# A Process Framework For Selecting Supply System Architecture In Manufacturing Supply Chains And Networks

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June, 2009

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## Thesis Summary

The thesis delivers a process framework for selecting supply system architecture for manufacturing supply chains and networks. The process framework comprises three phases, as follows: scope the supply chain/network; identify the options for supply system architecture and select supply system architecture. It facilitates a structured approach that analyses the supply chain/network contextual characteristics, in order to ensure alignment with the appropriate supply system architecture. The process framework was derived from comprehensive literature review and archival case study analysis. The review led to the classification of supply system architectures according to their orientation, whether integrated; partially integrated; co-ordinated or independent. The classification was combined with the characteristics that influence the selection of supply system architecture to encapsulate the conceptual framework. It builds upon existing frameworks and methodologies by focusing on structured procedure; supporting project management; facilitating participation and clarifying point of entry.

The process framework was initially tested in three case study applications from the food; automobile and hand tool industries. A variety of industrial settings was chosen to illustrate transferability. The case study applications indicate that the process framework is a valid approach to the problem; however, further testing is required. In particular, the use of group support system technologies to support the process and the steps involving the participation of software vendors need further testing. However, the process framework can be followed due to the clarity of its presentation. It considers the issue of timing by including alternative decision-making techniques, dependent on the constraints. It is useful for ensuring a sound business case is developed, with supporting documentation and analysis that identifies the strategic and functional requirements of supply system architecture. The focused analysis can be considered valid to overcome the need to focus on functionality, whilst considering compatibility and implementation issues.

## Keywords

Supply chain management; networks; enterprise systems; decision-making

To my late grandmother, Barbara Ellen Belgrove

# Acknowledgements

Firstly, I would like to thank Dr Doug Love for supervising me throughout the PhD and for mentoring my research career. I would like to acknowledge my family and friends for their constant support and encouragement throughout my journey towards a PhD. In particular, I would like to wholeheartedly thank my parents, Susan and JD Benton and sister, Janis Benton, who have always there for me, even during the most difficult of times. I would also like to thank certain friends in particular, Becky; Chris; Dheeraj; Helen; Joanna; Julia; Mario; Miles; Rachael; Siobhan; Tammy and Tony for their support and kindness.

I would also like to thank my research collaborators, who have also enriched the research process, provided inspiration and healthy debate. Particularly, I would like to thank the following members of the FUSION team from the University of Liverpool: Dr Julian Coleman; Dr Jessica Ho; Professor Denis Kehoe and Dr Andrew Lyons. The FUSION team provided me with vital industrial access for the case study applications. I would also like to acknowledge Dr Pavel Albores; Dr Peter Ball; Dr Stephen Disney; the late Dr Nelson Tang and Dr Don Taylor, who have helped me on my research journey.

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# Chapter 1 - Introduction

The thesis focuses on the development and testing of a process framework for selecting supply system architecture. This chapter focuses on introducing why selection of supply system architecture was considered to be important by exploring the research background. Within the field of supply chain management, considerable attention has been paid to managing the flow of information between parties in the supply chain/network. However, the selection of appropriate supply system architecture for managing the flow of information has been difficult. Three research objectives are articulated to address the problem of selecting supply system architecture: firstly, to identify the options and issues involved; secondly, to develop a process framework that guides the selection and thirdly, to test the framework.

The development of a process framework is justified as existing frameworks have various deficiencies, including focusing on single enterprise, rather than supply chain/network; focusing on a particular type of software and not considering the need for participation in the decision-making. Case study application was the main methodology used in the thesis to test the process framework; however, archival case study analysis was also used in the development. The terms "supply chain/network" and supply (chain) management are defined. The thesis is delimited in considering manufacturing supply chains/networks and focusing on design and selection of supply system architecture, rather than the whole process through to deployment and maintenance.

## 1.1 Research background

The term supply chain management (SCM) has been used since the early 1980's (Houlihan, 1985), however, due to the multi-disciplinary nature of SCM, definitions vary. There is convergence on the concept that supply chains/networks should be viewed as a whole system and that the flows between the parts of the system need to be managed (Lummus and Vokurka, 1999, Mentzer et al., 2001). This paradigm of managing interrelated flows and operating as a "unified system" was raised much earlier (Forrester, 1958). SCM is also viewed as an evolution from the concept of physical distribution management, into logistics and then into SCM (Gattorna and Walters, 1996). Despite the historical perspective, SCM still remains an emerging discipline (Harland, 2006), hence, contributions can be made to the coherence of this field through more high quality theoretical development and discussion.

There has been considerable attention paid to how to manage materials and information flows in a supply chain (Forrester, 1958, Forrester, 1961, Lee et al., 1997). The effective management of materials and information flow across supply chain/network continues to be a strategic issue (Akkermans et al., 1999, Power, 2005). Utilising information systems and technologies to manage supply chain/network flow can create significant benefits for a supply chain/network (e.g. Hendricks et al., 2007, Mabert et al., 2000). There are a wide array of commercially available systems for managing materials and information flow (AMR Research, 1998). The vast number of systems available and the conflicting paradigms for managing the flow in a supply chain/network make selecting supply system architecture difficult.

Utilising supply system architectures can generate significant benefits (Buxmann et al., 2004), but successful deployment is fraught with problems (Davenport, 1998). The majority of research indicates implementation as the main issue and a number of frameworks exist to manage systems implementation (e.g. Al-Mashari and Al-Mudimigh, 2003, Vogt, 2002, Yusuf et al., 2004). However, many of the issues raised by the research into implementation are actually concerned with the design and selection of supply system architecture, which needs further research exploration (e.g. Hecht, 1997, Wei and Wang, 2004). Hence, the focus of the research is to develop a process framework for designing or selecting supply system architecture for manufacturing supply chains/networks.

## 1.2 Research aim and objectives

The overall aim of the research is to de-mystify these solutions and develop a process framework to guide the selection of supply system architecture. The literature review stimulated the need for research in this area, specifically, previous work focused on considering implementation; optimisation and management of supply systems (Botta-Genoulaz et al., 2005), much less research was focused on the decision process. Hence, the research would focus on making a contribution by exploring supply system architecture selection decision.

The research aim was achieved by focusing on three research objectives; each objective is further specified into a series of research questions. The problem of selecting supply system architecture hinges on the evolution of different supply systems architectures to improve the management of supply chain/network flow (Biehl and Kim, 2003, Ho, 2002, Taylor, 2004). The evolution of different solutions has made selection difficult due to the overlapping functionality (Albright, 2004, Anon, 2006, Buxmann et al., 2004, Nairn, 2003, Taylor, 2004). Price/implementation costs (Buxmann et al., 2004) and compatibility within the company (Buxmann et al., 2004) are also important factors in selecting supply system architecture. Hence, firstly, the issues in selecting supply architecture would need to be determined (O1). This objective required exploration of the array of systems available (Q1 a) and the problems encountered in selection (Q1 b).

The second objective was to develop the process framework (O2). The process framework needs to pay due attention to Buxmann et al's (2004) identification of compatibility with the company (or supply chain/network) as an important factor and the other issues in selection raised by a number of authors (Al-Mashari and Al-Mudimigh, 2003, Al-Mashari and Zairi, 2000b, Bernroider and Koch, 2001, Cliffe, 1999, Hecht, 1997, Laughlin, 1999, Mandal and Gunasekaran, 2003, Rao, 2000, Wei and Wang, 2004). Hence, this second objective, explores the contextual issues for supply chains/networks (Q2 a), how supply system architectures have been selected (Q2 b), as well as considering the techniques available for analysis and decision making (Q2 c).

The final objective focuses on testing the resulting process framework (O3). The testing utilises Platts' criteria (1993) and involved verifying whether the process framework was feasible (Q3 a), how easy it was to follow the process framework (Q3 b), whether it was useful for making the decision (Q3 c) and also, whether it approaches validity (Q3 d). The research objectives, research questions and the sections in the thesis that address them are articulated in table 1.1.

**Table 1. 1 The research objectives and questions addressed by the thesis**

| Research objectives and questions | Addressed in |
|---|---|
| O1: To identify the options and issues in selecting supply system architecture | Chapters 2, 4 and 5 |
| Q1 a. What types of system are available to support supply chain/networks? | Chapter 2 |
| Q1 b. Why is selecting supply system architecture difficult? | Chapter 4 and Chapter 5 |
| O2: To develop a process framework to support the selection of the overall supply system architecture | Chapter 6 |
| Q2a. What are the contextual considerations for selecting supply system architecture? | Chapter 2 |
| Q2 b. How have supply system architectures been selected? | Chapters 4 and 5 |
| Q2 c. What analytical techniques can be used to select supply system architecture? | Chapter 4 |
| O3: To test the ability of the process framework to support the design of the overall supply system architecture | Chapters 7 and 8 |
| Q3 a. Could the process framework be followed (feasibility)? | Chapter 7 and 8.2 |
| Q3 b. How easily can the process framework be followed (usability)? | 8.3 |
| Q3 c. Was the process framework useful for designing supply system architecture (utility)? | 8.4 |
| Q3 d. How does the resulting process framework support the selection of supply system architecture (approach validity)? | 8.5 |

# 1.3 Justification for the research focus

The literature review process revealed that the problem of selecting a supply system arises due to the number of systems available and the overlap in functionality (Albright, 2004, Biehl, 2005) and issues in implementation (Al-Mashari and Zairi, 2000b, Hecht, 1997) and compatibility (Buxmann et al., 2004). Some frameworks do exist that begin to explore how a supply system should be selected (e.g. Blackwell et al., 2006, Sarkis and Talluri, 2004, Wei et al., 2005) However, these have tended to focus on a particular type of software (Albright, 2004, Hecht, 1997) or on single enterprises (e.g. Blackwell et al., 2006, McGarrie, 1993). The other shortcoming in existing frameworks is that they consider single enterprises, rather than the supply chain/network context, (e.g. Blackwell, 2003, Lee, 1998, Light et al., 2001). A number of frameworks also neglect the need for participation by the different parties involved in the supply chain/network (Biehl, 2005, Ho, 2002, Sarkis and Talluri, 2004, Sharifi et al., 2006).

Furthermore, all frameworks focused on using particular decision-making techniques, for example, mathematical modelling (Biehl, 2005) or Analytical Hierarchy Process (AHP) (e.g. Sarkis and Sundarraj, 2001, Wei et al., 2005). However, different decision making techniques have different implications on time, cost and also the quality and depth of the analysis. Therefore, different decision-making techniques could be employed to select supply system architecture dependent on the scenario. Hence, the research focuses on developing a process framework for selecting a supply system, which considers the variety of systems available; and can be used for supply chains through to complete supply networks. The process framework also exploits the most appropriate decision-making tool, depending on the constraints.

## 1.4 Research Methodological Programme

A deductive approach was taken to develop the process framework for selecting supply system architecture, in order to build upon the existing research that has been conducted (Harland, 2006). The need to build on existing research by following a deductive approach endorses the comprehensive literature review, which was utilised to determine the research aims, objectives and underlying research questions. Specifically, the literature review steered the research journey towards the development of a process framework for selecting supply systems architecture for manufacturing supply chains. The literature review identified the systems architecture available (Q1a); and the contextual issues in selecting supply systems (Q 2a), aiding the development of the process framework.

A five stage research programme was developed to meet the aims and objectives of the research, which included a review; archival case study research; framework development; case study application and a discussion. The main research method used was case study application; however, a review of existing frameworks and tools and archival case study analysis were also employed to develop the process framework. The first stage of the research process was to review the existing frameworks and tools. This review included analysing the different frameworks based on Platts (1994) criteria for successful strategy formulation methodologies and identifying potential tools to aid the decision-making process.

The second stage was to conduct the archival case study analysis to explore why the selection process is difficult (Q 1b) and how supply system architecture has been selected (Q2b). The archival case study analysis aided achieving the second objective, to develop the process framework. The case approach was deemed appropriate for addressing the research questions posed (Yin, 2003), despite its controversy (Dyer and Wilkins, 1991). Archival case studies existed in the literature, this use of such secondary sources is supported in the fields of supply chain management (Sachan and Datta, 2005); operations management (Lewis, 1998) and information systems (Jarvenpaa, 1991). An embedded multiple-case research design was followed (Yin, 2003). The third stage was to develop a process framework based on list of requirements derived from the review (stage 1) and the archival case study analysis (stage 2). The framework was developed using the classic beer game (Sterman, 1989) as a pilot or test case.

The fourth stage was the case study application, which involved applying the process framework to three industrial cases. Applying the process framework was the preferred research method, as the analysis would be contextually rich and exploratory. Three cases were selected to achieve literal replication (Yin, 2003) to show that the process framework can be considered feasible (Q3a); usable (Q3b); useful (Q3c) and approach validity (Q3d) (Platts, 1993). Two of the cases used were of external supply chains (Harland, 1997): a snack manufacturer maize supply chain and a luxury automobile seat set supply chain. The snack manufacturer supply chain data was collected by the Dynamic Operations Management Across the Internet (DOMAIN) research group and published in Ho (2002). The luxury automobile seat set supply chain data was available through collaborating with the FUSION research group, who collected the data. The final case study application is of network (Harland, 1997) scope and is based on a business simulation game used by Aston University and originally developed with Lucas (Parker and Mackness, 1986). The fifth and final stage was to conduct a discussion analysis of the feasibility; usability; utility and degree of validity of the process framework. Due to the fact that the process framework is based on three case studies alone, it approaches validity, however, it needs further testing.

## 1.5 Outline of the thesis

The thesis is organised into nine chapters and four main sections, as depicted in figure 1.1. Following this introduction is the literature review (chapter 2) which reviews the current research on the issue of supply system architecture selection to reveal a research gap. The research programme for addressing this gap follows (chapter 3). The first two research stages are described in the next chapters: reviewing current frameworks (chapter 4) and the archival case study analysis (chapter 5). These chapters enable a list of requirements to be made to enable the process framework to be developed (chapter 6). The third section is the application section that conducts preliminary testing of the process framework through case study applications (chapters 7-8). The final section concludes the thesis and indicates the contribution and further implications of the process framework (chapter 9). Briefly, the content of each chapter is summarised, as follows.

Chapter two is a literature review that focuses on demonstrating the gap in the literature of considering the selection of supply system architectures. It first positions the importance of information systems and technologies within the field of supply (chain) management. The literature review then explores the main theories and approaches for managing flow of materials and information in the supply chain/network. It expands on practitioners' identification that a wide array of solutions exists (Nairn, 2003) and aligns the supply system architectures available to the different perspectives in the literature (Hewitt, 1999, Hewitt, 2001, Kehoe and Boughton, 2001, Wong and Boon-itt, 2006), hence beginning to develop the conceptual framework. It also discussed the practitioner issue of overlapping functionality (Albright, 2004, Taylor, 2004); which has been considered in academic literature (Biehl, 2005, Biehl and Kim, 2003, Ho, 2002). Attention is then paid to the supply chain/network context, by reviewing different classifications to identify supply chain/network characteristics that the conceptual framework must take into account. This completes the conceptual framework, by including three categories of characteristics: product and end customer; network and geographical and relationships that could influence the effectiveness of the supply system architecture. The chapter concludes by clarifying the research gap and the aims and objectives of the research programme.

Chapter three focuses on justifying and explaining the chosen deductive approach to developing a process framework for selecting supply system architecture. The five stage research process is outlined, which included, firstly, the review of existing frameworks and tools; secondly, the archival case study analysis; thirdly, the process framework development; fourthly, the case study applications and fifthly, the discussion analysis. The main method used was the case study application, which used case study research protocols and hence, the cases were carefully selected with external chain and network depth (Harland, 1997). The case study selection and data collection methods are discussed. The reliability of the case study data is improved as triangulation is apparent. The validity of applying case study data to the process framework is also discussed.

The fourth chapter considers how the design and selection process could be conducted, by critiquing current frameworks and methodologies and reviewing decision-making tools available. A comprehensive review of the contributions that have been made towards the development of a process framework for selecting a supply system, through considering Platts (1994) and Platts et al (1996) 4 Ps: procedure; participation; project management and point of entry. It is revealed that none of the existing frameworks sufficiently cover the four areas. The remainder of this chapter focuses in on the tools available to help with the selection and design process. This review identifies the potential to use group decision room; analytical hierarchy process (AHP); quality function deployment (QFD) and simulation.

Chapter five then utilises empirical data, specifically, the archival case studies that have been disseminated by other researchers from the field (e.g. Bhattacherjee, 2000, Yusuf et al., 2004). The analysis revealed that consultants predominantly conducted the design and selection process. Hence, there is some indication of what happened, e.g. setting goals; business process alignment; existing systems management and software selection, but not how to actually design or select supply system architecture. This chapter concludes by detailing the requirements of a process framework, derived from the review (chapter 4) and the archival case study analysis detailed in chapter 5.

