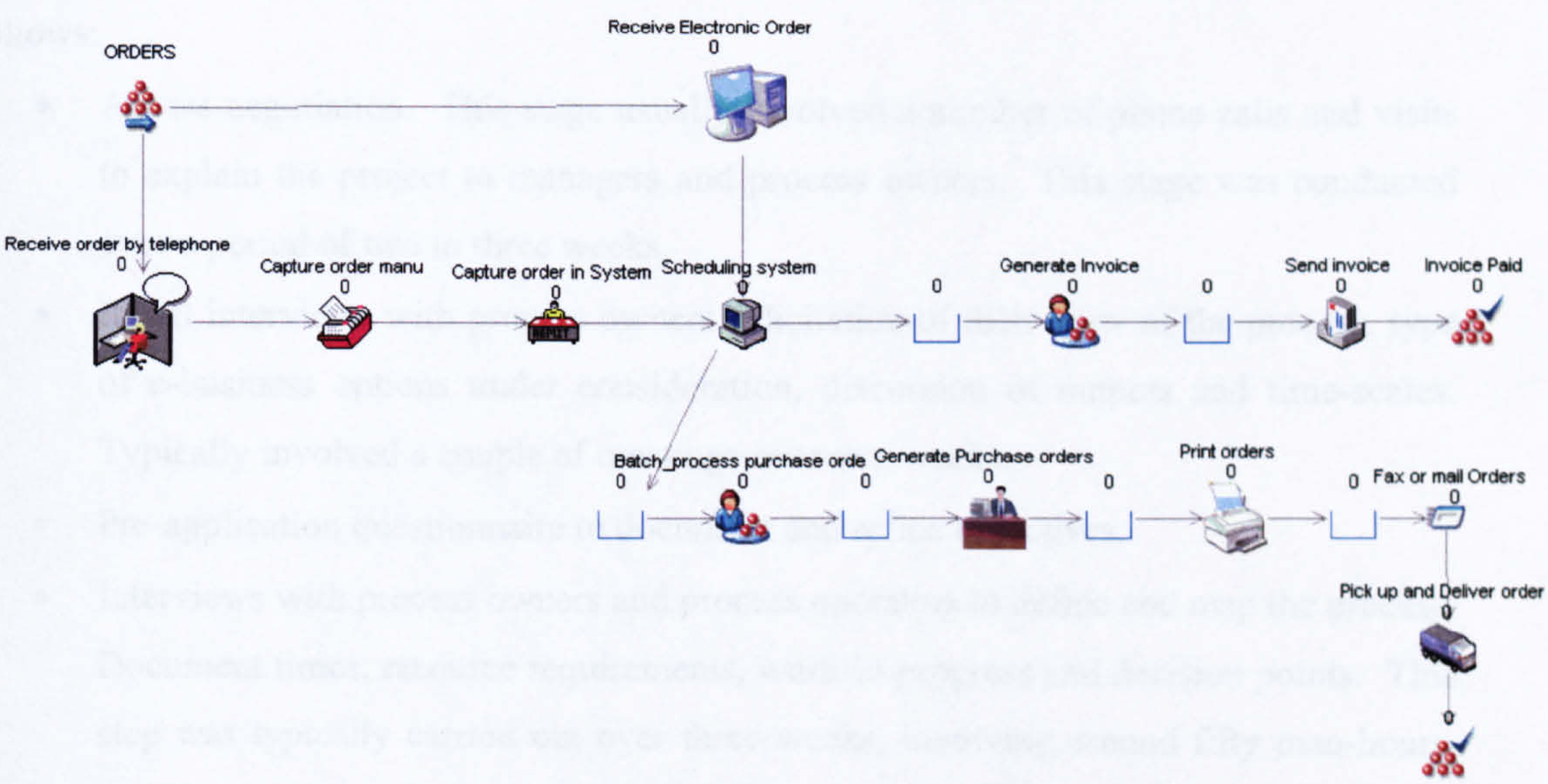


Figure 5.7. Comparison of simulation models
a) created from scratch b) created with components (without further customisation)

The component development followed the path explained in Table 5.4. Each component was derived from a case study (either primary or secondary) and tested in the next case. Figure 5.8 presents this in a graphical form.

Component	Case derived from	Case(s) tested on
Combined order taking	WaterCo	LabelCo, BottlingCo.
e-Purchasing	WaterCo.	PharmaCo, BottlingCo.
Order processing	LabelCo.	Tatsiopoulos et al, Shen et at
High level manufacturing	IEE	LabelCo, WindowCo,
Invoicing/ e-invoicing	WaterCo.	LabelCo, MotorCo.
Receiving	VirtualCo.	BottlingCo
Enquiry Management	LabelCo.	BottlingCo
Configure order	Pharma	Tastsiopoulos
Quote handling	LabelCo	BottlingCo, Cheng (Cheng et al.)
Shipping	Pharma	VirtualCo
Supplier selection	Tatsiopoulos	Shen et al.
e-Replenishment	MotorCo.	

Table 5.4 Component development and testing

For each of the primary case studies, the typical pattern followed can be described as follows:

- Access negotiation. This stage usually involved a number of phone calls and visits to explain the project to managers and process owners. This stage was conducted over a period of two to three weeks.
- Initial interviews with process owners. Elicitation of their view of the process, type of e-business options under consideration, discussion of outputs and time-scales. Typically involved a couple of meetings over two weeks.
- Pre-application questionnaire to document and refine objectives.
- Interviews with process owners and process operators to define and map the process. Document times, resource requirements, work-in-progress and decision points. This step was typically carried out over three weeks, involving around fifty man-hours.

This stage also involved spending some days following the process and timing the activities as a way of validating the information gained from the process owners and operators.

- Formal mapping of processes in process software (usually MS Visio).
- Validation interviews with process owners and process workers. Fine-tuning of process. Carried out over a week.
- Development of as-is simulation model.
- Meeting with process owners and process workers for simulation model validation. Two meetings over a week.
- Development of to-be (e-business) simulation model. One week.
- Experimentation and option comparison. The process included deriving the timing for the new processes in conjunction with the process owners. This process was around 20 man-hours spread over one week.
- Meeting with Managers, process owners and process workers to present results.
- Report writing and final documentation. Carried over a week.

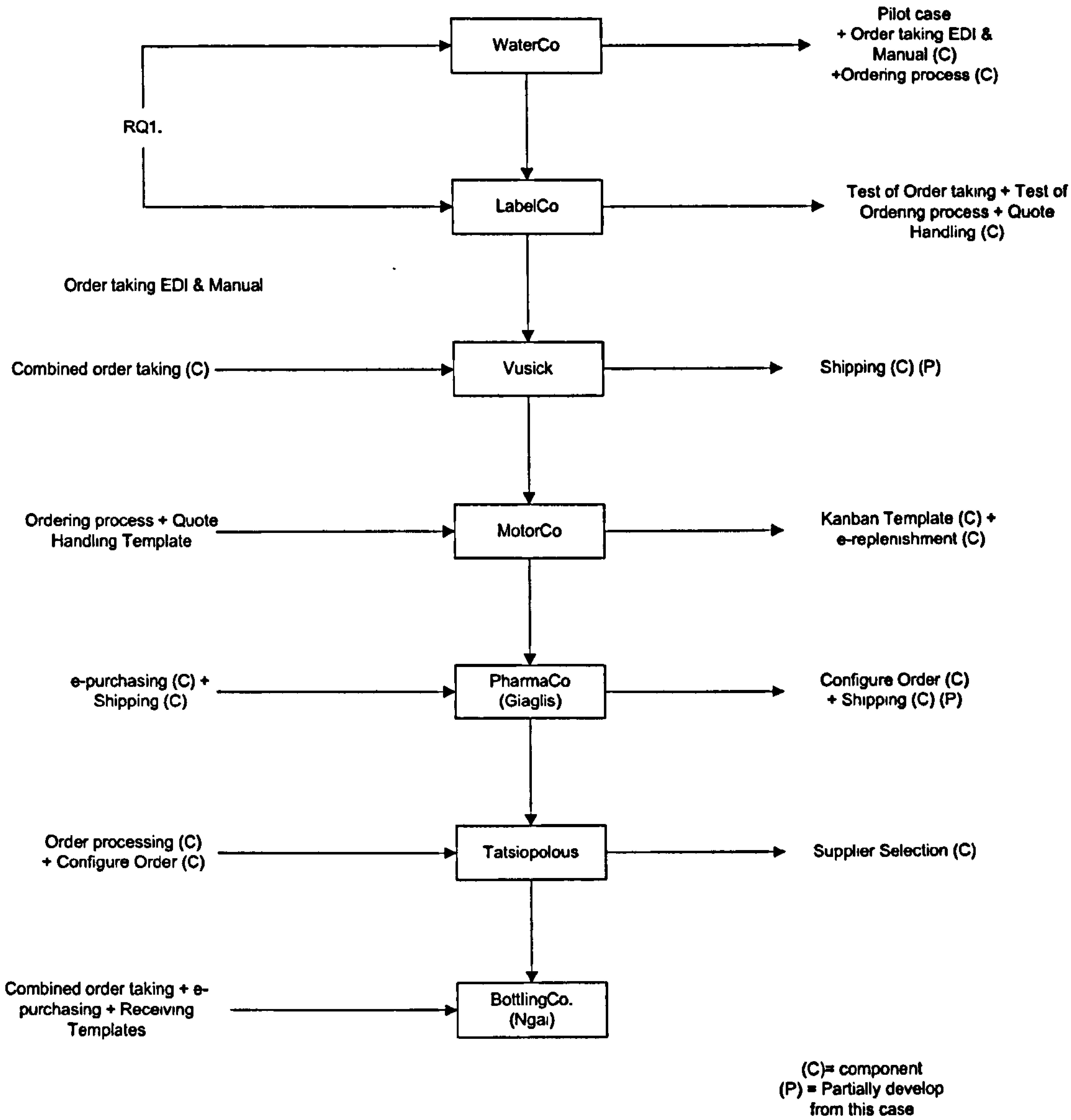


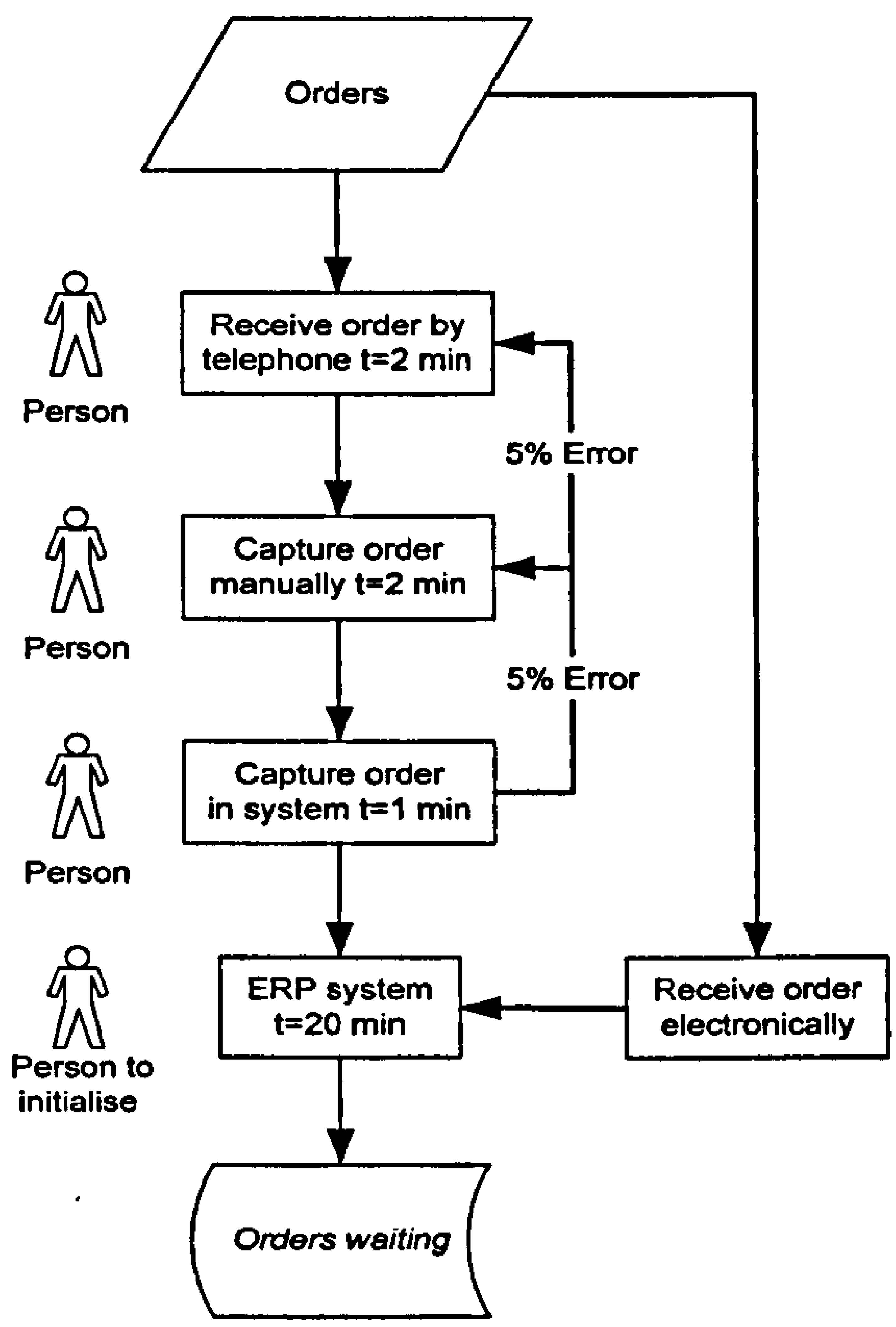
Figure 5.8. Iterative approach: case study sequence.

The components that have been developed in this research are an extension of the simulator concept. In the early stages of simulation development, the way of carrying out simulation was to write programming code in either a programming language or a simulation language. This has evolved to the current Visual Interactive Simulators, which allow the use of predefined elements to be dragged onto the screen to build a simulation model. The components are built on the concept of simulator and the assumptions that people have about these systems (e.g. visual, drag and drop, menu-driven model building). By extending the scope of the elements available to the user, the components are an easy next step in the functionality that simulators provide, without requiring a big change of paradigm in the simulation user's frame of mind.

A description of the components is presented next. These components were developed from the above case studies (case study process maps are presented in Appendix 2A). The origin of each component is explained, as well as the case studies where it was tested and any particular characteristics regarding the modelling of such activities highlighted.

Order Taking combining traditional an electronic orders

This was the first component that was derived from the WaterCo case study. This component combines both traditional manual order processing and orders that come via a website or EDI. Orders are then combined and accumulated in a central database where they wait to be processed.



The component was tested in the LabelCo and Ngai cases. As can be seen, the component fits both cases, albeit with slight modifications. This was one of the components which proved to be common amongst a number of case studies. It can be said that by applying the component in a number of cases and not needing to modify the basic structure anymore, theoretical saturation has been reached. This validates the component and makes it the first of the database.

The final operationalisation of the component is presented in Figure 5.9. This figure depicts what part of the model would be created by dragging the Order Taking Combined component into the simulation screen.

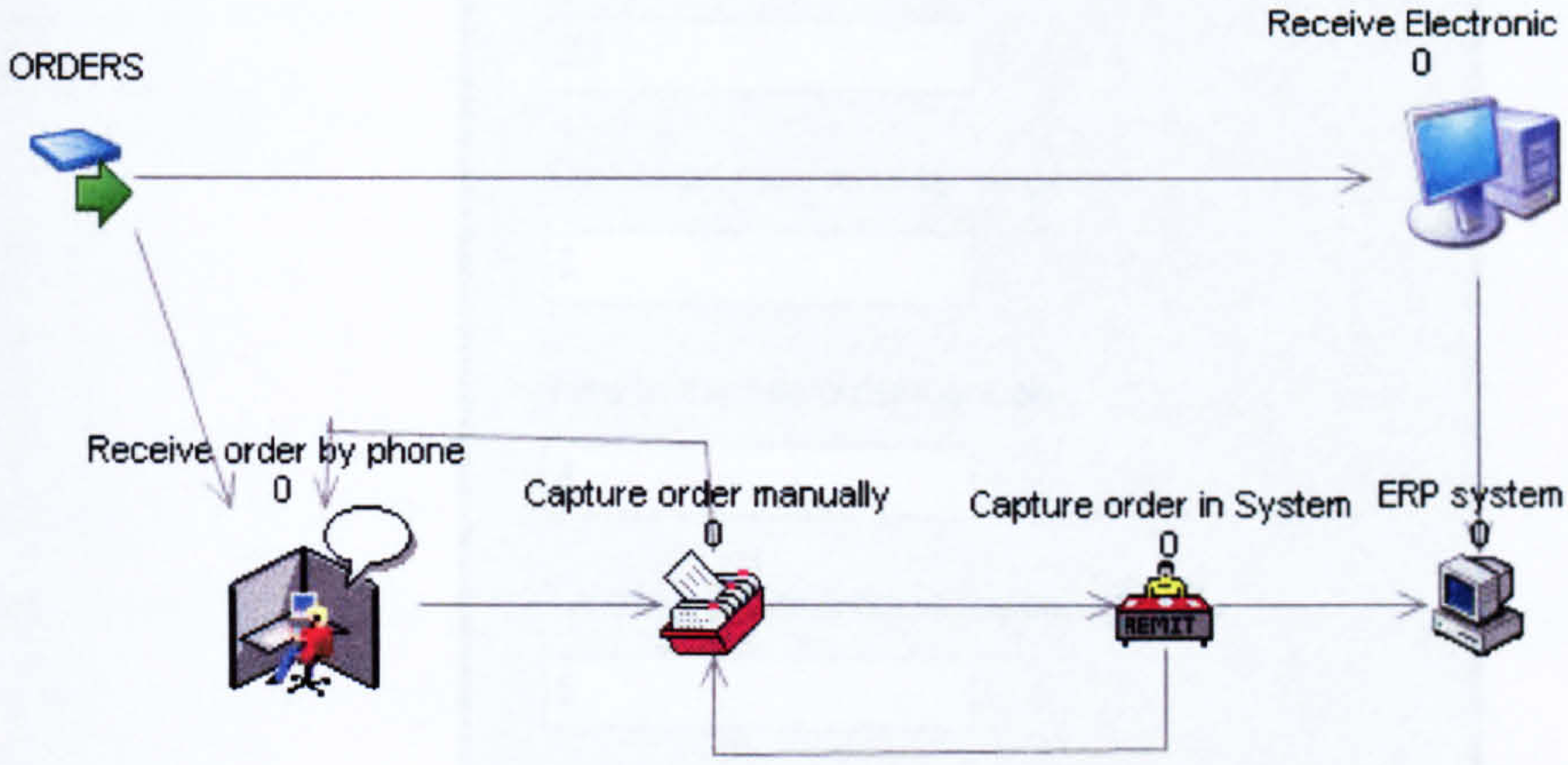


Figure 5.9 Order taking combined Simul8 component.

A dialog was created for each component, in which to input the initial values. Figure 5.10 presents the dialog for the order taking combined as an example. The main parameters for the component are inputted here and automatically transferred to the corresponding activities. Visual logic (Simul8's programming language) is used in some cases to transfer the data or modify the component based on the parameters inputted in the dialog. For example, the percentage of electronic orders field in the dialog presented in Figure 5.10 changes the percentage routing of orders coming into the system. This can be used to explore scenarios in which all orders are processed manually (Percentage electronic orders = 0), all orders processed electronically (Percentage electronic orders = 100) or any combination in between. Likewise, if a step (e.g. Capture order manually) is not present in the real process, the processing time can be set to zero, effectively "logically-removing" this activity.

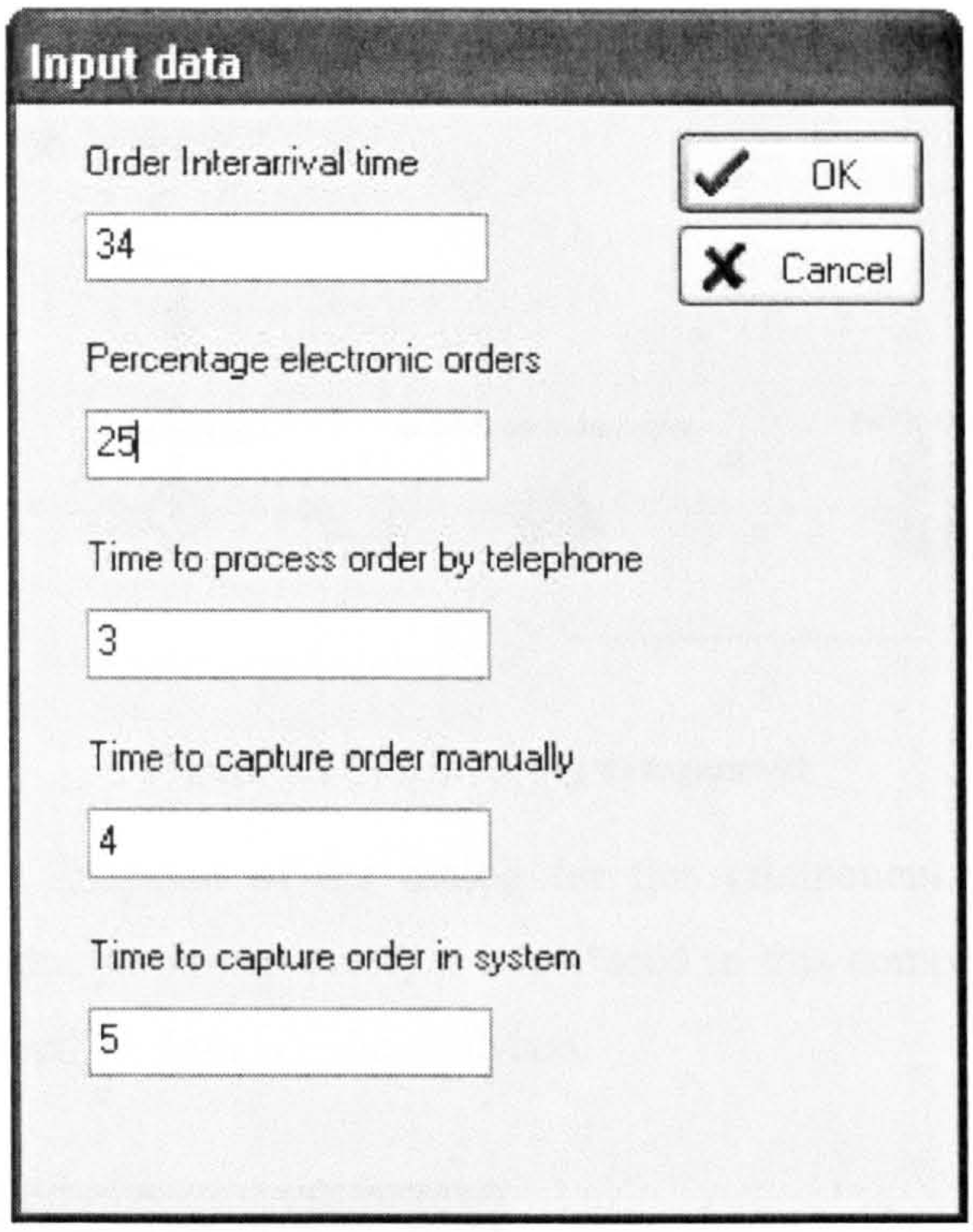


Figure 5.10 Dialog for the Order Taking combined component.

Purchasing (send purchase orders)

This process checks the system for purchase order to be sent, then a supplier is selected, order are captured in the system and printed and faxed or mailed to the customer

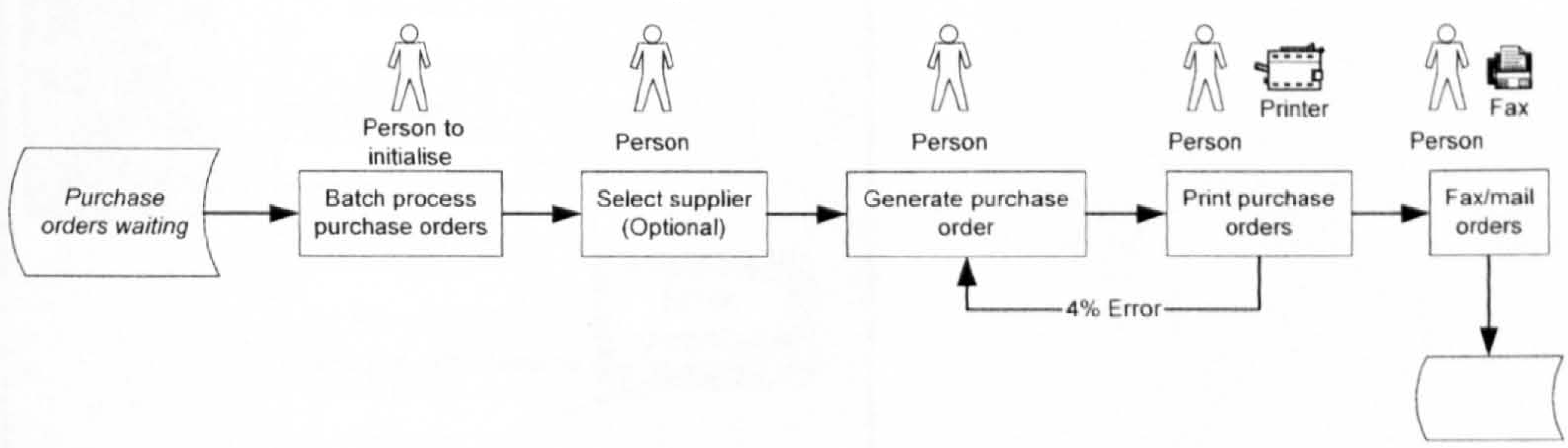


Figure 5.11 Purchasing Template

This component was derived from the WaterCo case. This presented one of the initial variations between a traditional process and an electronic enabled process. The need to batch the order to be processed and then sent in one go to the supplier is eliminated by the facility of sending individual orders that are automatically processed and that require very little (if any) human involvement. This is the first instance (from the components) in which alternative configurations were found for the same activity before and after the implementation of e-business. As it will become evident later, this change in structure is not always present when introducing e-business, making the dynamic element the only difference between traditional and e-enabled processes. The next component presents the e-enabled version of the sub-process.

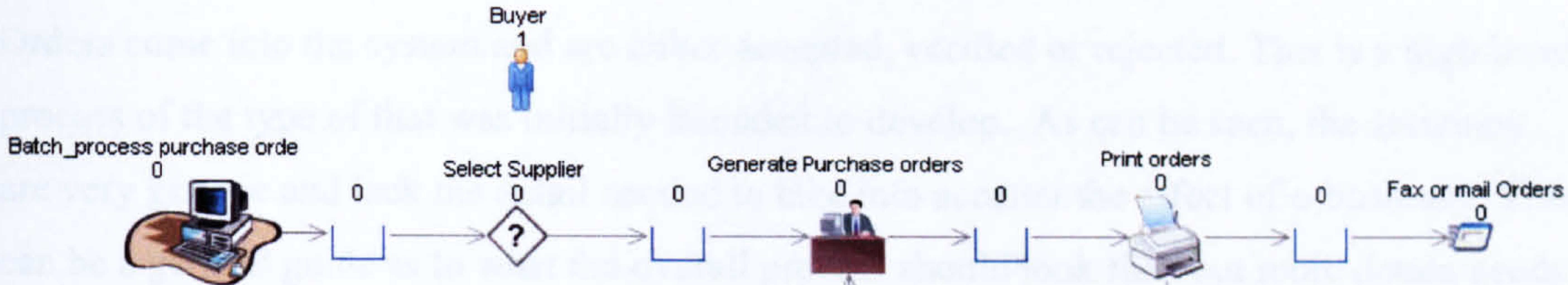


Figure 5.12 Purchasing component

Figure 5.13 presents a snapshot of the dialog for this component. As can be seen, a percentage of rework (due to human error) is introduced in this component. This figure can be set to zero if a "perfect" system is to be analysed.

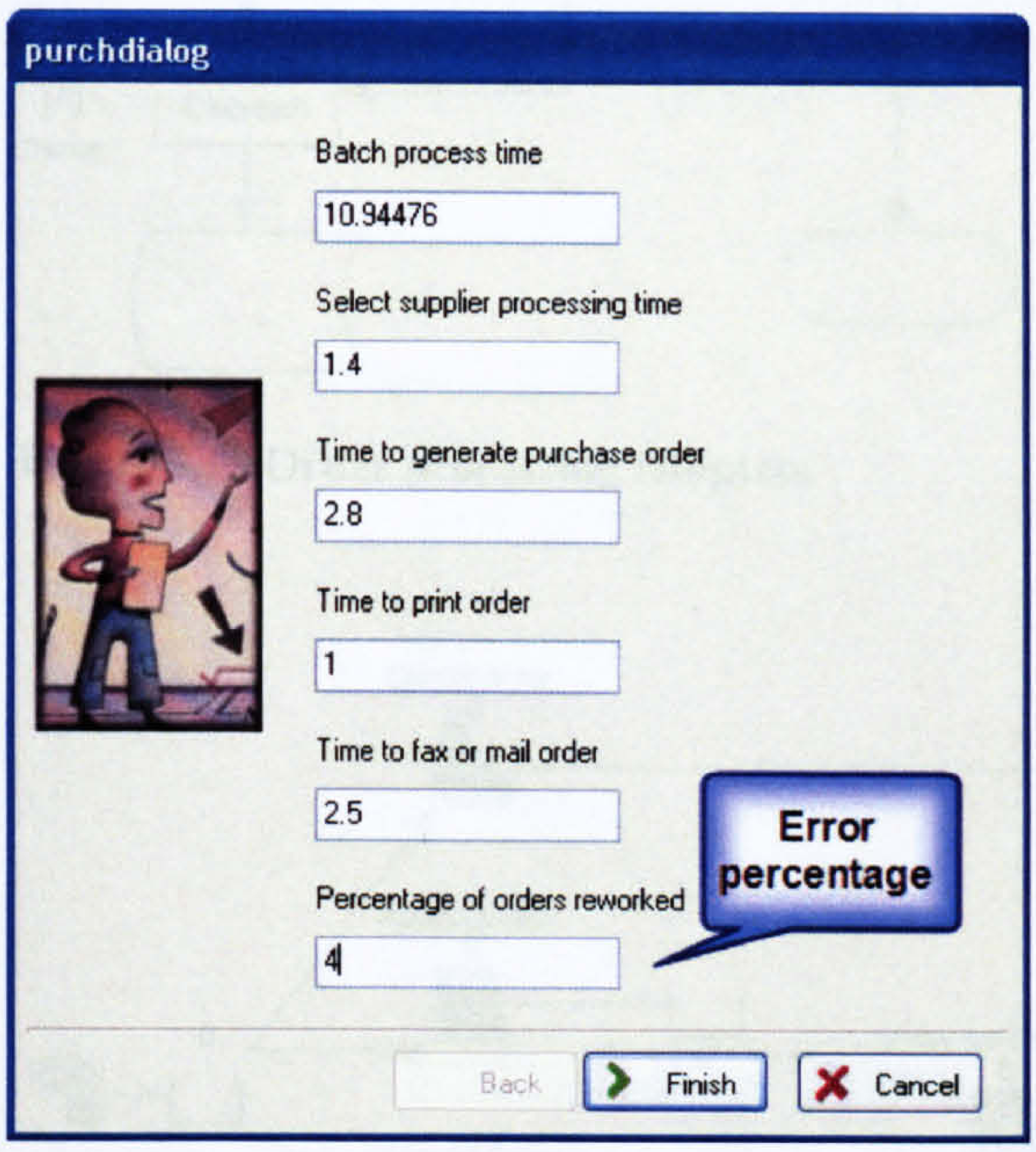


Figure 5.13 Purchasing component dialog

Electronic Purchase Order

Similar to the normal purchase process, orders are sent to the customer via email or e-fax

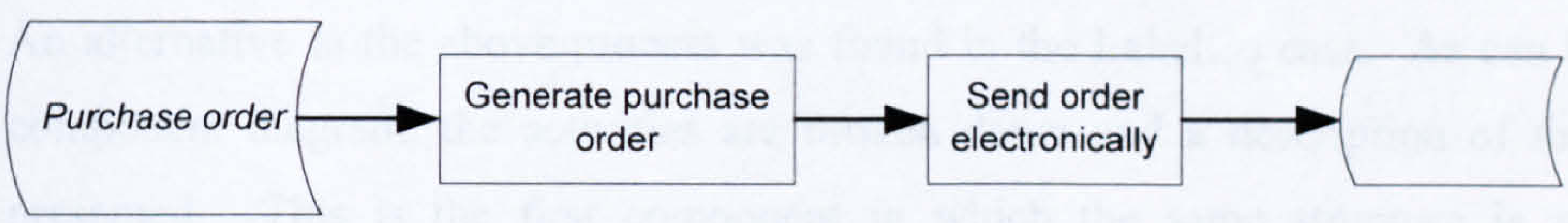


Figure 5.14 Electronic purchase order template

These components were tested in the BottlingCo. and PharmaCo cases.

Order processing

Orders come into the system and are either accepted, verified or rejected. This is a high level process of the type of that was initially intended to develop. As can be seen, the activities are very generic and lack the detail needed to take into account the effect of e-business. This can be a general guide as to what the overall process should look like, but more detain needs to be added under each activity. Alternatively, this component can be used as an interface between the order taking and shipping components.

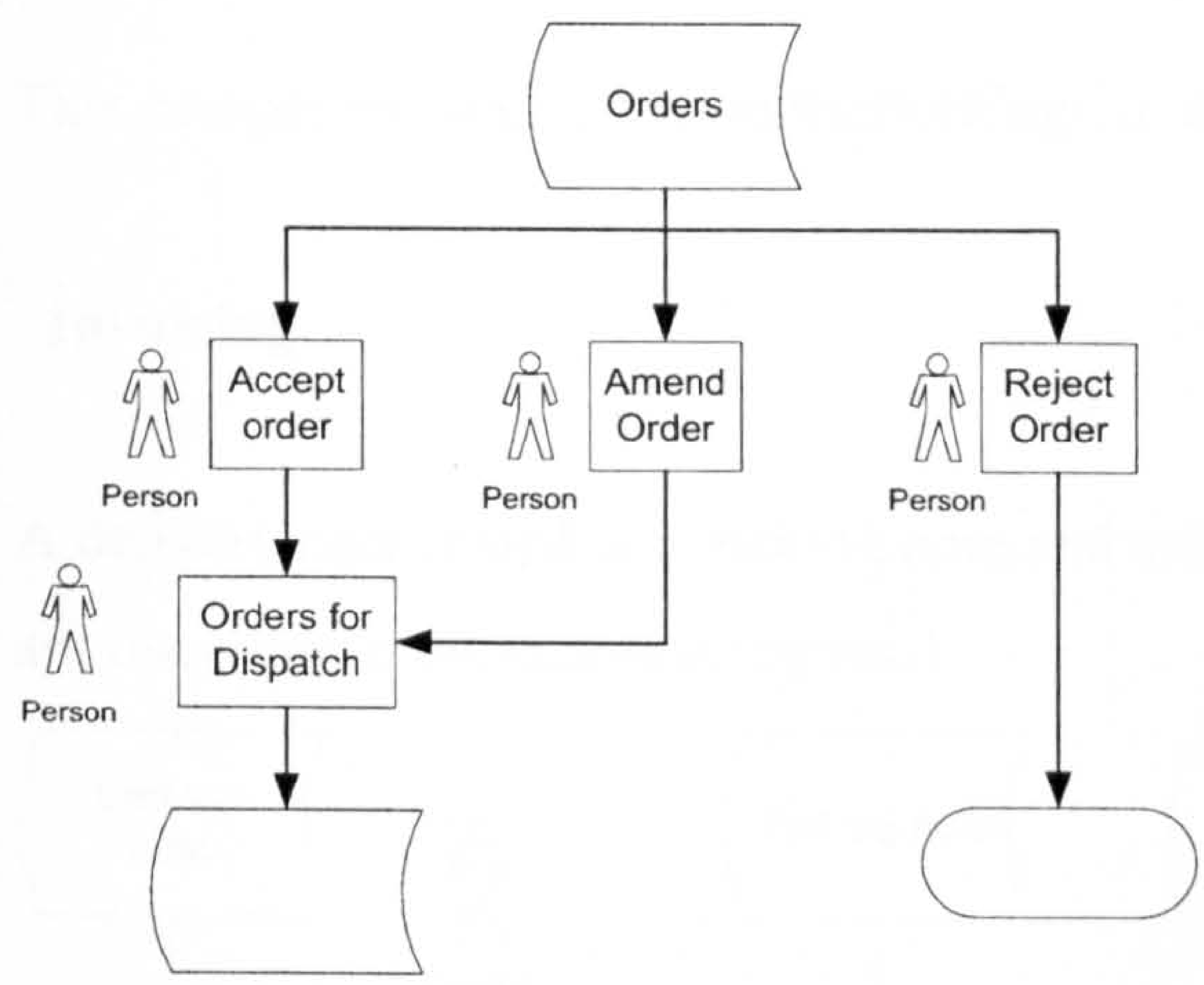


Figure 5.15 Order processing template

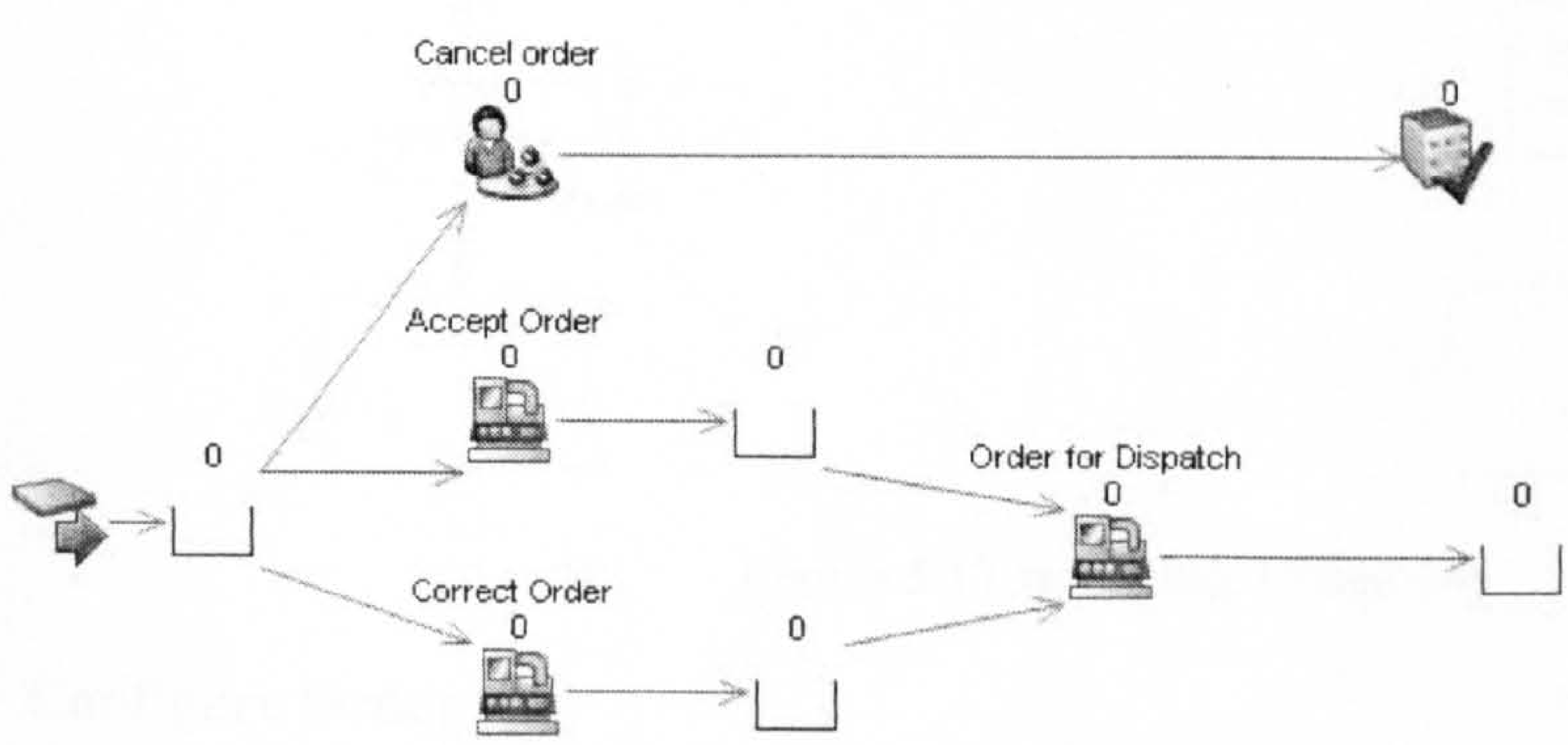
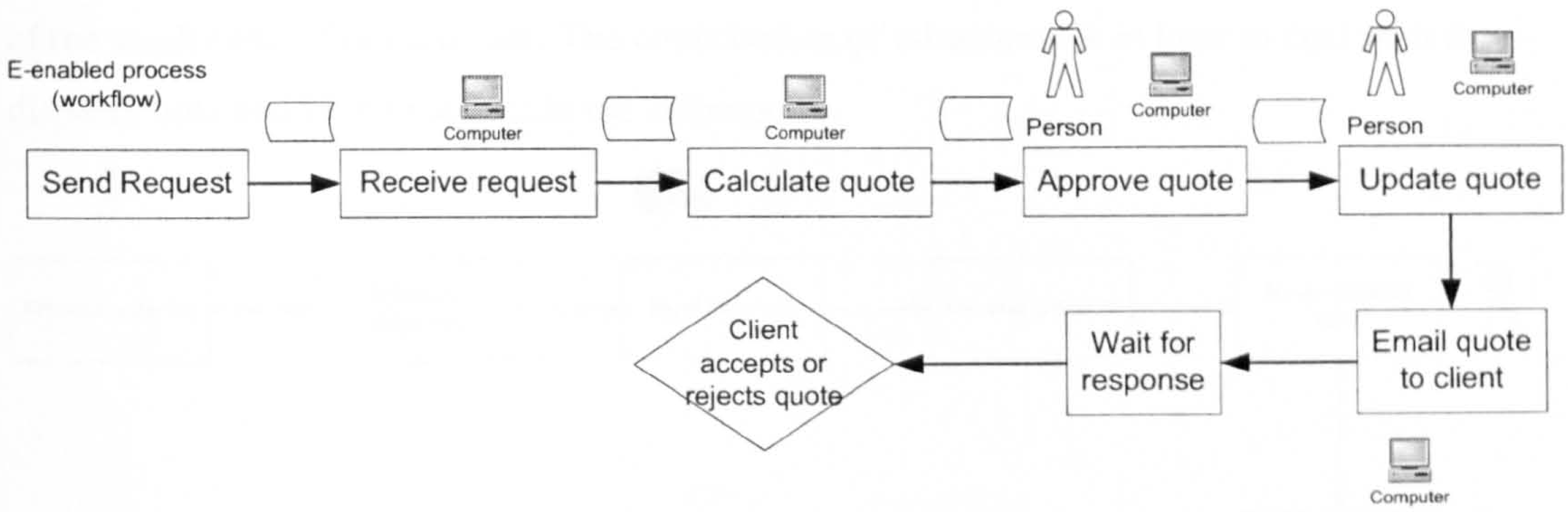


Figure 5.16 Order processing component.

Quote Management

An alternative to the above process was found in the LabelCo case. As can be seen in the component diagram, the activities are broken down and a description of the activities is presented. This is the first component in which the same structure is valid for both traditional and e-business processes. The difference lies in the dynamics of the process and the amount of time the entities (requests in this case) wait to be processed between stages and how long does it take to carry out each one of them..



This component was tested on theBottlingCo and Chen et al case.

Invoicing

A delivery note is tied to a picking note and an invoice is generated in the system. Invoices are then sent to the customer by mail.

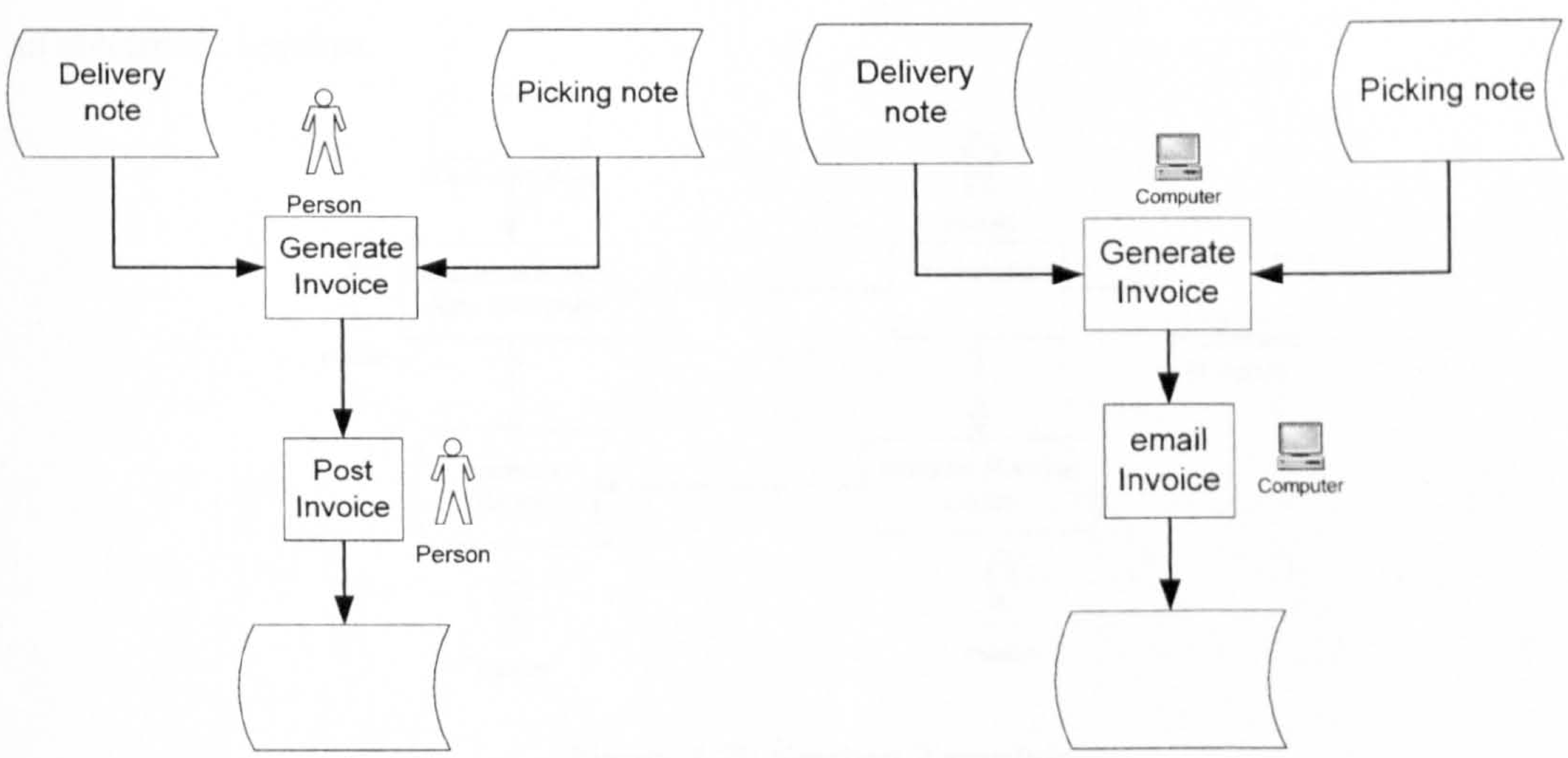


Figure 5.17 Invoicing Templates

Configure Order

This is a high-level order fulfilment process. Orders arrive, a schedule is created and parts are manufactured and shipped. Other components (e.g. Quote management) can be used to represent activities in this process. (e.g. Configure Quote)

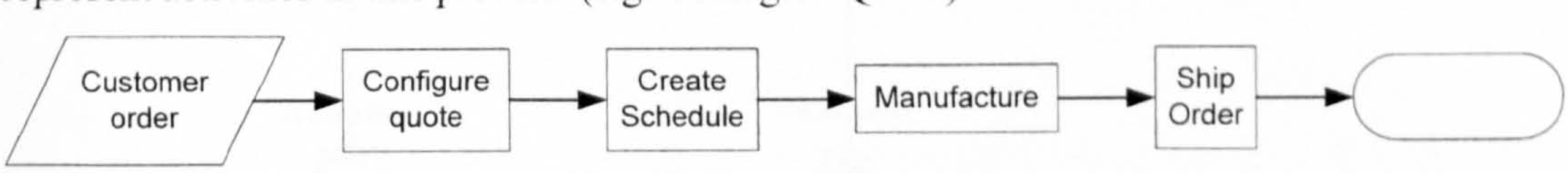


Figure 5.18 Configure order (high level)

Shipping

This component deals with the analysis of the shipping process, both from the point of view of the sender and of the receiver. The contribution of e-business is in how to deal with the dispatch note and how to schedule the shipments.

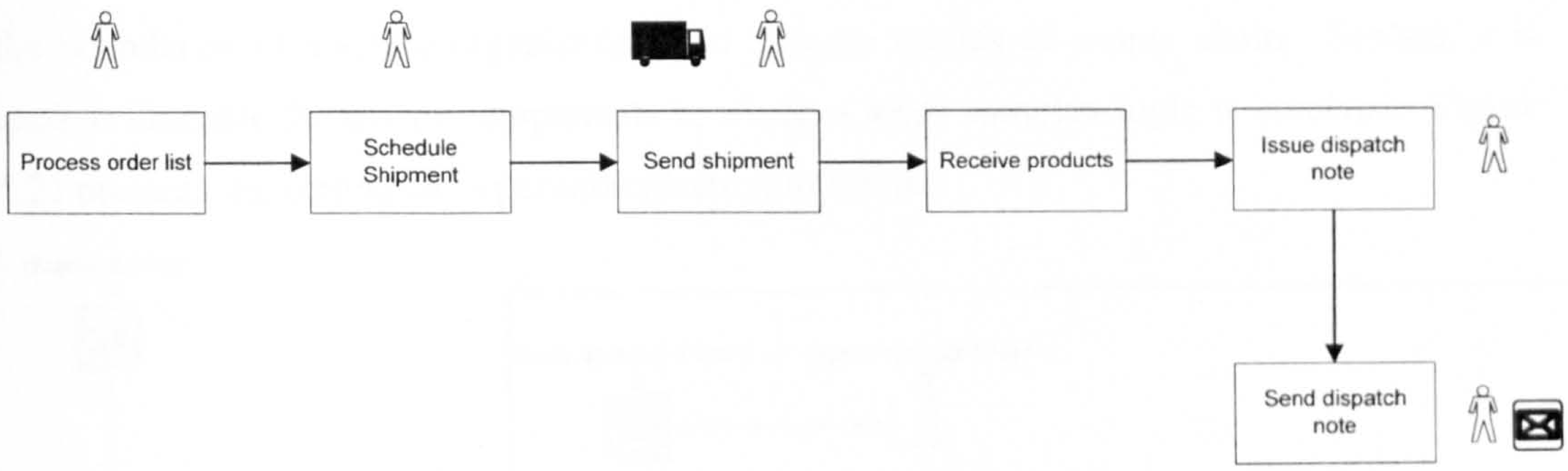


Figure 5.19 Shipping template

Kanban

A single-token kanban system. This is one of the components where the structure does not change, but the speed at which activities occur is significantly changed by the introduction of an electronic version.

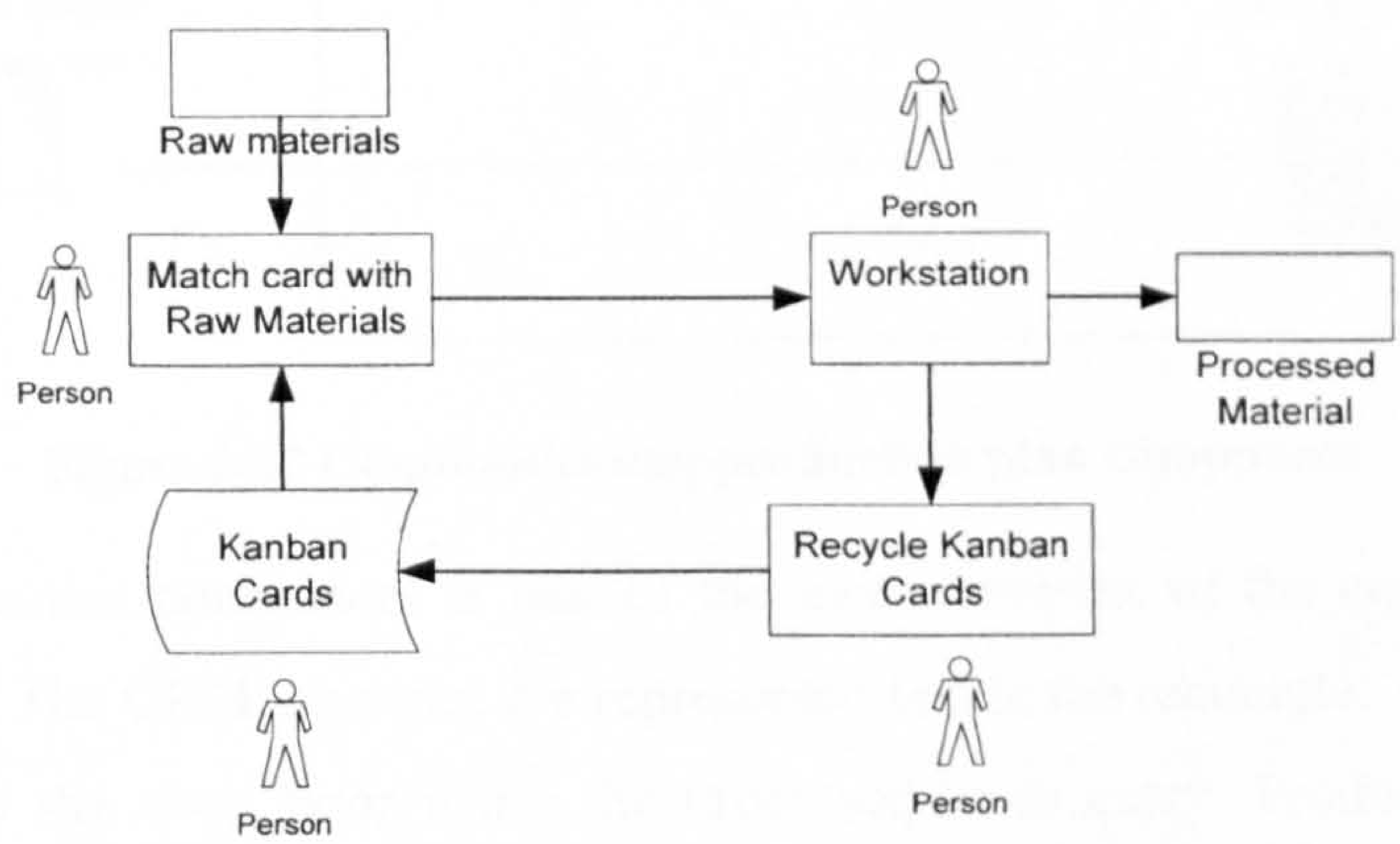


Figure 5.20 Kanban Template

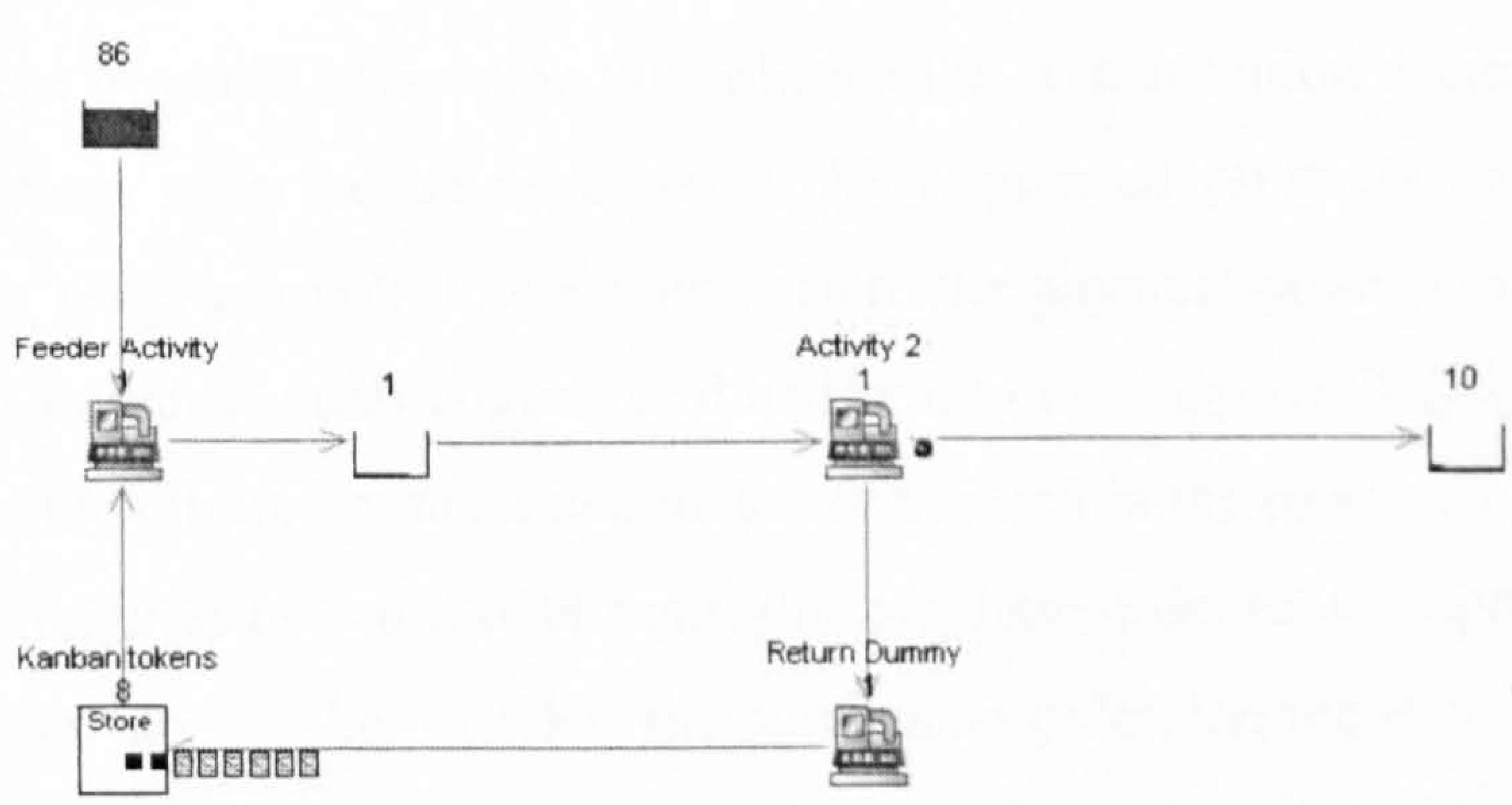


Figure 5.21 Kanban component

Communicating production plan.

This component was derived from the MotorCo case study. The component presents the sending of orders from one company to one of its suppliers. The objective of this component is twofold. First, it is used to illustrate the extendibility of the component concept beyond the boundaries of a single organisation and into the realms of supply chain. Second, it is used to illustrate the use of components in which a more complex logic is involved. Figure 5.22 presents the component operationalisation in Simul8 .

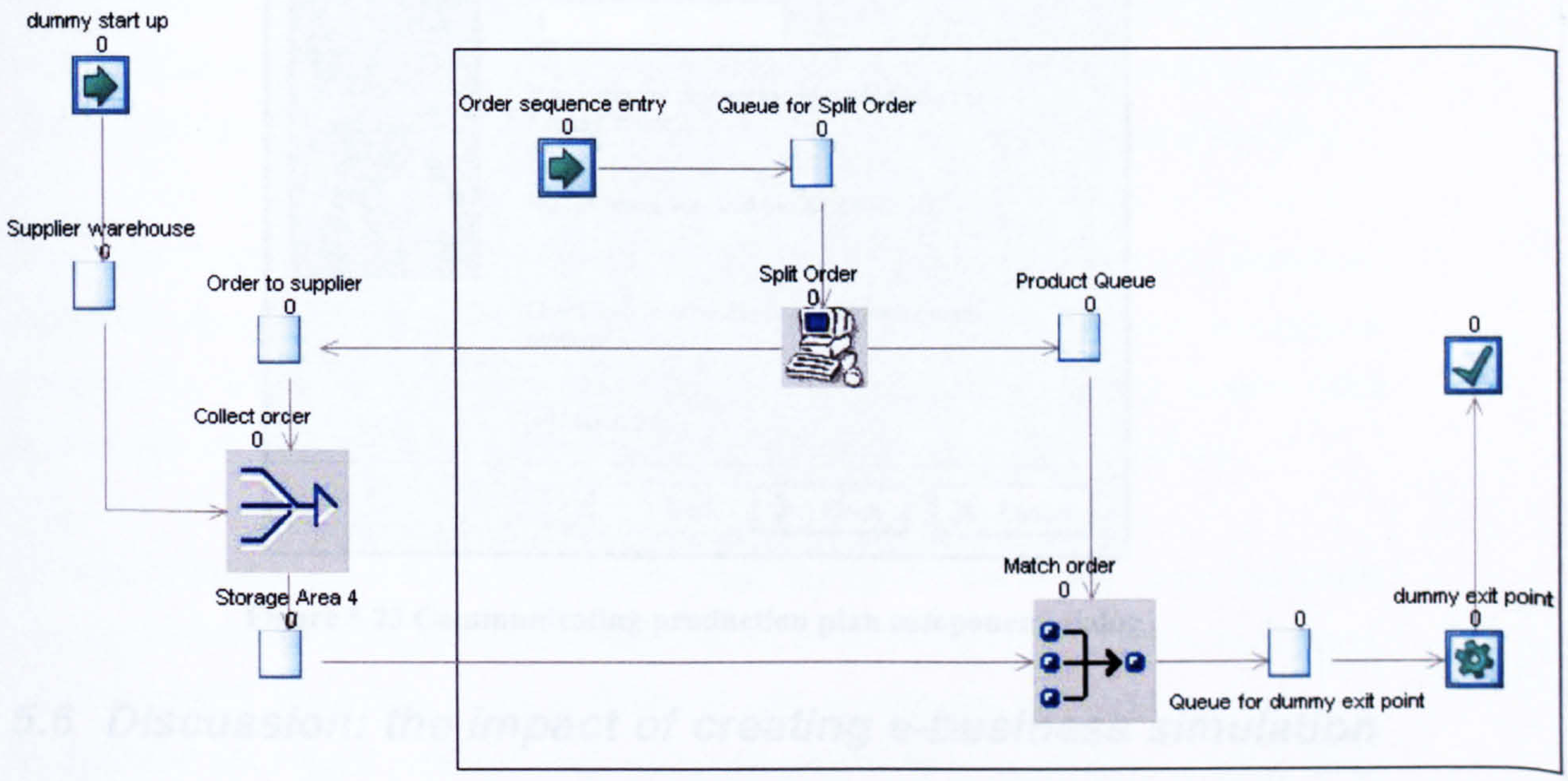


Figure 5.22 Communicating production plan component

The logic used in this component is one of the most complex of the components created during this study. The OEM activities are represented inside the rectangle. Production orders are dispatched to the shop floor using the order sequence entry. Products with different characteristics can be manufactured in this component. For example, cars with different seat colour. A dialog (Figure 5.23) asks the model user how many different products and the proportion of those products. Based on this information, a distribution is created and used to drive the production order sequence entry. The sequenced products move through the system until they reach the Split Order point. Here the physical product continues through the system, but a purchase order is generated and sent to the supplier. This order inherits the characteristics of the original product and looks for a match in the supplier's warehouse. For example, if a car requires brown leather seats, this purchase order to the supplier is for brown leather seats. Once the supplier matches the purchasing order, the requested material is sent to the OEM, where it is matched with the specific car that required it. This component can be split to include intermediate activities (e.g. the actual manufacturing of the supplies in case of a Make-to-Order process).

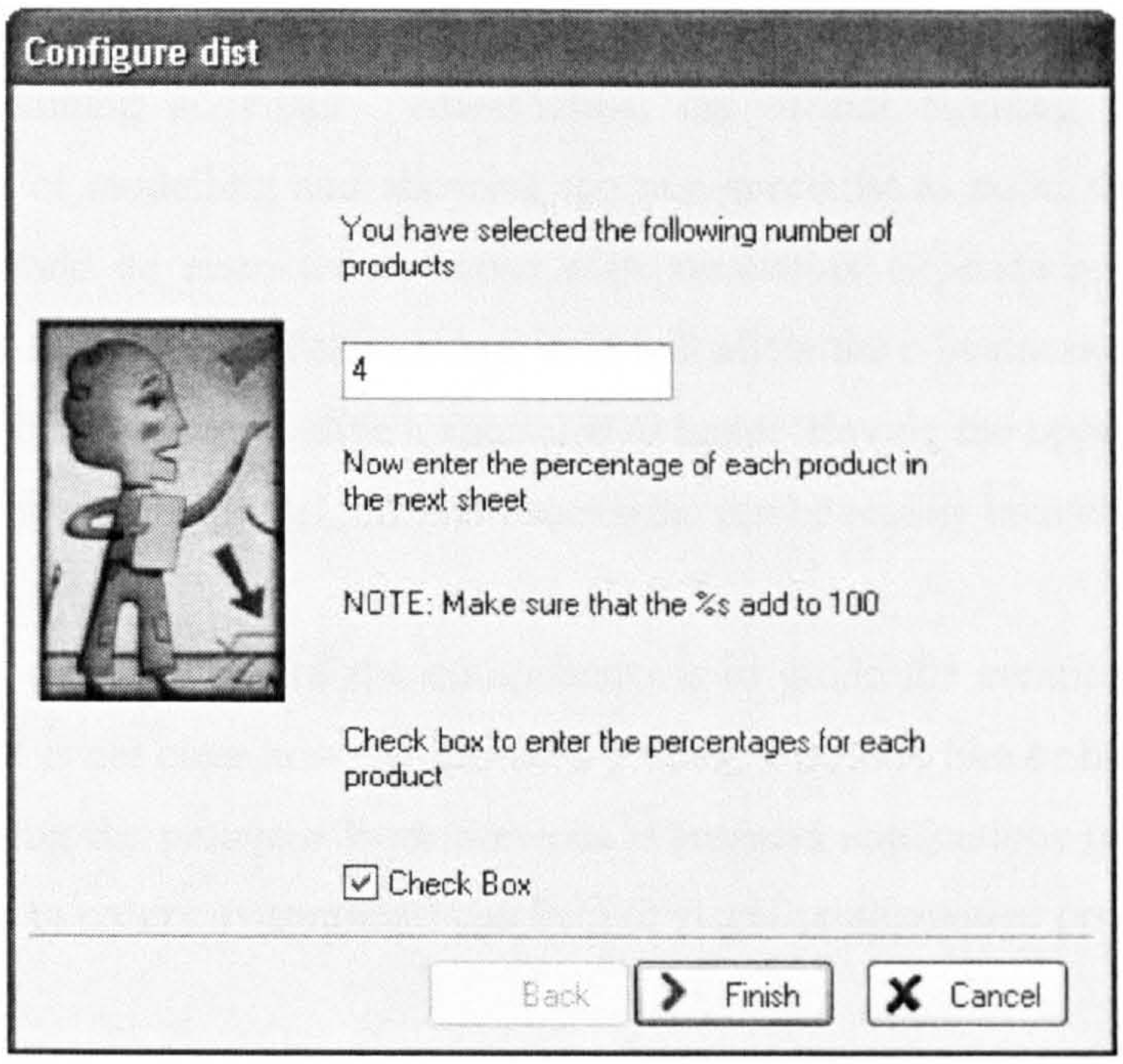


Figure 5.23 Communicating production plan component dialog

5.6 Discussion: the impact of creating e-business simulation components

Progressive testing as a way of develop and test the components was illustrated during this chapter. This novel approach allowed to reduce the number of case studies required for the development and testing of the components. By progressively testing the components, the reliability of the constructs was increased, reaching theoretical saturation, in which new cases did not add or modify the structure or behaviour of a component. This progressive testing also helped the verification of the components, which is one of the arguments for reuse in simulation. The limitations of the components developed in this chapter are in the somewhat restricted number of case studies, the limitation to mainly manufacturing case studies, which limits the area of generalisabilty of the components proposed here. However, as stated before, the objective of this research is to prove the concept of simulation use for e-business analysis and the proof of concept of component development. The purpose is not to develop an all-encompassing library of e-business components, but to understand how to create and use these components and prove the concept of using simulation and components in e-business.

The initial use of these components has shown that they can reduce the model building time and help guide the simulation build regarding relationships between activities and routing of products and information. However, the tasks of data collection and model population remain time-consuming activities. Nonetheless, the overall building time is reduced, reducing the cost of modelling and allowing the non-specialist to build simulation models that otherwise would be restricted to those with simulation experience. This will have implications for e-business decision-making, as it will allow the e-business user or analyst to create models without having to have a specialist at hand. Having the opportunity to "plug" different components to the model, different scenarios can be readily created and modified.

One of the main contributions of the components is to guide the creation of e-processes, especially when it is not clear how the business process will look like or how it will behave dynamically. Using the practices from previous e-business applications (e.g. internet sales process in a make to order environment) can help to visualise alternative processes.

From early use of these components, it can be predicted that the use of such components will help the use of simulation as an evaluating tool for e-business process analysis and design. Insights into the limitations of the usability of such components were also gained. It is thought that the biggest value of such components is to be gained when building large models. This, however, does not preclude their use in small processes, characteristic of SMEs, where it is unlikely to have a simulation expert. One concern is that the use of such components could become prescriptive or encourage laziness from the modeller when customising, accepting what the component proposes and not what the actual process is. Additionally, the components must be well documented and clearly explained for ease of use.

Work is still ongoing developing and testing new components with the application of simulation to study the effect of e-business on supply chains (Tang et al. 2004), in order to provide a wider application of the concept.

5.7 Conclusions of the chapter

The increasing dynamic nature of companies adopting e-business has made it more difficult to analyse the effect of decisions across the wider business. Modelling the business processes is a step towards a better analysis of such decisions. This chapter has presented an analysis of current generic business process maps and how well they capture the sometimes-subtle differences in structure, that e-business brings to business processes. It was found that existing generic process models do not cover the full range of options that e-business brings to manufacturing companies, the approach proposed by the MIT (MIT 2000) being the closest to this goal.

However, it was argued that process models alone cannot fully analyse the effect that e-business has on the business processes and that a dynamic analysis tools such a simulation is needed. The development of simulation process components as a way to reduce the modelling time was introduced and it is proposed that, by using these components for the detailed model building, more time can be devoted to the data collection, experimentation and analysis phases. The use of such components acts as a way of addressing deficiencies in the existing process models. However, in order to be useful, these components have to be well documented and care must be taken to avoid using the components as de-facto processes and ensure that they are customised to the individual processes of the case under analysis.

Next chapter will deal with the testing of these components in new cases studies and on users with different levels of simulation expertise.

Chapter 6 Testing of constructs.

6.1 Introduction

Having developed the simulation components derived from initial case studies, the next step was to test the value of the components in new cases and with final users. Baines and Kay (2002) propose a modification of three criteria initially postulated by Platts (1993). These criteria are:

- Feasibility: Can the modelling methodology be applied?
- Usability: Is the modelling methodology easy to apply?
- Utility/usefulness: Did the modelling methodology provide a useful output?

The feasibility of the approach was demonstrated in Chapter 4 and further expanded in Chapter 5. This chapter will deal with the issues of usability and utility. In order to test these two dimensions, a triangulation of methods was chosen to increase the validity and reliability of the results. The first method is the use of new case studies. These case studies were not used in the development of the components in Chapter 5 and hence provide a new set of modelling challenges. Three case studies are presented in this section: One case carried out by the authors, one case where the author was involved as advisor and one where a third party carried out the modelling. The purpose of these case studies is to test the applicability of the components in applications beyond the ones in which they were developed. Additionally this exercise provides an insight into how other users may use the components, testing whether the components are restricted by the modelling paradigm embedded by the creator of the initial components.

The second method used in the testing is the application of a quasi-experiment in which the components were given to two sets of users who were asked to build a simulation model of an e-business application. These experiments test in a more quantifiable manner the effects of using the components and the perceptions regarding their usability and utility of a larger sample of users.

6.2 Case Testing

6.2.1 Case selection

The cases were selected to represent different applications of e-business. Platts (1993) argues that in looking for case studies "the choice is between looking for consistency by trying to find similar types of company or looking to test the feasibility of the general process in a number of different situations". Chapter 5 followed the former, while in this chapter, the selection followed the latter criteria to explore the generalisability of the components concept and implementation, although they were similar in that they had e-business application as the objective of the project. The description of the cases and the application of the templates and components are illustrated next.