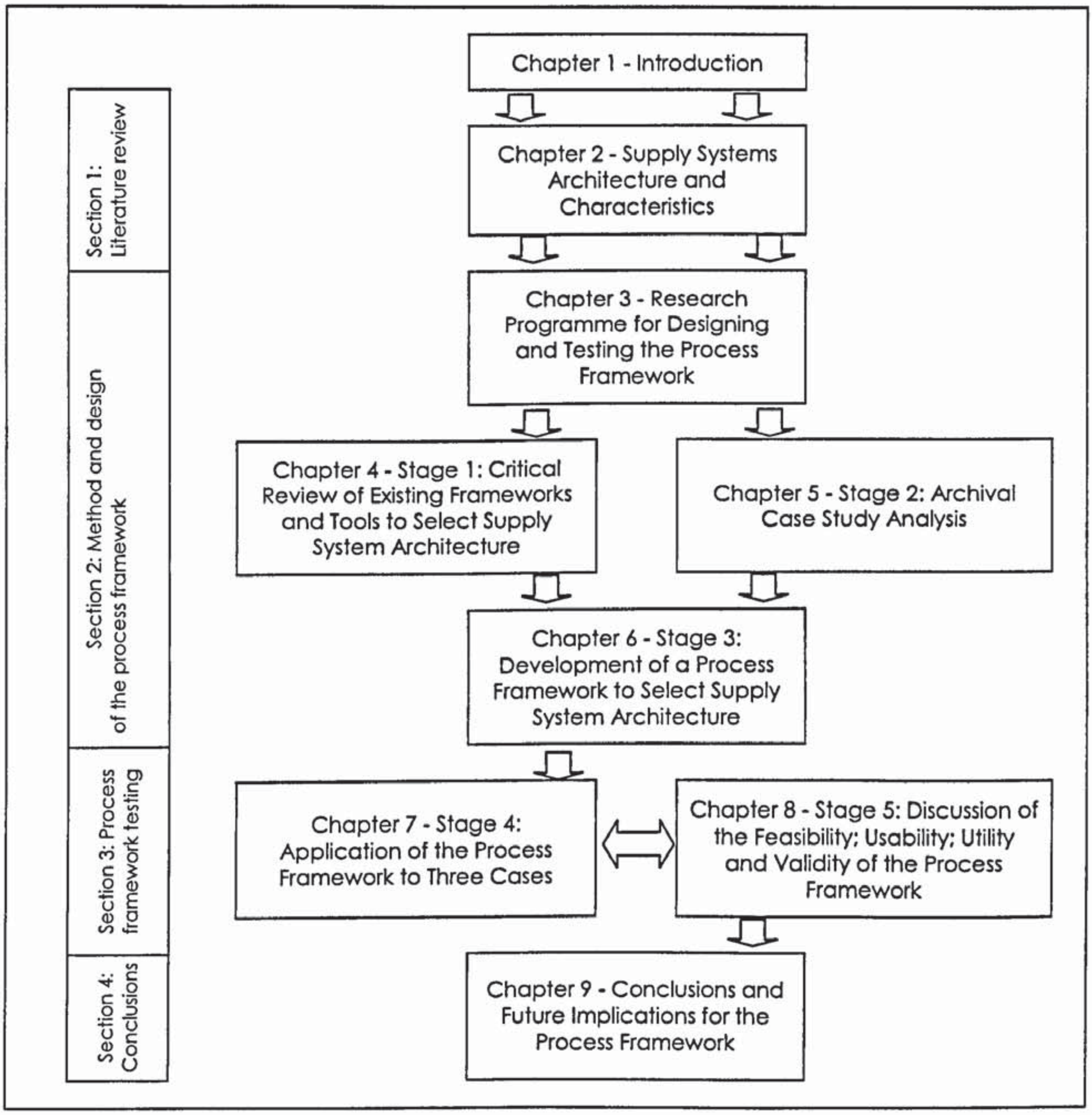
Chapter six describes the resulting process framework, which was derived from the archival case study analysis and developed according to the requirements developed in chapter 5. It focuses on developing the procedure based on building from the previous work on selecting supply system architecture in chapter 4. It also focused on using an appropriate analytical tool, dependent on time; cost and quality constraints. The result is a process framework consisting of three phases: scope the supply chain/network; identify options for supply systems architecture; select supply system architecture. The chapter explains how these phases were realised from the requirements that arose from the theoretical underpinnings (explored in chapters 4-5). Once, a supply system architecture is selected it can then be implemented, following the guidance in existing literature (e.g. Al-Mashari et al., 2003).

Chapter seven details how the process framework was applied to each of the three case studies, to demonstrate the feasibility in depth. The process framework phases are applied to each case and a summary of the analysis and outputs are given. The snack manufacturer maize supply chain is outlined first, followed by the luxury automobile seat set supply chain and finally the drill manufacturer supply chain. The application of the process framework reveals that the steps guide the process and ensure that outputs are generated to develop a sound business case for supply system architecture selection. The actual decision making process in selecting supply system architecture for a supply chain/network is also demonstrated, however the vendor demonstrations and software selection steps were not applied, as software vendors could not participate during the initial testing.

Chapter eight focuses on demonstrating the feasibility; usability; utility and validity of the process framework by analysing the case study applications. The feasibility is demonstrated in chapter seven; however, this chapter discusses how information is made available; how timing issues are handled with project management techniques and quicker analysis options and the use of group decision making and other simple tools and techniques to ensure participation. Usability is discussed in this chapter to demonstrate the ease with which the process framework can be followed, including the clarity of structure; phases and steps and terms used. Reflection is made on the ease of use and appropriateness of overall process framework and the decision making tools. The utility or usefulness of the process framework is discussed from the perspectives of industry; practitioners and academics and considering how the process framework facilitates the process.

Chapter nine concludes the work, by demonstrating the original contribution of the development and testing of the process framework for selecting supply system architecture. The process framework includes three further advances within it. Firstly, the spectrum to classify supply system architectures from integrated through to independent (used in Step 2b). Secondly, the characteristics diagram which is derived from the conceptual framework and used to define supply chains in Step 1b. Thirdly, the flow chart for selecting appropriate decision-making technique, according to the constraints, that is used in Step 3a. However, the testing of the framework is a limitation, specifically; there has been no testing of: dynamic industrial contexts; the group support system technologies or the two steps that involved software vendor participation. Further research includes testing the process framework and developing it for application in service supply chains/networks.

**Figure 1. 1 Outline of the thesis**




## 1.6 Delimitations of scope and definitions

The research focuses on manufacturing supply chains/networks, rather than retail and the service sector. Hence, the thesis focuses on the chains or networks of entities involved in getting a product (rather than delivering a service) to a customer. A debate in terminology also exists around the word "demand" to replace the word "supply" to highlight the need to manage from the end-customer backwards

(Childerhouse et al., 2002, Frohlich and Westbrook, 2002, Hewitt, 2001, Vollmann et al., 2000). Other debates exist around using the word "value," to replace the word "supply" carrying forward Porter's concept of value chain (Porter, 1985), into the wider network perspective (Andrews and Hahn, 1998). In order to avoid confusion from the different terminology origins, the thesis uses the words "supply chains/networks," which are defined as:

> "... entities directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to the customer." (Mentzer et al., 2001, pg. 4)

For a thorough review of the debates around defining supply chains and SCM, see Lummus and Vokurka (1999) and Mentzer et al. (2001). The above definition uses the word "entities," rather than organisations, and hence, is considered appropriate to encompasses all of Harland's (1997) systems levels. The four systems levels are considered to be: 1) internal processes within an organisation; 2) a dyadic, two-party relationship; 3) an external total chain: raw material to ultimate end customer; or to 4) a complete network based on a focal firm (Harland, 1997). The definition also acknowledges multi-directional flow; previous definitions often stated the flow of materials as feed-forward and information as feedback (Stevens, 1989). However, multi-directional flow is important from an information collaboration viewpoint (Cassivi, 2006) and because of the rise in reverse logistics activity for meeting environmental concerns and legislation for re-using and recycling materials (Stock, 1998).

Mentzer et al (2001) state that the phenomenon of supply chain/network exists in business, but the term SCM refers to overt efforts to manage this process. They go on to classify definitions of supply chain management into three categories: a management philosophy; implementation of a management philosophy and a set of management processes. Hence, the working definition of "supply management" is as follows:

> "conscious effort to manage the interrelated flow processes within either an internal supply chain, a dyadic relationship, external chain or network, as a whole system"

This definition reflects the further debate over the terminology, notably the use of the word "network" over "chain" in order to make the concept wider and more strategic

(Lamming et al., 2000, Mills et al., 2004). The definition reinforces the view taken in the thesis that the boundary of supply chain/network can be drawn depending on the focus of investigation (Harland et al., 2004). Hence, to avoid confusion, in this thesis, the "chain" and "network" have been removed, which has also been occurring in the literature (Harland, 2006, Lamming et al., 2000, Mills et al., 2004). Furthermore, the definition does not specifically mention which functions or processes are involved or which organisations, due to the further conflict in scoping the concept.

The Supply Chain Council (2006) identifies five main processes: Plan; Source; Make; Deliver and Return (Supply Chain Council, 2006). However, other models include further processes, e.g. customer relationship management and customer service (Cooper et al., 1997). The working definition considers the term supply management to refer to conscious effort to manage any of Harland's (1997) four systems levels, from internal processes within an organisation through to a complete network (Harland, 1997). However, the thesis focuses primarily on external supply chains and supply networks; with less emphasis on single enterprises or dyadic links. The reason for this focus is the assumption that external chains and networks are more complex and due to the contemporary importance of this emerging discipline (Harland, 2006, Lamming et al., 2000, Mills et al., 2004).

The term supply system architecture refers to the information systems and technologies used to manage the flow of materials and information in supply chains/networks. The thesis considers supply system architectures as a supportive part of any supply chain/network strategy and not a strategy in their own right. The thesis focuses on selection and design issues of supply system architectures, rather than the whole process of deploying supply system architecture through to implementation and eventual maintenance and review. The delimitation of actual implementation is based on the assumption that the issues raised in implementation phase are considered to be wider managerial issues, e.g. change management, which are not the primary focus in the emerging discipline (Harland, 2006) of supply management.

## 1.7 Conclusion

The aim of the research is to develop a process framework for selecting supply system architecture, in response to the need for clarification due to the array of systems available and their overlapping functionality (Albright, 2004, Biehl, 2005). Research into implementation has highlighted a number of issues that are related to design and selection of supply system architecture (e.g. Al-Mashari and Al-Mudimigh, 2003, Vogt, 2002, Yusuf et al., 2004). The existing frameworks available do not consider the full array of options available (Albright, 2004, Hecht, 1997) or are focused on single enterprises (e.g. Blackwell et al., 2006, McGarrie, 1993) or do not consider the participation (e.g. Ho, 2002) aspects. The process framework was developed by building on existing research from a comprehensive literature review and archival case study analysis. The process framework was then applied to three case studies to determine its feasibility and conduct initial testing on further feasibility; usability; utility and validity issues. Therefore, the remainder of the thesis explores the formulation and application of the process framework.

# Chapter 2 - Supply Systems Architecture and Characteristics

This chapter focuses on positioning the selection of supply systems architecture as an important gap in supply chain/network research, through reviewing the current literature. This review was not intended to broadly explore and critique supply chains/networks or supply management. Moreover, the review focused on the key issue of how to select systems architecture to suit a particular supply chain or network. The iterative literature review process hinged on exploring a number of interrelated concepts and a two chapter structure was formed to cover these topics, as shown in figure 2.1.

The first section (2.1) of the literature review sets the scene with an overview of the theory of ***supply chains, networks and management (2.1)*** (from a manufacturing perspective, c.f. section 1.6 in chapter 1) and summarises the parent theory: ***systems theory***[1] and the ***bullwhip effect (2.1)*** within the supply chain/network. Many authors discuss the lack of clarity in defining supply (chain) management, due to the fact that it has been considered in many different fields (Croom et al., 2000, Harland et al., 1999, Harland et al., 2004, Lamming et al., 2000). However, there is some convergence on concepts of being part of a system and the need to manage flows (Håkansson and Snehota, 1995, Lummus and Vokurka, 1999, Mentzer et al., 2001). There has been considerable research exists that supports the imperativeness of managing supply flows in manufacturing supply chains or networks, specifically the flows of materials and information to reduce the bull whip effect (Lee et al., 1997a, Lee et al., 1997b, Towill, 1996a). Supply system architecture can be considered to reduce the bullwhip effect and for process improvement; cost reduction; speed and market growth (e.g. Digital Union, 2001, Hendricks et al., 2007). Hence, the section concludes by highlighting the need for research into supply system architecture.

The second section (2.2) of the literature review focuses on the different ***supply system architectures (2.2)*** and ***e-business models (2.2)***, which are available to manage the flow and create benefits for the supply chains or networks. E-business has been prominent and pervasive in the supply chain/network literature (Sarkis and Talluri, 2004, Sharifi et al., 2006). Therefore, e-business models are included in this review as they are used to co-ordinate the flow of materials between organisations in a supply chain/network. The selection of supply system architecture continues to be a difficult and complex decision for manufacturing supply chains/networks due to the array of systems available (Nairn, 2003) and the overlap in functionality that the systems provide (Taylor, 2004).

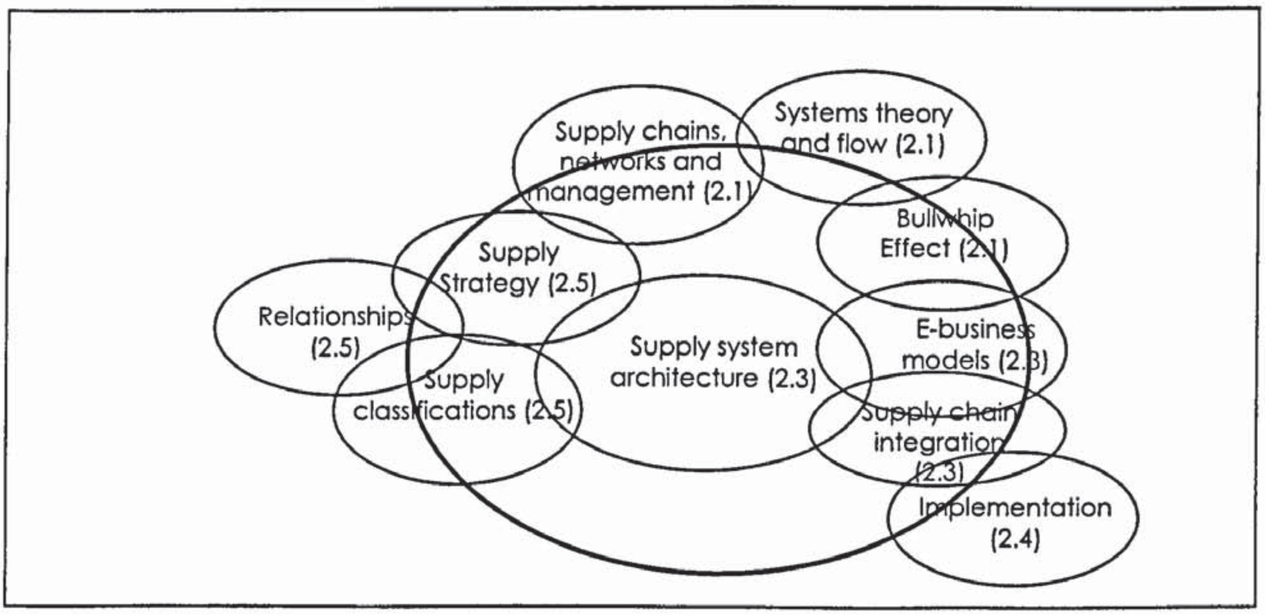
In the third section (2.3), current classifications of these supply system architectures (2.3) are then critiqued. A classification of supply system architectures, ranging from co-ordination, through co-operation to integration (2.3), is presented. A new classification is developed to clarify the different options available, it utilises the different paradigms for managing supply chain/network flows: co-ordination and integration (Wong and Boon-itt, 2006). The classification categorises supply system architectures, ranging from independence; co-ordination; partial integration; and integration.

Section four (2.4) focuses on the managerial issues that arise in ***supply system implementation*** **(2.4)** have been paid considerable attention by researchers (e.g. Al-Mashari and Al-Mudimigh, 2003, Mandal and Gunasekaran, 2003). This review reveals general issues of managing change; good communication and project management (Al-Mashari and Al-Mudimigh, 2003). It also reveals, more specifically, that when designing and selecting supply systems architecture it is important to have a clear business case; that business processes and existing systems must be managed and software carefully selected (Al-Mashari and Zairi, 2000a).

The fifth section (2.5) of the review focuses on identifying the contextual issues in selecting supply systems architectures by reviewing ***supply strategy (2.5)*** developments, before turning to ***classifications of supply chains/networks (2.5)***, including the nature of ***supply relationships (2.5)***, and ***networks (2.5)***. The issue of ensuring compatibility with the company is also evident (Buxmann et al., 2004). The chapter addresses the compatibility issue, by considering the contextual supply chain/network issues to explore the scope that supply system architectures need to support. Firstly, the impact the 21st century consumer has had on supply strategies is explored by outlining

Fisher's seminal dichotomy of innovative versus functional products. Fisher's (1997) work sparked further consideration of lean and agile manufacturing strategies and the paradigm of leagile was introduced (Naylor et al., 1999). The DWV³ (Christopher and Towill, 2000a) classification of supply chains/networks was developed. DWV³ was designed to focus on key aspects for applying lean, leagile or agile strategies, hence further characteristics are important when designing the supply system architecture to support these strategies. To this end, the conceptual framework was developed that seeks to clarify the business case for selecting supply system architecture by including the context of the selection decision. The conceptual framework proposes that the appropriateness of independent; co-ordinated and integrated supply system architectures depends on the combination of DWV³, as well as network (Beamon and Chen, 2001, Harland, 1997, Lamming et al., 2000); geographical (Bolstorff and Rosenbaum, 2003) and relationship (Håkansson and Snehota, 1982, Håkansson and Snehota, 1995) characteristics. The literature review concludes by summarising the gap in the literature and how the research objectives were derived from this literature.

**Figure 2. 1 The key concepts reviewed and the boundary of the literature review**



## 2.1 Theoretical context of supply system architecture

The term supply chain management (SCM) has been used since the early 1980's (Houlihan, 1987). Ambiguity exists in defining both SCM and supply chains (Croom et al., 2000, Lummus and Vokurka, 1999, Mentzer et al., 2001). The debate over terminology used to describe the concept was explored in section 1.6. One of the notable debates raised is over the use of the word "network" over "chain" which emphasises the more strategic aspects (Lamming et al., 2000, Mills et al., 2004). Considering this wider network view, it is important to note that Lummus and Vokurka (1999) and both Mentzer et al's (2001) efforts to define the concepts of supply chain and SCM arise out of the field of logistics and operations management. However, according to Lamming et al (2000) the area of supply networks has roots in two distinctive research streams: descriptive and prescriptive.

The prescriptive research into supply networks emerges from the fields of strategic management, operations management and logistics (Lamming et al., 2000). SCM is often viewed as an evolution from the concept of physical distribution management, into logistics and then into SCM (Cooper et al., 1997, Gattorna and Walters, 1996). The descriptive research stream emerges from the Industrial Marketing and Purchasing (IMP) group (Lamming et al., 2000). The IMP group have developed models for understanding industrial networks as inter-connected actors, activities and resources (Håkansson and Snehota, 1982, Håkansson and Snehota, 1995).

These descriptive and prescriptive research streams are not the only theoretical origins of the supply chain/network concept. Harland et al (1999) also include the service management area to externalise the customer orientation origins of supply management, but acknowledge that suppliers are neglected (Harland et al., 1999). Croom et al (2000) and Harland et al (2004) also include the body of literature in organisational behaviour as an important contributor to the concept of supply chain management (Croom et al., 2000) and supply networks (Harland et al., 2004), respectively. Organisational behaviour and sociology consider the embedded ness of organisations within networks, identifying that markets and hierarchies are not the only organisational forms (Podolny and Page, 1998). Croom et al (2000) take a particularly broad multi-disciplinary approach to the origins of supply chain management, including also contingency theory and best practices among others.