6.2.2 Copier Manufacturer (CopierCo)

The first case is that of the laboratories for a large photocopier manufacturer. The management was looking to move the test control from a manual process to an e-business enabled process. The objective of this change is to allow the clients of the laboratory to be able to access the results online, avoiding them having to come to the laboratories to get the test results.

6.2.2.1 CopierCo process

The laboratories perform tests for different internal and external clients. These tests are divided into Material's tests, Electronics' tests and Metrology tests. Each one of the sections had a manual control/log book for their tests. The processes to follow when requesting a test are documented for accreditation purposes (ISO 9002, ISO 14000 and internal standards). The proposed change is focused on the implementation of electronic management of the tests in the laboratories. The process was initially done manually and the laboratories manager wanted to see the effect that implementing an electronic management system would have on the output (tests/month), as well as a the effect on speed of getting the information to the internal clients (Material Quality Assurance (MQA) engineers). A description of the current process is presented in Figure 6.1

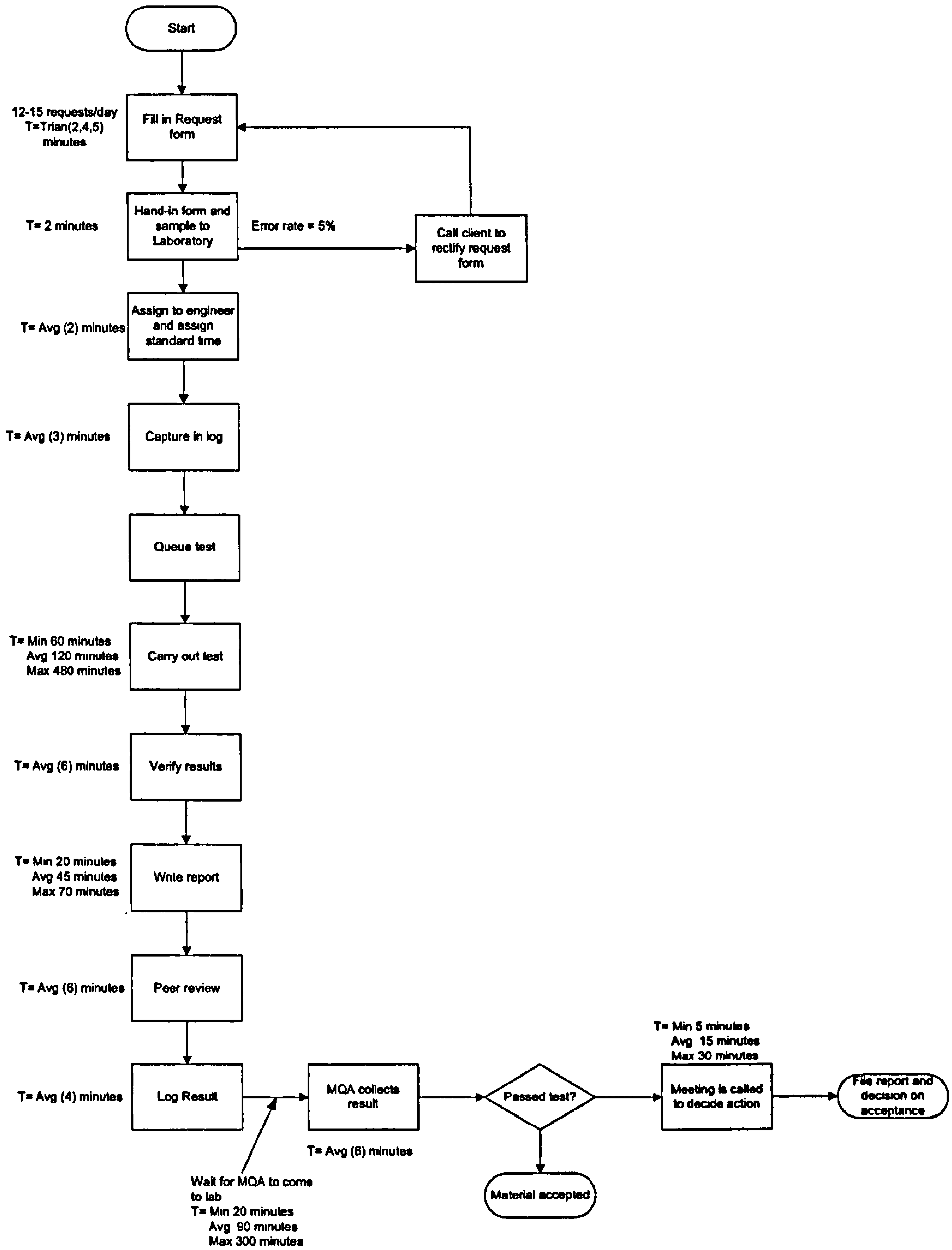


Figure 6.1 Copier Manufacturer as-is process.

The process was then mapped in the simulation software for the as-is stage. Figure 6.2 shows the representation of the process in Simul8. For this process, the Order Taking and Quote

Management components were used. These components were used with small modifications. For example, in the Order Taking Combined component, the receive orders electronically was removed. The rest of the activities stayed the same, only the names were changed to represent the particular activities of this process.

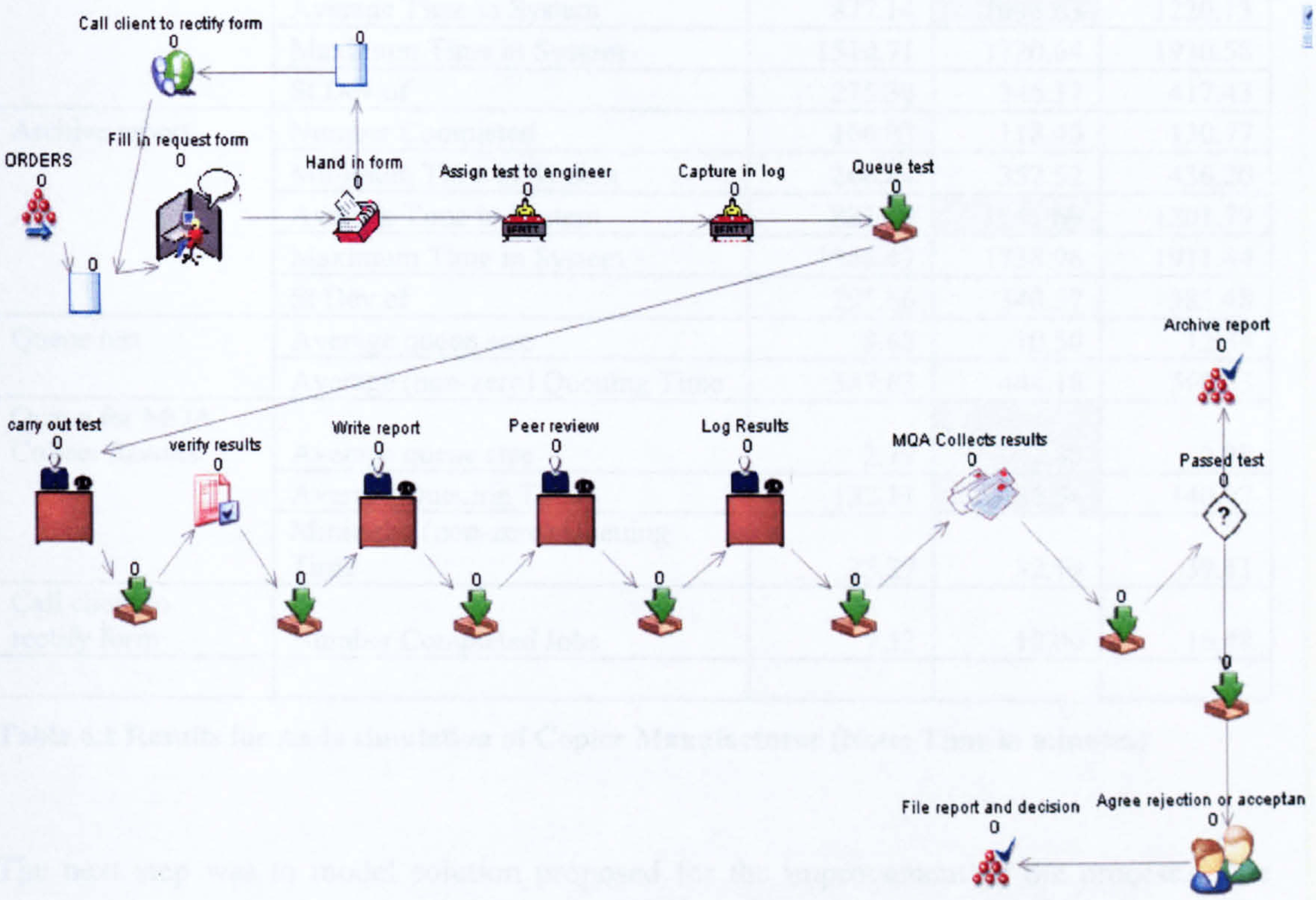


Figure 6.2 Copier manufacturer as-is process in Simul8.

The use of these components in a new process shows the applicability and utility of the components outside their original applications. For example, the order taking process, despite being initially designed and tested for receiving purchase orders, can be applied in a setting like laboratory control.

The Quote management process was used for the actual process of carrying out the test, writing the report and verifying it. Again, this component is used in a different context that where originally was developed from. The use of these components in a different setting demonstrates that selecting to reuse at the component level provides capabilities that could not have been achieved if a larger grained level had been selected, while still providing the benefits inherent in reuse.

The results from the as-is case are presented in Table 6.1

Simulation Object	Performance Measure	-95% confidence interval	Average	95% confidence interval
File report and decision	Number Completed	67.96	81.60	95.24
	Minimum Time in System	325.51	350.48	375.46
	Average Time in System	877.14	1048.63	1220.13
	Maximum Time in System	1510.71	1720.64	1930.58
	St Dev of	275.30	346.37	417.43
Archive report	Number Completed	106.03	118.40	130.77
	Minimum Time in System	268.84	352.52	436.20
	Average Time in System	881.59	1041.69	1201.79
	Maximum Time in System	1566.47	1738.96	1911.44
	St Dev of	295.66	340.57	385.48
Queue test	Average queue size	8.68	10.50	12.33
	Average (non-zero) Queuing Time	387.63	444.18	500.73
Queue for MQA Collect Results	Average queue size	2.79	2.88	2.98
	Average Queuing Time	132.11	136.54	140.97
	Minimum (non-zero) Queuing Time	25.27	32.19	39.11
Call client to rectify form	Number Completed Jobs	7.52	12.00	16.48

Table 6.1 Results for As-Is simulation of Copier Manufacturer (Note: Time in minutes)

The next step was to model solution proposed for the improvement of the process. The proposed system is a very simple MS Access database, which can be shared over an intranet with the clients of the laboratories. The thinking behind the solution is to allow the MQA engineers to request a test online and to verify from their desk whether a part has been approved to be used in the production lines or whether further actions are required (e.g. meeting to decide whether to accept or reject the part).

The second model built for this purpose was based on the as-is model and dealt with the implementation of the above-mentioned system. For this model, the components used were the electronic order processing and the electronic invoicing components.

As can be seen in Table 6.2 the results of the simulation of the proposed system show that the whole process will take less time. Crucially, this reduction in time will be at the interface between the laboratory and its clients, where the improvement is sought. One point to make here is that even if the overall processing time is reduced, there are constraints inherent to the system that limit the amount of time that can be reduced. The major of these constraints is the material test itself, since they have set procedures that must be followed (e.g. for paint testing, a test plate is painted and then it has to dry in an oven for three hours before performing the actual tests). Nonetheless, the simulation of the process proved useful for the laboratories' manager and engineers, that is, it allowed them to quantify the potential benefits of the initiative and to explain these benefits to the plant management.

Simulation Object	Performance Measure	-0.95	Average	0.95
File report and decision	Number Completed	68.88	82.80	96.72
	Minimum Time in System	217.29	242.15	267.02
	Average Time in System	748.01	914.53	1081.05
	Maximum Time in System	1349.35	1569.53	1789.71
	St Dev of	266.64	346.05	425.46
Archive report	Number Completed	107.76	121.40	135.04
	Minimum Time in System	169.47	210.46	251.45
	Average Time in System	739.58	898.68	1057.78
	Maximum Time in System	1390.24	1565.78	1741.31
	St Dev of	302.31	343.73	385.15
Queue test	Average queue size	8.73	10.56	12.39
	Average (non-zero) Queuing Time	387.38	445.58	503.78
Queue for MQA Collect Results	Average queue size	0.00	0.00	0.00
	Average Queuing Time	0.00	0.00	0.00
	Minimum (non-zero) Queuing Time	0.00	0.00	0.00
Call client to rectify form	Number Completed Jobs	0.00	0.00	0.00

Table 6.2 Results for As-Is simulation of Copier Manufacturer (Note: Time in minutes)

6.2.2.2 User experience

The simulation provided the manager and personnel of the laboratories with a tool to experiment and to analyse different options. The simulation results were tied to an internal methodology called "Quick-JIT", (which, despite the name, is a established process for the re-engineering of processes and not directly related to Just-in-Time concept as commonly known). The results of the simulation were presented to the board of directors and in company's internal competition "Teamwork". The response from these two forums was overwhelmingly positive. The board of directors recommended the extension of simulation analysis to other areas of the company. The group involved in this project obtained the second place in the Teamwork event.

The responsible for the Materials Lab expressed "The use of simulation was a fundamental tool for the personnel in the labs to be able to convince the MQA engineers and the Quality Director of the benefit of moving towards electronic handling of the test requests and results".

6.2.3 Energy supplier (UtilityCo.)

Under the Kyoto Protocol, the UK Government has the target to reduce CO_2 emissions by 20% by 2010. As part of this target, it aims to increase the contribution of electricity supplied from renewable energy generators to 10% (was 2.8% in 2000) by the year 2010 implying a requirement of about 6 to 8 GW of new renewable capacity (DTI 2002; The Cabinet Office 2002). Increasing targets may be established for the post-2010 period (between 20 to 60%, implying capacities of 20 to 45 GW) (ETSU 2003).

Within the UK, Scotland is recognised for possessing considerable renewable energy (RE) resources: amounting to some 75% of the entire UK installed generation capacity (DTI February (2002)). The Scottish Executive is committed to developing and exploiting these resources, a commitment which lies at the heart of its Climate Change Programme. Presently, the Executive is already devoted to raising the overall proportion of electricity generated from renewable sources in Scotland to 18% by 2010 (including existing hydro-electric output) (Scottish Executive. 2002). However Scottish Ministers have indicated their ambitions to look beyond these short/medium term aims. For example, although there remain many challenges to be faced to fully exploit the resource potentials within Scotland, it is believed that producing as much as 40% of Scotland's electricity from renewable sources by 2020 is a realistic and sensible target. The introduction of the Renewable Obligation (Scotland) (ROS) is anticipated to further promote the deployment of renewable electricity generation projects over the coming years.

This case deals with the introduction of a new connection process to the grid. The intended customers are companies producing electricity using renewable sources and wanting to sell it to the distributors. The new tool will allow the calculation of the best route for the connection, using Geographical Information Systems and optimisation algorithms.

Although each utility company has standard technical and business practices defining the procedural and contractual requirements surrounding the connection of new generation to its network, there are a number of steps that are general and which must be addressed to ensure that all the issues are identified and dealt with in a systematic manner. In brief, these steps are:

- Exchange of general project information between the developer and the utility.
- Electrical engineering analysis performed by the utility (e.g. power flows and capacity checking).
- Developer acceptance of interconnection design/conditions.
- Engineering/project review meetings between the utility and the developer.
- Project engineering and construction.
- Final utility inspection of interconnection and protective equipment.

Figure 6.3 shows a high-level overview of the connection process. The case study focuses on how information is exchanged in the first two steps.

From the utility's perspective, the effort to deal with escalating numbers of applications for interconnecting new generation including wind farms can be substantial and it is an expense that must be recovered regardless of project outcome. Additionally, a problem recognised by utilities is that of poorly specified, ill-conceived applications requiring multiple iterations of analysis. (Quinonez-Varela et al. 2006). As a consequence, methods of reducing the cost and time of dealing with new connection enquiries are of great significance/importance. From the developer's perspective on the other hand, automating even part of the application process will allow a prompt response to potential developments in a reliable, consistent and secure fashion.

The aim of the project under study is the development of a software-based planning framework to assist the interconnection assessment of renewable generators, especially of wind farm developments, into the Scottish electricity network. In brief, the specific objectives are:

- Utilise the automated screening capabilities of Geographical Information Systems (GIS) to provide ease of use by planners and project developers.
- Develop suitable GIS algorithms, including appropriate constraints and suitable methodologies to perform routing and search functions for new grid connection.

- Interface the GIS tool to suitable power system simulation (PSS) tools such as load flow and stability software; e.g. the PSS/E platform, to carry out line capacity checks, voltage profile analysis and so forth.
- . Develop a front-end to facilitate easy access from users.
- . To investigate the potential of using this planning framework to facilitate possible 'aggregation' of a number of potential renewable generation developments under a single new grid connection

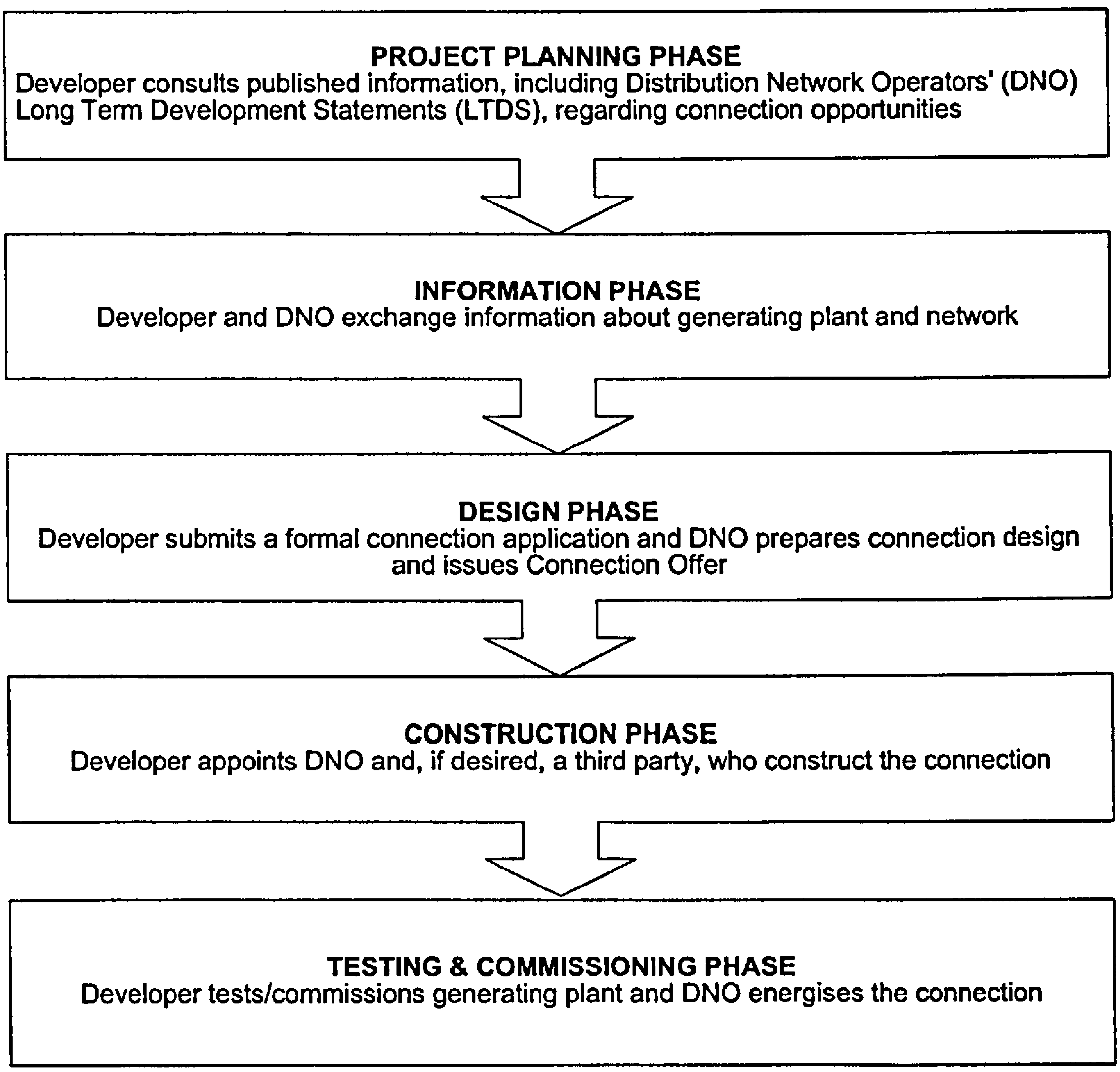


Figure 6.3 High level view of the interconnection process. (SourceJarrett et al. 2004)

A more detailed representation of the process which is going to be affected by the e-tool is presented in Figure 6.4

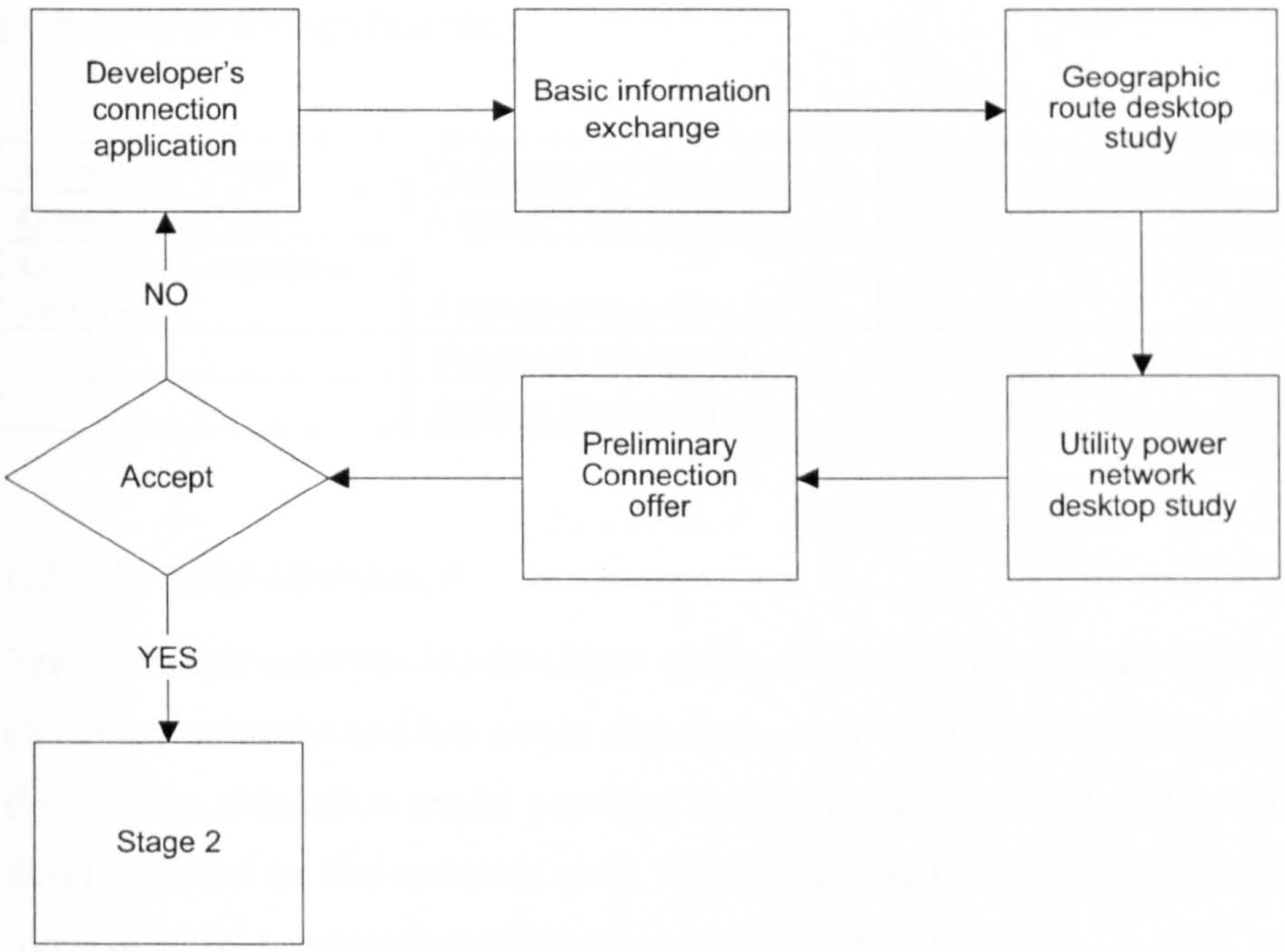


Figure 6.4 Planning process for interconnection. (Source Quinonez-Varela et al. 2006)

The analysis for this case study was done by comparing three scenarios: the current configuration, the option of using the new system internally and the option of making the system available for external users (potential suppliers of renewable energy). The first case involves doing the analysis manually, with the geographical routing made on paper. The second allows the user to submit data online and the geographical routing to be made by the utility engineer using the planning tools offline. The final option is to integrate the planning tool with an online interface to allow the user to input data, create the geographical routing and obtain the results without intervention from UtilityCo personnel.

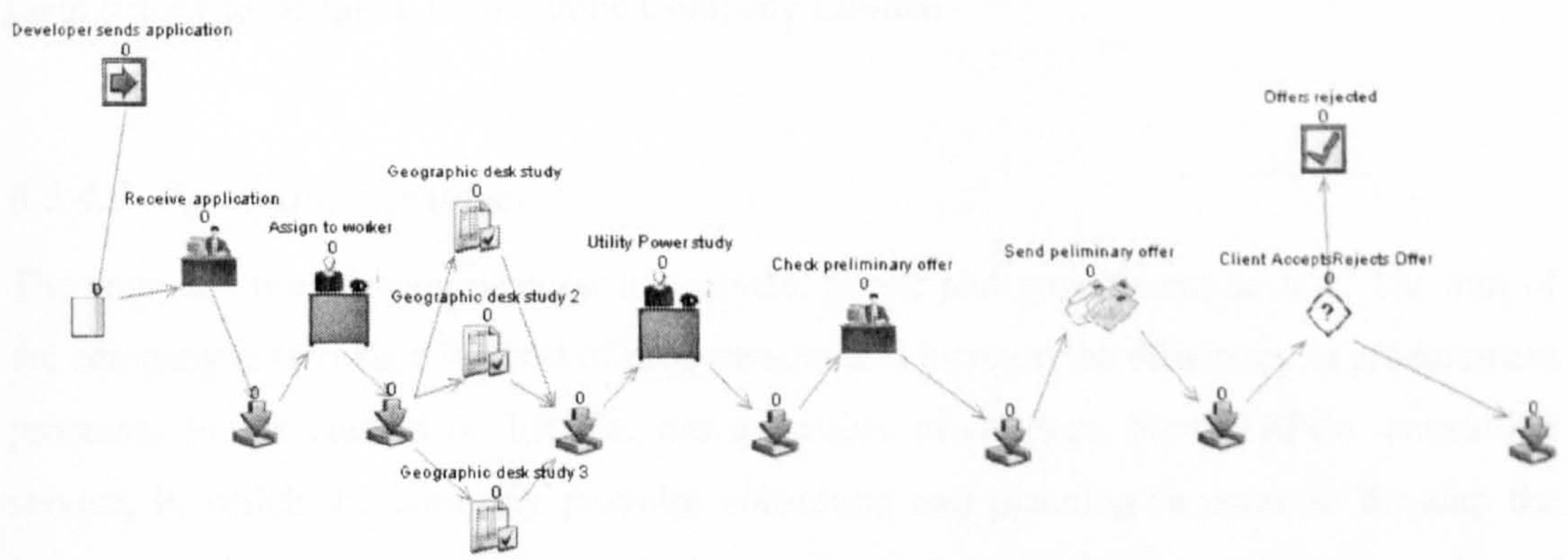


Figure 6.5 As-is model for UtilityCo. Interconnection process

The analysis showed the simulated predicted benefits of using the new system, reducing the processing times significantly.

Simulation Object	Performance Measure	As Is	Option 2
Quotes Accepted	Average Time in System	5123	4517
Queue for Geographic desk study	Average queue size	40	0
	Maximum queue size	85.4	1
	Average Queuing Time	2580	0

6.2.3.1 User experience

The use in this case was the developer of the system. This user is an expert in simulation of electricity networks and has ample experience with mathematical simulation software. For the user the simulation model provided a way of showing the benefits and savings of the developed tool to non-technical staff. It also allowed the analysis of the potential volume increase in inter-connection applications submitted to UtilityCo.

6.2.4 ERPCo.

ERPCo. is a professional service company in Online Purchasing and they are the first e-Procurement outsourcer in Thailand. In 2001, ERPCo was established as a joint venture of six large companies (Bangkok Bank Public Company Limited, The Siam Commercial Bank PCL., The Siam Cement Public Company Limited, United Communication Industries Public Company Limited, True Corporation, Public Company Limited, and Charoen Pokphand Foods Public Company Limited) . Nowadays, ERPCo. has two main shareholders, Charoen Pokphand Foods Public Company Limited has ninety percent of shareholder and the rest of them belong to Bangkok Bank Public Company Limited.

6.2.4.1 Company's product

The company provides services for the private, public and government sectors. The aim of the company is to reduce the cost of procurement and increase the efficiency in procurement processes for its customers. ERPCo. has a number of services. First, ERPCo. consulting service, in which the company provides consulting and planning in order to develop the customer's procurement abilities, increase efficiency and clarity, and reduce cost of operation. Second is ERPCo. strategic sourcing. This service helps customer to increase procurement efficiency by using systematic analysis of their supplier base. Third, ERPCo. Online Auction is the instrument which helps firms purchasing goods and services. Finally, ERPCo. purchasing, in which the company helps its clients to apply technology to increase flexibility and speed in the procurement process. The case presented is that of one of ERPCo.'s clients, in which the simulation was used to present the benefits of moving towards an integrated e-procurement solution.

This case presents a good opportunity to contrast different analysis approaches. At the moment, ERPCo. use simple spreadsheets to calculate the benefits (both in time and money) that an e-procurement applications brings to their clients. Having this data allowed us to compare the current (static) and the new (dynamic) analyses.

This particular case study was also used to extend the testing the concept of e-business simulation and the usability of the components by a third party. The components were given to an MSc student, who was in charge of developing the analysis for this company. No modelling was carried out by the author and the input to the modelling process was minimal. The resulting models are presented next.

6.2.4.2 The simulation of the traditional ERP system before interfacing with Online Purchasing system

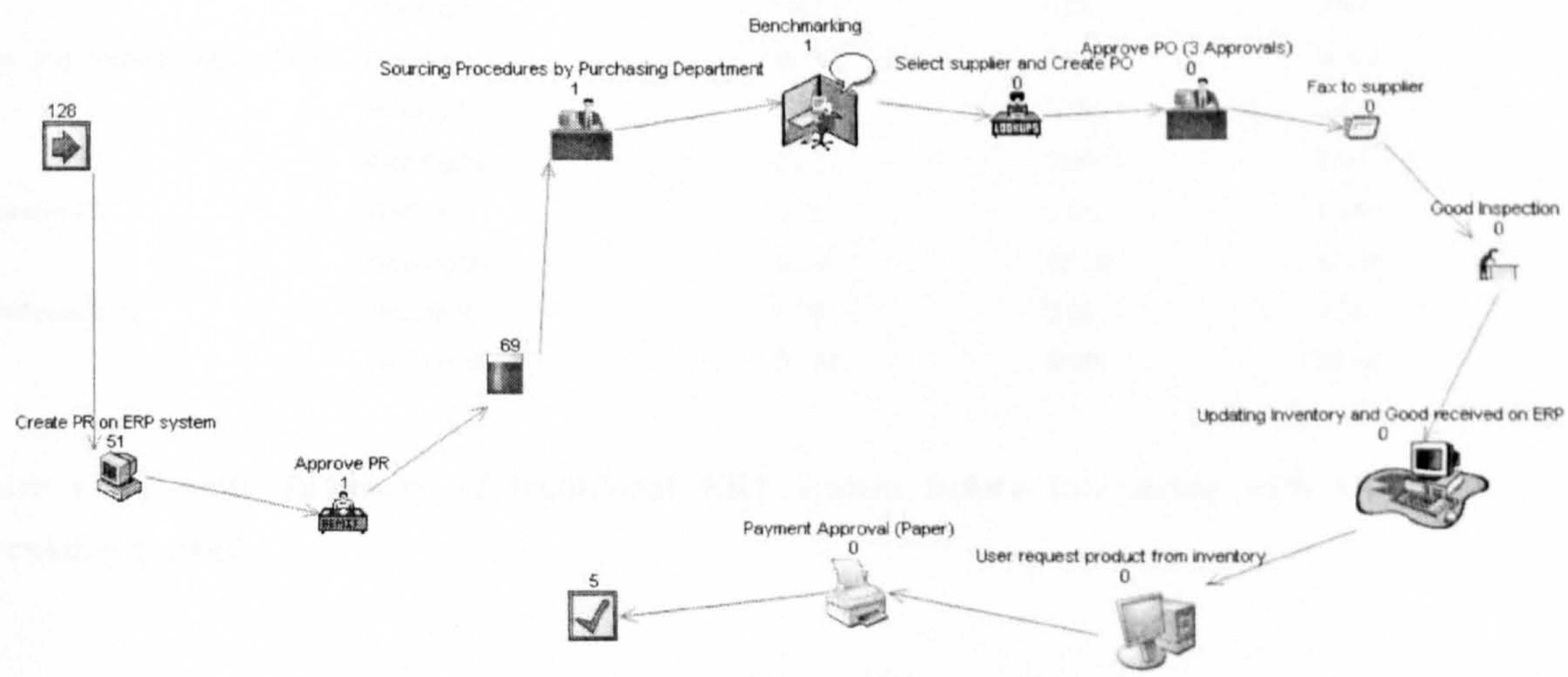


Figure 6.6 The simulation of the traditional ERP system before interfacing with Online Purchasing system

6.2.4.3 Results Summary of traditional ERP system before interfacing with Online Purchasing system

S8 SIMUL8 Results Summary

Results

Detail | Help | OK

		Low 95% Range	Average Result	High 95% Range
Work Complete 1	Average Time in System	1290.94	1314.86	1338.77
Work Entry Point 1	Number Entered	146.94	150.67	154.40
Work Complete 1	Number Completed	5.00	5.18	5.36
Approve PO (3 Approvals)	Waiting %	93.09	93.39	93.70
	Working %	6.30	6.61	6.91
Fax to supplier	Waiting %	99.32	99.35	99.38
	Working %	0.62	0.65	0.68
Good Inspection	Waiting %	97.74	97.84	97.94
	Working %	2.06	2.16	2.26
Select supplier and Create PO	Waiting %	97.21	97.34	97.46
	Working %	2.54	2.66	2.79
Updating Inventory and Good r	Waiting %	95.49	95.72	95.94
	Working %	4.06	4.28	4.51
User request product from inv	Waiting %	97.76	97.83	97.90
	Working %	2.10	2.17	2.24
Payment Approval (Paper)	Waiting %	99.32	99.35	99.38
	Working %	0.62	0.65	0.68
Sourcing Procedures by Purch	Blocked %	96.30	96.61	96.92
	Waiting %	3.08	3.39	3.70
	Working %	0.00	0.00	0.00
Approve PR	Waiting %	0.66	1.05	1.44
	Working %	98.56	98.95	99.34
Benchmarking	Waiting %	1.76	2.04	2.33
	Working %	97.67	97.96	98.24

Figure 6.7 Results Summary of traditional ERP system before interfacing with Online Purchasing system

6.2.4.4 *The simulation of the ERP system after interfacing with Online Purchasing system*

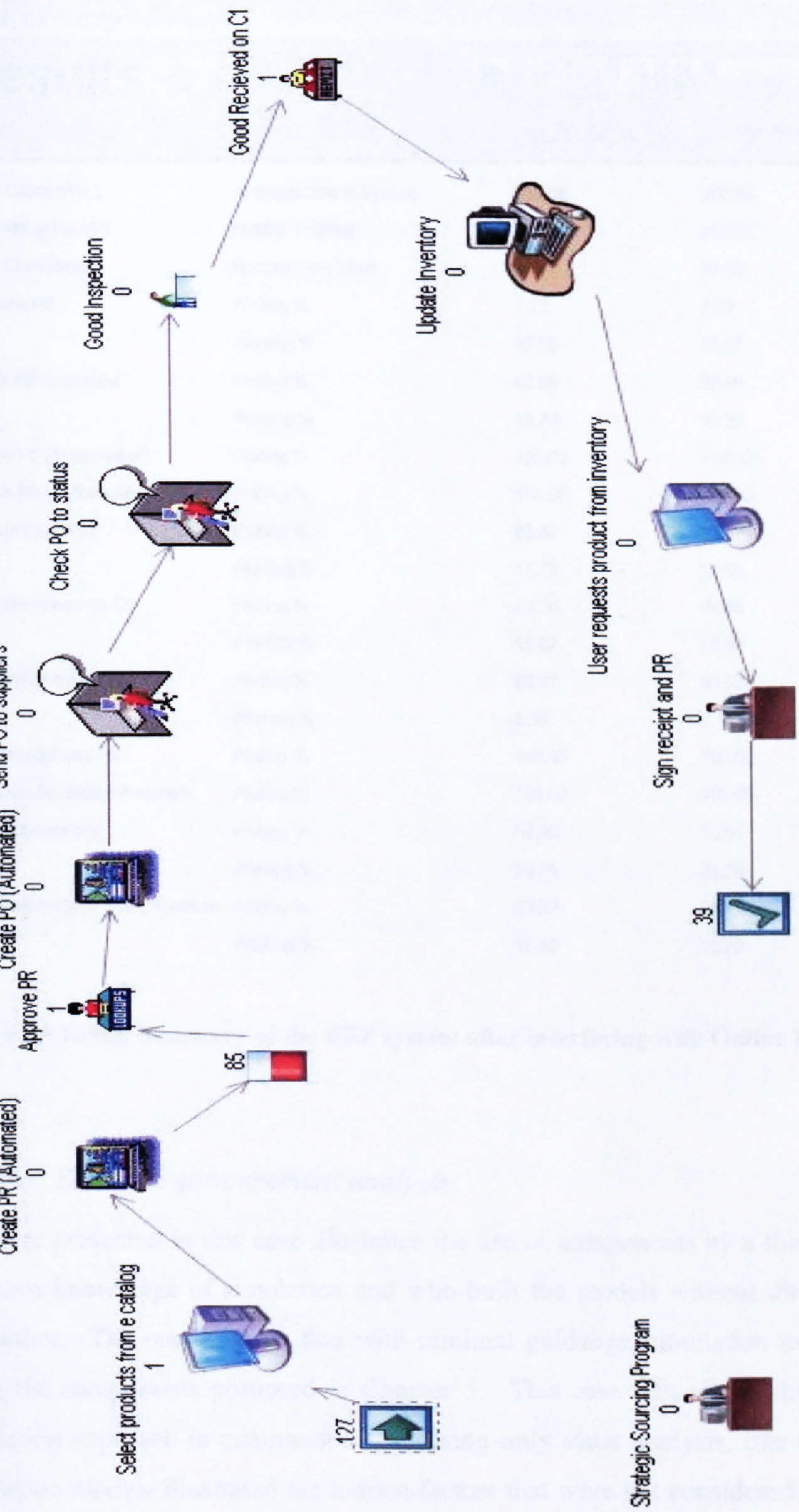


Figure 6.8 The simulation of the ERP system after interfacing with Online Purchasing system

6.2.4.5 Result Summary of the ERP system after interfacing with Online Purchasing system

SIMUL8 Results Summary

Results

		Low 95% Range	Average Result	High 95% Range
Work Complete 1	Average Time in System	943.08	960.96	978.84
Work Entry Point 1	Number Entered	146.55	150.24	153.94
Work Complete 1	Number Completed	37.13	37.62	38.11
Approve PR	Waiting %	1.72	1.93	2.14
	Working %	97.86	98.07	98.28
Check PO to status	Waiting %	83.66	83.98	84.30
	Working %	15.70	16.02	16.33
Create PO (Automated)	Waiting %	100.00	100.00	100.00
Create PR (Automated)	Waiting %	100.00	100.00	100.00
Good Inspection	Waiting %	83.67	83.98	84.28
	Working %	15.72	16.02	16.32
Good Recieved on C1	Waiting %	83.78	84.08	84.37
	Working %	15.62	15.92	16.21
Send PO to suppliers	Waiting %	93.41	93.52	93.64
	Working %	6.36	6.47	6.58
Sign receipt and PR	Waiting %	100.00	100.00	100.00
Strategic Sourcing Program	Waiting %	100.00	100.00	100.00
Update Inventory	Waiting %	67.96	68.61	69.26
	Working %	30.74	31.39	32.04
User requests product from in	Waiting %	83.82	84.13	84.44
	Working %	15.47	15.78	16.09

Figure 6.9 Result Summary of the ERP system after interfacing with Online Purchasing system

6.2.4.6 ERPCo e-procurement analysis

The case presented in this case illustrates the use of components by a third person, who did not have knowledge of simulation and who built the models without direct supervision by the author. The results show that with minimal guidance, simulation models can be built using the components proposed in Chapter 5. This case also shows the value of using a simulation approach in comparison with using only static analysis, like spreadsheets. The simulation models illustrated the hidden factors that were not considered when carrying out the static analysis. For example, the utilisation of workers and waiting times of orders in the system have a big impact on the total cost of the processes. Moving from a manual process to an enabled process saves around 1,400,000 Baht/year. The throughput of orders is higher and waiting times (e.g. for approval) are reduced.

This part of the testing illustrates the usability and usefulness of the components, as well as their generalisability. This generalisability extends not only to the use of components in a different industry setting and geographical location, but also to the use of the components by people who were not involved in their development, showing that the use of these components is not hampered by personal bias or modelling preferences.
The company appreciated the use of simulation and the components and will adopt the approach for future projects with clients. They mentioned that the use of simulation provides them with a better tool to show their clients the changes that can be achieved by implementing e-business.

6.2.5 Case testing discussion

The testing of the components on the cases shows that the components can be used on different cases, contributing to the generalisabilty, external validity and reliability of the research. By using different components in "new" applications, I showed that their utility extends beyond the cases from which the components were derived. Testing the components in this manner also goes some way towards validating the methodology developed for their creation. It has been shown that the iterative sampling and progressive testing allow the creation of components that can be generalised (up to a certain extent).

An aspects that was tested in this section is the involvement of the component's originator. By having three different cases in which the originator was involved to different degrees (fully involved in the CopierCo case, as a guide in the UtilityCo. Case and at arm's-length in the ERPCo. case), it was possible to investigate the use of the simulation and the developed e-business components by different users. This was particularly important because it was necessary to show that the personal preferences of the originator did not introduce bias in the proving of the constructs developed in this research. This set of cases also showed that there is no need to be a simulation expert to apply the concept of e-business simulation (e.g. ERPCo). A more detailed exploration of this issue will be presented in the following section.

An important point to make here is the fact that the components are normally used with (minor) modifications to their logic or structure. This indicates that the components are a good guide for model building, but that they still need to be customised to reflect the particular processes of each case. This finding is in line with the expectation of this research. The researcher set out to develop guidelines for e-business processes, rather than prescriptive configurations for these processes.

Table 6.3 shows a summary of the cases and the characteristics of the modelling task in each one of the cases.

This testing has also shown the usefulness and utility of the components in contexts which are different from the original cases in which they were developed.

	CopierCo	UtilityCo	ERPCo
Component originator involvement	Develop model	Support user in developing model	Arm's-lenght
e-business application	Control database	Grid connection system	e-procurement
Internal or external application	Internal	Internal/External	External
User role	Data provider	Modeller (assisted)	Independent modeller
Setting of e-business application	Laboratory	Engineering	Consultancy
Final user of the system	Internal clients	Internal user/ External client	Internal user
Industry sector	Manufacturing	Energy	Service
Key Performance Indicators	Time and Cost	Time	Cost

Table 6.3 Comparison of testing cases.

6.3 User testing.

Once the components were tested by modelling further case studies, the next step was to test how users would react to the use of the components. This part of the testing is important because it is necessary to elicit whether the utility of such approach is restricted by the particular modelling idiosyncrasies of the component developer and/or user. Additionally, Banks et al (2003) argue that the nature of the simulation user in the future will be more diverse:

> "The makeup of the simulation user community is also going to change. While the number of users will be greater, it will take a much wider net to encompass the community... "simulation user" could mean many things. It could mean an occasional user of simulation ...using a basic simulation tool. It could refer to the traditional simulation users, who are general purpose 'simulationists'... Lastly, it could refer to a specialist who knows the basics of simulation but is familiar with how simulation integrates with another technology like conveyor PLC controls".

This thesis argues that the components developed in Chapter 5 can be of help for all the users described by Banks et al. For the occasional user and the specialist, they can provide a tool to build simulation models without having to learn the inner workings of simulation. For the traditional 'simulationist', they can help speed-up model building and reduce model verification time. These benefits, however, are conditional on these types of users being able and wanting to use the components in the first place. This section will deal with exploring user perceptions and gauging their willingness to use the components.

Traditionally, user usability testing has been used in Information Systems development. Nielsen (1994) describes the four basic ways of evaluating a system as "automatically, empirically, formally and informally." He also argues that "automatic methods do not work and formal methods are very difficult to apply". This leaves us with the options of empirical testing ("usability assessed by testing the interface with real users") and informal testing ("based on rules of thumb and the general skill and experience of the evaluators"). Karat et al (1992) found that "the empirical testing condition identified the largest number of problems, and identified a significant number of relatively severe problems". An empirical testing was then chosen for the evaluation of the components. Users were asked to create simulation models that involved both manufacturing processes and e-business processes.

In order to test the usability of the components, a quasi-experiment was designed. The design of the quasi-experiment involved two phases: Phase one tested the use of the components by simulation learners with a working knowledge of simulation; phase two tested the components on simulation novices. The reason for having these two phases is to evaluate the differences between user with knowledge of simulation and those without. It is one of the premises of this work that the development of components will aid both simulation modellers and people who are not familiar with simulation techniques, by giving them a starting point for model-building. As stated in Chapter 3, a quasi-experiment design was selected, since it allows a comparison of those who get the "treatment" and those who do not. The description of each phase is presented below.

6.3.1 Phase 1: Simulation learners

6.3.1.1 Phase 1 Design

This phase involved 31 users building models over a period of three months. The users were simulation learners that had to analyse investment options on both business and manufacturing processes for a company. The components were explained to half of the sample. The selection of which half would get the components was completely random. The explanation of how to use the e-business components was done verbally during the introduction session to the problem. An important note to make here is that the author was not involved in the teaching or assessment of these simulation learners

An initial assessment was carried out (the "pre" stage) . This initial assessment tested the confidence of users using simulation tools, templates concepts (the closest approximation to components), and quantitative tools in general. The questionnaire used for pre-testing is presented in Appendix 4. Users were also tested at the end of the exercise in order to see how their confidence using simulation was affected, whether they had used the components, whether they had modified the components while using them, as well as what barriers they found. The questionnaire used for post-testing is presented in Appendix 5.

In addition to the pre- and post-questionnaires, the users were asked to write about their experience using the components as part of their report. There was no template or specific instructions for the structure of this part of the report. The intention with this was to allow them to express freely and to gain a deeper understanding of the user experience, something that is somewhat restricted by a structured questionnaire. The free-writing section allows also having a way to triangulate information, a requirement to add validity to the results. Part of the assessment was based on providing an objective assessment of the experience.

6.3.1.2 Phase 1 Results

Phase 1 started with an analysis of what experience and confidence the subjects had in using simulation tools and templates. The results of the pre-treatment questionnaire show that 78 % of users are confident or very confident of their understanding of simulation theory;

however, more than half of the sample (56%) is not confident on their abilities to map business processes. Fifty-six percent are confident of using simulation software, while another 30% have some confidence in using simulation software. (NOTE: Full statistical analysis for Phase 1 results is presented in *Appendix 6*)

As for the use of modelling tools, 100% of the sample had used spreadsheets, 65% had used some form of discrete event simulation software, 47 % had used queuing theory and 13% had used systems dynamics, while no one had used agent-based simulation. Seventy-four percent had used one simulation tool (most of them during the simulation class), while 22% had used 2 and 4% had used none. Sixty-two percent had used simulation tools for less than 5 hours, while 15% had more extensive experience (more than 24 hours) with simulation tools. Three quarters of the sample had used templates in other applications, of which 59% had used them in more than three different applications (e.g. letter template in MS Word).

Ninety-three percent considered that using templates had made the task easier, while 80% felt that the use of templates allowed them to perform the task quicker. Seventy-seven percent modified the templates to fit their needs and of these, 80% found them easy to modify. (NOTE: The percentages in the last paragraph are based on the valid answers for each question and not in the total sample size).

The picture that this analysis presents is one of users that are confident with the theory behind simulation, that have had some experience with simulation tools, have used templates, and in general adapted them for their specific purposes, finding this adaptation an easy task.

The results of Phase 1 show that after the simulation class and the exercise in modelling the case presented to them, 80% of the sample were very confident in understanding the theory behind simulation, while 20% were confident. Eighty-five percent used the components for building the models, of which 88% found them useful. Everyone that used the component modified them and everyone that modified them found it an easy process. A summary of the main issues that resulted from this exercise are presented next and summarised in Figure 6.10:

- Components save time building the model.
- Reduced likeness of building-in errors.
- Useful for setting up a base structure

- Useful for inexperienced people
- Encourages standardization and uniformity

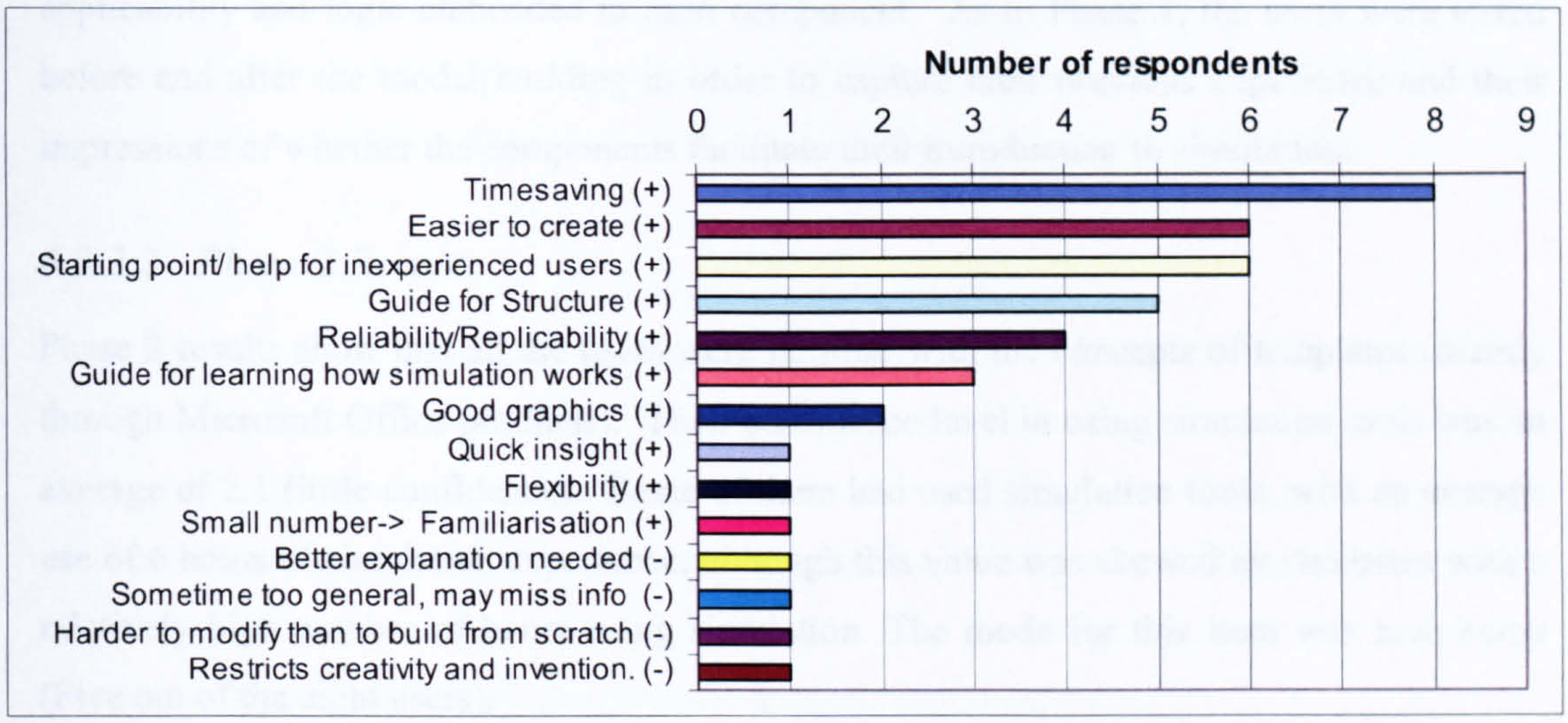


Figure 6.10 Positive and negative effects of using e-business simulation components

As can be seen, the perceived benefits outweigh the drawbacks. In addition, some of the drawbacks are related to the process of using the templates, rather than to the templates themselves. From the feedback gained in Phase 1, it was decided to create a general user guide for the templates, explaining the function and logic of each templates and to provide said guide to the users for Phase 2.

6.3.2 Phase 2: Simulation novices

6.3.2.1 Phase 2 Design

The second phase of the quasi-experiment involved giving the components to people that had not used simulation and that were not learning to use it. The motivation behind this design was to test whether components could be used as a way of introducing simulation to non-specialists. This is particularly important if we take into consideration the argument presented by Banks et al (2003) that the spectrum of simulation users is widening (see Section 6.3).

The sample size of this phase was eight users. The users were researchers in the area of manufacturing management, although none of them was focused on simulation research.

This testing was carried out over one day. They were asked to produce the same simulation model that was used in Phase 1. Following the recommendations emerging from Phase 1, a detailed written user manual was provided (see *Appendix 2A*), explaining the structure, applicability and logic embedded in each component. As in Phase 1, the users were tested before and after the model building in order to capture their previous experience and their impressions of whether the components facilitate their introduction to simulation.

6.3.2.2 Phase 2 Results

Phase 2 results show that all the users were familiar with the concepts of templates (mainly through Microsoft Office products). Their confidence level in using simulation tools was an average of 2.1 (little confidence). Some of them had used simulation tools, with an average use of 6 hours of simulation experience, although this value was skewed by two users with a relatively high number of hours using simulation. The mode for this item was zero hours (Five out of the eight users).

The picture presented here is one of users who are generally confident using and learning to use software. Most of them are confident mapping processes and differentiating between manufacturing and business processes, although not very confident in understanding the theory behind simulation.

The post-treatment analysis shows that 87% of the sample used the components to create the simulation model. From the user that used the templates, 83.3 % modified them while 16.7% used them without any modification. All those who modified the components found it easy to do so. The same proportion (83.3%) found that the components made the task quicker, while 100% found it made it easy. As above, 83% found that the use components made the modelling task more explicit. A more detailed statistical analysis of the questionnaire results for Phase 2 can be seen in *Appendix 7*

Some of the comments made by Phase 2 and Phase 2 users are transcribed below. They are grouped by theme as presented in Figure 6.10 (NOTE: These comments are a mix of all the user responses and do not represent only one respondent):

-Time saving

These comments support one of the main assertions of this thesis: that the use of components helps faster model building.

"The components speed up model building"
"We don't have to draw the same thing/a lot of things regularly, hence making the process quicker."
"Building the model was easier because mapping the process was quicker"
Interestingly, the last quote is also related with the components providing guidelines for the process structure, while the second quote basically describes the concept of re-use.

-Easier to build.

Another main reason for developing components for e-business is that it is proposed that they make model building easier. The following quotes illustrate this perception from the user's point of view.
"Some components did make the task easier, particularly those of standard applications, like e-invoicing"
"By using the components we don't have to remember a lot of things"
"The components make it easier to understand the process by reminding us about the order of the processes"
Some of these comments are also linked to the concept of providing a guide for the user. From this comments, we can speculate that if there is a guide of what the process may look like, mapping and building the model such process would be easier.

-Starting point/guide for structure

The following comments reflect the user's perceptions regarding the utility of the components as a starting point for the simulation or as a guide for how the structure of the e-processes may look like.
"Intuitive structure and useful graphics"
"The components support design and understanding. It is an important starting point."
"The components acted as a guide for the understanding of the process and the software"
"The components gave an initial idea of how the software works; after having this initial idea, the components don't add much to the ease of use".
The last quote is interesting because the perception of the user in this case is that the utility of the components is limited to the starting of the modelling process, being used as a useful way of learning the software capabilities, but not beyond this step. This expands (and in a way contradicts) one of the arguments of this thesis, which states that the benefits of using components is the re-use of constructs across a number of applications and that such re-use is useful whether you are a novice to simulation or an experienced user.

-Software use and validation

These quotes describe the perception of the users about how the components help the learning and use of the simulation software and other advantages that the use of components brings about.

"Components simplify the understanding and the use of software"

"Only minor changes were required for the templates to represent the process".

"Since the components are pre-built, they eliminate errors".

Important points to highlight here are the fact that modifying the components is seen as required, but easy to do and that by having a predefined element, a reduced validation and verification time is required. This line of reasoning ties in with the argument of verification and validation being built into the components by their constant re-use. (e.g. Aronson and Bose 1999)

-Suggestions/ Criticisms

This section illustrates either criticism expressed about the use of components or suggestions for improvement to the components. Each one of the comments will be discussed individually.

"I suggest focusing the development of component for parts outside the manufacturing process"

This user described the usefulness of the components outside manufacturing, particularly because the majority of simulation objects that are included as default in most modern simulators are focused on manufacturing and/or have manufacturing specific functions (an example can be a conveyor, present in most simulators). The user expressed the idea that then components could be used to tackle the lack of objects that can be used for the business process side of organisations..

"It may be confusing if you increase the number of templates"

This is something that needs careful thought when escalating the component concept to include a larger number of components. A database with descriptions of what each component does, coupled with keywords (e.g. e-invoice, procurement) and an efficient search algorithm is needed if the concept is to escalate properly. An approach like the one proposed by Ball (1994) or Love and Barton (2003) can be explored. Further discussion on this issue is presented in Chapter 7.

"I suggest attach resources if necessary."

The use of resources is something that can increase the utility of the components. Depending on the type of process that a component deals with, different resources can be attached to it: People, computers, machines, etc.

6.3.3 User testing discussion

This section (6.3) described the testing of the components on users. The objective was to gather evidence of the perceived utility and usability of the components. Table 6.4 shows a summary of some of the characteristics of the different samples used in the user testing.

	Phase 1	Phase2
Sample Size	31	8
Pre-treatment questionnaire		
Familiar with template concepts	73.9%	100%
Simulation confidence level (1 None at all, 5 Very confident)	3.91	2.1
Time of use of modelling tools (Average)	11.81 hours	6.85 hours
Time of use of modelling tools (Mode)	2 hours	0 hours
Post-treatment questionnaire		
Used components	43%* (86% of sample with components)	87%
Modified components (% of users who used them)	84 %	83%
Found components useful (% of users who used them)	72%	83%

Table 6.4 User testing: Comparison between Phase 1 and Phase 2 *NOTE: This figure was derived from the questionnaire and the free-text analysis.

The two samples are different in terms of the previous experience in using simulation, with those in Phase 1 more experienced in the use of simulation software and more confident about the theory behind simulation. As can be seen in the post-treatment phase, despite this difference in background, the results of perceived utility and usability are similar for both phases. The uptake of the components is comparable in both samples. In addition, a big majority of both samples found the components useful. Another interesting finding from the user testing is that the users perceive the need to modify the components when using them to map the processes. This thesis argues that the components need to be modified to fit the particular case in which they are being used. A point worth making at this point is the idea of ownership of the model. It can be speculated that by modifying the components, the user is taking ownership of the components and personalising the model, instead of accepting what is being prescribed. This point is only a conjecture and not something that this research set out to test, but that may be of interest for future research.

Even though the samples are relatively small to be statistically significant, the results from the descriptive statistics and the qualitative data not only do not give cause for concern, but support the premises put forward on this thesis.

6.4 Conclusions of the chapter

This chapter has sought to test the components in a variety of settings. The components were tested for their feasibility, utility and usability, according to the criteria outlined by Platts (1993).

First, the application of the templates to three new case studies was presented. This application showed that the components can be used in cases which are different from the ones from which the components were derived. These applications illustrated that people other than the originator can use the components. They also confirmed the value that users see in using the more structured approach provided by simulation. The users perceived that the decision making was more robust and that allowed the exploration of issues that had not been taken into account previously. This confirms the value of bringing together simulation, business processes and e-business.
The use of the components in the different applications also showed the generalisability of the concept of components and served as a confirmation of the utility of the components in different contexts. It is acknowledged that the number of components created and tested is limited; however, this number is considered to be enough to prove that the concept of e-business process components is sound and useful when modelling e-business.

The second part of the testing dealt with the perception of a bigger sample of users. This testing confirms the usability of the components and provides some interesting insights about how users see them. It was found that the majority of users found the components useful, citing time saving and ease of model building as the main advantages of having the components available.

The testing on this chapter has then proved the utility and usability of the components, not only on application in which the original authors of the components are involved, but also in situations in which users who had never seen the components are able to understand the concept and use them straight away.

The evidence from this chapter helps also answer research questions 4 and 5. By using the components in further cases and on new users, I can confirm that re-usable components can be created from e-business templates and that they can be used in modelling e-business applications.

The next chapter will present the discussion of the whole research process, from the setting up of a methodology for the creation of the components, the actual development of these constructs to their testing. It will also deal with evaluating the research according to the criteria established in Chapter 3.

Chapter 7 Discussion and Evaluation

7.1 Introduction

Chapter 4 presented the feasibility analysis of using simulation for the analysis of e-business implementation. Chapters 5 and 6 presented the development of constructs (templates and components for e-business) and their testing. This chapter presents the discussion of both the development process and the results. The chapter starts with a discussion of the findings, how these findings contribute to knowledge and practice and how they relate to current research. The chapter then continues by analysing the research quality using the criteria presented in Chapter 3. The chapter concludes with an analysis of the emergent literature in the field (i.e. work that emerged during the period of this research) and its relevance to the research topic.

7.2 Discussion of findings

This research set out to study the benefits that a structured modelling approach (specifically simulation) could bring to the analysis of the effect of e-business on business processes. The research questions that were set out were:

1. Is simulation suitable as a tool to analyse the effect of e-business implementation in the business processes of manufacturing companies?.
2. What is the role of static modelling in understanding change brought about by e-business, and can generic business process maps be a useful starting point?
3. Can patterns be identified that characterise the e-business processes of manufacturing companies?
4. Can re-usable simulation templates be derived from these patterns?
5. What are the limitations, scope and range of applicability of these templates? and what methodology must be followed when using simulation in this context?

7.2.1 Simulation for e-business processes

The initial finding was that simulation does provide new insights into the analysis of e-business implementations (Chapter 4). The feasibility of using simulation for the analysis of e-business processes was demonstrated. The use of simulation provided a more complete analysis of the effects that e-business has on business processes.

The study of the use of simulation to analyse the changes brought about by e-business has brought out some results that were expected, but also some that were contrary to the initial expectation of the researcher. For example, one of the findings from the pilot case and other initial case studies was the fact that e-business was being used to automate processes, rather than as an opportunity to re-engineer and/or improve them.

While carrying out the theoretical grounding and the case studies it was evident that simulation brings benefits to the analysis of e-business processes. Simulation allows the analysis of the dynamics of the system, presenting not only a snapshot of the process, but an understanding of how the introduction of e-business affects the actual running of the process. All the process owners were enthusiastic about the information that the simulation provided and about the ability to experiment in a safe environment.

It must be said that in some cases the application of the simulation approach yielded more questions than the ones that the users initially had. This can be seen as a downside (i.e. they did not get a definite answer), but also can be seen as a positive effect by allowing a more comprehensive analysis to be carried out and to consider issues that had not been taken into account before. It is the argument of this research that the positive aspects outweigh the negative aspects. This is in line with one of the tenets of this research, namely that the implementation of e-business activities has to be thoroughly analysed before implementation. As has been shown, in some of the cases, this thorough analysis made the company realise that other issues needed to be addressed in order to take full advantage of e-business.

7.2.2 Difference between BPS and eBPS

An important distinction to make at this point is the difference between Business Process Simulation and e-Business Process simulation. E-business process simulation is seen as a subset of business process simulation. The differences between the approach used in this research and traditional business process simulation are:

- Field of focus. So far, business process simulation has not focused on the analysis of e-business. This work is one of the first to look at the analysis of e-business within the business process simulation arena.

- E-business templates. The approach that was followed in this research was based on an initial static analysis of the processes to identify general patterns in e-business activities that can be generalised. Most traditional business process simulations have dealt with the application of simulation to specific cases, without extracting generic processes/activities. This research expands the body of knowledge in this area.
- E-business components. As a consequence of the previous point, re-usable simulation components are proposed in this research. This is a novel approach in business process simulation, particularly at the level of aggregation (medium-grained) that this research proposes.
- Error investigation. This research started to investigate the effect of introducing errors in the manual processes, comparing this with the reduction of errors that can be enabled by an e-business application. Error investigation is a topic that had not been studied in business process simulation and this research provides the foundation for further exploration of this issue.

7.2.3 Analysis of existing process models

The analysis of existing business process models showed that many did not take into account e-business activities. This analysis showed that there is value in using existing business process models to start mapping e-business processes, however, there are gaps that need to be filled regarding e-business. The proposed approach to fill these gaps was to look at case studies in which e-business is being implemented and extract the e-business activities from these processes. This led to the creation of templates (static representation of e-business activities) which in itself adds to the existing knowledge in the field. This contribution was then further extended by "operationalising" these templates into re-usable simulation components. During the development of these templates/components there was some confusion regarding the terminology used to describe these constructs. At the end, it was decided to use the template/component terms to describe the static/dynamic representation of the e-business activities.

7.2.4 Development of e-business templates and components

The use of the components has proved to be a good guide for people with limited knowledge of simulation. The availability of the components helped these users to feel more confident when using simulation software, particularly in the model building stage. This was supported by evidence collected in the testing stage (Chapter 6), both from the case study users and from the two stages of the quasi-experiment.

One of the potential drawbacks of providing components to help people build e-business process models is that of what happens after the models are built. Traditionally, model building is only a part of the simulation analysis. How to set the experiments and analyse the data is as important as model building. Accordingly, to exploit the full potential that simulation offers, the users of the components need to be instructed on how to decide the number of replications to be run, the meaning of confidence levels and how to carry out sensitivity analysis. However, even if this is not the case, there are benefits to using the components, either on a static way as complements to current business process frameworks or even as a single run analysis of the dynamic behaviour of the processes.

An important issue of the simulation modelling of e-business is that, by virtue of needing to populate the model, a more detailed data collection needs to be carried out (compared with a simple static process model). This issue has its advantages and disadvantages. The advantages are that people start thinking about the process in a new way, understanding how each part of the system behaves by itself and how it contributes to the (dynamic) behaviour of the system. Having a full set of data that describes this behaviour should lead to better understanding of the system and hence to better decision making. On the other hand, collecting all this data may prove difficult or in some cases unachievable. From the (albeit limited) experience gained during this research, I can say that organisations are more likely to have process data about the manufacturing shop floor, but very limited or non-existent on the non-manufacturing activities of the business processes. This problem is compounded when analysing new, e-business processes, for which no data is available nor collectable. One way of jumping this hurdle is to get consensus between the process owners, together with people in the IT department, about what a sensible figure for the new process would be. A recommendation here is to be conservative when estimating the timings of e-business enabled activities. If when running this conservative estimate there are benefits to be gained, then it can be assumed that with more realistic figures the benefits would be increased or at least sustained. This is where traditional simulation techniques like sensitivity analysis come into play.

7.2.5 Level of complexity and use of simulation components

A theme that emerged after discussing this research with process owners and other academics is the fact that the level of process complexity has an important role to play when using simulation to analyse the effect of e-business on business processes. It is thought that the biggest potential for the re-usable simulation component to be applied is when the process is complex and has a lot of interdependencies and non-linearity. Further research is needed to elucidate the exact level of complexity at which the use of component will bring the most benefit.

7.2.6 Potential evolution of the approach

As next step of this research, a super-set of component could be developed based on the components that have been created during this research (i.e. use the existing components to create an aggregate component). These super sets could be used to represent full blown e-business strategies or systems (e.g. workflow). However, I come back to the discussion of granularity and of at what level should components be created. One potential benefit of having a super-set of components created by using other components is that the original problem of having large-grained components is reduced by being able to modify, add or remove original small-grained components to customise the super-component. Some software tools developed in recent years have used this concept. For example e-SCOR (Gensym Corporation 2003) presents this type of hierarchical arrangement for supply chain modelling.

7.3 Research Evaluation

This thesis has taken us from the initial analysis of e-business process simulation, to the description of the research process, the construct creation and testing. To reach high quality research standards, it is important to critically assess several aspects of this research against the criteria of evaluation (Martinez 2003). Section 3.4 described a set of criteria for the evaluation of research quality, which are presented in (Martinez and Albores 2003c). The following section will describe how each of these criteria was fulfilled during the development of this research

	Generic Criteria of Evaluation 'controls'	Criteria identified in	Did the research fulfil this criteria?
1	The construct increases understanding	Chapters 4, 5	✓
1	The construct allows predictions.	Chapter 4,5 and	½

		6	
2	The construct is non-trivial	Chapter 6	✓
3	The construct includes attributes, variables, etc.	Chapters 4 and 5	✓
4	Provides research boundary 'scope of the construct'	Chapter 5	✓
5	Rigour of the research methodology process a) shows proof of logical research methodology design b) Internal validity c) Construct validity d) External validity e) Reliability	Chapter 3	✓
6	Contains evidence to support the construct a) Select relevant samples and cases b) Provide sufficient evidence to substantiate the conclusions that have been drawn	Chapter 6	✓
7	Contribution to knowledge	Chapter 4,5,6 and 8	✓
8	Contribution to practice a) practical relevance b) practical functionality	Chapter 8	✓
9	Link existing theory with theoretical novelty of the construct	Chapter 2,5	✓
10	Application of the construct on other environments	Chapter 6	✓

Table 7.1 Research quality evaluation criteria (Martinez and Albores 2003b)

The construct increases understanding. The proposed constructs should enhance the comprehension of existing knowledge and/or new knowledge by providing a logic and reasonable explanation of the phenomena. This thesis increased our understanding of how simulation, business process analysis and e-business can be combined in order to have a better analysis of what the implications of implementing e-business are.

The construct allows predictions. Based on certain inputs, constructs should estimate or model different scenarios. The prediction that can be made at this high level is that a simulation analysis will give a better understanding of the changes that e-business brings. However, it could be argued that at a high level, the constructs and the concept (e-business simulation) being tested in this research do not allow specific predictions. However, at a lower level, the whole idea behind the research is to predict the performance of different e-business options. Therefore, the author thinks it is better to err on the side of caution and mark this criterion as partially achieved.

The construct is non-trivial. It refers that constructs should avoid the obviousness and bareness, although, this does not imply that constructs should be complicated. The constructs developed during this research work are filling a number of gaps in theory and practice that were identified in current business process models. These gaps and the templates/components developed to fill them were derived from a careful analysis of case studies and theory. The main construct/concept proposed in this thesis is also non-trivial because it brings three research strands together for the first time (simulation, BPR and e-business). .

•

Provides research boundary (scope of the construct) Constructs should define their area of applicability by establishing the environment where it can make accurate predictions. The area in which the research was carried out was focused on business processes in manufacturing and service organisations. Within these organizations, the analysis was carried out focusing on the operate processes, and mainly the order fulfilment process. Chapter 5 presented the case studies which illustrate this scope. This research boundary was, however, expanded to test the applicability of the use of simulation outside the manufacturing operate processes (Chapter 6).

7.3.1 Rigour of the research methodology process.

The rigour of the research process is demonstrated through:

7.3.1.1 Proof of logical research methodology design.

It is concerned with the evidence that show a mastery research process, research protocol and a rational selection of research methods tools and techniques, which address the research issue (Sekaran 1992). This criterion was documented in Chapter 3: research methodology and is reflected throughout the thesis. This section (7.3) is part of this design and of the aim of have a clear methodology. Chapter 5 also demonstrated the use of a research protocol to analyse existent business process models and to develop templates and components from this analysis.