The re-naming (described in section 1.6) and multi-disciplinary origins of the concept make it complex to define; however, there is some congruence in views. Firstly, the paradigm of being involved in a wider system or network perspective is important (Håkansson and Snehota, 1995, Lummus and Vokurka, 1999, Mentzer et al., 2001). Secondly, the concept of managing the flows or links between the entities or actors of the system (Håkansson and Snehota, 1995, Lummus and Vokurka, 1999, Mentzer et al., 2001). This paradigm of managing interrelated flows and operating as a "unified system" in supply chains/networks was raised much earlier by Forrester in 1958.

Although the concept has historical roots, this lack of clarity in supply management remains endemic. Hence, Harland (2006) conclude that supply management is an emerging discipline and, that contributions can be made to the coherence of this field through more high quality theoretical development and discussion (Croom et al., 2000, Harland et al., 2006). Despite the relative infancy of the discipline, systems theory is long established and within supply chains/networks, the phenomenon of the bullwhip effect is not disputed.

### 2.1.1 Systems theory and systems thinking

Systems theory (Von Bertalanfy, 1950) considers that system boundaries can be drawn to define the scope of the system, in supply chain/network research; Harland's (1997) classification of systems levels is frequently referred to (c.f section 1.6). Another key aspect is the concept of "holism", that the sum of the whole is greater than the parts (Senge, 1990). Emergent behaviours are another key aspect, which are behaviours that could not be predicted by looking at each part separately (Senge, 1990), hence the connections between parts of the system are important. Within the supply chain/network disciple, the idea of managing cross-organisational (or internal supply chain) processes and flows (or *connections*) was brought to the fore by Forrester's work in the late 1950s and early 1960s (Forrester, 1958, Forrester, 1961). Forrester concluded that "manufacturing, finance, distribution, organization, advertising and research have too often been viewed as separate skills and not as part of a unified system" (Forrester, 1958, page 38). Forrester also discussed the "unified system" in terms of managing the five interrelated flows of "information, materials, manpower, money, and capital equipment" (Forrester, 1958, page 38).

Focusing on information and material flow, Forrester proved that these flows need to be managed as a system through his pioneering DYNAMO simulation work. Information in the form of orders received by a retailer are translated via forecasting and inventory policies to generate orders for the distributor, the distributor then repeats the translation process to generate orders for the factory. The forecasting and inventory policies magnify the effect of an increase in demand; this magnification is acerbated as it transmitted upstream. Thus the term, the Forrester Effect was coined to describe the phenomenon (or emergent behaviour) that even a small increase in demand is magnified by stock policies, which leaves organisations encountering "boom and bust" inventory scenarios. Forrester also indicated ways to improve the situation, for example by removing a layer; he suggested that the distribution layer was removed. Partnership sourcing in lean supply is a contemporary example of reducing layers in the supply chain/network (Lamming, 1992). However, some industrial trends have done the opposite with many supply chains introducing more warehousing and distribution layers via regional distribution centres (RDCs) and third-party logistics providers (3PLs), moreover, vertical integration is sparse (Lummus and Vokurka, 1999).

### 2.1.2 The bullwhip effect

Despite Forrester's early recognition of the demand amplification problem, research activity in business that utilised Forrester's simulation work, remained fairly dormant until the famous beer game (Sterman, 1989). The beer game was based on Forrester's (1961) retailer; wholesaler; distributor and factory supply chain. Managers would play a role in the chain and make the ordering decision, balancing the cost of not delivering to the customer with the cost of holding stock. The game highlighted the

Forrester effect, as players experienced "boom" and "bust" inventory and escalating costs, when the demand made a step increase from 4 to 8 barrels a day. The early 1990's saw industrial recognition of these "functional silos", and hence, business process reengineering (BPR) was born (Hammer and Champy, 1993). Hewitt (2001) considers supply chain management to be the most successful example of cross-functional business process management to emerge out of BPR (Hewitt, 2001). In the late 1990's, the Cardiff based systems dynamics group were using the modelling techniques to reengineer supply chains (Towill and Naim, 1993, Towill, 1996a). Towill (1997a) had described how to minimise Forrester and Burbidge effects, through integration, which he called "Forridge" (Towill, 1997). Meanwhile, across the Atlantic, academics at Stanford University Lee, Padmanabhan and Whang (1997) also started to redefine the concept, coining the phrase "Bullwhip Effect," shown in figure 2.2, they define it as:

> "the phenomenon where orders to the supplier tend to have larger variance than sales to the buyer (i.e., demand distortion), and the distortion propagates upstream in an amplified form (i.e., variance amplification)." (Lee et al., 1997b, pg. 546)

They prove the theory using both case study evidence, specifically from Procter and Gamble and Hewlett Packard (Lee et al., 1997a, Lee et al., 1997b) and mathematical modelling (Lee et al., 1997b). A considerable number of industrial examples of cases that proved the bullwhip effect phenomenon occurring in a variety of different industries have since emerged (McCullen and Towill, 2001). Lee et al (1997a,b) define four causes of the Bullwhip Effect: 1) Demand Forecast Updating (Lee et al., 1997a)/Demand Signal Processing (Lee et al., 1997b); 2) Order batching; 3) Price fluctuation and 4) Rationing and shortage gaming. Lee et al's (1997a,b) Bullwhip Effect did pull the four phenomenon together for the first time, and they make reference to Forrester's (1961) and Sterman's (1989) work. However, Disney and Towill (2001) trace the origins of these effects back to previous research (notably Burbidge, 1991, Forrester, 1961, Houlihan, 1987). Although, Lee et al (1997a,b) should have referred to these works, this inadvertently achieved theory, methodological, data and investigator triangulation, which validates the theory.

**Figure 2. 2 The bullwhip effect and it's origins**

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Source: Holweg, 2002

Hence, Disney and Towill (2001) clarify the following original contributions. Firstly, the Demand Forecast Updating/Signal Processing is the Forrester Effect (Forrester, 1958, Forrester, 1961) where there is no visibility of end demand and multiple conflicting forecasts exist. Order batching is the Burbidge effect (Burbidge, 1991), which occurs when companies batch or accumulate demand due to infrequent ordering, often due to the economics of scale, order quantities or transportation. Price fluctuation causes manufacturers and distributors to "forward buy" usually due to an attractive price offer. The result is the consumer buys in bulk and then stops buying until their inventory is depleted; Holweg (2002) links this to economic theory. Rationing and Shortage Gaming is the Houlihan effect (1987) which occurs when demand exceeds supply so customers get a portion of what they ordered. Therefore they then over order to compensate for the rationing and then orders will disappear or be cancelled due to an overreaction in anticipation by customers.

A variety of supply chain management techniques have been considered to reduce the bullwhip effect, including partnership sourcing (Towill and Naim, 1993); agile or rapid response manufacturing (McCullen and Towill, 2001, Towill and McCullen, 1999), vendor- managed inventory (VMI) (Disney and Towill, 2001) and e-business (Disney et al., 2004). Not surprisingly, there is also considerable acknowledgement from both the Cardiff and the Stanford research that highlights the use of information systems technology to reduce the bullwhip effect, specifically:

- using electronic point of sale (EPOS) data (Lee et al., 1997a),
- using electronic data interchange (EDI) between manufacturing resource planning (MRP) systems (Lee et al., 1997a, Towill, 1996a)
- using Internet, internet ordering and computer assisted ordering (Lee et al., 1997a) and e-business (Disney et al., 2004)
- improving ordering and distribution systems (Towill, 1996a, Towill, 1996b), including use of vendor managed inventory (VMI) and Automatic Pipeline, Inventory and Order Based Production Control System (APIOBPCS) (Disney and Towill, 2002)
- Sharing sales, capacity and inventory data (Lee et al., 1997a)

## 2.1.3 The need for research in supply system architecture

The previous section highlighted that information systems have a role to play in reducing the bullwhip effect. In more general terms, it is also often stated that information systems or technologies enable effective supply chain management (e.g. Lummus and Vokurka, 1999, Sridharan et al., 2005). Validation of this statement includes qualitative focus group research (Akkermans et al., 1999); literature survey (Gunasekaran and Ngai, 2004) and quantitative surveys (Buxmann et al., 2002, Buxmann et al., 2004). The more prominent and pervasive of these information systems and technologies include: the internet, extranets and real-time consumption monitoring and virtual manufacturing (Kehoe and Bougton, 1999). There is also evidence of supply chain improvements using longer established Enterprise Resource Planning (ERP) systems (Bitran, 2006, Mabert et al., 2000) and SCM specific solutions (Vollman et al., 2005). Broadly speaking the benefits of deploying information systems and technologies to improve supply management can be placed in four categories: cost reduction; process improvements (including visibility); revenue growth and time reduction, see table 2.1.

**Table 2. 1 Benefits of systems to improve supply management**

| | System | Source |
|---|---|---|
| **Cost reduction** | | |
| Eliminate costs and mistakes associated to manual work | SCM Solutions | Bitran, 2006 |
| More control of organization's costs/expenses/improve cash-to-cash cycle times | ERP | Bitran, 2006<br>Mabert et al., 2000<br>Mabert et al., 2003<br>McAfee, 2002<br>Stratman, 2001 |
| Reduced cost of purchasing and associated administration costs | E-business | Digital Union, 2001 |
| **Process improvements** | | |
| Automate an internal process/operate more efficiently | ERP | Bitran, 2006<br>Digital Union, 2001 |
| Better operational and business planning – from rough-cut capacity planning logic to finite capacity planning algorithms | SCM | Vollman et al 2005 |
| Better visibility of the performance of the business | ERP | Boston Consulting Group, 2000 |
| Eliminate manual work | ERP | Bitran, 2006 |
| Facilitate governance of the business | ERP | Scott and Vessey, 2000 |
| Have better control of organization's information – central storage and updating | ERP | Bancraft et al., 1998<br>Bitran, 2006<br>Hendricks et al., 2007 |
| Increase demand forecast precision | SCM Solutions | Bitran, 2006 |
| Information integration (with supply chain provider/client user) | ERP<br>SCM Solutions | Bitran, 2006<br>Hendricks et al., 2007 |
| Optimise stock/inventory management | SCM Solutions | Bitran, 2006 |
| **Revenue or market growth** | | |
| Find new partners and get to market quicker | E-business | Bitran, 2006<br>Digital Union, 2001 |
| **Speed or time reduction** | | |
| Reduction of the order cycle time (time from order placed to order delivery) – improves throughput, customer response times and delivery speeds | ERP<br>E-business | Cotteleer and Bendoly, 2006<br>Digital Union, 2001<br>Forrester Research, 2000<br>Hendricks et al., 2007<br>Mabert et al., 2000<br>Mabert et al., 2003<br>McAfee, 2002 |

Table 2.1 also highlights the myriad of solutions is available to improve supply chains/networks, including ERP and other software solutions, which are explained in the following section. The different solutions have been considered in isolation from each other, for instance Taylor (2004) makes the clearest distinction between the software solutions to improve supply management. He explores ERP systems; Supply Chain

Execution Systems; Advanced Planning and Scheduling (APS) and simulation (Taylor, 2004), however, Taylor (2004) does not include e-business solutions (including e-marketplaces; e-procurement etc.). Biehl and Kim (2003) focus on considering ERP versus e-marketplaces, but they do not consider APS. Ho (2002) categorised and explored e-business solutions and demonstrated how these can generate cost savings for supply chains (Ho, 2002), but did not explore the potential of ERP. Therefore, there is a need to consider how these solutions can work together. Moreover, Gunasekaran and Ngai's (2004) provide further support the view that further research into the design of information systems and technologies for supply chains/networks is needed. Their comprehensive journal-based literature survey, led to the conclusion that:

> "Information systems architecture needs to be designed for SCM that could be different from that of traditional organisations." (Gunasekaran and Ngai, 2004, pg. 291)

This conclusion supports that, from an academic perspective, there is a need for further research into supply system architecture. The different solutions offer overlapping functionality (Albright, 2004, Anon, 2006, Buxmann et al., 2004, Nairn, 2003, Taylor, 2004), this was most important factor in supply chain management software selection identified in Buxmann et al's (2004) comprehensive survey of the automotive industry. The issue of functionality, was closely followed by price/implementation costs, and then compatibility within the company (Buxmann et al., 2004, pp.304). These three areas: functionality; price/implementation costs and compatibility, will be explored in turn, starting with functionality.

## 2.2 Functionality issues in designing supply system architecture

Practitioners also consider the difficulties in selecting supply chain systems, they conclude that no single product provides the functionality required (Taylor, 2004) and that there are hundreds of different vendors (Nairn, 2003). The supply chain software market has been consolidating, however Anon (2006) still states that "users must do their homework" (Anon, 2006, pg. 46), specifically to decide between generic versus niche software solutions. Albright (2004) sees the key problem as making the trade off between integration versus functionality (Albright, 2004). He is referring here to the fact that best of breed solutions have to be integrated, but single vendor solutions may lack the functionality the business requires (Light et al., 2001).

Biehl and Kim (2003) highlight the lack of comparisons of the functionality of different ERP systems, only finding one paper that addresses this. Their work extensively reviews the trade literature to articulate the functionality of two different systems: ERP and electronic marketplaces that could be used to improve the management supply chains/networks. Since their paper, Taylor (2004) describes each type of software based system in clear terms and highlights the functionality of the system using what he calls a "Supply Chain Management Process Matrix", as shown in figure 2.3. He highlights the three levels of planning vertically: design; planning and operations and supply; production and demand horizontally, thus, key functionality is mapped on to the matrix.

**Figure 2. 3 Taylor (2004)'s matrix of supply system architecture functionality**

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Source: exhibit 1, Taylor, 2004

As mentioned previously, his comparisons exclude e-marketplaces. Therefore, the thesis uses his matrix to discuss the different supply system architectures, including e-marketplaces by utilising Biehl and Kim's (2003) and Ho's (2002) work. Biehl and Kim (2003) consider e-marketplaces, whereas Taylor does not and they consider more detailed functionality aspects, e.g. Taylor (2004) states sales, where Biehl and Kim (2003) also include billing and handling quotations. Ho's (2002) work adds further solutions, as she also considers e-procurement; divides e-marketplaces into private and public and considers e-fulfilment and customer relationship management (CRM). Analysing these three sources resulted in the production of a table, showing the functionality of the different systems, shown in table 2.2. Table 2.2 highlights the overlapping functionality clearly, and an explanation of each type of system follows, with the functionality indicated, using Taylor's (2004) matrix as a guide.

**Table 2. 2 Supply system architectures functionality**

| Functionality | ERP systems | Advanced Planning and Scheduling | Transportation Management System | Warehouse Management System | Customer Relationship Management System | Supplier Relationship Management system | Collaborative Forecasting, Planning and Replenishment | E-purchasing | E-commerce Market place |
|---|---|---|---|---|---|---|---|---|---|
| **Supply Planning and Operations (Taylor, 2004)** | | | | | | | | | |
| Catalog management (Biehl and Kim, 2003, Ho, 2002) | ✓ | × | × | × | ✓ | ✓ | × | × | ✓ |
| Contract creation and management (Biehl and Kim, 2003, Ho, 2002) | ✓ | × | × | × | × | ✓ | × | × | ✓ |
| Quotations, requests for quotes (Biehl and Kim, 2003, Ho, 2002) | ✓ | × | × | × | × | ✓ | × | ✓ | ✓ |
| Negotiation (Biehl and Kim, 2003) | × | × | × | × | × | ✓ | × | × | ✓ |
| Reverse auctions (Biehl and Kim, 2003, Ho, 2002) | × | × | × | × | × | × | × | × | ✓ |
| Sourcing, billing, payment automation (Biehl and Kim, 2003, Ho, 2002, Taylor, 2004) | ✓ | × | × | × | × | ✓ | × | ✓ | ✓ |
| Supplier management and performance (Biehl and Kim, 2003) | ✓ | × | × | × | × | ✓ | × | × | ✓ |
| **Production Planning and Management (Taylor, 2004)** | | | | | | | | | |
| Materials/Inventory planning and management (Taylor, 2004) | ✓ | ✓ | × | ✓ | × | × | ✓ | × | × |
| Operational performance (Biehl and Kim, 2003) | ✓ | × | × | ✓ | × | × | × | × | × |
| Production planning, scheduling and control (Biehl and Kim, 2003, Taylor, 2004) | ✓ | ✓ | × | ✓ | × | × | × | × | ✓ |
| **Demand Planning and Management (Taylor, 2004)** | | | | | | | | | |
| Auctions (Biehl and Kim, 2003) | × | × | × | × | × | × | × | × | ✓ |
| Collaboration and collaborative planning (Biehl and Kim, 2003, Ho, 2002) | × | × | × | × | ✓ | × | ✓ | × | ✓ |
| Forecasting (Taylor, 2004) | ✓ | × | × | × | ✓ | × | ✓ | × | × |
| Logistics management (Biehl and Kim, 2003) | × | ✓ | ✓ | × | × | × | × | × | × |
| Distribution planning and management (Biehl and Kim, 2003 and Taylor, 2004) | ✓ | ✓ | ✓ | × | × | × | × | × | × |
| Sales (Taylor, 2004) | ✓ | × | × | ✓ | ✓ | × | ✓ | × | ✓ |
| Shipment (Taylor, 2004) | ✓ | × | ✓ | ✓ | ✓ | × | × | × | × |
| **Integration (Biehl and Kim, 2003)** | | | | | | | | | |
| Supply chain integration (Biehl and Kim, 2003) | ✓ | ✓ | × | × | × | × | ✓ | × | ✓ |

Complied by the author from Biehl and Kim, 2003, Ho, 2002, Taylor, 2004

### 2.2.1 Enterprise Resource Planning (ERP) systems

ERP systems are the large enterprise-wide systems that utilise MRP logic for materials planning; capacity planning, distribution planning and master planning (Vollman et al., 2005). ERP systems plan based on the forecast and then working back from the forward prediction, they schedule distribution and production, see figure 2.4. Therefore, firstly, the demand forecast is fed into the distribution requirements planning (DRP module), which works backwards from required delivery dates to figure out when finished good must be shipped. The DRP then passes to the master production scheduling (MPS) module, which determines when production needs to start on each batch. The material requirements planning module (MRP), then identified all the associated materials on the bill of materials and works out when these need to be ordered. The capacity requirements planning (CRP) module checks that the necessary resources are available and schedules the activities. (Taylor, 2004). ERP uses a central database, which integrates these functions with the other parts of the business, e.g. sales and accounting. There is considerable support for the idea that ERP alone will not support an external supply chain/network (Akkermans et al., 2003), for instance, it is no help in deciding where to locate facilities and distribution centres (Taylor, 2004). The top issue identified by Akkerman et al's (2003) Delphi study was to further integrate supply processes, hence utilise other solutions.