7.3.1.2 Internal validity

Internal validity is the extent to which the researcher can establish a causal relationship; whereby certain conditions are shown to lead to other conditions as distinguished from spurious relationships (Easterby-Smith et al. 1999; Yin 1994):. Some of the techniques that were used to ensure internal validity in this project were:

- Methodological triangulation was used by having case studies, interviews and questionnaires used to collect data and test the constructs.
- Different respondents were used for the different phases of the testing.
- Cross case analysis was carried out in Chapters 5 and 6, first for the development of templates and components and later for their testing.

7.3.1.3 Construct validity

Construct validity is concerned with the idea that the research design fully addresses the research questions and the research objectives (Thomas and Tymon 1982; Easterby-Smith et al. 1999:41; Kasanen et al. 1993; White 2000:25). The common techniques used to ensure construct validity are: triangulation of data (in my case data from primary and secondary case studies, interviews and quasi-experiments), use of different source of evidence, selection of multiple data collection techniques (In my case questionnaires, case studies, interviews, archival data), standard data reduction tools and enfolding theory.

7.3.1.4 External validity

External validity establishes the domain to which a study's findings can be generalised (Yin 1994:33). Multiple case studies were used to ensure external validity. These cases present different e-business scenarios, different industrial sectors and even different types of economic sectors (Manufacturing and Services). The nature of the development of the components means that replication logic is also used during this project, which adds to the external validity of the research. The analytical generalisation derived from the use of the cases support also the external validity.

7.3.1.5 Reliability

Reliability is the extent to which a study's operations can be repeated. It is also about consistency of research, and whether another researcher could use the same research design and obtain similar findings. The common techniques used to build reliability on the research are: implementation of controls to evaluate the research outcomes, use of case study protocol, pilot cases and use of standard databases (White 2000:25; Sekaran 1992; Kekäle 2001; Easterby-Smith et al. 1999:41; Thomas and Tymon 1982; Sekaran 1992).. This research uses the controls presented in Section 3.4 to evaluate the research outcomes. A case study protocol was set-up in Section 3.3.2.1. This protocol was used in the pilot case study presented in Chapter 4 and in the rest of the cases. Table 7.2 presents the mapping of the elements of the research rigour criteria.

Stages	Link to Research Questions	Internal Validity	Construct Validity	External Validity	Reliability
Research Design	RQ 1, 2, 3, 4 and 5. (See Chapter 2,)	▪ Methodological triangulation	▪ Selection of multiple data collection techniques	▪ N/A	▪ Implementation of controls
Theory Building	RQ 1, 2, 3	▪ Decomposition ▪ Categorical Aggregation ▪ Interpretation	▪ Triangulation of data	▪ Theoretical replication logic	▪ Theoretical saturation ▪ Interpretation
Theory Testing	RQ 3,4 & 5	▪ Covered in Data collection and data analysis	▪ Research-controls ▪ Case study as framework to follow	▪ See data collection and data analysis stage	▪ Follow a Case Study protocol ▪ Questionnaires ▪ Quasi-experiment
Data Collection	RQ 1- Ch4 RQ2 – Ch5 RQ3 – Ch5 RQ4 – Ch5,6 RQ5 – Ch6	▪ Use of different respondents ▪ Use of stratified users.	▪ Multiple evidence ▪ Replication logic.	▪ Use of multiple case studies	▪ Use of case study protocol ▪ Pilot case study ▪ Review of questionnaires by other persons
Data Analysis	RQ 1- Ch4 RQ2 – Ch5 RQ3 – Ch5 RQ4 – Ch5,6 RQ5 – Ch6	▪ Cross-case analysis ▪ Methodological triangulation ▪ Pattern matching logic	▪ Triangulation of data ▪ Explanation building	▪ Analytical generalisations ▪ Some statistical generalisation	▪ Standard data base

N/A = Not Applicable
RQ = Research Question

Table 7.2 Methods, tools and techniques used to build validity and reliability throughout this research. (Adapted from Martinez 2003)

7.3.2 Contains evidence to support the construct.

It is concerned with the support data or proof that fully address the research issue 'construct' (Kekäle 2001). This is achieved by:

7.3.2.1 Selecting relevant samples and cases.

It is concerned with the quality of samples. Examples should rigorously test the features of the propose construct.

In building theory from case studies, Voss et al (2002) recommend case selection by using replication logic. i.e. cases should be selected to predict similar results (literal replication) or produce contrary results but predictable reasons (theoretical replication). Replication logic was used in this research to look for cases that had the implementation of e-business as common feature. Platts (1993) also argues that "the choice is between looking for consistency by trying to find similar types of company or looking to test the feasibility of the general process in a number of different situations". Both types of cases were used in this thesis. Similar types for confirmation (e.g. WaterCo, BottlingCo.) and different cases to test the generalisabilty of the approach (e.g. CopierCo, ERPCo).

7.3.2.2 Providing sufficient evidence to substantiate the conclusions.

This is concerned with the quantity of evidence to support the construct. This issue not just addresses the sample size e.g. number of case studies, survey samples, etc. but also, the different methods used to test a construct within the same sample e.g. interviews, documentation, observation, etc. (Forza 2002; Stake 1995). Evidence is provided in this research by using a pilot case study (Chapter 4), development cases (Chapter 5) and testing cases (Chapter 6), in addition to samples from different types of users using quasi-experiments (Chapter 6). Multiple data collection methods were used during the cases: interviews, questionnaires, document analysis.

7.3.3 Contributions to knowledge.

The final objective in doing research is to make a contribution either to theory or practice or both by proposing something new, not known before the research. The contribution to knowledge underpins the development of constructs to simplify the understanding of the world and /or make predictions.

The contribution to knowledge in this work can be classified as follows: The use of simulation in a new context (e-business) and the identification of gaps in current business process models when dealing with e-business. Modelling requirements for e-business and a methodology to extract e-business templates and components from case studies are also identified as contribution to knowledge. Chapter 8 presents a more detailed discussion of the contributions to theory.

7.3.4 Contribution to practice.

The aim is to provide:

a) Practical relevance. i.e. provide important information.

b) Practical functionality. i.e. provide something useful such as a tool, framework or process to simplify the understanding, or efficiently arrive to conclusions by saving time, making it easier, etc

The contributions to practice were developed and tested in Chapter 5 and 6. e-business templates and components are constructs that have practical relevance and functionality. Feasibility, utility and usability were tested in Chapter 6. These constructs will allow practitioners to develop e-business processes simulation models more effectively and without the need of a simulation expert to develop the models.

7.3.5 Linking existing theory with the theoretical novelty of the construct.

It strengthens the research findings by supporting them with previous theories, and potentially it increases the importance of the research (Kasanen, 1993; Voss et. al, 2002). The novel approach of combining simulation, e-business and process re-engineering was built on previous research in the area of business process modelling and simulation. Chapter 2 presented a detailed analysis of existing literature and how it supports this research. Section 7.4 also links the results of this research with emergent literature in the field.

7.3.6 Application of the construct in other environments.

The analysis of e-business process simulation was made originally in the manufacturing sector (Chapters 4 and 5). Chapter 6 presents the application of the concept of e-business simulation and the use of components in other areas (e.g. services). Further work in other areas (Tang et al. 2004) also show that the concept has been extended from its original company-centric approach to a wider supply chain analysis of e-business implementation.

Finally, as was presented in Chapter 3, Platts (1993) argues that the main implications for research in manufacturing are:

- the processes must link to existing frameworks;
- there must be adequate empirical testing and verification of any proposed process;
- the results of the research must be relevant to the world of the practising manager.

This research has demonstrated the links to existing frameworks and how this project extends the scope of those frameworks. Empirical testing was documented in Chapters 4, 5 and 6. This empirical testing dealt with the applicability of the concepts developed in the research and with the perceptions of user about these concepts. Finally, the results of this research have provided evidence about the relevance of the constructs (particularly the components) for practitioners (Section 7.2)

7.4 Emergent literature.

While carrying out the research project and writing up the thesis, a number of new publications in areas related to this topic have emerged. The whole area of business process simulation has received attention from the research community, some of which are focused on e-business simulation or modelling. For example, Chen et al (2006) present an analysis of critical factors for the implementation of web services. They propose a simulation analysis to analyse the combination of these factors, although their approach is more akin to Monte Carlo simulation than a true, dynamic Discrete Event Simulation (DES) as proposed in this thesis. Madhusudan and Son (2005) describe an analysis of web services and "a simulation-based framework to guide scheduling of composite service execution." They present a DES approach, but which is focused on the electronic transactions happening within the web services, rather than on the business process in which these web services are used.

In the area of business process modelling (although not necessarily simulation modelling), Shen et al (2004) present a methodology for business process modelling based on a combination of IDEF0, IDEF3 and DFD models. However, these models are static and not focused on e-business. Doerner et al (2006) describe the application of Petri Nets and stochastic branch-and-bound techniques for the analysis of workflow systems. They conclude that "modelling and evaluation techniques are becoming essential features of workflow systems ... [which] keep any potential losses low by identifying critical subprocesses and evaluate appropriate measures". Greasley (2006) presents the application of DES to the modelling of business processes in the service sector. He highlights "the ability of simulation to proof new designs was seen as particularly important in a government agency where past failures of information technology investments had contributed to a more risk averse approach to their implementation".

In applications which are closer to the research presented in this document, Gans et al (2005) present the use of simulation for "database-centric business process management", although the approach they describe is based on agent-based modelling and not on DES. Caridi et al (2004) introduce a case study of the use of DES for the analysis of e-procurement options in a pharmaceutical company. They conclude that "the application of BPS techniques provides a guide for a rational study of the AS-IS processes and can give interesting insights for the assessment of TO-BE ones". Their study, however, it is typical of simulation studies reported in the literature in that they present a single case study without extracting generalisable simulation constructs from the cases. Likewise, Sharp (2006) depicts a model which is related to sourcing decisions in e-commerce. The method he proposes is a combination of Simple Multi-Attribute Rating Technique (SMART) methods, EFQM and other TQM methods. According to Sharp (2006), "the method proposed adopts a standard model for every business process with a very restricted number of inputs and outputs." That is, simplifications of business processes are used to model the different sourcing options. This is an approach that has value for the analysis of static configurations and risk analysis, but which does not cover the dynamic behaviour of the system. Lastly, Melao and Pidd (2006) present the development of a component library for business process simulation in a proprietary simulator (BPSim++). The components developed for this application are fine-grained (as opposed to medium-grained as in this research) and represent individual activities, rather than a collection of activities that represents a sub-process.

Finally, evidence of the importance of business process simulation is the emergence of a new journal in the area (International Journal of Simulation and Process Modelling, Inderscience Publishers). This journal dedicated number 3 and 4 of its first volume to modelling and simulating business processes for e-business (Melao 2005). The research presented in this work was published in this special issue (Albores et al. 2005), together with applications ranging from the evaluation of supply chain business process improvement using simulation (Jain and Ervin 2005) to modelling of B2C e-business using system dynamics (Fang 2005), amongst other modelling applications not directly related to simulation.

Another area in which emerging literature is to be found is the development of composition and templates for business process modelling. Some of these developments are in the area of general modelling, with some reports focusing on simulation. Andersson et al (2005) present goal-oriented high-level processes and proposes using patterns to develop these processes. Danesh and Kock (2005) present initial evidence that implies that "using communication flow methodologies in the analysis stage should significantly help the design and the development processes". This communication flow methodology presented in their paper is akin to the simulation perspective of modelling. Nurcan et al (2005) present a static modelling approach that uses the concept of re-usable components at the strategic level.

However, some of the maps presented are at the operational level and incorporate a type of specialisation as described by Malone et al (1999), with the difference that all the specialisations are included in one map and do not constitute different components as it is in the case of Malone and the MIT business process repository (MIT 2000).

After having a brief review of the literature that has emerged during the development and writing of this research, it is worth noting that most of these applications complement the research presented in this thesis and are not in direct competition to the concepts presented here.

7.5 Conclusions of the chapter

This chapter dealt with the discussion of the results of the research. It discussed the use of simulation of the analysis of e-business, the differences between traditional business process simulation and e-business process simulation, the lessons learnt during the analysis of current business process model, as well as the reflections from the development of e-business templates and components.

The evaluation of the research against the quality criteria specified in Chapter 3 was also described. Indication of whether the criteria have been fulfilled and how they were fulfilled was presented, making cross-reference to other sections of the thesis for more detail.

Next chapter will deal with the summary of the research and a retrospective analysis of the research process.

Chapter 8 Contributions and Conclusions

8.1 Introduction

The previous chapter presented the discussion of the points that emerged from the development and testing of e-business components for simulation modelling, analysing the overall research quality and its indicators. This chapter will summarise the findings of this research, focusing on the contributions to knowledge and practice and the supporting evidence for each one of them. The chapter will start with a revision of the research questions that were tackled during the research and to what degree an answer was found for them. Next, a detailed description of the contributions, their significance and impact is presented, as well as a summary of the supporting evidence for each one. Then an analysis of the future research streams that arose as result of this research is introduced. Finally, a retrospective analysis of the research process is presented, both from the point of view of the research itself and also from a learning-to-do-research point of view.

Figure 8.1 presents research map, illustrating the research process, including gaps, inputs and outputs of each stage.

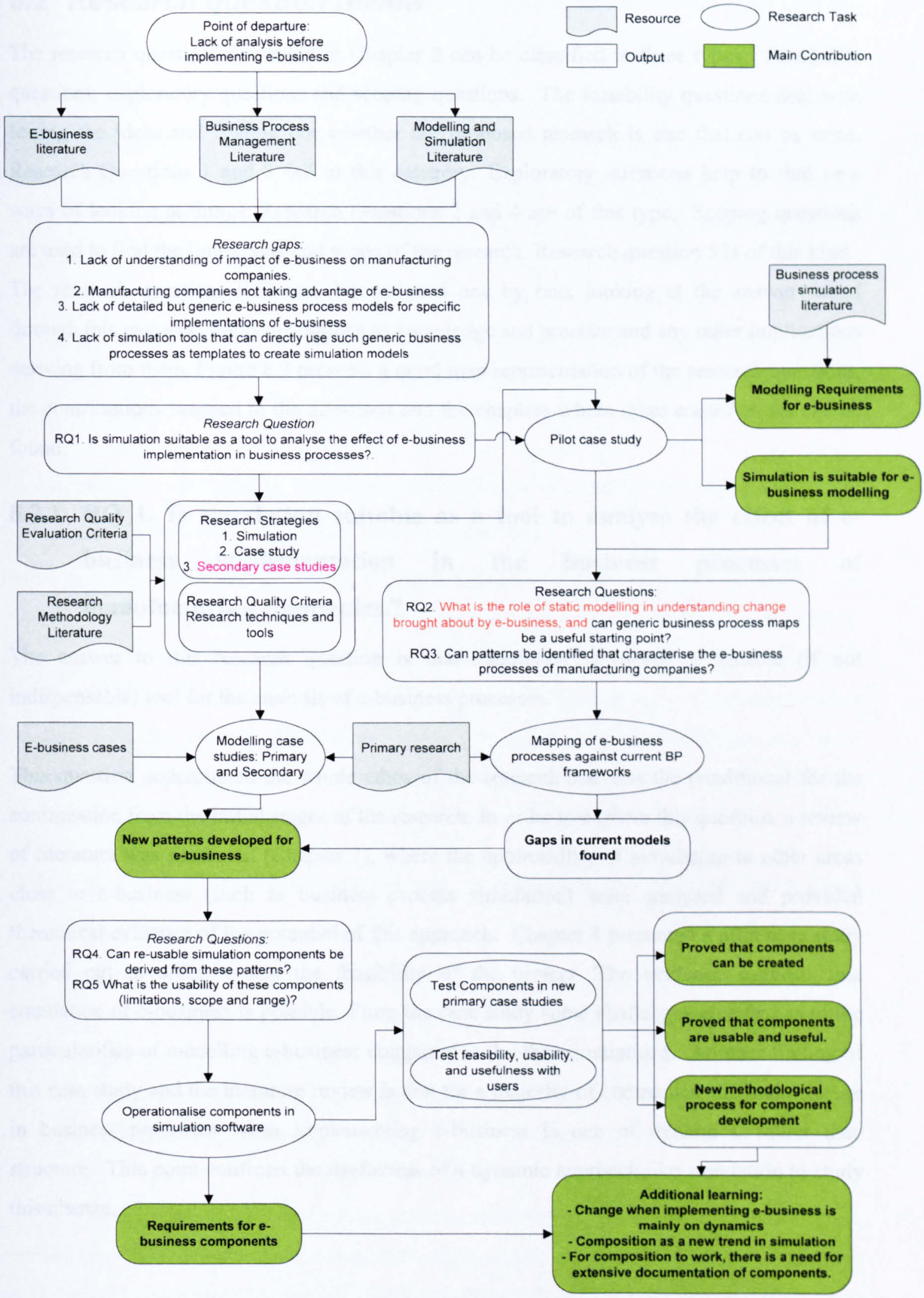


Figure 8.1 Research Map

8.2 Research question review

The research questions presented in Chapter 2 can be classified in three types: Feasibility questions, exploratory questions and scoping questions. The feasibility questions deal with testing the ideas and finding out whether the proposed research is one that can be done. Research Questions 1 and 3 fall in this category. Exploratory questions help to find new ways of looking at things. Research Questions 2 and 4 are of this type. Scoping questions are used to find the limitations and scope of the research. Research question 5 is of this kind. The research questions will now be analysed one by one, looking at the answer found through this research, the contributions to knowledge and practice and any other implications deriving from them. Figure 8.2 presents a mind map representation of the research questions, the contributions mapped to the questions and the chapters where these contributions can be found.

8.2.1 RQ 1. Is simulation suitable as a tool to analyse the effect of e-business implementation in the business processes of manufacturing companies.?

The answer to this research question is that simulation is indeed a suitable (if not indispensable) tool for the analysis of e-business processes.

This question underpinned the whole ethos of the research and was the conditional for the continuation from the initial stages of the research. In order to explore this question, a review of literature was presented (Chapter 2), where the applicability of simulation to other areas close to e-business (such as business process simulation) were analysed and provided theoretical evidence of the potential of this approach. Chapter 4 presented a pilot case study carried out in order to test the feasibility of the project. The evidence suggests that simulation of e-business is possible. From the case study some challenges emerged as to the particularities of modelling e-business compared with other simulations. Another finding of this case study and the literature review is that for a majority of companies, the main change in business processes when implementing e-business is one of dynamics, rather than structure. This point confirms the usefulness of a dynamic approach like simulation to study this change.

8.2.2 RQ 2. What is the role of static modelling in understanding change brought about by e-business, and can generic business process maps be a useful starting point?

Once the feasibility of the approach was established, the next step was to analyse the role of current business process models to see if they identify the differences between traditional and e-business activities. This question led us to map actual business processes against the activities presented in a series of business process models. Chapter 5 presents such mapping and concludes that current business process models do not faithfully represent e-business activities. These business process models, however, are a useful starting point for the identification of activities that can be affected by e-business and to identify the gaps that need to be filled.

8.2.3 RQ 3. Can patterns be identified that characterise the e-business processes of manufacturing companies?

From the gaps in the business process models identified in RQ2 and the mapping of case studies in which e-business is implemented, e-business patterns were identified in Chapter 5. The answer is that there are activities that can be identified as generic of e-business applications and can, therefore, be used as templates for applications. This identification brought about the development of a methodology to define such patterns. Chapters 3 and 5 present the reasoning behind this methodology. As part of this question, requirements for e-business modelling were also derived.

8.2.4 RQ 4. Can re-usable simulation components be derived from these patterns?

This question was answered in Chapter 5, where simulation components were derived from the templates and in Chapter 6, where the feasibility, usability and usefulness of said components was tested. As a result, it was proved that such components can be created and that they help the modelling of e-business processes in two counts: making model building speedier and providing a guide as to what a process may look like when e-business is introduced.

While searching for an answer to this question, the level of granularity was also studied, coming to the conclusion that the best level of granularity for reuse of e-business templates was that of a component (i.e. medium-grained). From this question derives one of the main contributions of this work: proving that simulation composition can be used to model e-business processes.

8.2.5 RQ5 What are the limitations, scope and range of applicability of these templates? What methodology must be followed when using simulation in this context?

This research question was discussed in Chapter 7. The limitations that were found in the use of components for e-business modelling are:

- As the number of components increases, an structured way of retrieving the right one is needed.
- Usually components need to me modified to apply them to each specific case.
- A danger that emerges from the previous point is that by having a predefined structure, the user may want to force the process to that specified in the component, rather than adapting the component to the process.
- At the moment the components developed cover only internal operations within a company. However, this work has provided a foundation to extend the work to intra-company processes (pan-supply chain), where the effect of e-business may be even evident.

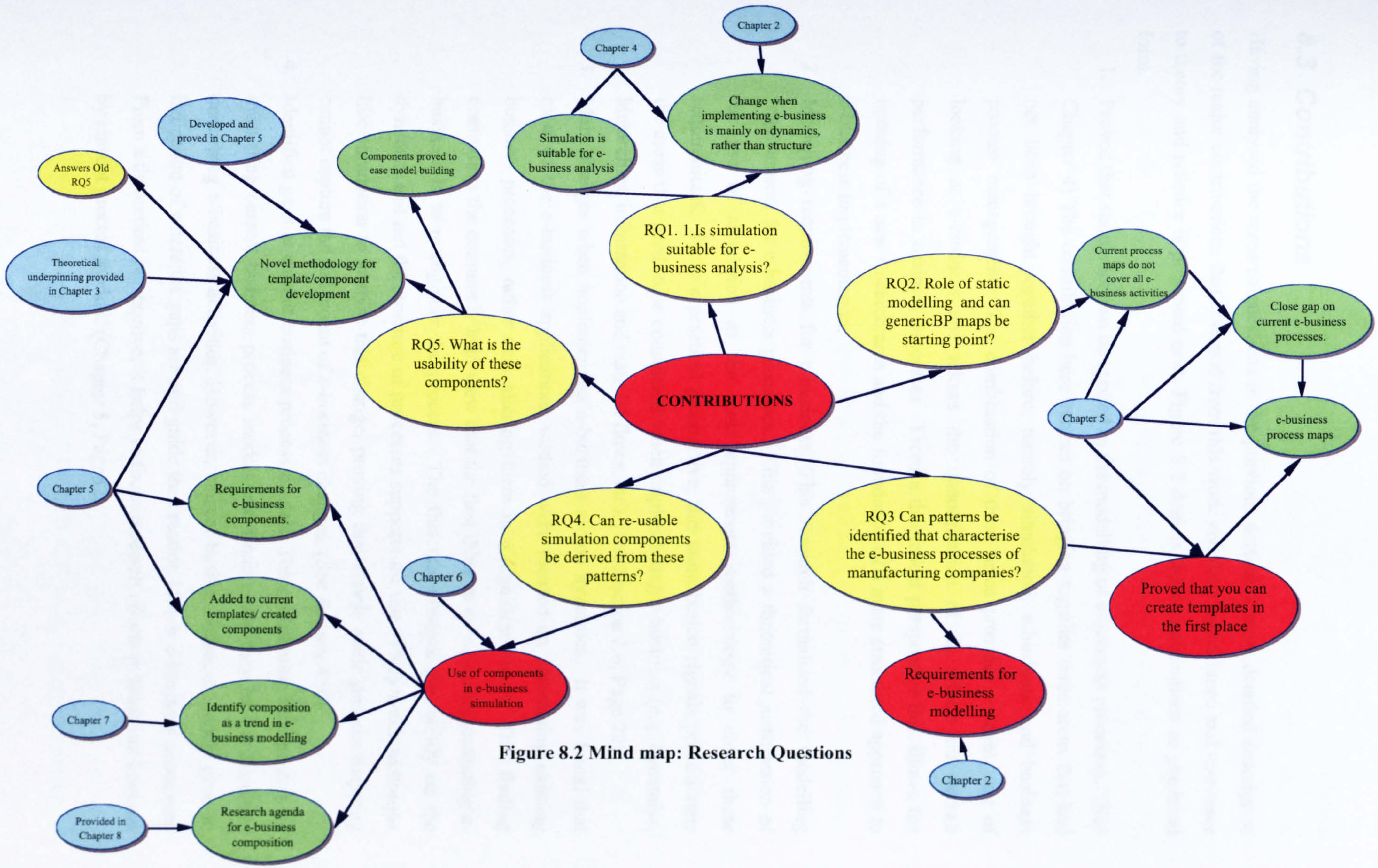


Figure 8.2 Mind map: Research Questions

8.3 Contributions

Having analysed the research questions in the previous section, a more detailed description of the major contributions that emerged from this work and their significance and relevance to theory and practice is presented next. Figure 8.2 depicts these contributions in graphical form.

1. Proved that simulation can be applied to the modelling of e-business processes. (See Chapter 4) The contribution here centres on bringing together three areas that had not been brought together before, namely simulation, e-business and business process management. The combination of these areas provides a novel way of looking at e-business and allows the quantification of its effects on overall performance in business processes. From a theoretical perspective this allows the opening of a new research area and the foundation of a more structured approach to e-business implementation.
2. Modelling requirements for e-business. This research formalised the modelling requirements for e-business processes. This provided a theoretical justification of the use of simulation as the most appropriate methodology to cover these requirements. From a practical perspective, this contribution signals practitioners the areas that need to be considered when implementing e-business (e.g. dynamics, hierarchies, information and material flows, etc). (See Section 2.6, Page 22)
3. Main changes when implementing e-business are on dynamics. It was found that most of the e-business applications studied were focused on automating existing business processes, rather than altering them in a significant way. This finding contradicts the commonly held view that the first thing to do when implementing e-business is to re-engineer the process. The fact that changes are mainly on the dynamics and not the structure of processes supports the use of a dynamic technique like simulation to analyse this change, proving that simple static process mapping cannot capture the full extent of e-business changes. (See Section 4.9).
4. Identified gaps in current business process models. The contribution here centres on evaluating current business process models and finding that they have difficulties describing e-business activities. However, current business process models give an indication of where the gaps are and guide the creation of new e-business processes. From a theoretical perspective, it helps to focus research efforts in areas not covered by current process models. (Chapter 5, Page82)

5. Developed e-business process templates. As a consequence of the previous contribution, e-business activities were identified and formalised. Even though the number of templates developed is not fully comprehensive, this research has served a proof of the feasibility of the development process.(Section 5.4)
6. Proved that composition is an appropriate way of operationalising the e-business templates. This contribution delves into reuse theory. Characteristics of the different reuse options are formalised and components identified as the most suitable form of reuse for e-business modelling. This provides relevance in theory since it is the first time that such approach is applied to e-business and to business processes in general. An extended contribution from this is the application of the composition concept (traditionally used in systems engineering) to simulation and the identification of a trend towards composable systems which are domain specific. From a practical relevance stand, composition allows faster and arguably better model building of e-business applications. This contribution facilitates the use of simulation for decision makers who are not expert modellers in their day-to-day job. .(Section 5.5 Page 93)
7. Developed a novel methodology to create templates/components in e-business. This methodology uses what is denominated "sequential testing" for the development and testing of templates and components. By using a case study both as test bed and as source of new components, the research cycle is shortened, the number of case studies reduced and the verification and validation of the components improved by means of constant reuse and refinement. (Section 5.5 Page 94)
8. Started study of error modelling. Error modelling had not been studied in the past in Business Process Simulation. This research started to analyse the effect of modelling human error when comparing manual transactions with electronic transactions (arguably one of the reasons to introduce e-business in the first place). It is thought that this is one of the areas in which simulation can bring benefits in the analysis of e-business application to business processes. (Section 5.5 Page 103)

8.4 Future Research

The future research streams that have been identified from this research are:

1. Expanding the simulation of e-business to supply chains. Having proved the value of e-business simulation and composition, a natural step is to expand this approach from intra-company modelling to inter-company modelling. Indeed, some work has been started in this area (e.g.Albores et al. 2003; Ball et al. 2006; e.g.Tang et al.

2004). New modelling tools have inbuilt capabilities that allow the creation of components. An example of this is e-SCOR, a supply chain simulator, based on the SCOR model which uses high-level composites to depict the roles proposed by the SCOR model, namely Plan, Source, Make and Deliver (Supply Chain Council 2002; Supply Chain Council 2005). There is a need, however, to develop low level mechanisms (including e-business activities) in order to represent all the range of activities, expanding capabilities currently representing strategic and tactical levels to include operational levels.

2. Research the possibility of creating more complex components, including complex control systems like MRP. The research carried out in this work presented a few, relatively uncomplicated components. Future research is needed to explore the value of developing more complex components. Questions that may be asked are: Does increasing complexity reduce the value of creating components? Will this increased complexity hinder the use of the components by non simulation experts?
3. Research the user perception of composition and investigate the relation between component developer and component user, investigating for example how pre-conceptions can affect the way that a component is built or for that matter interpreted.
4. Investigate the best way to document, search and retrieve large numbers of components. What is the best way of dealing with a large number of components?
5. Formalise the relationship between level of process complexity and benefits of using components.

8.5 Retrospective analysis

One of the aims of doing a PhD is to find something new and contribute to knowledge creation in the field of choice. Another objective (and some argue, the most important) is to learn how to do research, so that independently of the outcomes of the particular PhD topic, someone who is seen as worthy of the PhD initials is someone who knows how to carry out research, even if it is not in the original subject. Reflecting on past experience is one of the best ways to learn. Loughram (1996) cites Boud et al (1985) as saying: "Reflection is an important human activity in which people recapture their experience, think about it, mull it over and evaluate it. It is this working with experience that is important in learning". Accordingly, this section will describe a retrospective analysis of the work carried out, from the points of view of the research itself, but also looking at it from the "learning to do research" process. The tone of this section will be more personal than the rest of the thesis, since it will deal with the reflective learning form the point of view of the author.

8.5.1 The PhD process

The research process has allowed me to learn a number of skills which will be useful in my future career. Using a mixture of both qualitative and quantitative research techniques allowed me to appreciate the differences between these two strategies, but also made me appreciate their complementarities. I feel that by mixing both approaches I have been able to develop a more rounded research.

The step which I found of more difficulty was gaining access to case study companies. This was resolved with the help of my supervisors and contacts developed during my career. Ultimately, the set of case studies used is a good representation of different processes, industries and e-business applications, fulfilling the objective of the research.

As with every project, with the "wisdom of hindsight", there are some aspects of the research which I would do differently and some which I would repeat if I had to do this project again. These are described below:

Change:

- Compress case studies: I probably would try to carry out the case studies in a shorter time-span. More frequent visits to the companies would enable a quicker cycle for each case, shortening the overall duration of the research.
- Change the methodology to include three phases in the modelling task: pre-assessment, modelling (which was done) and post-assessment. I would add a post-assessment a few months after the initial intervention in order to learn from the implementation of the systems and how can this implementation feed back to the simulation methodology.
- Involve more modellers: Reduce modelling bias towards personal preferences and modelling styles. In this case this was not possible because of the nature of the research (PhD). However, if I had the opportunity and resources, I would like to have more people involved in order to avoid personal bias and enrich the creation of components.

Keep

- Sequential case studies. I think this approach proved to be beneficial to the research, allowing the use of a smaller number of case studies than if a normal case study protocol had been followed.
- Research quality criteria. Bring in earlier and set checkpoints at different stages. Having these criteria allowed me to check that the activities that I carried were aligned to fulfil one or more of these criteria. They also provided a guide when I got stuck deciding what to do next in the research process.
- Write early. Starting to write early (e.g. conference papers) helped me to focus the project and made me be structured. This also allowed the work to be presented in conferences, where feedback was obtained and incorporated into the research.
- Feasibility, utility and usability testing. Testing for these criteria allowed me to ensure that the constructs developed were applicable to real situations. Using quasi-experiments with samples of two different populations to test this is something I would repeat (I would do it with bigger samples next time).

The results of this PhD research have been presented at conferences and journal papers have been written as follow up from the conference papers. A couple of these papers are presented in Appendix 8 (Albores et al. 2005; Ball et al. 2004)

8.5.2 The learning process

From a learning to do research perspective, the process of the PhD has been generally very enjoyable, albeit with a few painful moments interspersed with some periods of self-doubt. I was warned of this during the different research methodology courses that I attended (e.g. Strathclyde Business School and the EPSRC-sponsored Research Methodology workshop at Cambridge University). By having shared a number of the years with fellow PhD researchers at different stages of their research, I realised that it is quite normal to go through these periods, that the world was not conspiring against me and that computers breakdown not because they are evil, but because this happens sometimes.

I was fortunate enough to be involved in a number of different research and consultancy projects during the duration of my PhD. These projects ranged from the writing of a Eureka proposal to the participation in a European Project with eight partners, to developing a research proposal in collaboration with two British universities, to different consultancy projects. Even if the negative side was that my own research was delayed as a result of this, the experience gained and contacts made far outweigh this delay. During these projects I was exposed to different methodological paradigms, different ways of looking at things and the all-important contact with users/clients in the "real" world. This allowed me to be more open to alternative views. It also allowed me to gain working knowledge of how to manage projects, of the bureaucracy that sometimes is attached to the funding and most importantly on how to transform research results into publishable papers (e.g. Bititci et al. 2003; Tang et al. 2004; Albores et al. 2003).

8.6 Chapter Summary

This chapter presented the conclusions from the research. The research questions were revisited and their answers summarised. The contributions from this research were also outlined and described. As in any research, future research avenues were identified. Finally, a retrospective analysis of the research process and the learning process was carried out.

Reference List

Albores, Pavel, Peter D. Ball, Helen Benton, Paul Drake, Doug Love, Jillian C. MacBryde, and Nelson K. H. Tang. 2003. Developing an enterprise simulator to support a supply chain design methodology . *European Forum on Market-Driven Supply Chains: Creating the Responsive Supply Chain* http://www.eiasm.org/frontoffice/event_announcement.asp?event_id=340.

Albores, Pavel, Peter D. Ball, and Jillian C. MacBryde. 2002. Generic Business Process Models For E-Business In Manufacturing Companies: Is Simulation Useful? *Proceedings of the 2002 IEEE International Engineering Management Conference* Tariq S. Durani, 685-90 .

———. 2003. Supply chain performance measurement hierarchies: validation through simulation . in *Proceedings of the 3rd. International Workshop on Performance Measurement.* Sergio Cavalieri, 507-17 ed. IFIP WG 5.7 Special Interest Group on Performance Measurement.

———. 2005. Simulation process templates for e-business modelling. *International Journal of Simulation and Process Modelling* Vol. 1, No. 3/4: 150-160.

American Productivity & Quality Center. 1992. "International Benchmarking Clearinghouse model." Web page, [accessed 15 August 2003]. Available at http://www.apqc.org.

Andersson, Birger, Ilia Bider, Paul Johannesson, and Erik Perjons. 2005. Towards a formal definition of goal-oriented business process patterns. *Business Process Management Journal* Vol. 11, No. 6: 650-662.

Aronson, Jesse, and Prasanta Bose. 1999. A model-based approach to simulation composition. *Proceedings of the 1999 symposium on Software Reusability*, 73--82 ACM Press.

Baines, T. S., and J. M. Kay. 2002. Human performance modelling as an aid in the process of manufacturing system design: a pilot study. *International Journal of Production Research* Vol. 40, No. 10: 2321-34(14).

Ball, Peter D. 1994. "Design of an expandable manufacturing simulator through the application of object-oriented principles." Aston University.

———. 1996. Introduction to discrete event simulation. *Proceedings of the 2nd DYCOMANS workshop on "Management and control: Tools in action"*, 367-76 Algarve, Portugal.

Ball, Peter D., Pavel Albores, and Jillian C. MacBryde. 2004. Requirements for modelling e-business processes. *Production Planning and Control* Vol. 15, No. 8: 776-85.

Ball, Peter D., Jillian C. MacBryde, and Pavel Albores. 2006.. Using simulation to validate performance measure hierarchies in supply chains (SUBMITED TO). *International Journal of Productivity and Performance Management.*

Banks, Jerry, Joseph C. Hugan, Peter Lendermann, Charles McLean, Ernest C. Page, C. Dennis Pegden, Onur Ulgen, and James R. Wilson. 2003. The future of the simulation industry. *Proceedings of the 2003 Winter Simulation Conference*, Editors S. Chick, Sánchez P. J. , D Ferrin, and D. J Morrice, 2033-43 .

Barnes, David, Matthew Hinton, and Suzanne Mieczkowska. 2001. Towards a Framework for investigating the impact of E-commerce on Internal Business Processes. *Proceedings of the European Operations Management Association 8th International Annual Conference* Kate Blackmond, Steve Brown, Paul Cousins, and Andrew Graves, 798-806 .

———. 2002. Developing a framework to investigate the impact of e-commerce on the management of internal business processes. *Knowledge and Process Management* Vol. 9, No. 3: 133-42.