**Figure 2. 4 ERP systems**



Source: exhibits 2 and 3, Taylor, 2004, pp. 22

### 2.2.2 Advanced Planning Systems

Advanced Planning and Scheduling (APS) is also used for planning supply chains, however, instead of using MRP, it uses optimisation. The focus of APS is on managing the network of facilities, rather than creating schedules for individual production facilities, which is the focus of ERP systems. The optimisation techniques used in APS are more advanced than MRP logic, they do not schedule from due date backwards. Instead, APS uses mathematical optimisation procedures to create an optimal schedule, given the constraints, the objectives can be cost minimisation; customer service or inventory flow, for example. APS, like ERP is forecast-driven, but the planning of materials; production and distribution is undertaken concurrently, see figure 2.5. APS successfully handles situations where time; capacity; or materials are scare. But, it uses linear programming, which makes some assumptions of linear relationships which may not be valid (Taylor 2004). APS doesn't manage the day to day operational processes and therefore, supply chain execution software is required.

**Figure 2. 5 APS systems**

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Source: exhibits 4 and 5, Taylor, 2004, pp. 23 and 24

### 2.2.3 Supply chain execution systems: CRM; SRM; WMS and TMS

The role of the different Supply Chain Execution Systems is explicit in their names and includes older warehouse management systems (WMS) and transportation management systems (TMS), as well as newer, customer relationship management (CRM) and supplier relationship management (SRM) systems (Taylor, 2004). WMS smooth the flow of inventory through the factory, including goods receiving; warehouse storage and assembly of shipments, see figure 2.6. TMS involve the design of the network as well as driver scheduling and shipment tracking (Taylor, 2004).

CRM systems focus on building long-term relationships with customers and include using analytical techniques like data warehousing, data mining and decision support to identify and maximize profitability from customers. (Laudon and Laudon, 2007) CRM also includes operational functionality including sales force automation and reporting tools (Laudon and Laudon, 2007). CRM systems are a centralised customer information database that replace systems maintained by individual sales people and therefore reduces the duplication in data entry and maintenance. Supplier Relationship Management (SRM) systems collect data to manage relationships with suppliers, including performance data; sourcing information and focus on developing long-term relationships with suppliers.

**Figure 2. 6 WMS; TMS; SRM and CRM systems**

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Articulated onto Taylor's (2004) matrix from figure 2.3 by the Author

### 2.2.4 Collaborative Planning, Forecasting and Replenishment

Collaborative Planning Forecasting and Replenishment - CPFR, (Kurt Salmon Associates, 2000), Efficient Consumer Response - ECR and Quick Response - QR (Kurt Salmon Associates, 1988) hinge on using centralised planning data in real-time across the supply chain/network. The focus is on category management, maximising the space in stores, based on profitability and automated replenishments (Holmström et al., 2002). They utilise the electronic point of sale (EPOS) data collected by retailers and create a joint forecast for the supply chain/network, and also joint plan promotions to maximise the retail space (Holmström et al., 2002), see figure 2.7.

### 2.2.5 E-business solutions – e-marketplaces and e-purchasing

Different e-marketplaces may offer differ functionality, however, Sharifi et al (2006) state that they are a platform where supply chain partners can buy, sell, auction, reverse auction, track, connect, integrate, collaborate and manage (electronic) payments, in a secure environment. AMR Research, cited by Sharifi et al (2006) listed the top ten capabilities required as: order status/tracking; product search; product catalogue; vendor search; back-end integration; supplier/buyer rating; request for proposal/quotation; transportation management; integration to other exchanges and collaborative planning (buyer/seller). There are private and public marketplaces, private marketplaces are focused on one company (company-centric), in this type of marketplace one company does all the buying or the selling (Sharifi et al., 2006). Public e-marketplaces can be vertical e-marketplaces, based on serving an industry sector, be they set up by industry consortia or a third party. The other type is horizontal e-market-places, which cut across industry sectors, they can be set up by a third party (Ho, 2002). E-purchasing automates the purchasing process by use of either electronic data interchange (EDI) and extensible markup language (XML) (Ho, 2002), the focus is on speeding up the process and preventing re-keying errors.

**Figure 2. 7 Collaborative Planning, Forecasting and Replenishment, e-marketplaces and e-purchasing**

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Articulated onto Taylor's (2004) matrix from figure 2.3 by the Author

## 2.2.6 Existing classifications of supply system architectures

Taylor's (2004) process matrix can be used to understand the array of supply systems (Nairn, 2003), with overlapping functionality (Albright, 2004, Taylor, 2004). However, it does not classify the different supply system architectures to determine which architecture may suit the relationship with the supplier or buyer. Traditional classifications of planning systems have focused on one company and considered whether the system operates in according to a demand pull or a technology push. Push systems are generally considered to be those based upon materials requirements planning (MRP) logic, e.g. ERP. These systems have evolved as the nature of competition changes and as technology improves (Rondeau and Litteral, 2001). Pull systems are generally considered to have evolved from the Japanese Just-In-Time (JiT) kanban based systems (Lu and Ohno, 1986).

Slack (1991) asserts that the type of production, in terms of the volume and variety characteristics, and the level of control determine which control techniques should be adopted (Slack, 1991), see figure 2.8. The volume and variety characteristics have long been established to indicate the complexity of manufacturing, i.e. the variation in processing lead times, complexity of product structures etc. The level of control indicates which set of production control tasks; high-level is the broad co-ordination of material flow, medium-level is allocation of orders to each part of the plant and low-level is day-to-day shop floor activities. These considerations of volume and variety will equally be important when considering supply chains/networks.

**Figure 2. 8 Single organisation categorisations**

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Illustration removed for copyright restrictions

Source: Slack (1991) Source: Voss and Harrison (1987)

Voss and Harrison (1987) indicate that JiT and MRP are more appropriate depending on the complexity of the structures and routings in the organization, as the complexity increases JiT becomes less appropriate compared to MRP (Voss and Harrison, 1987), see figure 2.8. Their logic is correct, however, the Toyota Production System (Lu and Ohno, 1986) or lean (Womack et al., 1990), emerged in the automobile industry, where structure and routings are complex, this further emphasises the role of softer issues in implementing systems. Kanbans used in JiT are simple to understand and highly visible, which makes them easier to explain which aids the implementation process. However, they require commitment and dedication to make them work. The lean waste reduction philosophy requires that kanbans are taken from the loop to expose process problems and further reduce buffer stocks as part of the continuous improvement process. Needless to say, different organisations in the supply chain/network may not want this level of involvement with suppliers or customers. Hence, Voss and Harrison

(1987)'s consideration of the complexity of routing in individual organisations is equally valid, if not more so, when attention is turned to supply chains/networks.

Voss and Harrison's (1987) consideration of structures and routings has not really been translated into a classification for supply chains/networks. Biehl (2005) does consider the criteria that could make electronic marketplaces more applicable than ERP, which considers the complexity of the bill of materials (BOM), see figure 2.9. But their classification focuses on ERP and e-marketplaces and does not consider the other solutions available.

**Figure 2. 9 Supply chain/network categorisations**

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Illustration removed for copyright restrictions

Source: Biehl (2005) Source: AMR Research (1998)

AMR Research do focus on supply chain/network systems, they consider the planning function from the perspective of the time horizon (seconds/minutes to years) and planning detail (AMR Research, 1998), see Figure 2.9. The term planning detail can be considered functionality; this functionality is placed on the matrix from the shortest time to the longest time. Hence the order of planning detail is as follows: execution systems; shipment scheduling; production scheduling; transportation planning; manufacturing planning; distribution planning; inventory planning; available to promise; supply chain planning; sales and operations planning; demand planning; supply chain network design and strategic planning. This classification is useful for identifying functionality, but has not been aligned with the SCM systems; e-business solutions or ERP systems available. Moreover, Guneskaran and Ngai's (2004) comprehensive literature review on the use of ICT in supply chains, they conclude:

> "The alignment between information model and supply chain model or objectives needs further investigation." (Gunasekaran and Ngai, 2004, pg 291).

## 2.3 Classification of supply system architecture: integration; partial integration and co-ordination

Hewitt's (1999) conference paper and later practitioner paper (2001) considers whether managers should focus on supply or demand; chains or pipelines and co-ordination or control. Hewitt's (1999, 2001) industry-focused and case-study based paper was the inspiration for Benton et al (2000) and Benton & Love's (2001) classification of supply chain planning and control systems. Benton et al (2000) and Benton and Love (2001) purported that when considering supply system architectures, there is a key dichotomy between those solutions aiming for centralised architectures and those striving for flexibility through decentralisation. The different supply system architectures were illustrated on a spectrum from centralised to decentralised (Benton and Love, 2001, Benton and Love, 2006a). Benton and Love (2001) placed these on the spectrum, according to the degree of central control of: the demand / forecasting; master production schedule and the locality of the co-ordinating mechanisms. They use the words "quasi-centralised" and "quasi-decentralised", however the literature in supply systems utilises the terms: collaboration; integration and co-ordination (Wong and Boon-itt, 2006).

Wong and Boon-itt (2006) considered the complexities of defining the terms integration and co-ordination, they highlight that these terms have been used inter-changeably through a comprehensive literature review of 245 articles. The key difference they identified is that integration is a wider concept that also includes collaboration. They define ***co-ordination*** as a "process" or effort, which involves:

1. Physical flow
2. Process and activity
3. Sharing of information; risk; goal; revenue and rewards
4. Cooperation and coordination of activities
5. Planning and ordering decisions

(abridged from Wong and Boon-itt, 2006)

They define ***integration*** as a "process" or "effort" to do all of the above (number 5 is considered to be done in a collaborative way) and they add:

6. Interaction and collaboration, trust and commitment for collaboration
7. Network integration

(abridged from Wong and Boon-itt, 2006)

Hence, their definition of integration is akin to Benton and Love's (2001) "centralised" and their definition of co-ordination, is akin to Benton and Love's (2001) definition of "quasi-decentralised".

Utilising Wong and Boon-itt's (2006) definitions of integration and co-ordination to consider supply system architectures, leaves the two parts of the categorisation not considered, those which share forecasting and demand data, which Benton and Love (2001) define as "quasi-centralised." The sharing of demand and forecasting decisions is particularly important when considering bullwhip reduction. The term "partially integrated" is used to refer to this aspect. There is also re-consideration of interactions were there is no real effort to co-ordinate, the interaction is based on the placing of orders, these have been termed "independent". The distinctions have been made between four paradigms of interaction: integration; partial integration; co-ordination and independence as shown in table 2.3.

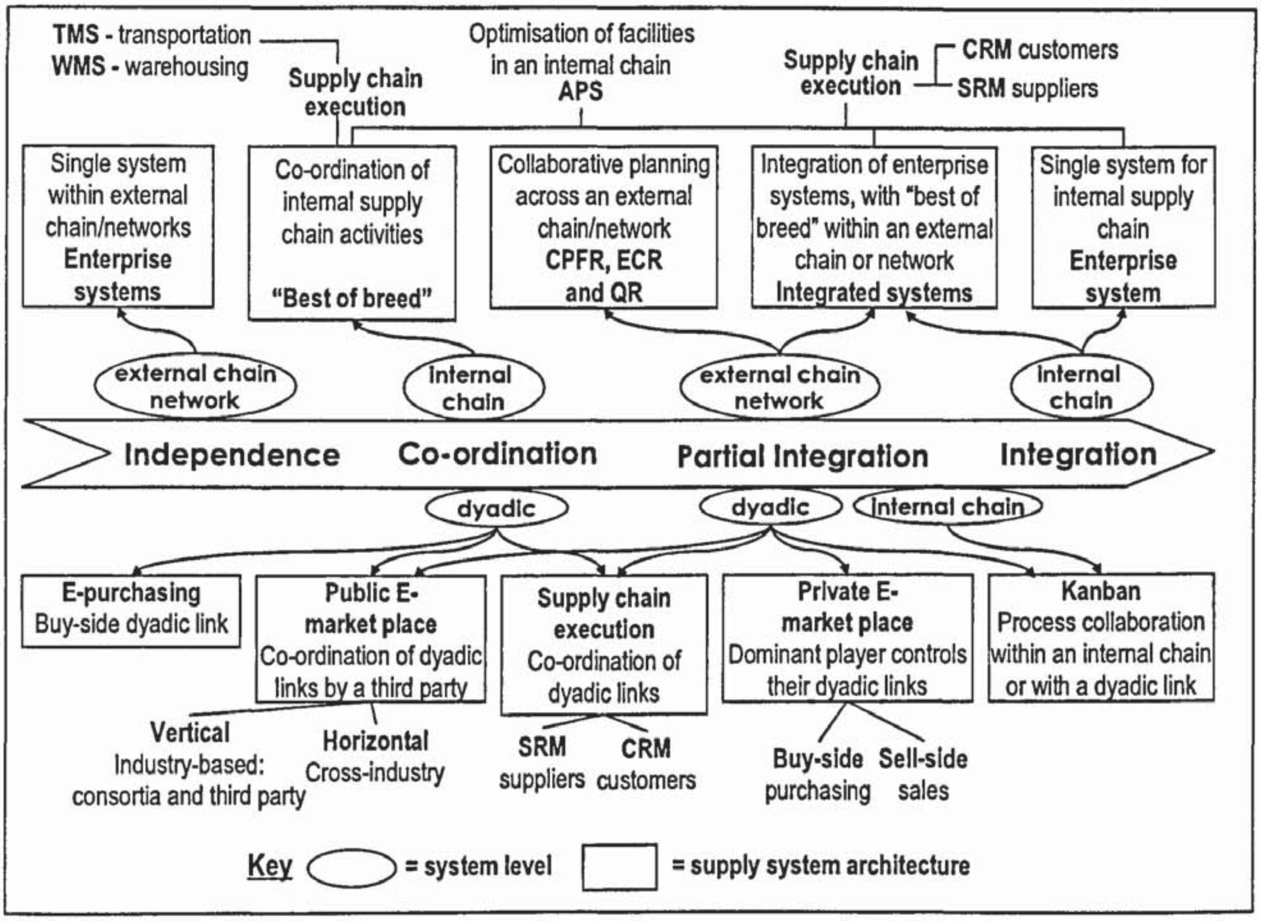
**Table 2. 3 Integration; partial integration and co-ordination**

| | Paradigm | | | |
|---|---|---|---|---|
| | **Independence**<br>like decentralised (Benton and Love, 2001) | **Co-ordination**<br>(Wong and Boon-itt, 2006) like quasi-decentralised (Benton and Love, 2001) | **Partial integration**<br>like quasi-centralised (Benton and Love, 2001) | **Integration**<br>(Wong and Boon-itt, 2006) like centralised (Benton and Love, 2001) |
| 1. Physical flow | ✓ | ✓ | ✓ | ✓ |
| 2. Process and activity | | ✓ | ✓ | ✓ |
| 3. Sharing of information; risk; goal; revenue and rewards | | ✓ | ✓ | ✓ |
| 4. Cooperation and coordination of activities | | ✓ | ✓ | ✓ |
| 5. Planning and ordering decisions | ✓ | ✓ | ✓ | ✓ |
| 6. Interaction and collaboration, trust and commitment for collaboration | | | ✓ | ✓ |
| 7. Network integration | | | | ✓ |

The author has reconsidered the previously presented spectrum that had been developed (Benton and Love, 2001, Benton and Love, 2006a) to create one based on the clearer terminology in table 2.3. The degree of interaction varies in supply systems across the four paradigms: integration, partial integration, co-ordination to independence, as shown in the central portion of figure 2.10. The decision of how integrated a supply chain/network wants to be will vary depending on where the boundary is drawn around the supply chain/network, i.e. which of Harland's (1997) levels is being considered: internal; dyadic; external or network. For each of the four paradigms of interaction, where applicable, Harland's (1997) levels are indicated as ovals in figure 2.10, next to the relevant type. A truly independent supply chain would be represented in an "external supply chain or network" (shown in an oval), where every participant has single systems and the passing of orders is the only form of communication. This type of supply system architecture is linked to the type of integration and shown in a box, in figure 2.10.

A co-ordinated supply system architecture could occur in internal chains and in dyadic links, hence these are shown in ovals in figure 2.10. Supply system architectures could create co-ordination of internal chains through the use of best of breed software, thus this is shown in a box linked to the "internal chains" oval next to the co-ordinated paradigm in the upper portion of figure 2.10. In a dyadic link scenario, there are three supply system architecture options: e-purchasing, public e-marketplace and supply chain execution, hence these three are shown in boxes, linked to the "dyadic" oval next to the co-ordinated paradigm in the lower part of figure 2.10. In the case of partial integration, all of Harland's (1997) levels could exhibit partial integration, hence, the three ovals, with the links to the options for supply system architecture shown in boxes in figure 2.10. The integration paradigm can only truly exist in an internal chain, with a single system. Hence, the two ends of the "spectrum" can be joined together, a truly integrated system existing in an internal supply chain and is considered independent in an external supply chain/network as it relies on orders from customers. The different system levels: internal; dyadic; external and network are now be discussed in turn.

Figure 2. 10 The spectrum of supply system architectures: independent, through co-ordinated, through partially integrated to integrated




## 2.3.1 Internal supply chains

*One single ERP system* with an internal supply chain would inherently achieve **integration** as the planning and ordering would be conducted by one system. *One single ERP system* would therefore, co-ordinate the process and physical flow. The other **integrated** option for an internal supply chain is to endeavour to integrate *enterprise systems* with other *best of breed* solutions, specifically *APS; WMS* and *TMS.* Although it is more difficult and costly to integrate these systems, they do provide more functionality. Implementing a *best of breed* solution that is not integrated would also provide **co-ordination** within the internal supply chain. **Partial integration** could be achieved by utilising *kanban,* which involves process collaboration, hence is not just a co-ordination mechanism.

### 2.3.2 Dyadic links

The use of ***public e-marketplaces*** could provide dyadic links with either **partial integration** or **co-ordination**, depending on the functionality that is used. Likewise, supply chain execution systems: *CRM* and *SRM* can be used to achieve either **partial integration** or **co-ordination** to a customer or supplier, respectively, depending on the extent to which they are implemented. A ***private e-marketplace*** would create **partial integration** within a *dyadic* link, due to the collaboration between the dominant player and their key suppliers (buy-side) or customers (sell-side). ***Kanbans*** are another example of **partial integration** in a dyadic link as collaboration on processes will occur to solve problems when a ***kanban*** is removed. ***E-purchasing*** could be used to **co-ordinate** purchasing in a dyadic link.

### 2.3.3 External chains and networks

**Partial integration,** based on collaborating on demand planning and replenishment can be realised using ***Collaborative Planning Forecasting and Replenishment (CPFR)*** within an external chain or network. ***Best of breed*** and ***enterprise systems*** can also be **partially integrated** in order to serve particular needs within an external chain or network, e.g. collaborative planning and ordering. Independent ERP systems within an external chain or network can be considered **independent.**

## 2.4 Implementation issues

Implementation of supply chain/network software, particularly ERP has received considerable attention by academics. The causes of failure are often cited as being managerial, rather than technical (Al-Mashari et al., 2003, Scott and Vessey, 2000). A summary of the issues identified is shown in table 2.4, these have been classified in the thesis as design and selection (pre-implementation); implementation; post-implementation and over-arching. The over-arching issues are those which are important in all three stages and include change management; project management and communications.

**Table 2. 4 Managerial aspects of pre-implementation; implementation and post-implementation**

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After Al-Mashari et al., 2003

Therefore, during the pre-implementation, or design and selection phase, processes and existing systems must be managed; a clear business case must be made and software carefully selected.

## 2.5 Compatibility issues in supply system architectures

Buxmann et al's (2004) survey also highlighted the need for compatibility within the company. The research on implementation already revealed the need to manage the business processes; existing systems and change within the supply chain/network. But compatibility will also depend on the context of the organisation or supply chain/network. Therefore, strategic and general context needs to be considered.

### 2.5.1 Supply chain strategy

The supply system architecture should support the wider supply strategy. In the strategic arena a variety of frameworks for categorising, summarising or defining supply chains have been developed. These frameworks vary in their scope and purpose, and include DMV[3] (Christopher and Towill, 2000b), and innovative and functional supply chain products (Fisher, 1997). Childerhouse et al (2002) reviewed and summarised classifications of supply chains within the literature, as shown in table 2.5. Childerhouse's (2002) thesis develops a methodology of moving towards a seamless market-orientated supply chain. Hence, his work is strategic in nature, and proves the theory of Fisher's (1997) seminal work. Fisher (1997) categorised products into those which are innovative and require market responsive supply chains due to unpredictable demand, versus those which are functional and require physically efficiency. These two types of product have been aligned with the two opposing supply strategies of lean and agile by Christopher and Towill (2000). They explore the two strategies and where to locate the decoupling point where lean has to change to agile to respond to customer demand. This leads to various combinations of leanness and agility, of which the best known is leagility (Naylor et al., 1999).

**Table 2. 5 Childerhouse et al's (2002) Comparison of Classification Approaches**



Source: Childerhouse et al (2002)

Christopher and Towill (2000) designed a simple classification system, which would define the value stream according to lean and agile principles. They use DWV[3] to classify supply chain, based on their industrial experience plus literature review, citing Shewchuck's (1998) review of agile manufacturing as being most influential (Shewchuck, 1998). They conclude that there are five key characteristics: duration of life cycle; time window for delivery; volume; variety; and variability. The aim of this work is to develop a conceptual framework that is focused on dealing with complexity of supply systems architecture, yet remain strategically focused on the key decision criteria, hence, Christopher and Towill's (2000) classification was drawn upon.

## 2.6 Conceptual framework for supply systems architecture

The thesis focus is on the design and selection of supply system architecture, rather than supply strategies, therefore, different frameworks and other bodies of work were incorporated to give an overall picture of the key characteristics for selecting supply system architectures, see figure 2.11. These characteristics were previously discussed and identified in Benton and Love (2001 and 2006 a, b). These include geographical characteristics (Bolstorff and Rosenbaum, 2003, Schary and Skjott-Larsen, 1995). Bolstorff and Rosenbaum (2003) recommend that a supply chain is defined by a combination of product; customer and geography. Christopher and Towill's (2000) work already emphasises the customer and product aspects. As well as geography, implementing a supply system architecture will depend upon the network considered (Beamon and Chen, 2001, Harland, 1997) and the relationships within that network (Håkansson and Snehota, 1982, Håkansson and Snehota, 1995). The full complement of characteristics that are important in selecting supply system architecture are shown in figure 2.11, the indicative supporting literature is summarised in table 2.6. Each of the categories will now be discussed in turn, DWV$^3$; relationships and network and geography.

**Figure 2. 11 Categories of characteristics that could influence the performance of supply system architecture**



(earlier forms in Benton and Love, 2001, Benton and Love, 2002, Benton and Love, 2006a, Benton and Love, 2006b)

**Table 2. 6 Summary of the Categories, Characteristics and Supporting Literature**

| Category | Characteristics | Indicative Key Supporting Literature |
|---|---|---|
| DWV[3]<br>(Christopher and Towill, 2000a, Christopher and Towill, 2000b)<br>Product and End Customer | • Duration of lifecycle<br>• Time Window for Delivery<br>• Volume<br>• Variety<br>• Variability | Hayes and Wheelwright, 1979a, Hayes and Wheelwright, 1979b<br>Fisher, 1997<br>Murphy, 1999<br>Fisher, 1997, Hill, 1991<br>Fisher, 1997, Hill, 1991<br>Grenoble, 1990 |
| Network and Geographical | • Network<br>• Horizontal length<br>• Vertical depth<br>• Spatial and geographical<br>• System level | Beamon and Chen, 2001<br>Voss and Harrison, 1987<br>Bolstorff and Rosenbaum, 2003, Schary and Skjott-Larsen, 1995<br>Harland, 1997 |
| Relationships | • Atmosphere<br>• Interaction<br>• Market<br>• Relationship Power | Cox, 2004b, Håkansson and Snehota, 1995 |

## 2.6.1 DWV3 (Christopher & Towill, 2001)

A variety of literature supports the $DWV^3$ classification, including the fact that it was based on the seminal work of Fisher (1997). Hill's (1991) work in the manufacturing arena, demonstrated the important of managing the different issues arising from the interlinked concepts of volume and variety (Hill, 1991). Hayes and Wheelwright (1979) highlighted the need to consider the stage of the product lifecycle with the production process (Hayes and Wheelwright, 1979a, Hayes and Wheelwright, 1979b). Murphy (1999) reviewed the challenges for the supply chain posed by the 21st century consumer, highlighting their evolving demanding nature, which affects the time window for delivery. Finally, seasonality (therefore variability) puts a strain on supply chain planning and control, as it challenges level scheduling, Grenoble (1990) created an inventory model to cope with seasonality and weather. Childerhouse et al (2002) further supports the consideration of $DWV^3$ in supply chains, their reasons are shown in table 2.7.

**Table 2. 7 Support for $DWV^3$ (Childerhouse et al, 2002)**

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Source: Childerhouse et al., 2002, adapted from Christopher and Towill, 2000a

## 2.6.2 Network and Geographical Category

Voss and Harrison's (1987) analysis of the complexity of flow-path routing can be carried forward into supply chains/networks. Harland (1997) also categorises the different complexities of supply chain into four areas: internal; dyadic; external and network, see section 1.7. A supply chain spanning countries and continents adds complexities and uncertainties to be managed. Many researchers and practitioners have been addressing the problems associated with global supply chains (e.g. Bolstorff and Rosenbaum, 2003, Schary and Skjott-Larsen, 1995).

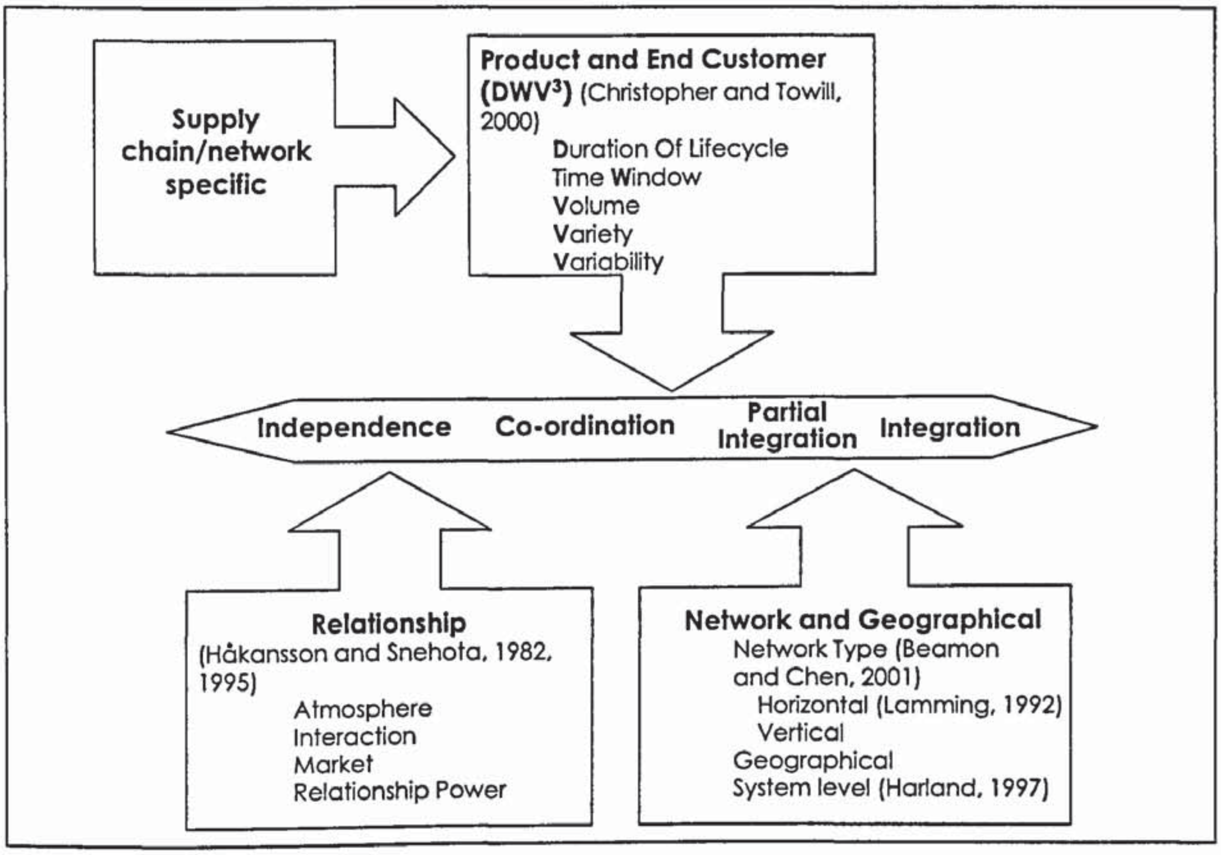
## 2.6.3 Relationships Category

The relationships research has been led mainly by the Industrial Marketing and Purchasing Group (IMP), whose model encompassed four variable types: elements and process of interaction; the participants; the environment and the atmosphere (Håkansson and Snehota, 1995). Relationships are continually being considered as a problematic area in managing supply chains and networks (Cox, 2004b). Cox (2004) questions how business relationships can be truly win-win and considers the range of other relationships that exist in supply chains/networks.

## 2.6.4 Conceptual Framework

The conceptual framework indicates that the different categories: DWV$^3$; network and geographical and relationships impact on the selection of supply system architecture, from co-ordinated to integrated, see figure 2.12. The conceptual framework also includes supply chain/network specific category. This category is to allow supply chains/networks to characterise themselves on other aspects that they deem important. Although the aspect may impact on other existing categories and characteristics, it is important to keep the conceptual framework flexible to support a variety of supply chains/networks. The supply chain/network specific category has also been included to ensure that the definition of the supply chain/network focuses on what the supply partners feel is important, hence the flexibility is important to reach agreement in defining the supply chain/network.

**Figure 2. 12 Supply system architecture conceptual framework**



## 2.7 The Research Gap and Aims and Objectives

There is considerable evidence to support the fact that information systems or technologies enable effective supply chain management (Akkermans et al., 1999, Buxmann et al., 2002, Buxmann et al., 2004, Gunasekaran and Ngai, 2004, Lummus and Vokurka, 1999, Sridharan et al., 2005). Numerous solutions exist for supply chain/network improvement, including ERP and other software solutions (Taylor, 2004) and e-business solutions (Ho, 2002). However, no study has considered all the options available and provided guidance for supply chains/networks in selecting the right solution for them, for instance, Taylor (2004) does not include e-business, Ho (2002) does not include ERP and Biehl and Kim (2003) do not consider APS. Therefore, there is a need to consider which supply system architecture/solutions would be the most appropriate for a given supply chain/network. Hence, the overall aim is to develop a process framework to guide the selection process and de-mystify the different solutions available.

The selection of the most appropriate supply system architecture is seen as a problem in the literature and there are some indications of what the issues consist of, these fall into three categories: firstly, the different solutions offer overlapping functionality (Albright, 2004, Anon, 2006, Buxmann et al., 2004, Nairn, 2003, Taylor, 2004); secondly, there are price/implementation costs (Buxmann et al., 2004); and finally, there needs to be compatibility within the company (Buxmann et al., 2004).

There is literature that explores the functionality of the different systems (Biehl and Kim, 2003, Ho, 2002, Taylor, 2004), which, when combined, can indicate what the myriad of solutions can do. However, apart from one survey (Buxmann et al., 2004) and single-case study research (Al-Mashari and Zairi, 2000b, Al-Mashari et al., 2003), there has not been considerable exploration of the reasons why selecting software is difficult. Hence, the first objective and it's underlying research questions emerge:

O1: To identify the options and issues in selecting supply system architecture

Q1 a. What types of system are available to support supply chain/networks?

Q1 b. Why is selecting supply system architecture difficult?

This first objective builds on the previous work that highlighted the selection of supply chain software as a difficult task (Albright, 2004, Anon, 2006, Buxmann et al., 2004, Nairn, 2003, Taylor, 2004) and seeks to further clarify the problem.

Understanding the problem is a key component, before, designing guidance for addressing the problem, which is the focus on the second objective and its underlying questions:

> O2: To develop a process framework to support the selection of the overall supply system architecture
>
> Q2 a. What are the contextual considerations for selecting supply system architecture?
>
> Q2 b. How have supply system architectures been selected?
>
> Q2 c. What analytical techniques can be used to select supply system architecture?

The first question seeks to address, Buxmann et al's (2004) identification of compatibility with the company (or supply chain/network) as an important factor. The second question, seeks to explore how supply system architectures have been selected to understand and explore the issues raised by a number of authors (Al-Mashari and Al-Mudimigh, 2003, Al-Mashari and Zairi, 2000b, Bernroider and Koch, 2001, Cliffe, 1999, Hecht, 1997, Laughlin, 1999, Mandal and Gunasekaran, 2003, Rao, 2000, Wei and Wang, 2004). The third question seeks to identify how selection can be conducted, by identifying techniques available.

The final objective seeks to test the ability of the process framework to support the design of supply system architecture and has four underlying questions:

> O3: To test the ability of the process framework to support the design of the overall supply system architecture
>
> Q3 a. Could the process framework be followed (feasibility)?
>
> Q3 b. How easily can the process framework be followed (usability)?
>
> Q3 c. Was the process framework useful for designing supply system architecture (utility)?
>
> Q3 d. How does the resulting process framework support the selection of supply system architecture (approach validity)?

The need for testing the process framework arises to ensure its ability to address the issues raised in previous research (Albright, 2004, Anon, 2006, Buxmann et al., 2004, Nairn, 2003, Taylor, 2004). The four underlying questions relate to evaluating the process framework according to Platts' (1993) criteria and Tan and Platts' (2002) sub-criteria for evaluating manufacturing strategy formulation methodologies. The three criteria being: feasibility, the ability to follow the process framework; 2) usability, the ease with which is can be followed and utility whether it was useful (Platts, 1993). Each of these criteria represent a question and together all three led to the last question, whether the process framework is valid.

## 2.8 Conclusion

This chapter considered the difficulties that supply chains and networks face in selecting appropriate architectures. Firstly, the systems available were revealed to be an issue, specifically, functionality versus integration. Therefore, the functionality of the different supply system architectures needs to be clear. Consideration need to be made as to whether integration is desirable according to the orientation of the interaction. Implementation issues were also raised and it was revealed that design and selection of supply system architecture must be supported with a business case; business processes must be managed, as well as existing systems and software selection. There are also three over-arching managerial aspects: change management; good communication and project management. It was also highlighted that the context or compatibility with the supply chain/network is an issue, due consideration should be made to key aspects of DWV3; network and geographical; relationships characteristics.

# Chapter 3 - Research Programme for Designing and Testing the Process Framework

The methodological approach was designed to address the research objectives and the underlying questions in an effective way. This chapter justifies that methodological approach, through first considering the methodological issues and debates in the research community. Specifically, the need to build more on existing theory (Camerer, 1985, Croom et al., 2000, Harland et al., 2006) and address the inductive-deductive dichotomy (Croom et al., 2000). Attention is then paid to the applicability of quantitative and qualitative approaches within the field of operations and logistics, before considering the applicability of these approaches to address the research questions. This debate leads to the adoption of a five stage research process, which is explained and justified. The five stages are as follows: firstly, a critical review of frameworks and tools; secondly, the archival case study analysis; thirdly, the development of the framework; fourthly, the case study applications and fifthly and finally the discussion analysis of the feasibility; usability; utility and degree of validity of the process framework. The remainder of the chapter considers the research limitations; validity and reliability and, finally, research ethics.

This chapter focuses on explaining the methodological approach of using the critical review of frameworks and tools and the archival case study analysis to build the process framework and case study application to test it. The critical review of existing frameworks and tools was the first stage of the research process and was used to find out how solutions have been selected (Q2b) and what analytical techniques could be used (Q2c). The critical review, firstly, used Platts' (1994) and the issues raised by the literature review (c.f. chapter 2) to critique the different frameworks identified in the literature and secondly, identified decision-making tools.

The archival case study analysis forms the second stage of the research process which primarily explored how supply system architecture has been selected (Q2b) and to expand on the difficulties in selecting supply system architecture (Q1b) and the contextual considerations (Q2a). Archival case studies existed in the literature, this use of such secondary sources is supported in both the operations management (Lewis, 1998) and information systems (Jarvenpaa, 1991) fields. An embedded multiple-case research design was followed (Yin, 2003). The unit of analysis for this archival case study research can be considered as "supply system design and selection process in manufacturing supply chains/networks". Six cases were selected and analysed to improve the validity of the research, six was deemed sufficient, to achieve literal replication (Eisenhardt, 1991, Yin, 2003).