Barton, J. A., D. M. Love, and G. D. Taylor. 2001. Evaluating design implementation strategies using enterprise simulation. *International Journal of Production Economics* Vol. 72, No. 3: 285-99.

Bititci, Umit S., Veronica Martinez, Pavel Albores, and Kepa Mendibil. 2003. Creating and Sustaining Competitive Advantage Through Collaborative Systems: The What? And The How? *Production Planning and Control* Vol. 15, No. 4: 410-424.

Bontis, Nick, and Akemi De Castro. 2000. The first World Congress on the Management of electronic Commerce: Review and commentary. *Internet Research: Electronic Networking Applications and Policy* Vol. 10, No. 5: 365-73.

Bosilj Vuksic, Vesna, Mojca Indihar Stemberg, and Jurij Jaklic. 2001. Simulation modelling towards e-business models development. *International Journal of Simulation* Vol. 2, No. 2: 16-29.

Boud, D. Keogh R. and Walker. 1985. *Reflection: Turning Experience into learning* .Kogan Page .

Bridge, K. 1990. " The application of computer modelling techniques in manufacturing system design. PhD Thesis." Aston University.

Bruce, C. S. 1994. Research student's early experiences of the dissertation literature review. *Studies in Higher Education* Vol. 19, No. 2: 217-29.

Caridi, Maria, Sergio Cavalieri, Cristina Pirovano, and Giorgio Diazzi. 2004. Assessing the impact of e-Procurement strategies through the use of business process modelling and simulation techniques. *Production Planning & Control* Vol. 15, No. 7: 647-61.

Chaffey, Dave. 2002. *E-business and e-commerce management: strategy, implementation, and practice*. Harlow, England : Financial Times/Prentice Hall.

Chan, Felix T. S., Nelson K. H. Tang, H. C. W Lau, and R. W. L. Ip. 2002. A simulation approach in supply chain management. *Integrated Manufacturing Systems* Vol. 13, No. 2: 117-22.

Chandra, Charu, Mark Everson, and Janis Grabis. 2005. Evaluation of enterprise-level benefits of manufacturing flexibility. *Omega* Vol. 33, No. 1: 17-31.

Chen, Andrew N. K., Sagnika Sen, and Benjamin B. M. Shao. 2006. Strategies for effective Web services adoption for dynamic e-businesses. *Decision Support Systems* Vol. 42, No. 2: 789-809.

Cheng, Min-Yuan, Ming-Hsiu Tsai, and Zhi-Wei Xiao Construction management process reengineering: Organizational human resource planning for multiple projects. *Automation in Construction* Vol. In Press, Corrected Proof.

Childe, S J, R. S Maull, and J Bennett. 1994. Frameworks for understanding Business Process Re-engineering. *International Journal of Operations & Production Management* Vol. 14, No. 12: 22-34.

Childe, S J, P. A Smart, and A. M Weaver. 1996. The use of generic process models for process transformation. *International Workshop on Modelling Techniques, Business Process Re-engineering (BPR) and Benchmarking*.

Coughland, Paul, and David Coghland. 2002. Action research for Operations Management. *International Journal of Operations and Production Management* 22, no. 2: 220-240.

Croom, S. 2002. Methodology Editorial. *International Journal of Operations and Production Management* 22, no. 2: 148-51.

Cupchik, Gerald. 2001. Constructivist Realism: An Ontology That Encompasses Positivist and Constructivist Approaches to the Social Sciences. *Forum: Qualitative Social Research (On Line Journal)* Vol. 2, No. 1.

Danesh, Azim, and Ned Kock. 2005. An experimental study of process representation approaches and their impact on perceived modeling quality and redesign success. *Business Process Management Journal* Vol. 11, No. 6: 724-35.

Davenport, Tom. H. 1993. Business process reengineering: Where it's been, where it's going. In

Strategic Information Technology Management. R. D. Banker, R. J. Kauffman, and M. A MahmoodHarrisburg, P.A.: Idea Group Publishing.

Davenport, Tom. H., and J. E. Short. 1990. The New Industrial Engineering: Information Technology and Business Process Redesign. *Sloan Management Review* Vol. 31, No. 4: 11-27.

Davis, Paul C, Paul A. Fishwick, C. Michael Overstreet, and C. Dennis Pegden. 2000. Model composability as a research investment: responses to the featured paper. *Proceedings of the 2000 Winter Simulation Conference, Vols 1 and 2,* 1585--1591 Society for Computer Simulation International.

Dennis, Simon, Ben King, Martin Hind, and Stewart Robinson. 2000. Applications of business process Simulation and lean techniques in British Telecommunications PLC. in *Proceedings of the 2000 Winter Simulation Conference*, Eds. J. A Joines, R. R. Barton, K Kang, and P. A. Fishwick, 2015-21 .

Doerner, Karl, Walter J. Gutjahr, Gabriele Kotsis, Martin Polaschek, and Christine Strauss. 2006. Enriched workflow modelling and Stochastic Branch-and-Bound. *European Journal of Operational Research* Vol. 175, No. 3: 1798-817.

DTI. 2002. "Digest of UK Energy Statistics 2001, Chapter 7- Renewable Energy Sources." Web page, [accessed 21 February 2002]. Available at http://www.dti.gov.uk/epa/digest01/07.pdf.

———. February (2002). *New Review*, No. 51: 1.

Dubin, R. 1969. *Theory Building.* New York: The Free Press.

Dusink, Liesbeth, and Jan van Katwijk. 1995. Reuse dimensions. *Proceedings of the 1995 Symposium on Software Reusability,* 137-49 ACM Press.

Easterby-Smith, Mark, Richard Thorpe, and Andy Lowe. 1999. *Management Research, an introduction.*Mark Easterby-Smith, Richard Thorpe, and Andy Lowe. London: SAGE Publications.

Easterby-Smith, Mark, Richard Thorpe, and Andy Lowe. 2002. *Management Research, an introduction.* London: Sage Publications, Second Edition.

Eatock, Julie, Ray J Paul, and Alan Serrano. 2001. A study of the impact of information technology on business processes using discrete event simulation: A Reprise. *International Journal of Simulation* Vol. 2, No. 2: 30-40.

Eisenhardt, Kathleen M. 1989. Building theory from case study research. *Academy of Management Review* Vol. 14, No. 4: 532-50.

Elder, Mark. 1992. "Visual Interactive Modelling: Some Guidelines for its Implementation and Some Aspects of its Potential Impact on Operational Research." University of Strathclyde.

Elliman, Tony, and Graham Orange. 2000. Electronic commerce to support construction design and supply-chain management: a research note . *International Journal of Physical Distribution & Logistics Management* Vol. 30, No. 3/4: 345-60.

ETSU. 2003. "Concept Study-Western Offshore Transmission Grid." Web page, [accessed 20 September 2003]. Available at http://www.dti.gov.uk/energy/publications/policy/west_coast_interconnector_study.pdf.

Fang, Yulin. 2005. Modelling B2C e-businesses in fast-growing industries using system dynamics. *International Journal of Simulation and Process Modelling* Vol. 1, No. 3/4: 171-78.

Farish, Mike. 2001. Quiet revolution. *Engineering* Vol. April 2001: 18.

Fathee, Mohsend, Ray Redd, Darcy Gorgas, and Batoul Modarres. 1998. The effects of complexity on business processes reengineering: Values and limitations of modeling and simulation technologies. *Proceedings of the 1998 Winter Simulation Conference*D. J Medeiros, E. F Watson, J. S Carson, and M. S Manivanna, 1339-45 .

Fielding, Nigel, and Margrit Schreier. 2001. Introduction: On the compatibility between Qualitative and Quantitative research methods. *Forum: Qualitative Social Research (On Line Journal)* 2, no. 1.

Forza, Cipriano. 2002. Survey research in operations management: A process-based perspective. *International Journal of Operations & Production Management* Vol. 22, No. 2: 152.

Fryer, Browyin. 2001. Competing for Supply, Conversation with Bryan Stolle. *Harvard Business Review* Vol. Feb 2001: 25-26.

Gans, Gunter, Matthias Jarke, Gerhard Lakemeyer, and Dominik Schmitz. 2005. Deliberation in a metadata-based modeling and simulation environment for inter-organizational networks. *Information Systems* Vol. 30, No. 7: 587-607.

Gensym Corporation. 2003. "G2 e-SCOR simulation software." Web page, [accessed 2004]. Available at http://www.gensym.com/.

Giaglis, George. M. 1996 . Modelling Electronic Data Interchange through simulation: and industry-wide perspective. *Proceedings of the 8th European Simulation Symposium*, 199-203 .

Giaglis, George. M, and Ray J Paul. 1996. It's time to Engineer Re-engineering: Investigating the potential of Simulation modelling in Business process Redesign. In *Business Process Modelling*. B Scholz-Reiter, and E. Stickel, 313-32. Berlin: Springer-Verlag.

Giaglis, George. M, Ray J Paul, and Georgios I. Doukidis. 1999a. Assessing the impact of electronic commerce on business performance: a simulation experiment. *Electronic Markets* Vol. 9, No. 1-2: 25-31.

———. 1999b. Dynamic modeling to asses the business value of Electronic Commerce. *International Journal of Electronic Commerce* Vol. 3, No. 3: 33-51.

Glaser, B. G., and A. L. Strauss. 1967. *The discovery of grounded theory: Strategy for qualitative research*. New York: Adline De Gruyter.

Greasley, A. 2006. Using process mapping and business process simulation to support a process-based approach to change in a public sector organisation. *Technovation* Vol. 26, No. 1: 95-103.

Greasley, Andrew. 2000. Effective uses of business Process Simulation. In *Proceedings of the 2000 Winter Simulation Conference*, Eds J. A Joines, R. R. Barton, K Kang, and P. A. Fishwick, 2004-9 .

———. 2003. A simulation of a workflow management system. *Work Study* Vol. 52, No. 4/5: 256-61.

Grover, Varun, and William Kettinger. 1995. *Business Process Change: Reengineering Concepts, Methods and Technologies*. Harrisburg PA: IDEA Publishing.

Gunasekaran, A, H. B. Marri, R. E. McGaughey, and M. D Nebhwani. 2002. E-commerce and its impact on operations management. *International Journal of Production Economics* Vol. 75, No. 1-2: 185-97.

Hammer, Michael. 1990. Re-engineering work: don't automate, obliterate. *Harvard Business Review* Vol. July-August: 104-12.

Hammer, Michael, and James Champy. 1993. *Re-engineering the corporation: a manifesto for business revolution*. New York : Harper Business.

Hammer, Michael, and Steven Stanton. 1999. How process enterprises really work. *Harvard Business Review* Vol. November-December: 108-18.

Hammersley, Martyn. 1992. Deconstructing the qualitative-quantitative divide. In *Mixing methods:qualitative and quantitative research* . Ed. Julia Brannen, 39-55. Aldershot, England: Avebury.

Hlupic, Vlatka, and Steward Robinson. 1998. Business Process Modelling and analysis using discrete-event simulation. in *Proceedings of the 1998 Winter Simulation Conference*D. J Medeiros, E. F Watson, J. S Carson, and M. S Manivanna, 1364-69 .

Hurwitz Group. 2000. "Business Processes: A Strategic Key to the e-Business." The Hurwitz Group, Framinham, MA, USA.

Irani, Zahir, Vlatka Hlupic, Lynne Baldwin, and Peter Love. 2000. Re-engineering manufacturing processes through simulation modelling. *Logistics Information Management* Vol. 13, No. 1: 7-13.

Jain, Sanjay, and Eric Ervin. 2005. Evaluation of supply chain business process improvements using simulation. *International Journal of Simulation and Process Modelling* Vol. 1, No. 3/4: 138-49.

Jarrett, Keith, Jonathan Hedgecock, Richard Gregory, and Tim Warham. 2004. *Technical guide to the connexion of generation to the distribution network*, K/EL/00318/REP. 97 DTI, London, UK.

Jones, Jeffry. 1995. Simprocess III: Object-oriented business process simulation. in *Proceedings of the 1995 Winter Simulation Conference*C Alexopuolos, K Kang, W. R. Lilegdon, and D. Goldsman, 548-51 . Proceedings of the 1995 Winter Simulation Conference.

Jones, M. 1994. Don't emancipate, exaggerate: rhetoric, reality and re-engineering. In *Transforming organisations with information technology.* Bakersville R., Smithson S., O. Ngwenyama, and J DeGross, 357-78. Amsterdam: Elservier Science, North Holland.

Karat, Claire-Marie, Robert Campbell, and Tarra Fiegel. 1992. Comparison of empirical testing and walkthrough methods in user interface evaluation . *Proceedings of the SIGCHI conference on Human factors in computing systems* , 397-404 Monterey, California, United States : ACM Press.

Karlsson, C. 2002. Guest Editorial: Special issue on research methodology in operations management. *International Journal of Operations and Production Management* Vol. 22, No. 2: 141-47.

Kasanen, Eero, Kari Lukka, and Arto Siitonen. 1993. The constructive approach in management accounting research. *Journal of Management Accounting Research* Fall: 243-64.

Kasputis, Stephen, and Henry C. Ng. 2000. Model composability: formulating a research thrust: composable simulations. *Proceedings of the 32nd conference on Winter simulation,* 1577–1584 Society for Computer Simulation International.

Kekäle, Tauno. 2001. Construction and triangulation: weapon for attempts to create and test theory. *Management Decision* 39, no. 7: 556-63.

Kettinger, William, James Teng, and Subashish Guha. 1997. Business process change: A study of methodologies, techniques, and tools . *MIS Quarterly* Vol. 21, No. 1: 55-80.

Larsen, M. A, and M. D Myers. 1999. When success turns into failure: a package-driven business process re-engineering project in the financial services industry. *Journal of Strategic Information Systems* Vol. 8, No. 4: 395-417.

Laurie, Heather, and Oriel Sullivan. 1991. Combining qualitative and quantitative data in the longitudinal study of household allocations. *The Sociological Review* Vol. 39, No. 1: 113-30.

Lehaney, Brian A, and Gerald Vintem. 1994. Methodology, an analysis of its meaning and use. *Work Study* 43, no. 3: 5-8.

Loughran, John J. 1996. Developing Reflective Practice: Learning about Teaching and Learning Through Modelling. Routledge (UK).

Love, Doug M., and Jeff A. Barton. 1996. Evaluation of design decisions through CIM and Simulation. *Integrated Manufacturing Systems* Vol. 7, No. 6: 3-11.

———. 2003. Stimulating Design Reuse Through Automated Coding. *International Journal for Manufacturing Science and Production* 5, no. 1-2: 41-44.

Madhusudan, T., and Young-Jun Son. 2005. A simulation-based approach for dynamic process management at web service platforms. *Computers & Industrial Engineering* Vol. 49, No. 2: 287-317.

Malone, Thomas W., Kevin Crowston, Jintae Lee, Brian Pentland, Chrysanthos Dellarocas, George Wyner, John Quimby, Charles S. Osborn, Abraham Bernstein, George Herman, Mark Klein, and Elissa O'Donnell. 1999. Tools for inventing organizations: Towards a handbook of organizational processes. *Management Science* Vol. 45, No. 3: 425-43.

Martinez, Veronica. 2003. *Understanding Value Creation: The Value Matrix and The Value Cube.*Veronica MartinezPhD Thesis University of Strathclyde in Glasgow.

Martinez, Veronica, and Pavel Albores. 2003a. Performance indicators for the evaluation and control of research in OM: the qualitative research case (ACCEPTED). in *Proceedings of the 3rd. International Workshop on Performance Measurement. IFIP WG 5.7 Special Interest Group on Performance Measurement*Sergio Cavalieri, 101-10 .

———. 2003b. Qualitative Research in OM: Criteria for Evaluation. in *Proceedings of the First International Joint Conference EurOMA (European Operations Management Association Conference) - POMS (Production and Operations Management Society): The challenges of integrating research and practice*Gianluca Spina, Andrea Vinelli, Raffaella Cagliano, Matteo Kalchschmidt, Pietro Romano, and Fabrizio Salvador, 959-68 .

———. 2003c. Qualitative Research in OM: Criteria for Evaluation . in *Proceedings of the First International Joint Conference EurOMA (European Operations Management Association Conference) - POMS (Production and Operations Management Society): The challenges of integrating research and practice*, 959-68 .

McFarlane, Duncan, Mike Gregory, and Alan Thorne. 2001. "E-manufacturing in Japan: Assessing the state of the art in Internet-Based Manufacturing and its impact on practice, strategy and policy ." DTI - OSTEMs Report. 25 pages Institute for Manufacturing, University of Cambridge, Cambridge, UK.

Mclean, C, and Gd Shao. 2003. Generic Case Studies for Manufacturing Simulation Applications. *Proceedings of the 2003 Winter Simulation Conference*, Editors S. Chick, Sânchez P. J. , D Ferrin, and D. J Morrice, 1217-24 .

Melao, Nuno. 2005. Editorial: Modelling and simulating business processes for e-business. *International Journal of Simulation and Process Modelling* Vol. 1, No. 3/4: 111-13.

Melao, Nuno, and Michael Pidd. 2000. A conceptual framework for understanding Business Processes and Business Process Modelling. *Information Systems Journal* Vol. 10, No. 2: 105-29.

Melao, Nuno, and Michael Pidd. 2006. Using component technology to develop a simulation library for business process modelling. *European Journal of Operational Research* Vol. 172, No. 1: 163-78.

Meredith, Jack. 1993. Theory building through conceptual methods. *International Journal of Operations and Production Management* 13, no. 5: 3-11.

Miles, Matthew B., and A Michael Huberman. 1994. *Qualitative data analysis -an expanded sourcebook.* London: Sage Publications.

MIT. 2000. "E-business process repository." Web page, [accessed 13 March 2003]. Available at http://process.mit.edu/.

Morgan, Gareth. 1979. Response to Mintzberg. *Administrative Science Quarterly* Vol. 24, No. 1: 137-39.

Murray, Rowena. 2002. *How to write a thesis*. Buckingham, UK: Open University Press.

Ngai, E. W. T., T. C. E. Cheng, and C. M. Y. Lee. 2003. Development of a web-based system for supporting sales in a mineral water manufacturing firm: A case study. *International Journal of Production Economics* Vol. 83, No. 2: 153-67.

Nielsen, Jakob. 1994. Usability inspection methods. *Conference on Human Factors in Computing Systems*, 413-14 Boston, Massachusetts, United States.

Nurcan, Selmin, Anne Etien, Rim Kaabi, Iyad Zoukar, and Colette Rolland. 2005. A strategy driven business process modelling approach. *Business Process Management Journal* Vol. 11, No. 6: 628-49.

Oussalah, Mourad. 2002. Component-Oriented KBS. *Proceedings of the 14th international conference on Software engineering and knowledge engineering.* ACM.

Paul, Ray J, George. M Giaglis, and Vlatka Hlupic. 1999. Simulation of Business Processes: a Review. *American Behavioral Scientist* Vol. 42, No. 10: 1551-76.

Phillips, Estelle M., and Derek S. Pugh. 2000. *How to get a PhD.* Buckingham: Open University Press.

Pidd, M. 2002. Simulation Software and Model Reuse: a Polemic. *Proceedings of the 2002 Winter Simulation Conference, Vols 1 and 2*, 772-75 .

Pidd, Michael, Noelia Oses, and Roger J. Brooks. 1999. Component-based simulation on the Web? *Proceedings of the 31st conference on Winter simulation*, 1438--1444 ACM Press.

Platts, Ken. 1993. A process approach to researching manufacturing strategy. *International Journal of Operations & Production Management* Vol. 13, No. 8: 4-17.

Porter, Michael. 2001. Strategy and the Internet. *Harvard Business Review* Vol. March: 63-77.

Quayle, Michael, and John Christiansen. 2002. Business issues in the 21st Century: an empirical study of SME's in UK and Denmark. in *Proceedings of the 9th International Conference of the European Operations Management Association Conference* , Eds. John Christiansen, and Harry Boer, Annex Aalborg University.

Quinonez-Varela, G., A. Cruden, C. Graham, B. Punton, L. Blair, and J. Thomson. 2006. A GIS/PSS Planning Tool for the Initial Grid Connection Assessment of Renewable Generation. *Renewable Energy* Forthcoming.

Robinson, Stewart. 1994. *Successful simulation, a practical approach to simulation projects.* Berkshire, England: McGraw - Hill.

Royer, Isabelle, and Philippe Zarlowsky. 2001. Sampling. *Doing Management Research.* 1st ed., Raymond-Alain Thiétart, 147-71. London: SAGE Publications Ltd.

Saludadez, Jean A., and Primo G Garcia. 2001. Seeing Our Quantitative Counterparts: Construction of Qualitative Research in a Roundtable Discussion. *Forum: Qualitative Social Research (On Line Journal)* Vol. 2, No. 1.

Scottish Enterprise. 2002. "Scottish e-Business Survey 2002 : Annual survey of Scottish businesses investigating attitudes to and adoption of e-business ." Glasgow, UK.

Scottish Executive. 2002. "Scotland's Renewable Energy Potential Beyond 2010: A Consultation Paper." Web page, [accessed 24 August 2002]. Available at http://www.scotland.gov.uk/library5/environment/renewenergy2010.pdf.

Sekaran, U. 1992. *Research Methods for Business.* New York, N.Y.: John Wiley & Sons.

Sharp, J. A. 2006. Evaluating the effect of sourcing decisions on e-commerce process operations risk. *European Journal of Operational Research* Vol. In Press, Corrected Proof.

Shen, Hui, Brian Wall, Michal Zaremba, Yuliu Chen, and Jim Browne. 2004. Integration of business modelling methods for enterprise information system analysis and user requirements gathering. *Computers in Industry* Vol. 54, No. 3: 307-23.

SIMSOC mailing list. 2003. "Discussion about Simulation and Explanation and Simulation and Theory." Web page, [accessed 25 November 2003].

Smart, P. A., R. S. Maull, and S. J. Childe. 1999. A Reference Model of 'operate' Processes for Process-Based Change. *International Journal of Computer Integrated Manufacturing* Vol. 12, No. 6: 471-82.

Smith, Joanne. 2002. "Multiple Viewpoint Modular Design Methodology." University of Strathclyde.

Stake, Robert E. 1995. *The art of case study research.* London: Sage Publications.

Strader, Troy J., Fu-ren Lin, and Michael J. Shaw. 1998. Simulation of Order Fulfilment in Divergent Assembly Supply Chains. *Journal of Artificial Societies and Social Simulation* Vol. 1, No. 2:

5.

Strauss, Judy, and Raymond Frost. 2001. *E-marketing*. Upper Saddle River, N.J: Prentice Hall.

Su, Yea-Huey, Ruey-Shan Guo, and Shi-Chung Chang. 2005. Virtual fab: an enabling framework and dynamic manufacturing service provision mechanism. *Information & Management* Vol. 42, No. 2: 329-48.

Supply Chain Council. 2002. "Supply Chain Operations Reference Model (SCOR Model)." Web page, [accessed 14 June 2002]. Available at http://www.supply-chain.org/default.htm.

Supply Chain Council. 2005. "Supply Chain Operations Reference Model (SCOR Model) Version 7." Web page, [accessed 14 August 2005]. Available at http://www.supply-chain.org/default.htm.

Suri, R. 1988. RMT puts manufacturing at the helm . *Manufacturing Engineering* Vol. 100, No. 2: 41-44.

Sweet, Pat. 2001. Time for a return. *CONSPECTUS* : 2-4.

Tang, Nelson K. H., Helen Benton, Doug Love, Pavel Albores, Peter D. Ball, Jillian C. MacBryde , Nick J. Boughton, and Paul Drake. 2004. Developing an Enterprise Simulator to Support Electronic Supply Chain for B2B Electronic Business. *Production Planning and Control* Vol. 15, No. 6. 572-83.

Tatsiopoulos, I. P., N. A. Panayiotou, and S. T. Ponis. 2002a. A modelling and evaluation methodology for E-Commerce enabled BPR. *Computers in Industry* Vol. 49, No. 1: 107-21.

———. 2002b. A modelling and evaluation methodology for E-Commerce enabled BPR. *Computers in Industry* Vol. 49, No. 1: 107-21.

Tellis, Winston. 1997. Introduction to Case Study. *The Qualitative Report* 3, no. 2: Available at http://www.nova.edu/ssss/QR/QR3-2/tellis1.html.

The Cabinet Office. 2002 . *The Energy Review*, 10-11 .

Thomas, K. W., and W. G. Tymon. 1982. Necessary properties of relevant research- lessons from recent criticism of the organisational science. *Academy of Management Review* 7, no. 3: 345-52.

Tranfield, David, David Denyer, and Palminder Smart. 2003. Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. *British Journal of Management* Vol. 14, No. 3: 207-22.

Trochim, W. 1989. Outcome pattern matching and program theory. *Evaluation and Program Planning* Vol. 12: 355-66.

Tumay, Kerry. 1996. Business Process Simulation . in *Proceedings of the 1996 Winter Simulation ConferenceJ.* M Charnes, D. J Morrice, D. T. Brunner, and J. J. Swain, 93-98 . Proceedings of the 1996 Winter Simulation Conference.

Voss, Chris, Nikos Tsikriktsis, and Mark Frohlich. 2002. Case Research in Operations Management. *International Journal of Operations and Production Management* 22, no. 2: 195-219.

Wacker, John G. 1998. A definition of theory: research guidelines for different theory-building research methods in operations management. *Journal of Operations Management* Vol. 16, No. 4: 361-85.

Wang, Q., C. R Chatwin, A Geha, Young R.C.D., and D. M. Budgett. 2002. Modelling and Simulation of Integrated Operations and Information Systems in Manufacturing. *International Journal of Advanced Manufacturing Technology* Vol. 19, No. 2: 142-50.

White, Brian. 2000. *Dissertation Skills for business and management students*. London, UK: Continuum.

Wolsthenholme, Eric, and Richard Stevenson. 1997. Business Process Re-engineering using *ithink* Simulation. *Engineering Data Newsletter* Vol. 5, No. 7.

Yen, B. P. C., and E. O. S Ng. 2001. The migration of Electronic Commerce (EC): from planning to assessing the impact of EC on supply chain. *Proceedings of the International Conference on Supply Chain Management and Information Systems in the Internet Age*, 493-504 Hong Kong.

Yin, Robert. 1994. *Case Study Research - Design and Methods*. London: Sage Publications.

Appendices

Appendix 1. Interview preparation notes

Example letter of initial approach to companies

Dear Paul,

My name is Pavel Albores, and I am currently doing my PhD with Peter Ball and Jill MacBryde at the University of Strathclyde. My project is focused on studying how simulation can be used as an analysis tool for the implementation of e-business. The idea behind the project is that e-business brings changes to the dynamics of business processes and simulation is the tool that can analyse and quantify this changes before implementation, so you can have a better idea of what actions are required to cope with the change brought about by e-business. .

The reason for contacting you is that Peter mentioned that you are planning to implement an ERP system and to extend this to support certain e-business functionality at CompanyCo.. I am at the moment looking for case studies for my research and I would like to explore the possibility of analysing your e-business implementation.

The benefits for your company would be the detailed mapping of relevant current business processes, the analysis of e-business options and scenarios, the creation of a simulation models for the analysis of e-business and to be used in the future in other analyses.

This project could be achieved quite quickly (two months). What I would need from you is access to the process and some of the people involved, in order to collect data to map the process and to populate the model.

Initially this would be probably two visits per week for 2-3 weeks and after that 1 visit per week for 4 weeks. I would provide updates on progress week by week so that you can see early results from the work. Please let me know if you are interested.

If you require more information, please do not hesitate to contact Peter or me.

Thank you

Best regards

Pavel Albores

Formal proposal for companies

e-Business Process Simulation

Project Proposal

Project Proposal

To study different alternatives for the introduction of electronic commerce capabilities and their effect in the internal business processes. Amongst the benefits expected for the Company are:

- A tool to analyse and quantify the outcome of different strategic options regarding e-business in the company
- Understanding of the dynamics of the system.
- Analysis of the interaction and effect of electronic transactions in the processes under study.
- Comparisons of different alternatives to implement this change and select the most suitable according to pre-established criteria.
- A tool to communicate and implement change.

For the researcher, the expected benefits will be:

- A better understanding of the needs of real-world companies.
- A case study to apply the modelling framework developed in the research.
- A source of research questions derived form the application of the case study.

Justification

Having the different options that e-business [e-tailing, e-marketing, CRM, e-supply chain, e-Fulfilment, Third party logistics (3PL), internet trading exchanges (ITE), e-procurement, e-Auctions, etc] presents to enterprises, it can become a daunting task to decide which one of them is better to apply, or if you decide to apply more than one, which one would be better to apply first.

In order to help companies decide which option would be more beneficial for the business and which are the implications of selecting each option, I am proposing the use of simulation tools for analysing the effects of such decisions not only in the processes directly affected, but also in other processes across the whole enterprise. For example, implementing e-tailing will have a direct effect on the ordering process, affecting the number of sales people dedicated to make contact with the clients and increasing the number of people dedicated to support clients. However, there is also an indirect effect on production plan strategies (maybe changing from make-to-order to make-to-stock or viceversa), stocking policies, etc.

The idea behind the project is to analyse the traditional business processes (model the As-Is process) consider the e-business scenarios (i.e.B2B or B2C in any of the forms described before), take into account the strategic priorities and then, using simulation, analyse the dynamic interactions in the enterprise. Performance measures should be selected to compare the different options and study the internal effects (people, machines), the external effects (suppliers, subcontractors, distributors), as well as the implications in the planning and control system of the company.

As a result of the project, I will come up with e-business process templates that can be reused in other implementations, thus saving analysis time and promoting a more confident adoption of e-business strategies.

Methodology

The project will be carried out in the following stages:

1. Objectives definition. Specific objectives of the project taking into account the Company needs, available resources and timeframe. (Tool: Requirements Questionnaire Q1)
2. Data collection. Process Cycle times, information routing, identification of triggers in the internal business processes, etc. (Outcome: Project Description PD1)
3. Model construction. (Tool: Simulation Software)
4. Experimentation. According to the defined objectives, experimentation and data analysis will be performed in this stage.
5. Results and recommendations. Findings and recommendations will be presented to the company. (Outcome: Project Report PR1)

Required Resources:

Company:

- Supply current process flows in agreed format.
- User time in the modelling phase. (workshop to adapt the Business process templates to meet the specific needs of the company)
- User time in the verification phase (workshop to verify and validate the model)
- Access for the modeller to follow the process in order to become familiar with it.

Activity	Responsible

Select modelling tools	CSM
Development of e-process templates	CSM
Provide current process flows	Company
Provide e-business options	Company
Workshop to customise templates to meet company's needs.	CSM / Company
Data collection	CSM/ Company
Workshop for verification and validation of the model	CSM/ Company
Experimentation and statistical analysis or results	CSM
Recommendations	CSM
Implementation of recommendations	Company

Remarks

Involvement form the user at different stages of the model construction is desirable. The objective of this is twofold. First, reflect the process as accurate as possible and second, involve people in the design of the new system in order to create ownership and reduce resistance to change.

Weekly advance reports and brief explanatory meetings will be conducted.

The project will be conducted with the objective in mind of minimising the time taken from the users/sponsor.

Initially, no investment will be required from the company, apart from the personnel time. However, if the company wants to continue using the simulation tools after the case study is completed, investment in the simulation software might be required.

Questionnaire for project definition

SETTING THE OBJECTIVES

- **Identifying the problem**

Why is the project being considered?

- **E-business application**

What e-business application is being considered?

What business areas will e-business affect?

- **Set the objectives**

Achievements

- ☐ To increase throughput
- ☐ To study working patterns
- ☐ To reduce average waiting time
- ☐ To understand the effects of breakdowns
- ☐ To compare scheduling strategies
- ☐ To select one method
- ☐ Other: ______________________________

Measurements

☐ By ________ per cent ☐ By ________ minutes

Constraints

- ☐ With the current facilities
- ☐ Within £__________ capital investment
- ☐ Without employing more labour
- ☐ By only making improvements to the production schedule
- ☐ In order to obtain ____ per cent utilisation of facilities
- ☐ While maintaining throughput level
- ☐ Other: ______________________________

Objectives (what do you want to achieve at the end of the project?):

____

____

- **Rank the objectives**

1st

2nd

3rd

- **Any further use for the model**

- **Time-scale objectives**

- **Level of visual display**

- **Check for consistency**

EXPERIMENTAL FACTORS

Identified methods by which the objectives of the project might be achieved

	Factors	Levels		Data Entry
		Max	Min	
☐	Changing cycle time			
☐	Changing level of labour			
☐	Changing buffer size			
☐	Changing conveyor capacity (related to buffer size)			
☐	Changing schedule (production order)			
☐	Changing lot size			
☐	Other:			
☐	Other:			
☐	Other:			

REPORTS

Data type

	Mean and S.D.	Median	Mode	Min and max	Statistical tests	Cumulative %
☐ Throughput (time-scale = ________)	☐	☐	☐	☐	☐	☐
☐ Machine utilisation	☐	☐	☐	☐	☐	☐
☐ Waiting time	☐	☐	☐	☐	☐	☐
☐ Staff utilisation	☐	☐	☐	☐	☐	☐
☐ Scrap	☐	☐	☐	☐	☐	☐
☐ Other: ________________	☐	☐	☐	☐	☐	☐
☐ Other: ________________						

Ways of reporting

Graphs:
- ☐ Pie chart
- ☐ Time series
- ☐ Histograms
- ☐ Gantt charts
- ☐ Scatter diagrams
- ☐ Other: ________________________________
- ☐ Other: ________________________________

SCOPE AND LEVEL OF THE MODEL

What should be included in the model?

____

____

____

____

How much detail should be modelled?