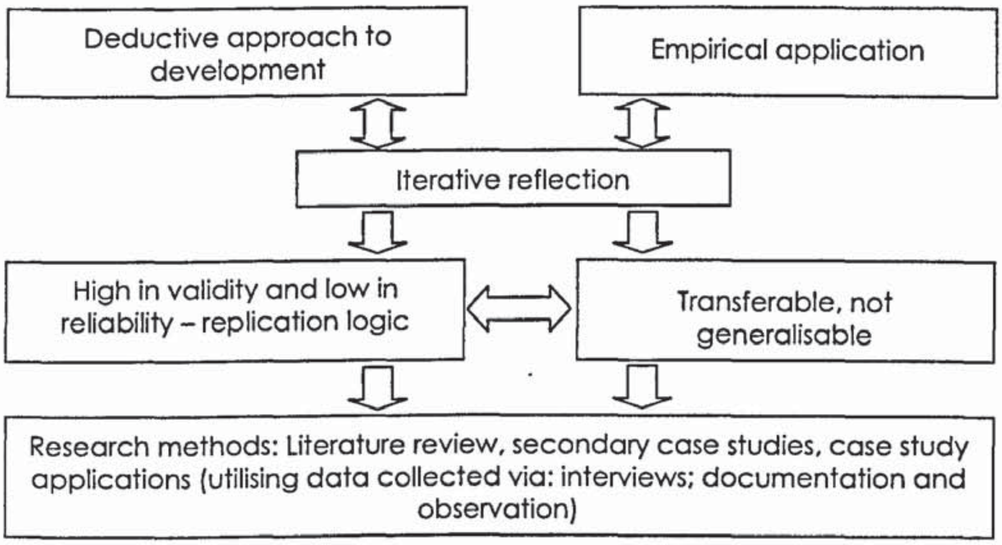
The third stage of the research was to develop the process framework based on the findings of stages one (critical review of frameworks and tools) and two (archival case study analysis). The process framework was developed and piloted using the beer game scenario (Sterman, 1989). The fourth stage of the research, the case study application approach was utilised because the issue of design and selection of supply system architecture is contextually so rich and relatively unexplored within the context of supply chains and networks. Hence, a qualitative research method was required to allow for deeper analysis and exploration. Platts (1993) indicates action research as being vital in the manufacturing arena, however, despite this case study application was chosen. The reason for the use of a case study application approach to testing the process framework, prior to action research, was to minimise risk and demonstrate feasibility.

The critical review (stage one) and archival case study analysis (stage two) determined the structure or "what" should be done when designing and selecting supply system architecture. Therefore, conducting further interviews was not deemed effective enough to test the framework, particularly when comparing the interview method to applying the framework to contextually rich cases. The procedure adopted in the case study application is detailed. The process framework was applied to three case studies: a snack manufacturer maize supply chain; a luxury automobile seat set supply chain and a drill manufacturer network. The detailed amount of data was available, which supported the ability to test the process framework in rich contexts was the key reason for selecting these cases. The fifth and final stage explored the feasibility, usability, utility and validity of the process framework. The research approach is then discussed in terms of validity; reliability and the ethical implications.

## 3.1 Justification of the methodological approach

The methodological approach is summarised in figure 3.1, the approach was deductive in nature, in response to Camerer's (1985) criticism that previous theories should be built upon more in business research (Camerer, 1985). In the field of supply management, Camerer's (1985) view is supported, as Harland (2006) and Croom et al (2000) indicate that more theoretical development and discussion is required. Croom et al (2000) highlight the fact that the majority of the work has been empirical-descriptive, while acknowledging the importance of this contribution, they also argue that theoretical development is essential. Furthermore, Croom et al (2000) feel that the inductive-deductive dichotomy should be addressed by constant reflection of empirical versus theoretical. Within the thesis this was initially achieved through combining the critical review (chapter 4) with the analysis of the empirical case studies in chapter 5. Furthermore, the conceptual framework and process framework are derived mainly from the theoretical perspective, and then applied to empirical case studies.

**Figure 3. 1 Summary of the methodological approach**




The approach is therefore high in validity due to the iterative reflection between theory and empirical data. However, the reliability of the conclusions drawn is low, due to the limited number of applications. The methodological approach focused on achieving, what Yin (2003) describes as analytical generalisability; as opposed to statistical generalisability. Analytical generalisability refers to being able to generalise theoretical propositions, as opposed to being able to generalise populations or universes (Yin, 2003). The process framework developed may not exactly fit the selection of supply system architecture in every supply chain/network setting. However, the process framework has been proven to be transferable to a number of different supply chain/network settings. Therefore, the process framework is valid, but cannot be considered to be reliable. The reliability of the process framework improves with further application and testing, this is discussed in more detail in section 3.9.

Research methods are an issue of continual debate in the social science community; specifically many debates have arisen around using quantitative-based natural sciences research methods to describe social sciences. This debate has fuelled the adoption of qualitative methods as an alternative and to supplement quantitative methodologies in management research. Quantitative methodology is considered to be characteristic of a positivist approach, it emerges from scientific investigation, which seeks to quantify phenomenon, hence generalise reality. Quantitative methods analyse data using mathematical and statistical algorithms, this data can arise from surveys or experiments. Within the field of logistics and supply management, these quantitative techniques are still the dominant research methodology, this is indicated by Sachan and Datta's (2005) [1] review of supply chain and logistics journal papers that found 50% of journal articles followed a quantitative methodology. Specifically, 34.6% of articles utilised surveys; 10.4% used mathematical models and 5% used simulation[1]. Reviewing a different set of academic journals (with one common journal, the International Journal of Physical Distribution and Logistics Management), Reichhart and Holweg (2006)[2] found that 60% of journal articles utilised quantitative methods. Specifically, they found that

[1] Sachan and Datta (2005) reviewed 442 journal papers from 1999-2003, focusing on SCM and logistics research published in three journals: the Journal of Business Logistics; International Journal of Physical Distribution and Logistics Management and Supply Chain Management: An International Journal.

mathematical solutions dominated at 26%; simulation at 11%; quantitative analysis of archived/contextual data at 3% and experimentation at 1%[2].

The positivist traditions behind quantitative methodologies are criticised for many reasons; the following list is abridged from Guba and Lincoln (1994):

1. *Context Stripping* – Using subsets of variables, excludes other variables that may greatly effect findings;
2. *Exclusion of meaning and purpose* – Cannot understand human behaviour without reference to the meanings and purposes that humans attach to activities;
3. *Disjunction of grand theories with local contexts: The ettic/emic dilemma* – The outsider (ettic) theory may have little meaning for the insiders (emic);
4. *Inapplicability of general data to individual cases: nomothetic/idiographic disjunction* – Generalisations, although statistically meaningful, have no applicability to the individual case;
5. *Exclusion of the discovery dimension in inquiry* - Hypotheses determined in advance, less creative input;
6. *The theory-ladenness of facts* - Using same terminology in hypothesis testing can be unobjective, facts are proven within a particular theoretical window;
7. *The underdetermination of theory* - The problem of induction - same facts support different theories;
8. *The value-ladenness of facts* - Using a specific set of values for determining theories leads to theories only being appropriate in a particular value window;
9. *The interactive nature of the inquirer-inquired into dyad* - Investigator cannot be totally objective, they can influence the phenomenon.

These criticisms have resonance when considering supply chains and networks. For instance, stripping out the context (1) and being inapplicable to individual cases (4) or within a particular value window (8) would undermine any findings that deal with supply chains/networks which are inherently complex. Developing a process framework for selecting supply system architecture needs to be meaningful for insiders,

[2] Reichhart and Holweg (2006) reviewed 89 journal papers from 2004, focusing on supply chains, published in six journals: Journal of Operations Management; International Journal of Operations and Production Management; Management Science; International Journal of Production Research; Journal of Business Logistics and International Journal of Physical Distribution and Logistics Management.

i.e. those making the decision (3). Despite these criticisms quantitative research has been vital in building understanding supply chains (Croom et al., 2000, Sachan and Datta, 2005).

Further criticism has arisen over the historical use of "safe" research methods, namely, surveys, interviews and one-day visits within business research which Platts (1993) considers to be unrewarding for industrial collaborators. Utilising a narrow approach has also been criticised in the field of information systems research (Orlikowski and Baroudi, 1991). Hence, the methodologies adopted in research projects have begun to embrace different epistemological approaches and hence a wider range of research methods are being employed, including the extensive use of interviews; case studies and the action research method. The interview method was not utilised to test the process framework, for two reasons. Firstly, the existing research had already used interviews to determine the implementation issues. Secondly, it would be difficult for the interviewees to reflect on the validity of the process framework, without seeing it applied to real data. The other alternative, action research, was considered too risky at the initial testing phase. The process framework had been derived from literature, but more evidence and testing should be conducted prior to implementing it in practice. Hence, at the initial testing stage, case study application was considered to be more appropriate. Case study applications would allow for the application of the process framework to real business scenarios, without the risk. Analysis of the case study applications could then be conducted to ensure its usefulness and feasibility before use in practice.

The use of case studies has been explored as an effective and important research method, within the fields of information systems (Benbasat et al., 1987), operations management (Voss, 2002) and logistics (Ellram, 1996). Case studies are important for addressing those how and why questions (Benbasat et al., 1987, Yin, 2003). Yin's (2003) definition of a case study is as follows:

> "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident" (Yin, 2003, pp. 13)

Stake (1995) distinguishes between intrinsic and instrumental case studies. Intrinsic are focused on the better understanding of one particular case, whereas instrumental case studies examine to provide insight into an issue or refinement of theory. The research problem will be focused on instrumental cases; here the case is seen as secondary, it is designed to play a supportive role. If access can be gained, a collective case study would be particularly valuable due to the number of parties involved in a supply chain; collective case studies as the name suggests use a number of cases to inquire into the phenomenon. Case study research is not only used for describing phenomenon (Stake, 1995, Yin, 2003), it can also be used to develop theory (Eisenhardt, 1989) and test theory (Sarker and Lee, 2002).

The characteristics of case study research, identified by Benbasat (1987), from reviewing, Benbasat, 1984, Bonoma, 1983, Kaplan, 1985, Stone, 1978, Yin, 1984, are as follows:

1. Phenomenon is examined in a natural setting;
2. Data are collected by a multiple of means;
3. One or few entities (person, group, or organisation) are examined;
4. The complexity of the unit is studied intensively;
5. Case studies are more suitable for the exploration, classification and hypothesis development stages of the knowledge building process; the investigator should have a receptive attitude towards exploration;
6. No experimental controls or manipulation are involved;
7. The investigator may not specify the set of independent and dependent variables in advance;
8. The results derived depend heavily on the integrative powers of the investigator;
9. Changes in site selection and data collection methods could take place as the investigator develops new hypotheses;
10. Case research is useful in the study of "why" and "how" questions because these deal with operational links to be traced over time rather than frequency or incidence;
11. The focus is on contemporary events.

These characteristics support the use of the case study method to investigate how supply system architecture should be selected. It would not be possible to analyse all scenarios of supply system architecture selection, so focusing in on particular organisations (number 3) allows for detailed exploration. Specifically, when investigating supply system architecture selection it is important to understand the complexity of the setting (number 4), without manipulation (number 6), which is supported by the examination of the natural setting (number 1) and the collection of multiple means of data (number 2). Yin (2003) describes the multiple data means as an 'envelope' with the unique ability to deal with a great variety of evidence - documents, archival records, artefacts, interviews, and observation. He states that the great variety of evidence enables grouping the holistic and meaningful characteristics of reality which, therefore, generates understanding of complex social phenomena (Yin, 2003).

The exploratory (number 5) and contemporary (number 11) emphasis in case study research makes it suitable for investigating supply system architecture selection. It is a contemporary issue facing supply chains/networks and relatively little is know about "how" (number 10) to conduct the analysis. The unconstrained exploration of the situation (number 7) is also important in considering supply system architecture. The conceptual framework (c.f. figure 2.12) developed cannot yet predict which characteristics will make a particular supply system architecture more suitable. The ability to change site location (number 9) is also important as when considering supply chains/networks the focus and boundary may shift over time.

These characteristics of case study research emphasise flexibility and depth of analysis, which has led to it becoming the most popular qualitative research method in the field of supply management. Both Sachan and Datta's (2005) and Reichhart and Holweg's (2006) reviews identified case studies as the most commonly employed qualitative research method, with 16.1% and 15% of papers studied employing the case study method respectively. Voss et al. (2002) state:

> "case research has consistently been one of the most powerful research methods in operations management" (Voss et al., 2002, pp. 195).

The strengths of case studies include the wealth of information that is revealed, however, this can also be a downfall as cause and effect are difficult to ascertain. This problem is compounded by post hoc rationalisation, whereby individuals ascribe meaning to their activities to justify their decisions and actions. Another weakness is that case studies can be very time consuming. Case studies involve respondents reflecting on the past, which can be distorted account. Access to organisations willing to participate in case studies is required, which can present difficulties. The selection of cases to provide phenomenon explanations can also be difficult. Despite these difficulties the case study approach was adopted due to the contextually rich exploration it provides. The case study approach was supplemented by the use of a critical review, the next section summarises how the research was conducted.

## 3.2 Summary of the methodological approach

This section firstly by explains the unit of analysis and secondly outlines the five stage research procedure to address the research objectives. The five stages of the research were, firstly, the critical review of frameworks and tools; secondly, the archival case study analysis; thirdly, the development of the process framework; fourthly, the testing of the process framework via case study application and fifthly, the discussion analysis of the feasibility, usability, utility and validity of the process framework.

### 3.2.1 Unit of analysis

The selection of supply system architecture was revealed to be problematic for organisations and supply chains/networks in the literature review (chapter 2). The research, therefore, focuses on developing a process framework for selecting supply system architecture. The research focuses on testing this process framework, specifically, utilising case study application research. The unit of analysis for this research can be defined as "manufacturing supply chains/networks amenable to changing supply system architecture". Therefore, case studies were located that were in the manufacturing sector, where more than two organisations were involved, these delimitations were previously discussed in section 1.6. Further to these previously justified delimitations, it was also important that the supply chains/networks had scope to change/alter their supply system architecture, in order to explore the viability of the proposed process framework.

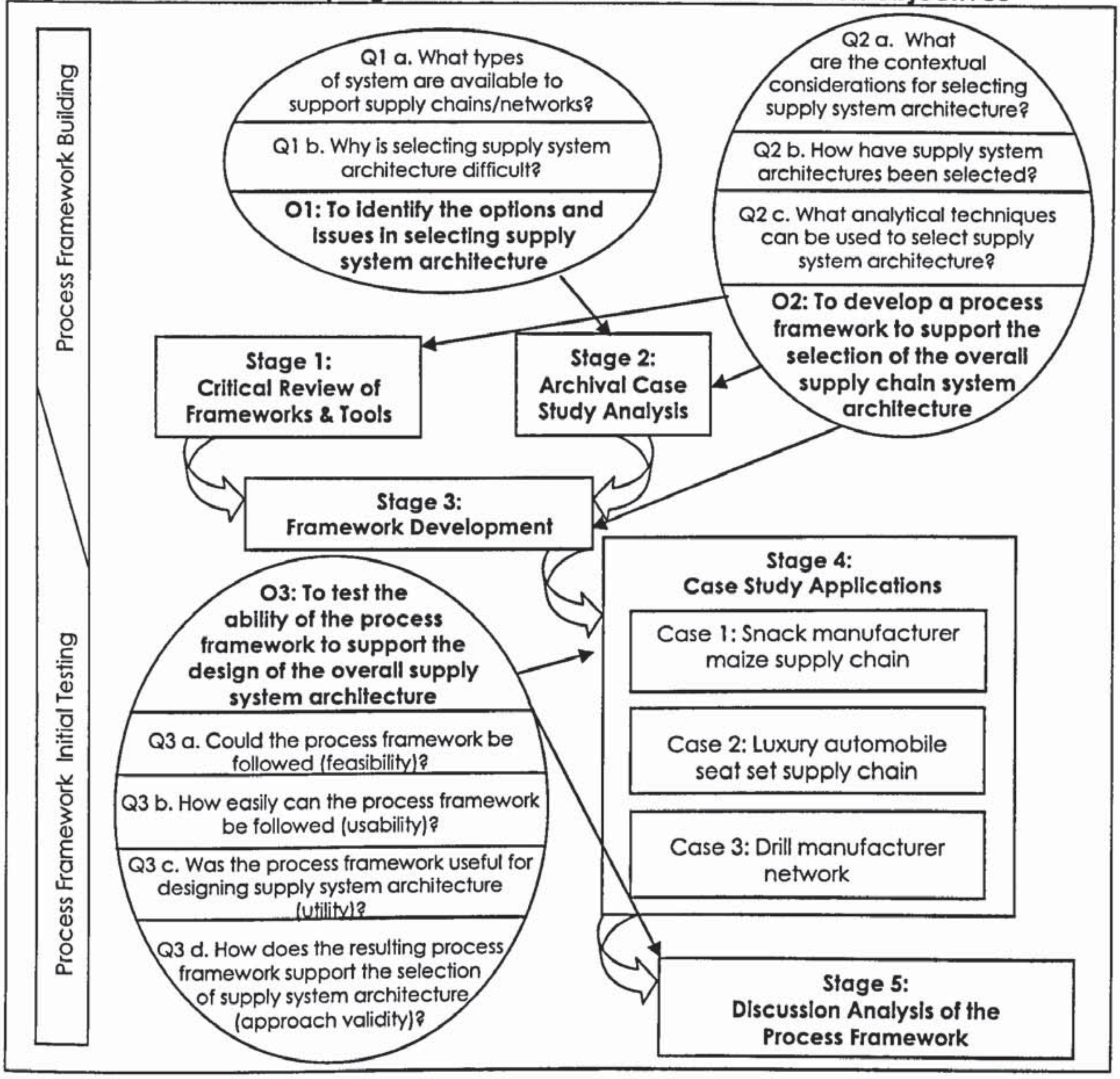
### 3.2.2 Summary of research programme

The previously stated research objectives and underlying questions (see table 1.1) require the use of a number of different research methods. The objectives and the research methods used to meet the objectives are summarised in figure 3.2. The first stage was to conduct a critical review of the frameworks and tools contained in chapter 4. The first focus of the review was on how the supply system architectures have been selected Q2b) and analytical tools available (Q2c) for supply system architecture selection. The critical review was, therefore, used to steer the development of a process framework for deciding on supply systems architecture.

The second stage involved archival case study analysis of companies and supply chains/networks that had adopted new supply system architectures, shown in chapter 5. The archival case study analysis considered the issues (Q1b) in selecting supply system architecture, the contextual considerations (Q2a) and explored how supply system architectures have been selected (Q2b). These two stages resulted in a list of requirements for a new process framework for the selection of supply system architecture. The third stage realised these requirements through structuring and designing the process framework for selecting supply system architecture (O2), depicted in chapter 6. The requirements were deduced from previous research; hence this stage also utilised the information obtained by completing both the first and second stages.

The fourth stage involved testing the framework by applying it to three industrial case studies (O3), thus testing it in different industrial settings, contained in chapter 7. Different industrial settings were explored in order to determine whether the process framework was transferable. The fifth stage considered whether the process framework could be followed (Q3a); how easy it was to follow (Q3b); whether it was useful (Q3c) and how valid it was for guiding the process of selecting supply system architecture (Q3d), shown in chapter 8.