____

____

____

____

Appendix 2. Case studies maps against current BP models

Water Co Case study

Co. Activity	**Childe et al (Childe et al. 1996)**	**SCOR**	**MIT (MIT 2000)**
Order Arrives	A141 Manage customer query	M1.1 Receive, Enter & Validate Order	Obtain order
Order Arrives Fax/Tel			Receive order by tel
Order Arrives EDI			Obtain order via EDI
Capture order in Card			
Capture order in ERP system			Enter orders into production and delivery {PCF 4.2.2}
Phone client to book-in delivery time	A343 Schedule delivery	D1.3 Determine Delivery Date & Reserve Inventory	Schedule delivery activities
Run batch allocation process	A31223 Compare requirements to existing schedule + A31234 Add order to main schedule		Enter order, commit resources and launch program {SCOR D3.3}
POH batch allocation process (check which orders are ready to be dispatched)	A143 Accept / release order	Mx.6 Release product to deliver	Release product to deliver {SCOR Mx.6}
Assign haulier	A3221 Identify sources for each item	D1.7 Select Carriers & Rate Shipments	Select supplier
Generate POH in system	A32222 Generate PO for bought-out items	Procurement Signal (Supplier) ? (output of S2.1)	Place order using own application
Print POH			
Fax POX			Place order by fax
Send POH electronically			Place order over internet
Haulier picks order	Dispatch customer order	D1.9 Pick Product	Pick product {SCOR D1a.9}
Haulier sends delivery note		D1.11 Receive & Verify Product at Customer Site	Document delivery of service
Generate invoice		Dx.13 Invoice and receive payment	Invoice and receive payment {SCOR Dx.13}/ Invoice the customer {PCF 7.1.2}
Send invoice			

Co. Activity	Childe et al (Childe et al. 1996)	SCOR	MIT (MIT 2000)
Receive enquiry	Receive enquiry from customer	Process enquiry and quote	Process enquiry
Produce estimate	Estimate process times/apply standard cost rates		Calculate product/process requirement
Commercial review of quote	A141 Manage customer query		Review/oversee
Update quote			
Send quote to customer			Send quote
Wait for customer to decide			Wait on customer
Receive order	A141 Accept/ release order	M1.1 Receive, Enter & Validate Order	Obtain order
Pass Artwork to origination	Develop preliminary design		Customer provides specifications
Check artwork/ highlight issues & print	A3123211 Check Drawing issue		Conduct initial technical review
Log order & create order spec	Identify process required		Enter orders into production and delivery {PCF 4.2.2
Create method	Generate process instructions	Finalize Engineering	Develop product and process design
Schedule delivery date –proof & job	Compare requirement to existing schedule	Schedule manufacturing activities {SCOR M3.2}	Schedule manufacturing activities {SCOR M3.2} / Schedule prototype build
Proof bag sent to origination			
Produce proof	Develop product to meet specifications		Develop prototypes {PCF 3.2.5}
Send proof to customer			Send physical object/ send information externally
Approve proof & date	Confirm with customer	Approve Request Authorization	Approve transaction
Update order, produce job bag, print spec			
Order materials	Obtain required items	Source	Buy raw materials
Send acknowledgement to customer	Confirm order to customer		Confirm specific service requirements for customer {PCF 5.3.4}
Pass updated job bag to planning			
Check specs and job bag			
Order tooling	Issue work orders		
Run manufacture	*****	*****	****
Despatch goods	Dispatch customer order	D1.9 Pick Product	Pick product {SCOR D1a.9}
Ship goods.	Deliver product	Load Vehicle Generate Ship Docs. Verify Credit & Ship Product	Load Vehicle Generate Ship Docs. Verify Credit & Ship Product

VirtualCo. Case study (Bosilj-Vuksic et al. 2002)

Co. Activity	Childe et al (Childe et al. 1996)	SCOR	MIT (MIT 2000)
1 Identify a need	A1 Identify opportunities		Identify needs or requirements
2 Inventory level checking	A31123 Check material availability	P4.2 Inventory Availability	Provide information from inventory
3 Inventory level is sufficient?			
4 Reservation of goods	A31231 Allocate material	D1.3 Reserve Inventory & Determine Delivery Date	
5 Select items from the authorized e-buying catalogues and create requisition			
6 Requisition approval			Approve
7 Purchase order (PO) generation and transmission	A32222 Generate PO for bought-out items	Procurement Signal (Supplier) (output of S2.1)	Send EDI purchase order
8 Waiting for delivery		Mx.6 Release product to deliver	
9 Accepting delivery note	A3231 Check goods against delivery note	Procurement Signal (Supplier) (output of S2.1)	Verify delivery
10 Filling in acceptance slip (confirming acceptance)			
11Agreement?			
12 Reject delivery	A32323 Raise Reject note		
13 Inform purchase dept.			Informhttp://repository.phios.com/Public/Activity.asp?ID=3993
14Reconciliation		D1.9 Pick Product	
15 Sending goods for unloading	A3233 Relocate Goods	D1.11 Receive & Verify Product at Customer Site	
16 Delivery acceptance		S3.4 and S3.5 Receive and Verify product	Document delivery of service
17 Accepting invoice			Receive invoice

18 Confirming invoice for payment		Dx.13 Invoice and receive payment	Pay against invoice
19 Creating, transmitting and booking payment orders			Authorize vendor payment {SCOR S0.8} +Transfer payment

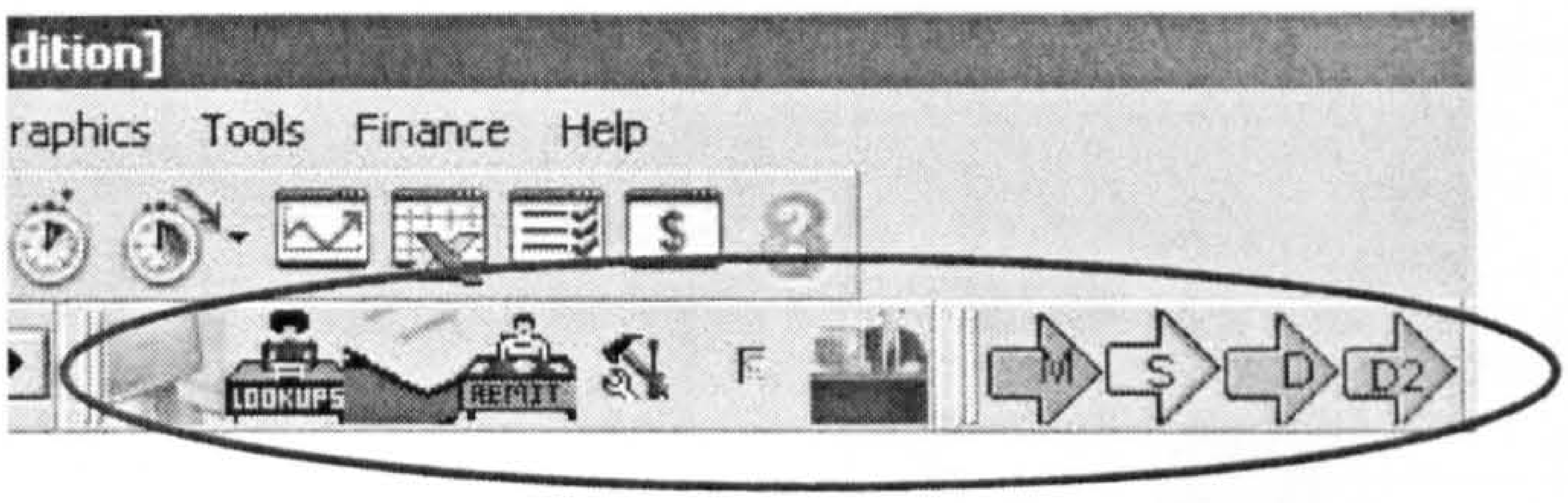
Appendix 2A. Components user guide for Quasi-experiment

In order to use the components, the user must follow the following procedure:

1. Before using the simulation software
    a. Define the problem.
    b. Identify the process boundaries of the study.
    c. Identify the main activities involved in the process to be improved (e.g. Invoicing, Ordering, Purchasing, Receiving) or identify the potential e-business solutions to the problem.
    d. Search the component guide (See below) for the components that have activity or e-business application.
    e. List these components and rank according to their fit to the actual process.
2. Using the simulation software
    a. Select the first chosen components from the Build toolbar or the component stencil
    b. Click and drag the component to the main Simul8 Window.
    c. The component should "unwrap" into the window.
    d. Analyse the process and modify to suit your process.
    e. If the component does not fit your application, select the entities, delete them and test the next component in the ranked list. Repeat from 2a

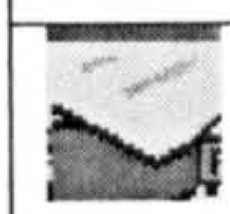
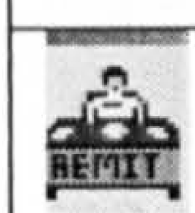
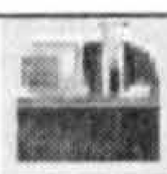
The component's toolbar.

Components are called from the "Build toolbars" as shown below.



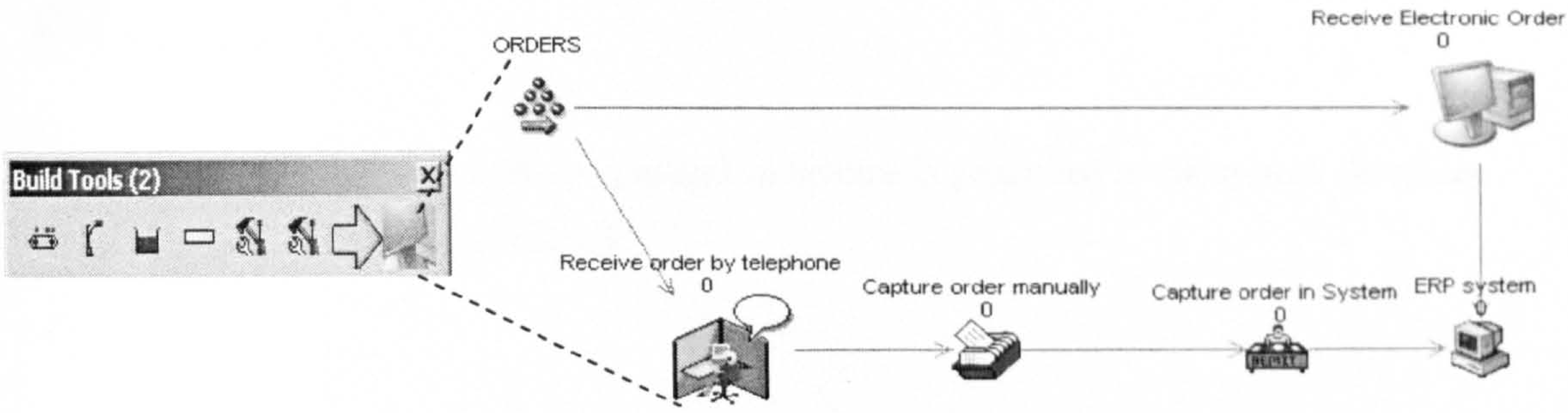
In order to call a component, you have to click on the desired icon and then click in the part of the simulation screen where you want to place it.

The templates loaded in the system are as follows.

Icon	Template
	Order Taking combining traditional an electronic orders
	Purchasing (send purchase orders)
	Order processing
	Invoicing
	Configure Order
	Kanban
	Electronic Purchase Order

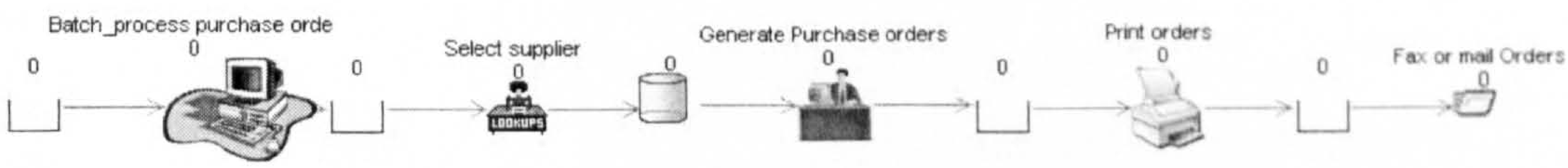
 **Order Taking combining traditional an electronic orders**

This template combines both traditional manual order processing and orders that come via a website or EDI. Orders are then combined and accumulated in a central database



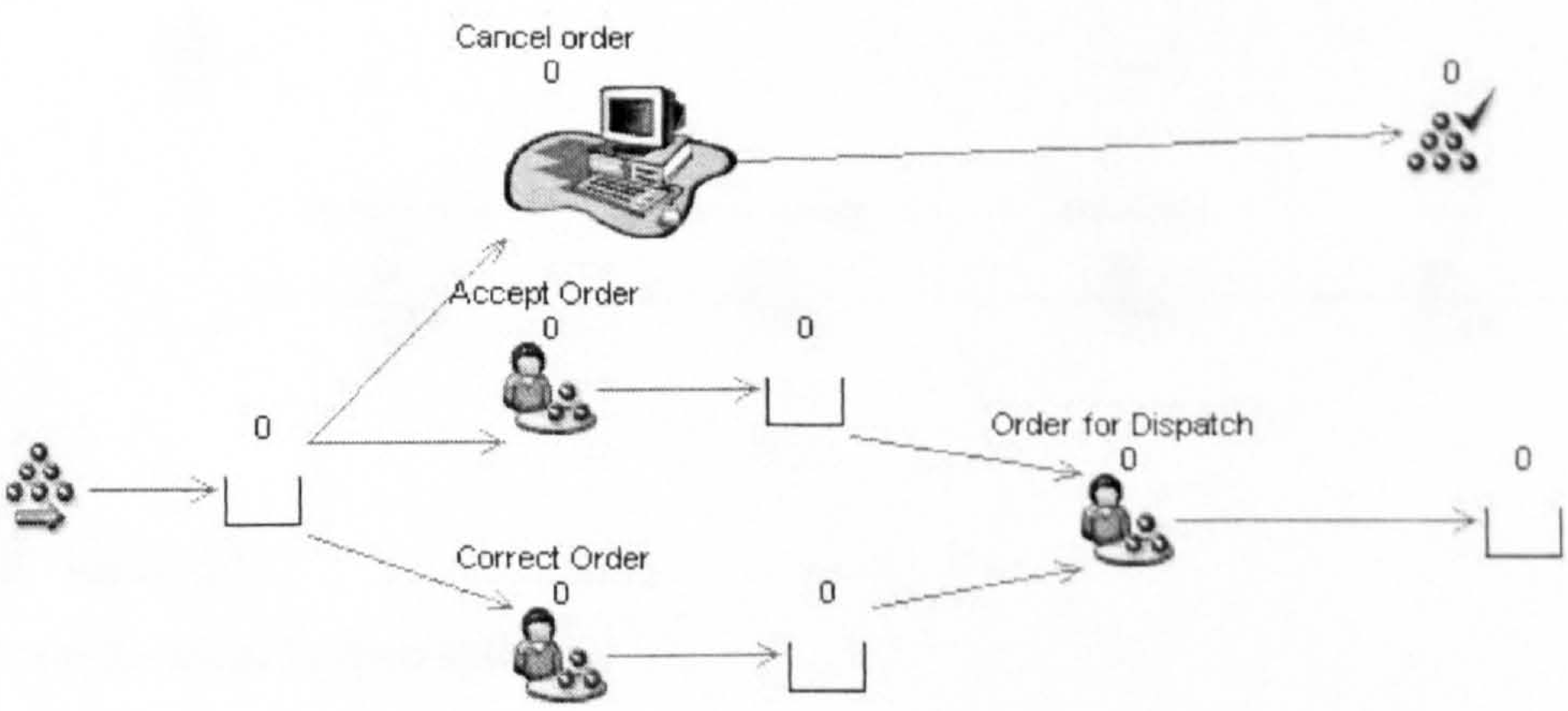
Purchasing (send purchase orders)

This process checks the system for purchase order to be sent, then a supplier is selected, order are captured in the system and printed and faxed or mailed to the customer



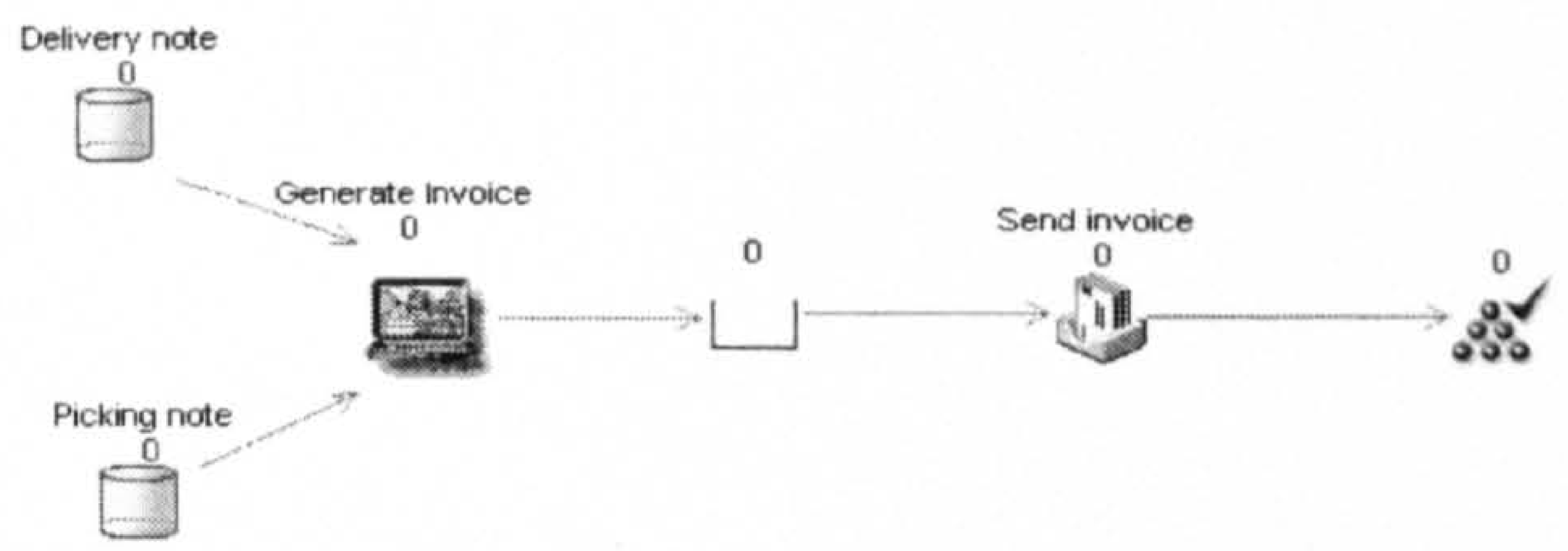
Order processing

Orders come into the system and are either accepted, verified or rejected.



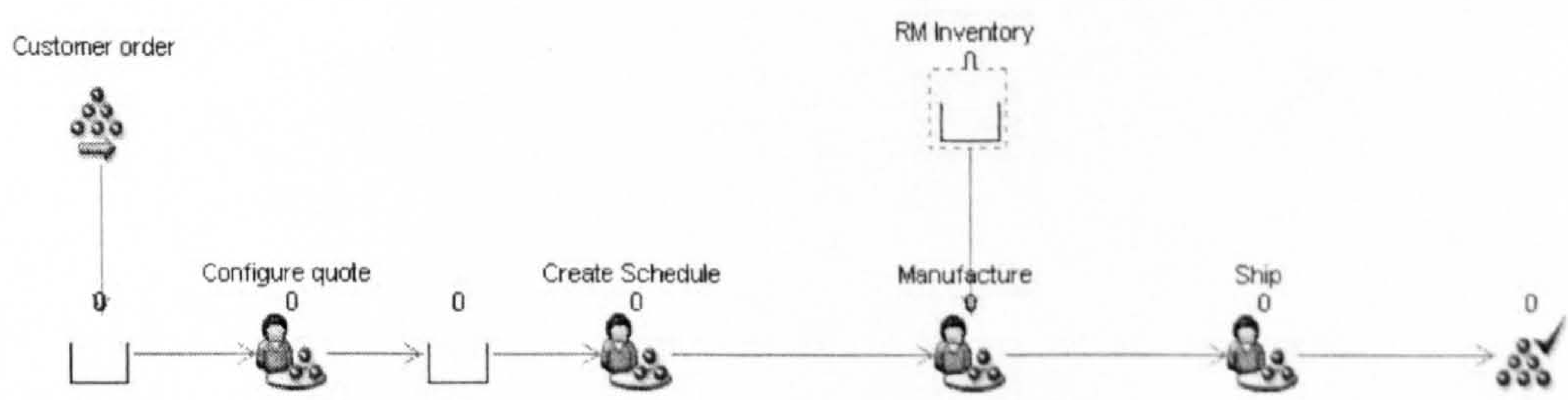
Invoicing

A delivery note is tied to a picking note and an invoice is generated in the system. Invoices are then sent to the customer by mail.



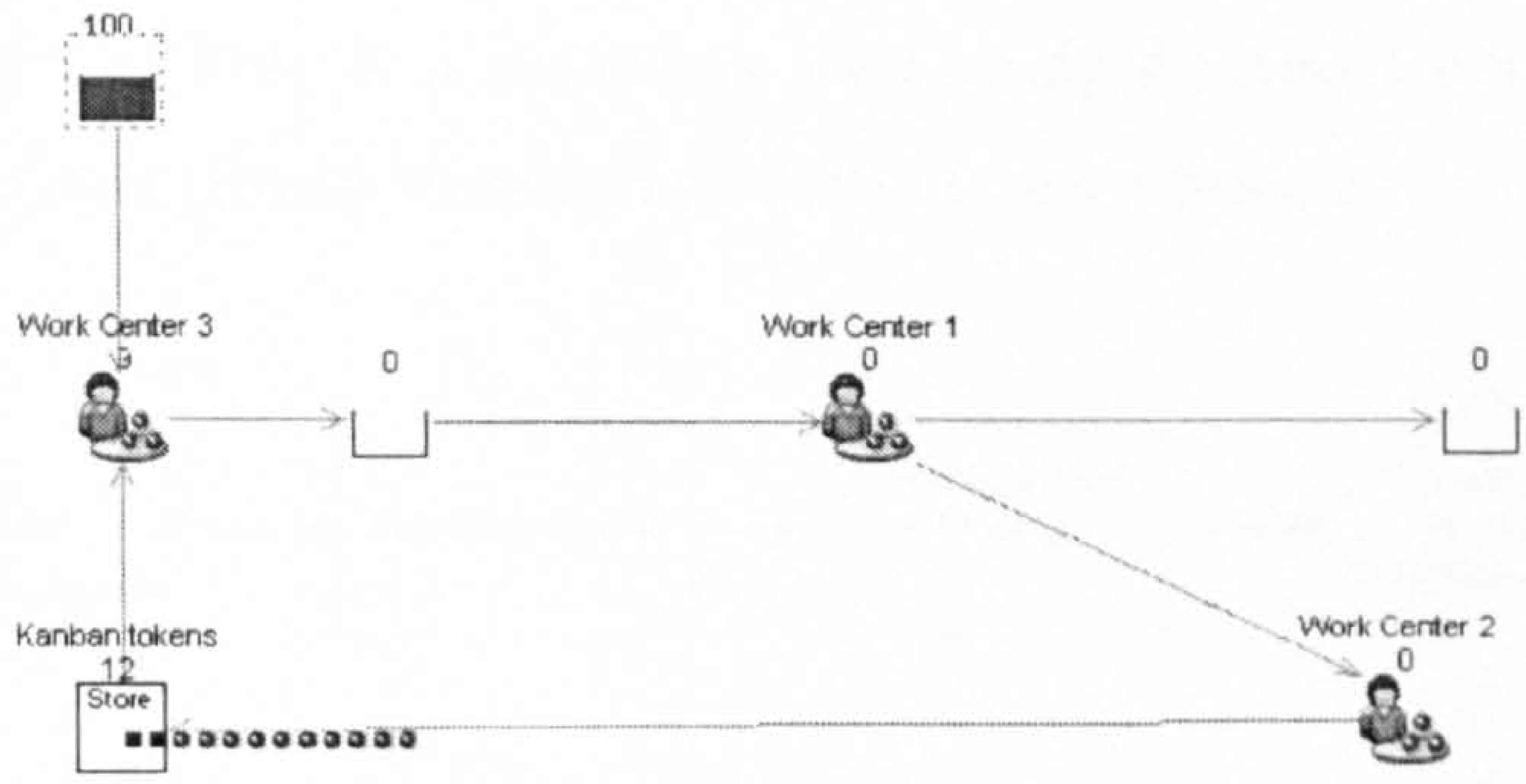
Configure Order

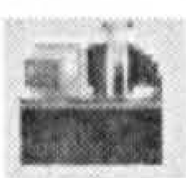
This is a high-level order fulfilment process. Orders arrive, a schedule is created and parts are manufactured and shipped.



Kanban

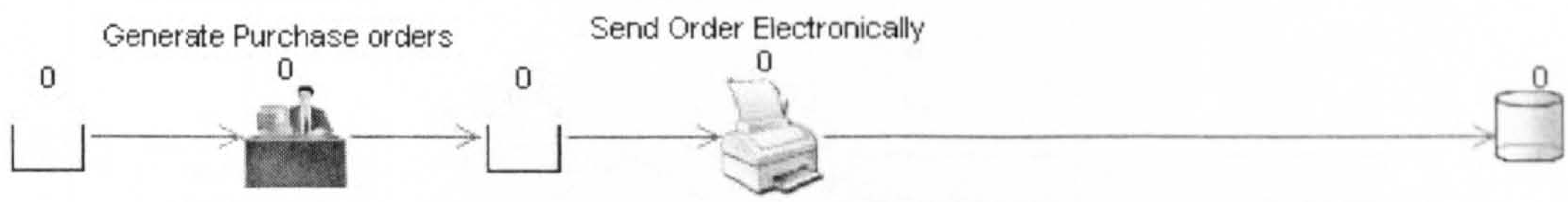
A single-token kanban system.





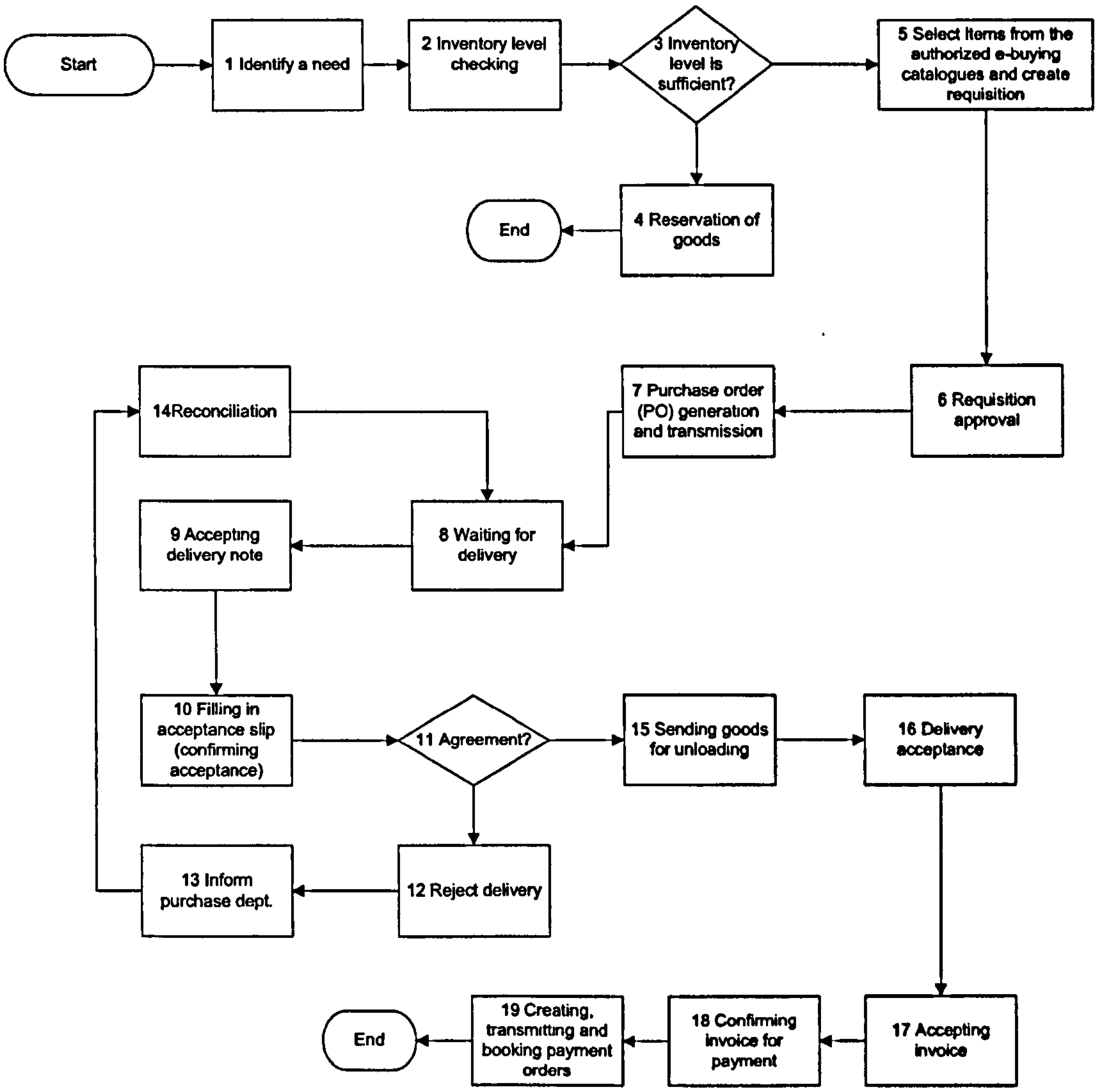
Electronic Purchase Order

Similar to the normal purchase process, orders are sent to the customer via email or e-fax



Appendix 3. Case studies process maps and simulation models

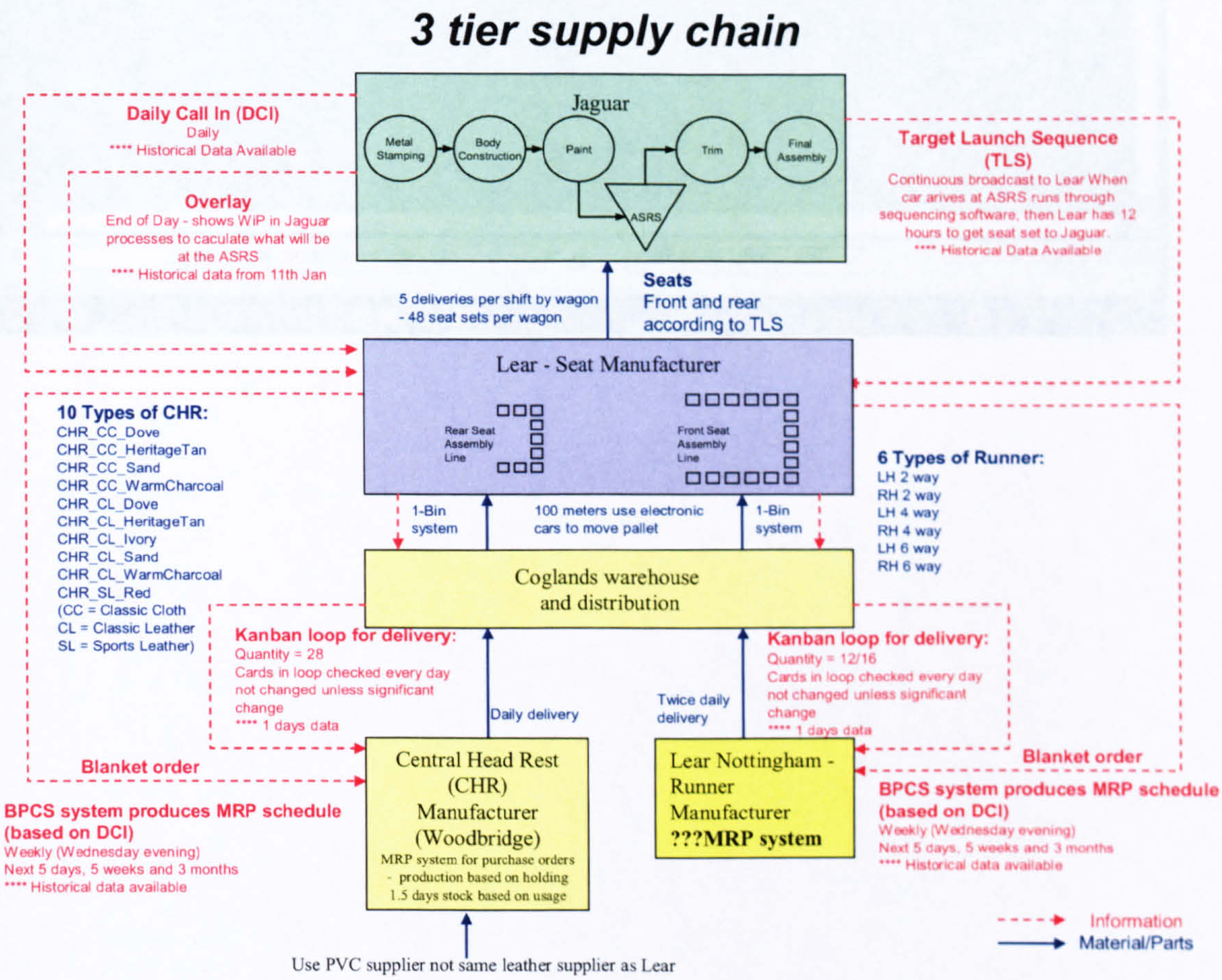
Virtual Co. This is a secondary case study derived from application reported by Bosilj-Vuskic et al (Bosilj Vuksic et al. 2001) It describes the

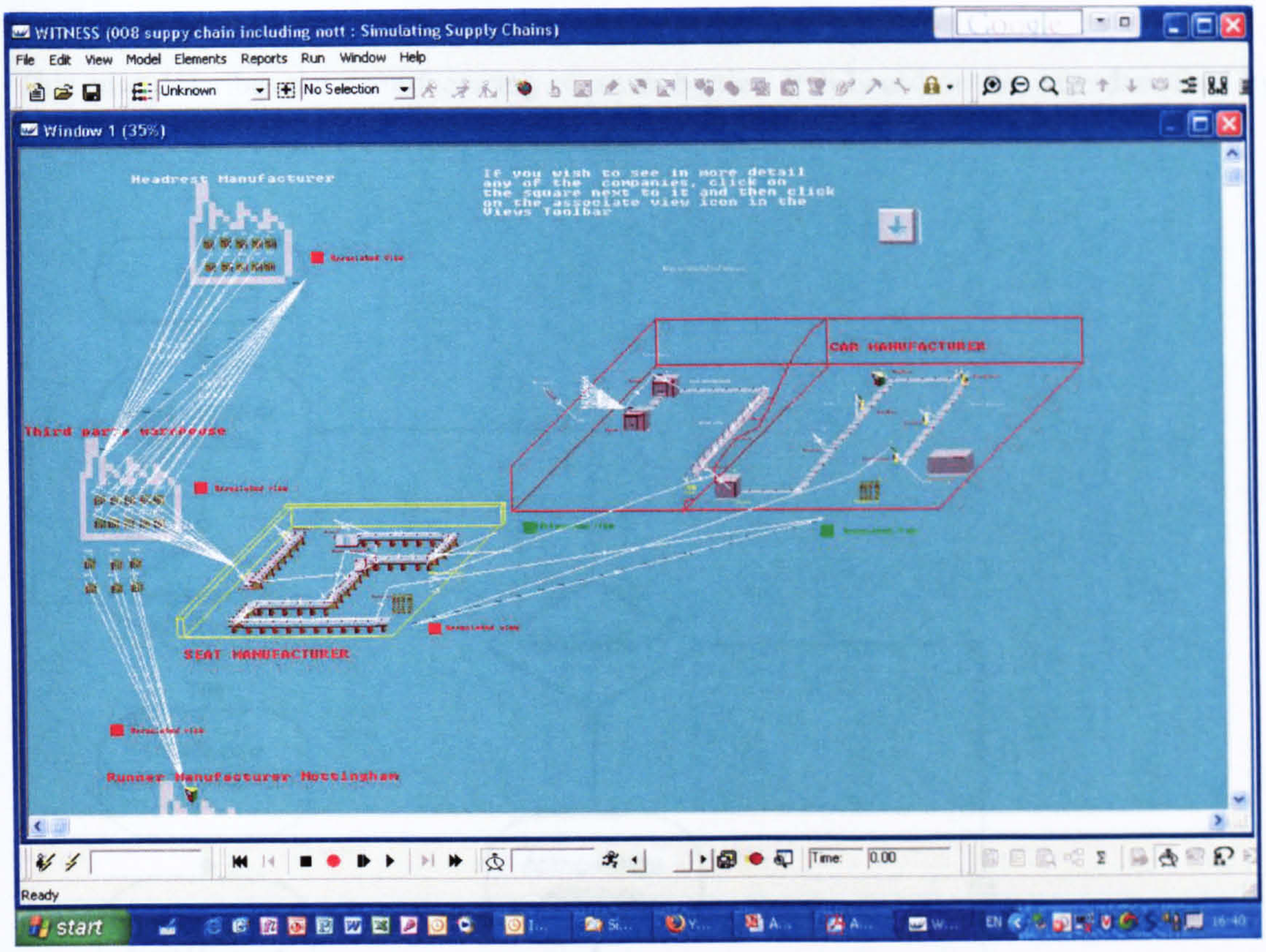


Motor Co.