**Figure 3. 2 Research programme to address the three research objectives**




# 3.3 Stage 1: Critical review of existing frameworks and tools

The critical review was focused on addressing two research questions, how have supply system architectures been selected (Q2 b) and what techniques can be used to aid selection (Q2 c). A review of the literature showed that not many frameworks for selecting supply system architecture were available, only eight different frameworks for ERP selection and five for supply software or e-business software were located. These existing frameworks and methodologies for selecting supply systems were assessed according to the general characteristics of successful methodologies in manufacturing strategy (Platts, 1994, Platts et al., 1996) and the specific issues in the selection of supply system architecture identified in chapter 2. The specific issues were to address the functionality issue in the analysis (section 2.2); to consider implementation aspects (section 2.4) and to consider compatibility with the supply chain/network (section 2.5). The four characteristics identified by Platts (1994) and Platts et al (1996) are procedure; participation; project management and point of entry. The combination of these four and the findings from the literature review (c.f. chapter 2) led to a list of criteria to assess the different frameworks and methodologies against. The evaluation of these was supplemented by a review of the different decision-making tools and techniques that could be used in the selection of supply system architecture.

## 3.4 Stage 2: Archival case study analysis

The archival case studies were analysed to further shed light on how supply system architectures been selected (Q2 b), which was also addressed in stage one. Further to this, the archival case studies would address two other research questions: firstly, why is selecting supply system architecture difficult (Q1 b) and secondly, what are the contextual considerations (Q2 a). Archival case studies were used, which Yin (2003) states can be valid and high quality, also advocated in the field of OM (Lewis, 1998); IS (Jarvenpaa, 1991) and logistics (Sachan and Datta, 2005).

An embedded multiple-case study design (Yin, 2003) was used, cases were identified that were at the correct unit of analysis (supply system design and selection process in manufacturing supply chains) and were reported on reliably. There has been debate on how many cases should be studied in case study research (e.g. Eisenhardt, 1989, Yin, 2003) six were chosen to meet both Yin (2003) and Eisenhardt's (1989) views and utilise sufficient replication logic (Eisenhardt, 1989, Yin, 2003) and consequently improve the analytical generalisation of the findings. The six cases analysed were: Geneva Pharmaceuticals (Bhattacherjee, 2000); Manco (Al-Mashari and Al-Mudimigh, 2003, Al-Mashari and Zairi, 2000b); Paper Co (Koh et al., 2006); Rolls Royce (Yusuf et al., 2004) ;

Texas Instruments (Sarkis and Sundarraj, 2003) and Wine Co (Mandal and Gunasekaran, 2002). The analysis of the cases was conducted following Miles and Huberman's (1994) guidelines.

## 3.5 Stage 3: Development of the process framework

The third stage was to develop a process framework based on the list of requirements derived from the previous stages. The process was iterative, utilising the beer game as an illustration to enlighten how the process would work. The developmental stage involved conducting the different analysis to determine their usefulness and application at various stages. The structured approach of the process framework was created by following Herbert Simon's (1977, 1991) model of decision making: intelligence; design and choice. Simon (1991) added an implementation phase, which is not included in the process framework, due to the previous delimitation around the design and selection problem, discussed in section 1.6. Phase 1 of the process framework, scope the supply chain/network, is the intelligence phase was tailored to the selection of supply system architecture. In this first phase the problem is identified and stated. Phase 2 of the process framework, identify options for supply system architecture, is the design phase. This phase focuses on developing a model of the supply chain/network; identifying options and setting criteria for assessing the options, through functionality requirements and key performance indicators (KPIs). The third phase, select supply system architecture, is the choice phase, which involves the selection of the best alternative and the vendor. The supporting tools and techniques were applied to the beer game to verify their suitability and the outputs that could emerge from their application. The logic of the analysis was, therefore, piloted with the beer game.

## 3.6 Stage 4: Case study applications

The fourth stage was the case study applications, which involved utilising the process framework in three industrial cases. Applying the framework was the preferred research method, as the analysis would be contextually rich and exploratory. Three cases were selected to achieve literal replication (Yin, 2003). These cases were used to demonstrate that the framework can be considered feasible (Q3a); usable (Q3b); useful (Q3c) and approach validity (Q3d) (Platts, 1993). Two of the cases used were of external supply chains (Harland, 1997): a snack manufacturer maize supply chain and a luxury automobile seat set supply chain. The snack manufacturer supply chain data was collected by the Dynamic Operations Management Across the Internet (DOMAIN) research group and published in Ho (2002). The luxury automobile seat set supply chain data was available through collaborating with the FUSION research group, who collected the data. The final case study application is of network (Harland, 1997) scope and is based on a business simulation game used by Aston University and originally developed with Lucas (Parker and Mackness, 1986). Due to the fact that the framework is based on three case studies alone, it approaches validity, however, needs further testing.

The case study application approach was selected as an appropriate method for testing the framework, as this would allow for practical exploration of the effectiveness of the different stages across a variety of different industrial contexts. There are other examples where case study applications have been employed to test processes; frameworks and methodologies, including within the supply system architecture arena to one case study (Ho and Lin, 2004, Light et al., 2001, Sarkis and Sundarraj, 2001, Wei et al., 2005, Wei and Wang, 2004) and multiple case studies (Ho, 2002, McGarrie, 1993, Sharifi et al., 2006). According to Platts (1993) there are three initial issues that must be considered when designing how to test a framework/methodology: 1) the involvement of the researcher; 2) the consistency of the process and 3) the choice of cases to be studied (Platts, 1993), these are now discussed in turn, followed by a discussion of the data collection methods and a summary of the testing approach.

### 3.6.1 The involvement and reflexivity of the researcher

Gold (1958) identified that there are different roles that the researcher can take: non-participant observer; participant observer; and action research (Gold, 1958). These vary in the degree to which the researcher is involved, a non-participant observer merely witnesses and remains detached. Whereas, a participant observer is a member of the group and takes part, although does not direct or influence the tasks, at the same time as observing the scenario. Action research takes participant observation a stage further, whereby the researcher does direct and influence the way the activity is conducted. The purpose of the testing phase was to develop and refine the framework, through application; hence, action research was an appropriate approach. The action research role of the researcher would enable a consultancy and facilitator role to be adopted. However, it can be argued that adopting a role this involved invalidates the testing process because the process framework is being altered and modified during its application if necessary to respond to the needs of the supply chain/network. However, if case study application is used, the process framework can be applied, as it was designed, without risk that action should have been taken. Applying the process framework in this way will enable for reflection and critique of its feasibility; usability and utility across consistent applications.

Therefore, utilising the case study application approach the involvement of the researcher is confined to the non-participant observer for data collection, to ensure independence in the application stage. The reflexivity of the researcher must be considered to determine whether any potential bias in the articulation of the case study scenario exists. The use of more than one investigator in two of the cases (see table 3.2), minimises the potential bias and thus improves the validity of the case information as investigator triangulation has occurred. Furthermore, all three cases were part of large scale supply chain or education projects, therefore, a wide range of evidence and data was collected, which increases the holistic encapsulation of the case. Therefore, any bias or influence within the data collection phase is reduced. However, reflexivity of the researcher has a greater impact in the actual testing. Moreover, the process framework was developed and tested by the same person, and hence, a bias exists in the desire to prove, rather then disprove its viability. However, due to the consistency of application and documentation of the applications (shown in chapter 7), the reflexivity issue is addressed somewhat in the depth of evidence.

### 3.6.2 The consistency of the process

To ensure consistency in application of the process framework the same researcher was utilised. However, if different researchers tested the process framework by applying it in their own way, the testing would be more robust and valid as investigator triangulation would have occurred. At the initial testing phase, it was more important to ensure consistency of the process of application; therefore, single investigator was appropriate. The documentation of the different phases and individual steps illustrates consistent application of the process framework (see chapter 7). Furthermore, the case study application analysis was conducted over the same time frame to ensure consistency.

### 3.6.3 Selection of case study supply chains

The choice had to be made whether to test the framework using similar supply chains/networks or whether to test the feasibility of the general process in a number of different scenarios. The aim was to test the process and consider the potential to refine it; hence, a broader spectrum of supply chains/networks was required. The case studies were selected to reflect a range of situations and across external supply chains and networks, as justified in section 1.6. Table 3.1 below shows the supply chains/networks selected for application. Three cases were chosen, firstly, in the food industry a snack manufacturer maize supply chain, secondly in the automotive industry a luxury automobile seat set supply chain was selected and thirdly, within the hand tools industry a drill manufacturer network. These supply chains/networks were selected due to the depth of data available, which facilitated in-depth analysis of the industrial context. Two of the cases were based on cases from projects funded by EPSRC and the other case was an in-depth teaching case utilised by Aston Business School.

**Table 3. 1 Summary of cases used for experimentation**

| | Case 1: Snack Manufacturer Maize Supply Chain | Case 2: Luxury Automobile Seat Set Supply Chain | Case 3: Drill Manufacturer Network |
|---|---|---|---|
| **Supply chain level** | External chain | External chain | Network |
| **Industry** | Food | Automotive | Hand tools |
| **Source** | Ho, 2002 | Collaboration with FUSION research group | Parker and Mackness, 1986 |
| **Project Background** | DOMAIN research group project, funded by EPSRC | FUSION research group project, funded by EPSRC | ***Fictionalised*** case study and extensive simulation game used by Aston Business School |

The data collected from three case studies was used to apply the framework and test whether it was a feasible; usable and useful approach to the problem. The methods of data collection are now discussed.

## 3.6.4 Data collection methods

Yin (2003) defines six sources of evidence in case study research: documentation; archival records; interviews; direct observation; participant observation and physical artefacts. As far as possible, the different sources of evidence were collected and used to describe and define the supply chain/network to enable the fullest application of the process framework, shown in table 3.2.

Documentation was strongly relied upon in all three cases; documentation was in both qualitative and quantitative forms. The two EPSRC based cases used interviews considerably, and these interviews were conducted by a range of interviewers which meant that investigator triangulation occurred which strengths the validity of the case. Direct observation of the processes occurred in the two EPSRC project cases, including observation by the author. The data collection was mainly by other researchers to ensure independence in the eventual application of the process framework. The independence was considered important in the testing approach.

### Table 3. 2 Summary of data collection methods

| | | Case 1: Snack Manufacturer Maize Supply Chain | Case 2: Luxury Automobile Seat Set | Case 3: Drill Manufacturer |
|---|---|---|---|---|
| **Data collection (6 sources of evidence)** | | | | |
| **Documentation** | ***Qualitative*** | Internal documents, no examples specified | Internal documents, e.g. process flowcharts | ***Fictionalised*** Internal documents, e.g. process documentation |
| | ***Quantitative*** | Including: purchase orders, invoices and return orders | Including: demand information, MRP results, kanban calculations, overlay data | ***Fictionalised*** performance data, inventory data, demand data |
| | ***Collected by*** | DOMAIN research group members | FUSION research group members | ***Fictionalised,*** based on Lucas semi-conductors |
| **Archival records** | | N/A | N/A | N/A |
| **Interviews** | ***Type*** | Structured, unstructured and semi-structured | Structured, unstructured and semi-structured | N/A |
| | ***Sample*** | Key individuals in Maize supplier and with haulier | Key individuals from all companies | N/A |
| | ***Interviewer*** | DOMAIN research group members | FUSION research group members | N/A |
| **Direct observation** | ***Locations*** | Cleaning and milling in maize supplier | Different plants | N/A |
| | ***Observor*** | DOMAIN research group members | FUSION group members Author (luxury automobile only) | N/A |
| **Participant observation** | | N/A | N/A | N/A |
| **Physical artefacts** | | N/A | N/A | N/A |
| **Triangulation** | | Data and investigator | Data and investigator | Data |

## 3.6.5 Testing approach

The framework was tested by applying the framework to each supply chain/network, and performing the analysis based on the individual situation for that supply chain/network. Hence, it was important to have access to the appropriate data to apply the framework as fully as possible to the case. The framework needed to be tested to ensure it was a useful contribution to the field and establish whether it did provide a practical, step-by-step approach to selecting the appropriate supply chain system.

## 3.7 Stage 5: Discussion analysis of the process framework

Stage five focuses on evaluating and discussing the four underlying research questions linked to objective three, testing the feasibility; usability; utility and validity of the process framework. Hence, in order to test the framework, Platts' (1993) criteria were adopted, his three criteria for evaluation are: feasibility; usability and utility (Platts, 1993). Platts' (1993) criteria have since been employed in a range of different contexts, e.g. manufacturing action plans (Tan and Platts, 2002) human performance modelling methodology (Baines and Kay, 2002) and make or buy decisions (Cánez et al., 2000). Platts' (1993) criteria were posed as the following questions in Platts et al (2001):

1. Feasibility - can the processes be followed?
2. Usability - are the procedures, tools and techniques in the process easy to use?
3. Utility - is the process worth following?

Tan and Platts (2002) break each of these criteria into sub-criteria, in their research that focuses on manufacturing action plans, as shown in table 3.3. These sub-criteria were considered to be appropriate to evaluate the process framework developed for selecting supply system architecture. Therefore, once the framework had been applied to the three case studies discussed in 3.6.3, the framework was critiqued against the three criteria and their sub-criteria. The sub-criteria were further broken down in places, as stipulated in section 8.1. The resulting evaluation is discussed in sections 8.2-8.4.

**Table 3. 3 Tan and Platts (2002) criteria and sub-criteria for evaluation**



Source: Tan and Platts (2002)

## 3.8 Limitations of the research approach

The research approach has a number of limitations, firstly, the number of cases explored. Three cases is sufficient for literal replication (prediction of similar results), therefore and a further 4 to 6 for theoretical replication (predicts contrasting results but for predictable reasons) (Yin, 2003). Secondly, the limitation of initial testing of the process framework, rather than full testing in practice. Initial testing was necessary to develop confidence and assurance in the process framework. Further work is discussed in section 9.5.

## 3.9 Validity and reliability

The research approach utilised triangulation to overcome weaknesses and potential bias (Denzin, 1978, Miles and Huberman, 1994). The thesis combined theory triangulation and data triangulation within the literature review, as a variety of sources and theories were investigated. The "utility and power" of these theories was assessed in the literature, resulting in what Denzin (1978) has termed theory triangulation. Therefore, the resulting process framework was created in a holistic way. Within methods methodological triangulation also occurred to improve the validity of the process frameworks as the literature review was combined with archival case study analysis. Within the initial testing stage of the research both data and investigator triangulation was apparent in the case study applications. Therefore, the case data utilised to test the process framework was validated.

Validity of the process framework is improved through the successful application to three case studies, shown in chapter seven. Although three case studies are not sufficient to declare theoretical replication; this number of cases does show literal replication (Yin, 2003). Therefore, the process framework can be considered to be transferable into different industrial contexts. The validity of the process framework could be further enhanced by more testing; this is considered in section 9.5.1.

## 3.10 Ethical considerations

The utilisation of case study applications, rather than action research reduces the ethical implications. However, data had to be handled in an ethical way. Specifically the supply chains/networks wanted to maintain anonymity. Anonymity was maintained by changing the names of the organisations and products within the cases.

## 3.11 Conclusion

The research methodology was a combination of literature review and archival case study analysis for the development of a process framework for the selection of supply system architecture. The research methodology for the initial testing of the process framework stage was case study application. The cases were carefully selected for the depth of data available and suitability. The case study applications utilised the same researcher for consistency. The testing approach involved the application of the process framework to the cases (chapter 7) as well as a discussion and critique of feasibility; usability and utility (chapter 8).

# Chapter 4 - Stage 1: Critical Review of Existing Frameworks and Tools to Select Supply System Architecture

Existing frameworks in the literature are explored to find out "how" supply system architectures could be designed and selected. These frameworks were revealed to often focus on one type of solution, e.g. ERP (Lee, 1998, Sarkis and Sundarraj, 2001, Wei and Wang, 2004,) or e-marketplaces (Sharifi et al., 2006). Those that do consider different types of solution do not mention the specific systems and the discussion is quite generic (Light et al., 2001, McGarrie, 1993, Sahay and Gupta, 2003). Other frameworks do not do the necessary analysis of business processes and existing systems (Sarkis and Talluri, 2004, Wei et al., 2005). Frequently the supply chain/network is not the focus (Blackwell, 2003, Ho and Lin, 2004, Sarkis and Sundarraj, 2001). The one framework that considers the different supply system architectures in detail (Ho, 2002), excludes ERP and neglects the participation and point of entry requirements.

A process framework for designing and selecting supply system architecture will utilise decision-making techniques. The remainder of this chapter considers the effective group decision making techniques that the process framework will exploit. Firstly, group support systems are explored. The discussion then focuses on analytical hierarchy process (AHP); quality function deployment (QFD) and simulation. These decision-making tools were considered particularly appropriate due to their interactive nature, which is vital for group decisions.

## 4.1 Critical review of frameworks for selection

The existing frameworks and methodologies for selecting supply systems, including integrated enterprise systems (e.g. Blackwell, 2003, Blackwell et al., 2006) and e-marketplaces (e.g. Sharifi et al., 2006), were critiqued. The critique assessed the frameworks according to the specific issues in the selection of supply system architecture identified in chapter 2 and the general characteristics of successful methodologies in manufacturing strategy (Platts, 1994, Platts et al., 1996). These general characteristics were included because even though they were identified for manufacturing strategy formulation, they are logical and can be coherently translated to considering the design and selection of supply system architecture.

The specific issues were to address the functionality issue in the analysis (section 2.2); to consider compatibility with the supply chain/network (section 2.5) and to pay attention to the direct and overarching managerial aspects derived from the implementation literature (section 2.4). There is some overlap the previously identified overarching managerial aspects in section 2.4 and Platts' (1994) desirable characteristics of successful strategy formulation methodologies. Platts (1994) identifies: procedure; participation; project management and point of entry, see table 4.1. The identification of change and structural management and good communications from section 2.4, falls under participation in Platts' (1994) list. Both section 2.4 and Platts' work (1994) indicate that project management is required. The managerial aspects that are directly important in design and selection: business case; business process management; existing systems management and software selection from section 2.4, would need to be included as part of the procedure, as the procedure is for design and selection of supply system architecture, not strategy formulation.

**Table 4. 1 Platts' (1994) characteristics of successful strategy formulation methodologies**

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Illustration removed for copyright restrictions

Source: Platts (1994)

Therefore, the list of criteria for evaluating the different frameworks and methodologies in the literature is as follows:

- Procedure (Platts, 1994, Platts et al., 1996), specifically:
  Gathering information:
  - Business process management (section 2.4);
  - Existing systems management (section 2.4).