This case study describes the supply chain of an automotive manufacturer. There are four echelons involved in the supply chain: the car company, the seat supplier, a third party VMI warehouse, and two suppliers of seat components

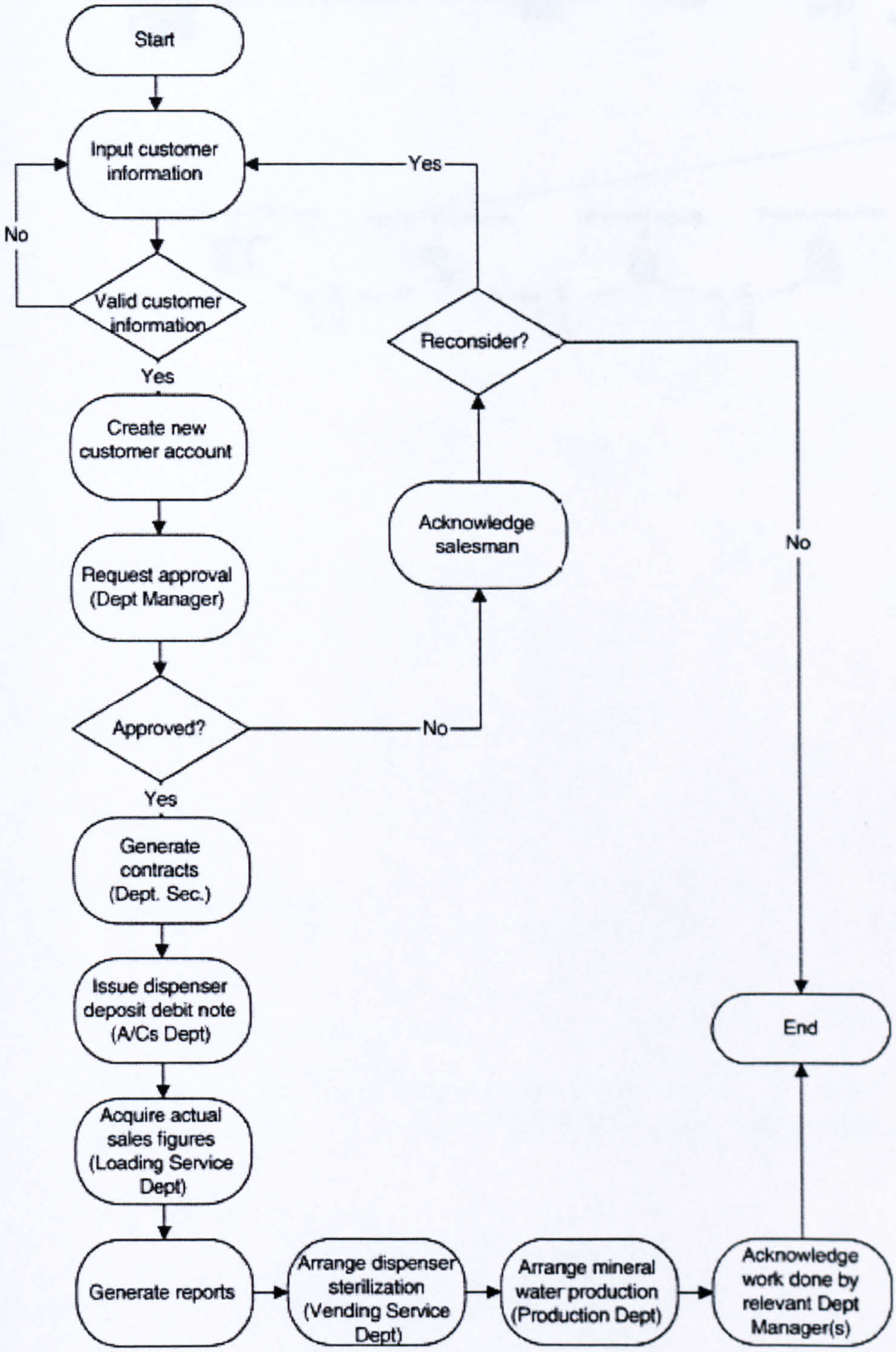
This case study was modelled using a different simulation tool (Witness) from the other cases. The reason for this was that an initial model had been built in Witness and the complexity and nature of the system (heavy emphasis on manufacturing processes) made using this tool the best option.

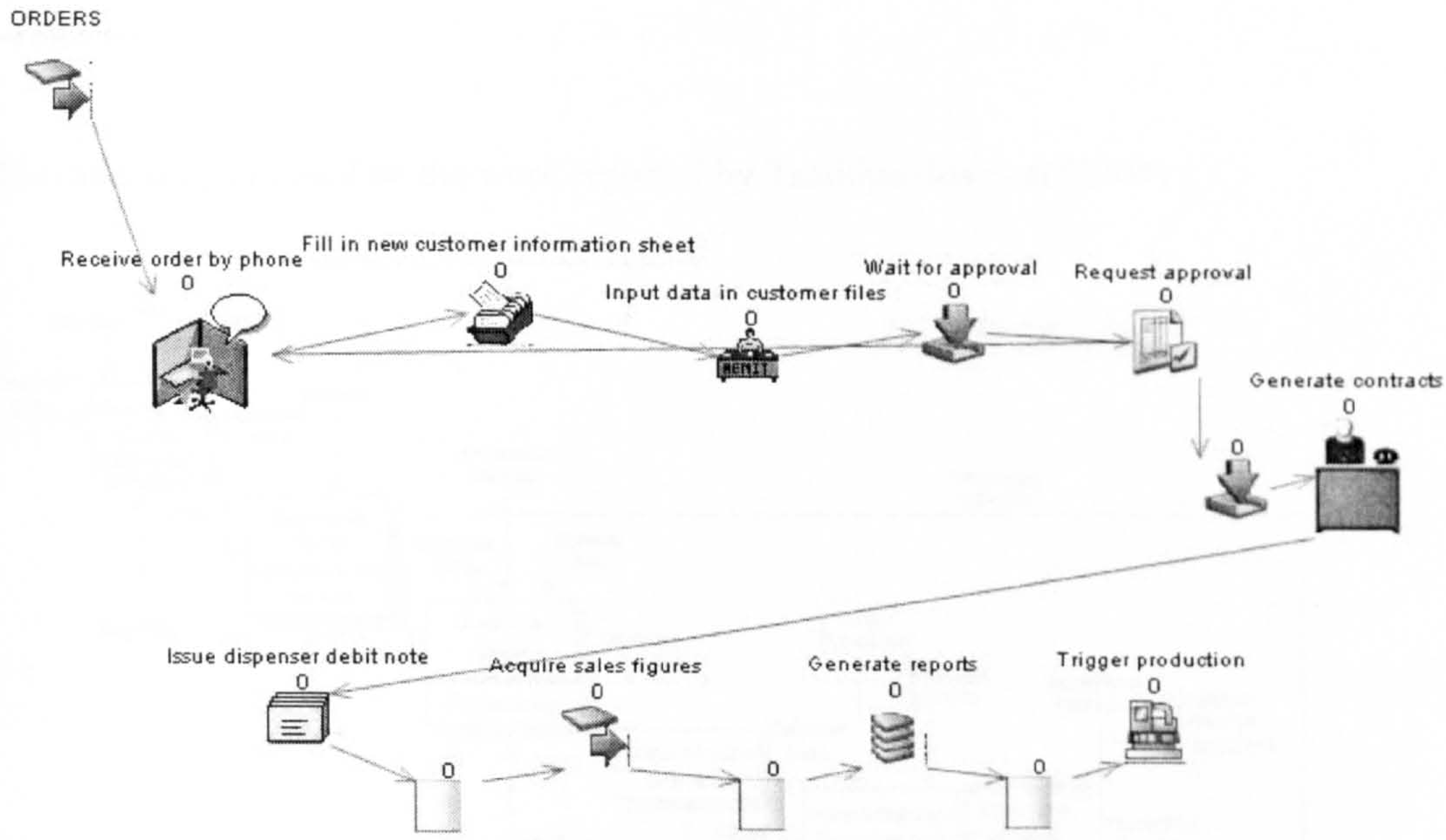



WITNESS (008 suppy chain including nott : Simulating Supply Chains)
File Edit View Model Elements Reports Run Window Help
Unknown
No Selection
Window 1 (35%)
Headrest Manufacturer
If you wish to see in more detail any of the companies, click on the square next to it and then click on the associate view icon in the Views Toolbar
CAR MANUFACTURER
Third party warehouse
SEAT MANUFACTURER
Runner Manufacturer Nottingham
Time 0.00
Ready
start

BottlingCo.

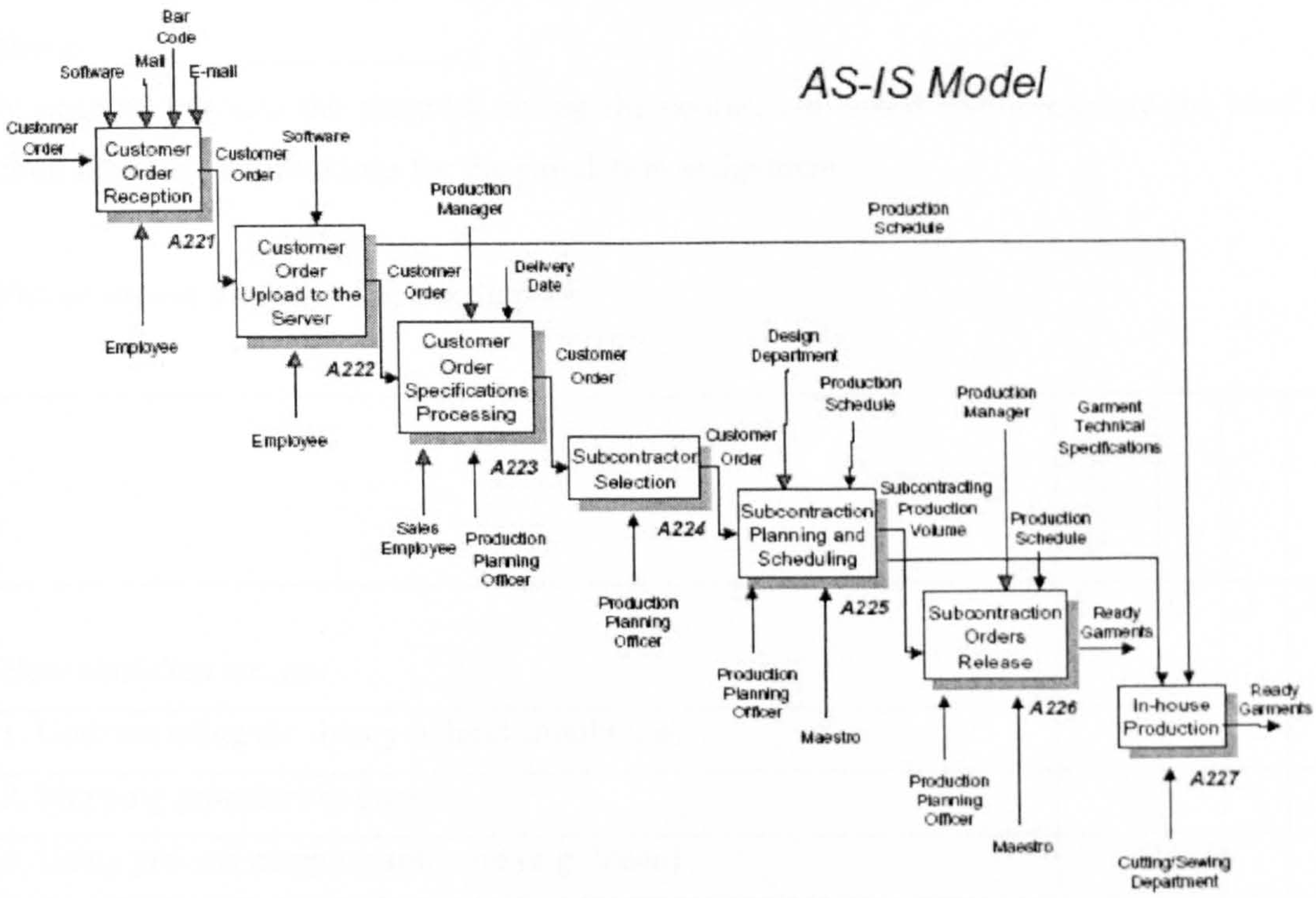
This case describes the manufacturing of water bottles. It is based on the case described by Ngai et al (2003) about a Chinese manufacturer



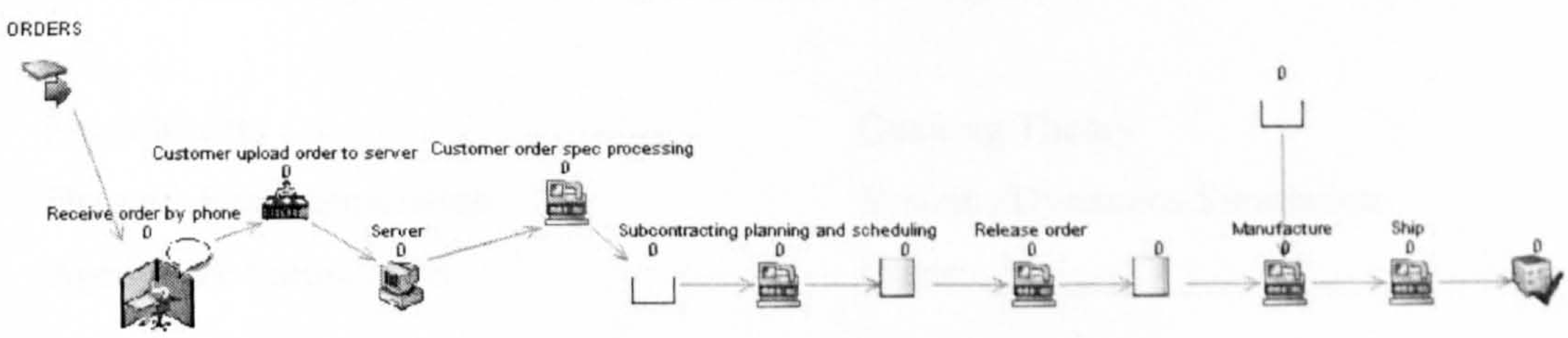

ORDERS
Receive order by phone
0
Fill in new customer information sheet
0
Input data in customer files
0
Wait for approval
0
Request approval
0
Generate contracts
0
0
Issue dispenser debit note
0
0
Acquire sales figures
0
0
Generate reports
0
0
Trigger production
0

E-releaser

This case study is based on the work reported by Tatsiopoulos et al (2004)



Operationalisation in Simul8



Appendix 4 Pre-testing questionnaire

Simul8 Simulation Assignment

Pre-assignment questionnaire.

Name : ____________________

In order to evaluate the progress during the course, we would like to explore the level of confidence and expectations for the simulation assignment.

Please answer the following questions.

	Not at all				Very
How confident are you	1	2	3	4	5
1. Understanding the theory behind simulation?					
2. Mapping processes in paper					
3. Using process mapping software (e.g. Visio)					
4. Differentiating business processes from manufacturing processes					
5. Learning to use new software?					
6. Using simulation software?					

7. Have you used any of the following simulation techniques?

Spreadsheets
Queuing Theory
Discrete Event Simulation
Systems Dynamics Simulation
Agent based Simulation
Other: ____________________

8. Have you used any of the following simulation tools?

Arena
Simul8
Witness
Igrafx Process
Simprocess
Other: ____________

9. If you have used a simulation tool/software, for how long? : ______________

10. Templates are pre-defined formats that allow you to create common applications or documents (e.g. CV templates in Word). Have you used templates in any of the following applications?

Word	Excel	Access
Webpage design	Visio	Simulation Software
Handheld computer	MS. Project	Other: __________

11. Did the templates make the task easier?

YES NO Not applicable

12. Did the templates allow you to complete the task quicker?

YES NO Not applicable

13. Were you able to use the templates directly or did you need to modify them?

Directly Modified Not applicable

14. Were the templates easy to modify?

YES NO Not applicable

15. Any other comments?

____

____

____

____

Appendix 5 Post-testing questionnaire

Simul8 Simulation Assignment

Post-assignment questionnaire.

Name : ____________________ Course: MSE/MsysE/MEM

TBS

Erasmus

PostGraduate

In order to evaluate the progress during the course, we would like to evaluate the learning experience gained from the Simul8 assignment.

Please answer the following questions.

	Not at all				Very
How confident are you	1	2	3	4	5
1. Understanding the theory behind simulation?					
2. Mapping processes in paper					
3. Using process mapping software (e.g. Visio)					
4. Differentiating business processes from manufacturing processes					
5. Learning to use new software?					
6. Using simulation software?					

7. Did you use the templates provided for building of your simulation model?

YES NO Not applicable

8. Did the templates make the task easier?

YES NO Not applicable

Why? ____

9. Did the templates allow you to complete the task quicker?

YES NO Not applicable

Why? ____

10. Did the templates make the process more explicit/easier to understand?

YES NO Not applicable

Why? ____

11. In which other way do you feel that the templates were useful?

____

11. Were you able to use the templates directly or did you need to modify them?

Directly Modified Not applicable

12. Were the templates easy to modify?

YES NO Not applicable

13. If you did not use the templates provided, what was the reason?

Not relevant

Not enough documentation for the templates

I like to build models from scratch

Confusing

The templates did not represent the processes under analysis.

Other: ____

____

14. Do you think that you would have benefited from having more templates (e.g. for the manufacturing process)

YES NO Not applicable

15. Which element of the simulation did you find easier to build?

Business process

Interface between business and manufacturing processes

Manufacturing process

Control Rules

Why? ____________________

____

16. Which element of the simulation did you find more difficult to build?

Business process | Manufacturing process
Interface between business and manufacturing processes | Control Rules

Why? ____________________

____

17. What suggestions do you have for the improvements of the templates?

____

____

____

____

18. Any other comments?

____

____

____

____

Appendix 6 Statistical analysis phase 1

Frequencies Pre-Questionnaire

Statistics

		Confidence understanding theory	Confidence mapping processes	Confidence using mapping software	Confidence differentiating business and manufacturing processes	Confidence learning to use new software	Confidence using simulation software	Have you used spreadhseets?	DES	Agents
N	Valid	23	23	23	23	23	23	23	23	23
	Missing	0	0	0	0	0	0	0	0	0
Mean		3.9130	3.2609	2.4783	3.3478	3.8261	3.4348	1.0000	.6522	.0000
Mode		4.00	3.00(a)	3.00	3.00	4.00	4.00	1.00	1.00	.00
Std. Deviation		.73318	.81002	1.16266	.83168	.57621	.72777	.00000	.48698	.00000
Percentiles	25	4.0000	3.0000	1.0000	3.0000	3.0000	3.0000	1.0000	.0000	.0000
	50	4.0000	3.0000	3.0000	3.0000	4.0000	4.0000	1.0000	1.0000	.0000
	75	4.0000	4.0000	3.0000	4.0000	4.0000	4.0000	1.0000	1.0000	.0000

a Multiple modes exist. The smallest value is shown

		Queueing theory	Systems Dynamics	Number of simulation tools used	Time that used simulation (Hours)	Have you used templates? (how many applications?)	Q11. Did the templates make the task easier?	Q12. Did the templates make the task quicker?	Q13. Did you modify the templates?	Q14 Were templates easy to modify?
N	Valid	23	23	23	21	17	15	15	13	11
	Missing	0	0	0	2	6	8	8	10	12
Mean		.5217	.1304	1.1739	11.8571	3.1765	.9333	.8000	1.6154	.8182
Mode		1.00	.00	1.00	2.00	2.00	1.00	1.00	2.00	1.00
Std. Deviation		.51075	.34435	.49103	17.93679	1.38000	.25820	.41404	.65044	.40452
Percentiles	25	.0000	.0000	1.0000	2.0000	2.0000	1.0000	1.0000	1.0000	1.0000
	50	1.0000	.0000	1.0000	3.0000	3.0000	1.0000	1.0000	2.0000	1.0000
	75	1.0000	.0000	1.0000	14.0000	4.0000	1.0000	1.0000	2.0000	1.0000

Frequency Table

Confidence understanding theory

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A little	1	4.3	4.3	4.3
	Some	4	17.4	17.4	21.7
	Confident	14	60.9	60.9	82.6
	Very confident	4	17.4	17.4	100.0
	Total	23	100.0	100.0	

Confidence mapping processes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	1	4.3	4.3	4.3
	A little	2	8.7	8.7	13.0
	Some	10	43.5	43.5	56.5
	Confident	10	43.5	43.5	100.0
	Total	23	100.0	100.0	

Confidence using mapping software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	7	30.4	30.4	30.4
	A little	3	13.0	13.0	43.5
	Some	8	34.8	34.8	78.3
	Confident	5	21.7	21.7	100.0
	Total	23	100.0	100.0	

Confidence differentiating business and manufacturing processes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A little	3	13.0	13.0	13.0

		Frequency	Percent	Valid Percent	Cumulative Percent
	Some	11	47.8	47.8	60.9
	Confident	7	30.4	30.4	91.3
	Very confident	2	8.7	8.7	100.0
	Total	23	100.0	100.0	

Confidence learning to use new software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Some	6	26.1	26.1	26.1
	Confident	15	65.2	65.2	91.3
	Very confident	2	8.7	8.7	100.0
	Total	23	100.0	100.0	

Confidence using simulation software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2.00	3	13.0	13.0	13.0
	3.00	7	30.4	30.4	43.5
	4.00	13	56.5	56.5	100.0
	Total	23	100.0	100.0	

Have you used spreadhseets?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	23	100.0	100.0	100.0

DES

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	8	34.8	34.8	34.8
	Yes	15	65.2	65.2	100.0
	Total	23	100.0	100.0	

Agents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	23	100.0	100.0	100.0

Queueing theory

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	11	47.8	47.8	47.8
	Yes	12	52.2	52.2	100.0
	Total	23	100.0	100.0	

Systems Dynamics

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	20	87.0	87.0	87.0
	Yes	3	13.0	13.0	100.0
	Total	23	100.0	100.0	

Number of simulation tools used

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	1	4.3	4.3	4.3
	1.00	17	73.9	73.9	78.3
	2.00	5	21.7	21.7	100.0
	Total	23	100.0	100.0	

Time that used simulation (Hours)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	1	4.3	4.8	4.8
	2.00	9	39.1	42.9	47.6

	3.00	1	4.3	4.8	52.4
	4.00	2	8.7	9.5	61.9
	5.00	1	4.3	4.8	66.7
	6.00	1	4.3	4.8	71.4
	8.00	1	4.3	4.8	76.2
	20.00	1	4.3	4.8	81.0
	24.00	1	4.3	4.8	85.7
	48.00	2	8.7	9.5	95.2
	60.00	1	4.3	4.8	100.0
	Total	21	91.3	100.0	
Missing	System	2	8.7		
Total		23	100.0		

Have you used templates? (how many applications?)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	1	4.3	5.9	5.9
	2.00	6	26.1	35.3	41.2
	3.00	3	13.0	17.6	58.8
	4.00	4	17.4	23.5	82.4
	5.00	2	8.7	11.8	94.1
	6.00	1	4.3	5.9	100.0
	Total	17	73.9	100.0	
Missing	System	6	26.1		
Total		23	100.0		

Q11. Did the templates make the task easier?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	1	4.3	6.7	6.7
	Yes	14	60.9	93.3	100.0
	Total	15	65.2	100.0	
Missing	System	8	34.8		
Total		23	100.0		

Q12. Did the templates make the task quicker?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	3	13.0	20.0	20.0
	Yes	12	52.2	80.0	100.0
	Total	15	65.2	100.0	
Missing	System	8	34.8		
Total		23	100.0		

Q13. Did you modify the templates?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Directly	3	13.0	23.1	23.1
	Modified	10	43.5	76.9	100.0
	Total	13	56.5	100.0	
Missing	System	10	43.5		
Total		23	100.0		

Q14 Were templates easy to modify?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	2	8.7	18.2	18.2
	Yes	9	39.1	81.8	100.0
	Total	11	47.8	100.0	
Missing	System	12	52.2		
Total		23	100.0		

Frequencies

Notes

Confidence using simulation software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A little	3	13.0	13.0	13.0
	Some	7	30.4	30.4	43.5
	Confident	13	56.5	56.5	100.0
	Total	23	100.0	100.0	

Frequency Tables. After treatment

Confidence using simulation software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Some	1	4.3	20.0	20.0
	Confident	3	13.0	60.0	80.0
	Very confident	1	4.3	20.0	100.0
	Total	5	21.7	100.0	

Confidence learning to use new software

		Frequency	Valid Percent	Cumulative Percent
Valid	Confident	4	80.0	80.0
	Very confident	1	20.0	100.0
	Total	5	100.0	

Confidence differentiating business and manufacturing processes

		Frequency	Valid Percent	Cumulative Percent
Valid	Confident	2	40.0	40.0
	Very confident	3	60.0	100.0

	Total	5	100.0	

Confidence using mapping software

		Frequency	Valid Percent	Cumulative Percent
Valid	Some	4	80.0	80.0
	Very confident	1	20.0	100.0
	Total	5	100.0	

Confidence mapping processes

		Frequency	Valid Percent	Cumulative Percent
Valid	Confident	2	40.0	40.0
	Very confident	3	60.0	100.0
	Total	5	100.0	

Confidence understanding theory

		Frequency	Valid Percent	Cumulative Percent
Valid	Confident	1	20.0	20.0
	Very confident	4	80.0	100.0
	Total	5	100.0	

Did you use the templates provided?

		Frequency	Valid Percent	Cumulative Percent
Valid	No	1	20.0	20.0
	Yes	4	80.0	100.0
	Total	5	100.0	

Did the templates make the task easier?

		Frequency	Valid Percent	Cumulative Percent
Valid	No	2	50.0	50.0
	Yes	2	50.0	100.0
	Total	4	100.0	

Did the templates make the task quicker?

		Frequency	Valid Percent	Cumulative Percent
Valid	No	2	50.0	50.0
	Yes	2	50.0	100.0
	Total	4	100.0	

Did the templates made it more explicit?

		Frequency	Valid Percent	Cumulative Percent
Valid	Yes	4	100.0	100.0

Q13. Did you modify the templates?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Directly	4	17.4	100.0	100.0
Missing	System	19	82.6		
Total		23	100.0		

were templates easy to modify?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	4	17.4	100.0	100.0

Appendix 7 Statistical analysis phase 2 section

Frequencies

	Pre-Confidence understanding theory	Pre-Confidence mapping processes	Pre-Confidence using mapping software	Pre-Confidence differentiating business and manufacturing processes	Pre-Confidence learning to use new software	Pre-Confidence using simulation software	Have you used spreadsheets?	DES	Agents	Queuing theory	Systems Dynamics	Number of simulation tools used	Time that used simulation (Hours)	Have you used templates? (how many applications?)	Q11. Did the templates make the task easier?	Q12. Did the templates make the task quicker?
Mean	2.7500	3.5000	2.8750	3.6250	3.8750	2.8750	.7500	.2500	.0000	.2500	.2500	.3750	6 8750	3.1250	1.0000	.8750
Median	3.0000	4.0000	3.0000	4.0000	3.5000	3.0000	1.0000	.0000	.0000	.0000	.0000	.0000	.0000	3.0000	1.0000	1.0000
Mode	4.00	4.00	3 00(a)	4.00	3.00	3.00	1.00	.00	.00	.00	.00	.00	.00	2.00(a)	1.00	1.00
Std. Deviation	1.28174	1.19523	1.24642	.51755	.99103	.99103	.46291	.46291	.00000	.46291	.46291	.51755	9 61305	1.45774	.00000	.35355
Variance	1.64286	1.42857	1.55357	.26786	.98214	.98214	.21429	.21429	.00000	.21429	.21429	.26786	92.41071	2.12500	.00000	.12500
Range	3.00	4.00	3.00	1.00	2.00	3 00	1.00	1.00	.00	1.00	1.00	1.00	20.00	4.00	.00	1.00
Minimum	1.00	1.00	1.00	3.00	3.00	1.00	.00	.00	.00	.00	.00	.00	.00	1.00	1.00	.00
Maximum	4.00	5.00	4.00	4.00	5.00	4.00	1.00	1.00	.00	1.00	1.00	1.00	20.00	5.00	1.00	1.00
Sum	22.00	28.00	23.00	29.00	31.00	23.00	6.00	2.00	.00	2.00	2.00	3.00	55.00	25.00	8.00	7.00
25	1.2500	3.0000	1.5000	3.0000	3.0000	2.2500	.2500	.0000	.0000	.0000	.0000	.0000	.0000	2.0000	1.0000	1.0000
50	3.0000	4.0000	3.0000	4 0000	3.5000	3.0000	1.0000	.0000	.0000	.0000	.0000	.0000	.0000	3.0000	1.0000	1.0000
75	4.0000	4.0000	4.0000	4.0000	5.0000	3.7500	1.0000	.7500	.0000	.7500	.7500	1.0000	18.7500	4.7500	1.0000	1.0000

	Q13. Did you modify the templates?	Q14 Were templates easy to modify?	Post-Confidence understanding theory	Post-Confidence mapping processes	Post-Confidence using mapping software	Post-Confidence differentiating business and manufacturing processes	Post-Confidence learning to use new software	Post-Confidence using simulation software	Did you use the templates provided?	Did the templates make the task easier?	Did the templates make the task quicker?	did the templates made it more explicit?	Q13. Did you modify the templates?	were templates easy to modify?
Mean	1.5000	.7143	2.8333	3.6667	3.6667	4.0000	4.3333	3.6667	1.0000	1.0000	.8333	.8333	1.8333	1.0000

Median	1.5000	1.0000	3.0000	4.0000	4.0000	4.0000	4.5000	4.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000
Mode	1.00(a)	1.00	3.00(a)	4.00	4.00	4.00	5.00	4.00	1.00	1.00	1.00	1.00	2.00	1.00
Std. Deviation	.53452	.48795	1.16905	.51640	.51640	.00000	.81650	1.03280	.00000	.00000	.40825	.40825	.40825	.00000
Variance	.28571	.23810	1.36667	.26667	.26667	.00000	.66667	1.06667	.00000	.00000	.16667	.16667	.16667	.00000
Range	1.00	1.00	3.00	1.00	1.00	.00	2.00	3.00	.00	.00	1.00	1.00	1.00	.00
Minimum	1.00	.00	1.00	3.00	3.00	4.00	3.00	2.00	1.00	1.00	.00	.00	1.00	1.00
Maximum	2.00	1.00	4.00	4.00	4.00	4.00	5.00	5.00	1.00	1.00	1.00	1.00	2.00	1.00
Sum	12.00	5.00	17.00	22.00	22.00	24.00	26.00	22.00	6.00	6.00	5.00	5.00	11.00	6.00
25	1.0000	.0000	1.7500	3.0000	3.0000	4.0000	3.7500	2.7500	1.0000	1.0000	.7500	.7500	1.7500	1.0000
50	1.5000	1.0000	3.0000	4.0000	4.0000	4.0000	4.5000	4.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000
75	2.0000	1.0000	4.0000	4.0000	4.0000	4.0000	5.0000	4 2500	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000

a Multiple modes exist. The smallest value is shown

	DIFUNDER	DIFMAPPI	DIFFSOFT	DIFFDIFF	DIFSOFTW	DIFUSING
Mean	.1667	.5000	1.1667	.5000	.5000	.8333
Median	.0000	.0000	1.0000	.5000	.0000	1.0000
Mode	.00	.00	.00(a)	.00(a)	.00	1.00
Std. Deviation	.40825	.83666	1.16905	.54772	.83666	.75277
Variance	.16667	.70000	1.36667	.30000	.70000	.56667
Range	1.00	2.00	3.00	1.00	2.00	2.00
Minimum	.00	.00	.00	.00	.00	.00
Maximum	1.00	2.00	3.00	1.00	2.00	2.00
Sum	1.00	3.00	7.00	3.00	3.00	5.00

25	.0000	.0000	.0000	.0000	.0000	.0000
50	.0000	.0000	1.0000	.5000	.0000	1.0000
75	.2500	1.2500	2.2500	1.0000	1.2500	1.2500

Frequency Pre-treatment Questionnaire

Pre- Confidence understanding theory

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	2	25.0	25.0	25.0
	A little	1	12.5	12.5	37.5
	Some	2	25.0	25.0	62.5
	Confident	3	37.5	37.5	100.0
	Total	8	100.0	100.0	

Pre- Confidence mapping processes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	1	12.5	12.5	12.5
	Some	2	25.0	25.0	37.5
	Confident	4	50.0	50.0	87.5
	Very confident	1	12.5	12.5	100.0
	Total	8	100.0	100.0	

Pre- Confidence using mapping software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	2	25.0	25.0	25.0
	Some	3	37.5	37.5	62.5
	Confident	3	37.5	37.5	100.0
	Total	8	100.0	100.0	

Pre- Confidence differentiating business and manufacturing processes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Some	3	37.5	37.5	37.5
	Confident	5	62.5	62.5	100.0
	Total	8	100.0	100.0	

Pre- Confidence learning to use new software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Some	4	50.0	50.0	50.0
	Confident	1	12.5	12.5	62.5
	Very confident	3	37.5	37.5	100.0
	Total	8	100.0	100.0	

Pre- Confidence using simulation software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	1	12.5	12.5	12.5
	A little	1	12.5	12.5	25.0
	Some	4	50.0	50.0	75.0
	Confident	2	25.0	25.0	100.0
	Total	8	100.0	100.0	

Have you used spreadhseets?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	2	25.0	25.0	25.0
	Yes	6	75.0	75.0	100.0
	Total	8	100.0	100.0	

DES

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	6	75.0	75.0	75.0
	Yes	2	25.0	25.0	100.0
	Total	8	100.0	100.0	

Agents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	8	100.0	100.0	100.0

Queueing theory

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	6	75.0	75.0	75.0
	Yes	2	25.0	25.0	100.0
	Total	8	100.0	100.0	

Systems Dynamics

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	6	75.0	75.0	75.0
	Yes	2	25.0	25.0	100.0
	Total	8	100.0	100.0	

Number of simulation tools used

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	5	62.5	62.5	62.5
	1.00	3	37.5	37.5	100.0
	Total	8	100.0	100.0	

Time that used simulation (Hours)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	5	62.5	62.5	62.5
	15.00	1	12.5	12.5	75.0
	20.00	2	25.0	25.0	100.0
	Total	8	100.0	100.0	

Have you used templates? (how many applications?)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	1	12.5	12.5	12.5
	2.00	2	25.0	25.0	37.5
	3.00	2	25.0	25.0	62.5
	4.00	1	12.5	12.5	75.0
	5.00	2	25.0	25.0	100.0
	Total	8	100.0	100.0	

Q11. Did the templates make the task easier?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	8	100.0	100.0	100.0

Q12. Did the templates make the task quicker?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	1	12.5	12.5	12.5
	Yes	7	87.5	87.5	100.0
	Total	8	100.0	100.0	

Q13. Did you modify the templates?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Directly	4	50.0	50.0	50.0
	Modified	4	50.0	50.0	100.0
	Total	8	100.0	100.0	

Q14 Were templates easy to modify?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	2	25.0	28.6	28.6
	Yes	5	62.5	71.4	100.0
	Total	7	87.5	100.0	
Missing	System	1	12.5		
Total		8	100.0		

Frequencies Post-treatment Questionnaire

Post- Confidence understanding theory

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	1	12.5	16.7	16.7
	A little	1	12.5	16.7	33.3
	Some	2	25.0	33.3	66.7
	Confident	2	25.0	33.3	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

Post- Confidence mapping processes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Some	2	25.0	33.3	33.3
	Confident	4	50.0	66.7	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

Post- Confidence using mapping software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Some	2	25.0	33.3	33.3
	Confident	4	50.0	66.7	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

Post- Confidence differentiating business and manufacturing processes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Confident	6	75.0	100.0	100.0
Missing	System	2	25.0		
Total		8	100.0		

Post- Confidence learning to use new software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Some	1	12.5	16.7	16.7
	Confident	2	25.0	33.3	50.0
	Very confident	3	37.5	50.0	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

Post- Confidence using simulation software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A little	1	12.5	16.7	16.7
	Some	1	12.5	16.7	33.3
	Confident	3	37.5	50.0	83.3
	Very confident	1	12.5	16.7	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

Did you use the templates provided?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	75.0	100.0	100.0
Missing	System	2	25.0		
Total		8	100.0		

Did the templates make the task easier?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	75.0	100.0	100.0
Missing	System	2	25.0		
Total		8	100.0		

Did the templates make the task quicker?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	1	12.5	16.7	16.7
	Yes	5	62.5	83.3	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

did the templates made it more explicit?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	1	12.5	16.7	16.7
	Yes	5	62.5	83.3	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

Q13. Did you modify the templates?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Directly	1	12.5	16.7	16.7
	Modified	5	62.5	83.3	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

were templates easy to modify?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	75.0	100.0	100.0
Missing	System	2	25.0		
Total		8	100.0		

Difference between Post and Pre Questionnaires for Questions 1 to 6. (Confidence level using simulation and mapping tools)

There is evidence of growing confidence in mapping processes, using mapping software, differentiating between manufacturing process and business processes, and using simulation software. Not a big difference is perceived in the understanding of simulation concepts or learning to use new software.

1.Understanding the theory behind simulation?

DIFUNDER

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	5	62.5	83.3	83.3
	1.00	1	12.5	16.7	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

2. Mapping processes in paper

DIFMAPPI

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	4	50.0	66.7	66.7
	1.00	1	12.5	16.7	83.3
	2.00	1	12.5	16.7	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

3. Using process mapping software (e.g. Visio)

DIFFSOFT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	2	25.0	33.3	33.3
	1.00	2	25.0	33.3	66.7
	2.00	1	12.5	16.7	83.3
	3.00	1	12.5	16.7	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

4. Differentiating business processes from manufacturing processes

DIFFDIFF

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	3	37.5	50.0	50.0
	1.00	3	37.5	50.0	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

5. Learning to use new software?

DIFSOFTW

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	4	50.0	66.7	66.7
	1.00	1	12.5	16.7	83.3
	2.00	1	12.5	16.7	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

6. Using simulation software?

DIFUSING

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	2	25.0	33.3	33.3
	1.00	3	37.5	50.0	83.3
	2.00	1	12.5	16.7	100.0
	Total	6	75.0	100.0	
Missing	System	2	25.0		
Total		8	100.0		

Appendix 8 Examples of papers resulting from this research

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