  Analysing information:
  - Functionality of different software and e-business systems (section 2.2);
  - Compatibility with strategy (section 2.5);
  - Compatibility with supply chain/network (section 2.5);
  - Software selection (section 2.5).

  Identifying Improvements (Platts, 1994, Platts et al., 1996)
  - Written record: Business case (section 2.4);
  - Tools and techniques (Platts, 1994, Platts et al., 1996) – also discussed in section 4.2.
- Participation (Platts, 1994, Platts et al., 1996), including:
  - Groups (Platts, 1994, Platts et al., 1996) ;
  - Workshop style (Platts, 1994, Platts et al., 1996);
  - Change management (section 2.4);
  - Good communications (section 2.4);
  - Decision making forum (Platts, 1994, Platts et al., 1996).
- Project management
  - Resourcing (Platts, 1994, Platts et al., 1996);
  - Timescales (Platts, 1994, Platts et al., 1996).
- Point of Entry
  - Expectations; understanding and commitment (Platts, 1994, Platts et al., 1996).

It was difficult to find comprehensive frameworks that did compare the different types of systems to support supply chains/networks discussed in section 2.2. However, eight different frameworks for ERP selection and five for supply software or e-business software were found. These thirteen frameworks are as follows:

1. Selecting internal and external supply chain functionality, the case of ERP systems versus electronic marketplaces (Biehl, 2005, Biehl and Kim, 2003)
2. Decision-support framework for implementing enterprise information systems within SMEs (Blackwell, 2003, Blackwell et al., 2006)
3. Methodology for the selection and evaluation of e-business models within supply chains (Ho, 2002)
4. Design part of the critical success factor framework for the implementation of integrated-enterprise systems in the manufacturing environment (Ho and Lin, 2004)

5. An enterprise decision framework for information system selection (Lee, 1998)
6. ERP and best of breed: a comparative analysis (Light et al., 2001)
7. A framework for the selection and implementation of production planning and control systems for small manufacturing companies (McGarrie, 1993, McGarrie, 1998)
8. Development of software selection criteria for supply chain solutions (Sahay and Gupta, 2003)
9. A decision model for strategic evaluation of enterprise information technologies (Sarkis and Sundarraj, 2001)
10. Evaluating and selecting e-commerce software and communications systems for a supply chain (Sarkis and Talluri, 2004)
11. A classification and selection model of e-marketplaces for better alignment of supply chains (Sharifi et al., 2006)
12. A comprehensive framework for selecting an ERP system (Wei and Wang, 2004)
13. An AHP-based approach to ERP system selection (Wei et al., 2005)

The thirteen different frameworks are summarised in appendix 1. They vary in their scope and due to the purpose of many of them could not be expected to meet all the criteria that they were being evaluated against. They did provide a good insight into the strengths; potential analytical tools and confirm that there is a gap to develop a new process framework. The analysis is based on considering the criteria outlined: procedure; participation; project management and point of entry as follows.

### 4.1.1 Procedure: gathering information; analysing information and identifying improvements

The different frameworks were designed for different applications; hence there was some variability in meeting the procedure requirements, which is summarised in table 4.2. The gathering information on business processes and existing systems was fairly consistently considered by the ERP selection frameworks. Three of the frameworks (Sarkis and Sundarraj, 2001, Wei et al., 2005, Wei and Wang, 2004) excluded existing systems, but the assumption could have already been made that an ERP system would replace existing systems. Wei and Wang (2005) also exclude business process management. The e-business and supply chain frameworks, except for Ho's (2002) methodology all ignore business processes and existing systems. In the analysing information section, as anticipated the ERP selection frameworks did not evaluate other software (Blackwell, 2003, Ho and Lin, 2004, Lee, 1998, McGarrie, 1993, McGarrie, 1998, Sarkis and Sundarraj, 2001, Wei et al., 2005, Wei and Wang, 2004), except Light et al (2001) who consider the alternative of best of breed. Light et al (2001) do not really explore the functionality of these solutions in depth. Biehl (2005); Biehl and Kim (2003) and Ho (2002) are the only frameworks that compare solutions together, focusing on functionality. However, Biehl (2005) and Biehl and Kim's (2003) model makes some assumptions on the ability to determine the costs prior to implementation.

Ho's (2002) methodology has the broadest scope of those that consider supply chain and e-business frameworks. Others has a far more narrow scope, e.g. focusing just on e-marketplaces (Sharifi et al., 2006) or not mentioning specific systems (Sahay and Gupta, 2003, Sarkis and Talluri, 2004). The narrow scope is due to the focus addressed by the researchers. There was variable handling of compatibility with strategy and the supply chain/network. Many frameworks were specifically focused on software selection (e.g. Sahay and Gupta, 2003, Wei et al., 2005, Wei and Wang, 2004), so these often took functionality as a given and focused in on other aspects like scalability etc. All frameworks considered written records and business case to varying degrees.

Platts (1994) indicates that simple tools and techniques should be used. The different frameworks used a variety of different tools and techniques in their analysis, including more qualitative analytical tools, like: strengths; weaknesses; opportunities and threats (SWOT) analysis (Blackwell, 2003, Blackwell et al., 2006); audit documentation (McGarrie, 1998, McGrath, 2001) and business process mapping (Light et al., 2001) in the initial stages. Different analytical tools were used for the short listing and selection process, including matrices (Ho, 2002, Sharifi et al., 2006); gap analysis (Lee, 1998); 80/20 rule (Light et al., 2001) and analytical hierarchy process (Sarkis and Sundarraj, 2001, Sarkis and Talluri, 2004, Wei et al., 2005).

**Table 4. 2 Comparison of how the different frameworks meet the procedure requirements**

| | Gathering information: | Business process management | Existing systems management | Analysing information: | Functionality of different software systems | Functionality of e-business systems | Compatibility with strategy | Compatibility with supply chain/network | Software selection | Identifying Improvements and written record: Business case |
|---|---|---|---|---|---|---|---|---|---|---|
| Biehl and Kim, 2003 Biehl, 2005 | | | | | ERP | e-marketplaces | ** | | * | ** |
| Blackwell, 2003, Blackwell et al., 2006 | | ** | ** | | ERP | | *** | | *** | *** |
| Ho, 2002 | | *** | | | SC; CRM and fulfilment | e-marketplaces and e-procurement | ** | *** | *** | ** |
| Ho and Lin, 2004 | | *** | ** | | "Application software" | | *** | | *** | *** |
| Lee, 1998 | | *** | *** | | ERP | | ** | | *** | *** |
| Light et al., 2001 | | *** | ** | | Not explicit, but could include: ERP; APS; TMS; WMS; CRM and SRM. | | *** | | ** | ** |
| McGarrie, 1993, McGarrie, 1998 | | *** | *** | | Not explicit – production control system | | *** | ** | ** | *** |
| Sahay and Gupta, 2003 | | | | | Features included in tree model | | | | * | * |
| Sarkis and Sundarraj, 2001 | | *** | | | ERP | | *** | | *** | *** |
| Sarkis and Talluri, 2004 | | | | | | E-commerce communications | | | * | * |
| Sharifi et al., 2006 | | | | | | E-marketplaces | | ** | * | * |
| Wei and Wang, 2004 | | *** | | | ERP | | *** | | *** | *** |
| Wei et al., 2005 | | | | | ERP | | *** | | *** | *** |

Key: *** = considered in detail, ** = partially considered, * = mentioned and blank is not included

## 4.1.2 Participation; project management and point of entry

Many of the frameworks focused heavily on the procedure and neglected participation; project management and point of entry (Biehl, 2005, Biehl and Kim, 2003, Ho, 2002, Sahay and Gupta, 2003, Sarkis and Talluri, 2004, Sharifi et al., 2006), as shown in table 4.3. Three of the frameworks were particularly strong in the areas of participation;

project management and point of entry (Blackwell, 2003, Blackwell et al., 2006, Light et al., 2001, Wei et al., 2005). Those that emphasised the participation; project management and point of entry were focused on just ERP solutions, with the exclusion of Light et al (2001), who also considered best of breed.

**Table 4. 3 Comparison of how the different frameworks meet the participation; project management and point of entry requirements**

| | Participation: | Groups | Workshop style | Change management | Good communications | Decision-making forum | Project management | Resourcing | Timescales | Point of Entry: expectations; understanding and commitment |
|---|---|---|---|---|---|---|---|---|---|---|
| Biehl and Kim, 2003 Biehl, 2005 | | | | | | | | | | |
| Blackwell, 2003, Blackwell et al., 2006 | | ** | ** | *** | *** | *** | | *** | ** | *** |
| Ho, 2002 | | | | | | | | | ** | |
| Ho and Lin, 2004 | | | | *** | ** | | | *** | *** | ** |
| Lee, 1998 | | | | ** | ** | | | * | *** | ** |
| Light et al., 2001 | | *** | | ** | | ** | | ** | *** | ** |
| McGarrie, 1993, McGarrie, 1998 | | *** | *** | *** | *** | * | | | ** | |
| Sahay and Gupta, 2003 | | | | | | | | | | |
| Sarkis and Sundarraj, 2001 | | | ** | ** | ** | *** | | ** | | |
| Sarkis and Talluri, 2004 | | | | | | | | | | |
| Sharifi et al., 2006 | | | | | | | | | | |
| Wei and Wang, 2004 | | *** | | *** | | ** | | ** | ** | |
| Wei et al., 2005 | | ** | *** | ** | *** | *** | | ** | ** | ** |

Key: *** = considered in detail, ** = partially considered, * = mentioned and blank = not included

## 4.1.3 Overall critique

The frameworks that do exist appear are mainly generic to one kind of solution, specifically, ERP (Blackwell, 2003, Blackwell et al., 2006, Lee, 1998, Sarkis and Sundarraj, 2001, Wei et al., 2005, Wei and Wang, 2004) and e-marketplaces (Sharifi et al., 2006). Other frameworks do not specify the software, and instead focus on creating a framework to manage selection that is more generic (Ho and Lin, 2004, Light et al., 2001, Sahay and Gupta, 2003) or explore other key elements, e.g. communication between the different supply chain partners (e.g. Sarkis and Talluri, 2004). These frameworks rely heavily on accurate and in-depth information from the software vendors themselves and dramatically underplay the need for the software to have the required functionality, which was revealed as the most important in Buxmann et al's Delphi study (2004) (Buxmann et al., 2004). The most comprehensive consideration of different types of system was in Ho's (2002) methodology, although ERP is not included and the participation and point of entry elements are neglected.

There was a considerable lack of concentration on supply chain issues within these frameworks (Blackwell, 2003, Blackwell et al., 2006, Ho and Lin, 2004, Lee, 1998, Light et al., 2001, Sahay and Gupta, 2003, Sarkis and Sundarraj, 2001, Wei et al., 2005, Wei and Wang, 2004). Some frameworks were based on harnessing specific decision-making techniques, e.g. AHP (Sarkis and Sundarraj, 2001, Sarkis and Talluri, 2004, Wei et al., 2005). The consideration of participation; project management and point of entry was far more patchy, with some frameworks focusing most strongly on procedure (Ho, 2002, Sahay and Gupta, 2003, Sarkis and Talluri, 2004, Sharifi et al., 2006).

The review of these frameworks demonstrated that there are some existing frameworks that can be built upon. Specifically, Ho's (2002) consideration of many types of system and supply chain issues will be drawn upon. The use of AHP as a tool for analysis (Sarkis and Sundarraj, 2001, Sarkis and Talluri, 2004, Wei et al., 2005) is another important consideration. In order to ensure that design and selection process includes participation; project management and point of entry, the frameworks developed by Blackwell (2003); Blackwell et al (2006); McGarrie (1993) and Wei et al (2005) can be used as a source of information. None of the existing frameworks delivered on all of the requirements; therefore, there is scope to develop a new process framework for design and selection of supply system architecture. The new process framework will need to utilise effective decision-making tools (drawn out in the procedure section, 4.1.1), these tools are discussed in more detail in the next section.

## 4.2 Decision making tools and techniques

Previous frameworks utilised a variety of decision-making tools and techniques, which is indicative of those available to select supply system architecture. The tools and techniques utilised, were as follows:

- AHP (Sarkis and Sundarraj, 2001, Sarkis and Talluri, 2004, Wei et al., 2005);
- audit document (McGarrie, 1993);
- business process map and 80/20 rule (Light et al., 2001);
- cost modelling (Biehl, 2005, Biehl and Kim, 2003);
- critical success factor analysis in Ho and Lin (2004);
- flowchart and gap analysis Lee (1998);
- percentage weighted tree model (Sahay and Gupta, 2003);
- QFD/other matrices (Ho, 2002, Sharifi et al., 2006);
- two-dimensional analysis and fuzzy set theory (Wei and Wang, 2004);
- simulation (Ho, 2002);
- workbook-based set of tools (Blackwell, 2003, Blackwell et al., 2006).

The majority of the authors do not justify why a particular decision-making tool or technique should be used. Blackwell (2003) does justify the use of workbooks, but not the individual tools and techniques utilised within the workbook. Sarkis and Sundarraj (2000) do justify the use of AHP in their previous paper.

The supply system architecture decision is inherently a group decision, which will need to be made by the key individuals from the supply chain/network. Platts (1994) further highlights the need for a decision-making forum. Group work and group decisions can generate both process gains and process losses (Turban et al., 2005), summarised in table 4.4. These gains and losses further emphasise the need for a decision-making forum. The archival case studies indicated that consultants dominated the process, which could tenuously indicate that the problem was not owned (gain 2) by the organisation and hence, there was a lack of commitment (gain 3). Project management was previously identified (sections 2.4 and 4.1.2), hence, the process framework will need to plan and co-ordinate well the work to minimise losses 2, 3, and 7.

**Table 4. 4 Process gains and process losses of group work**

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Illustration removed for copyright restrictions

Source: abridged from Turban et al., 2005, pgs 376-377

Considering the design of supply system architecture, Sarkis and Sundarraj (2000) indicate the following options for handling multiple criteria decisions:

- Analytical hierarchy process (AHP);
- Data envelopment analysis (DEA);
- Expert systems
- Goal programming
- Multi-attribute-utility theory (MAUT);
- Outranking
- Simulation
- Scoring models

Not all of the techniques they list would involve enough interaction and support the group decision-making process. This is not to say that these techniques would not be useful, moreover that getting ownership (issue 2) would be more difficult, as the group would need to "believe" the results of the analysis.

Group support systems technologies are inherently designed to support group work, which Turban et al (2005) indicate can improve decision-making; collaboration; communication, they also highlight the dysfunctions of (Turban et al., 2005). Group support systems use a variety of functionality, including brainstorming tools; group outliner; voting and surveying (Turban et al., 2005). Due to the nature of design and selection of supply system architectures, the decision-making could be well-supported by using AHP (used by Sarkis and Sundarraj, 2001, Sarkis and Talluri, 2004, Wei et al., 2005) and scoring models. AHP and scoring models would allow team members can conduct weight the important of different options and these can be aggregated and any differences of opinion can then be discussed. Quality function deployment (QFD) was considered as an appropriate scoring model as team members can rank the importance of different supply system requirements against how they can be delivered and the differences of opinion can be discussed (used by Ho, 2002). Finally, simulation is included, due to the fact that it produces AS_IS models, which can be viewed and the results validated by the team, to ensure buy-in to the results from analysing TO_BE models of different supply system architectures (used by Ho, 2002).

### 4.2.1 Analytical Hierarchy Process (AHP)

The analytic hierarchy process (AHP) method (Saaty, 1980) is a decision-making technique that directs how multiple criteria and alternatives can be handled. Using AHP, the relative importance weightings of the criteria that the decision is based on are derived by comparing them against each other in pairs. The alternatives are compared in pairs to determine how well the alternative met the criterion in comparison with each other. Each criterion is then compared to the alternatives in pairs, to indicate how they compare to each other in meeting the criterion. Therefore, AHP reaches an effective decision by quantifying the criteria for selecting from the alternatives. The procedure of AHP can be summarised as follows:

1. The weight of each criterion is calculated by giving a weight to every pair of criteria.
2. Total score (100 points) is divided among criteria according to the weight of each criterion (score of each criterion based on pair wise weight).
3. At each criterion, the weight of each alternative is calculated by giving a weight to every pairs of alternative. The score of each criterion is divided among alternatives according to the weight.
4. The score of each alternative is calculated by adding the scores of every criterion.

AHP has been used for enterprise and supply chain software selection (Sarkis and Sundarraj, 2001, Wei et al., 2005); supply chain design (Korpela et al., 2002, Korpela et al., 2001b, Wang et al., 2004) and supplier development (Korpela et al., 2001a). A weakness of AHP is the heavy reliance on the decision-makers to be able to analyse the situation and be able to score the scenarios accurately.

### 4.2.2 Quality Function Deployment (QFD)

Quality Function Deployment (QFD) focuses the design on meeting the needs of customers (Slack et al., 2007). QFD is used to capture *what* the customer/ client's needs and *how* it might be achieved. It is also called: 'House of Quality' (because of the shape) and 'Voice of the Customer' (because of its purpose). QFD was developed in Japan at Mitsubishi's Kobe shipyard and used extensively at Toyota. The first step is to list the *whats,* these are the needs of the product or service, the *relative priority* of these is recorded (e.g. highest number to highest priority). The ***whats*** and their priorities are added to left-hand side of the QFD matrix, see figure 4.1. The second step is to consider how these needs can be met and add them to the top of the matrix, see figure 4.1. The third step is to work out the relationships between the ***whats*** and the ***hows.*** These relationships are entered into the central matrix by rating the inter-relationship between the ***whats*** and the ***hows,*** using 1 to indicate a weak relationship; 3 to indicate a medium relationship and 9 to indicate a strong relationship, see figure 4.1. The fourth step is to computate the analysis, as follows, multiply the importance to the customer by the relationship rating (importance to customer * *what, how* rating) + (importance to customer * ***what, how*** rating), etc. thus totalling up the multiplications. The ***hows*** can then be ranked and it should be stated how difficult they are to achieve at the bottom of the matrix, see figure 4.1. The ***hows*** can also be evaluated against each other, in terms of whether they are positive or negatively related, these are added to the roof of the matrix, see figure 4.1. Teamset ™ is a commercially available software package that can be used for QFD analysis. A weakness of QFD is that the decision-makers need to be able to prioritise accurately the needs and align carefully how this can be achieved.

**Figure 4. 1 Example of a QFD matrix for an information system product**



Source: Slack et al., 2007

## 4.2.3 Simulation

Simulation provides a convenient experimental laboratory for the real system (Anderson et al., 1998). An advantage of simulation experiments is their flexibility which means that they can be used to describe complex systems without requiring as many simplifying assumptions, or approximations, that are often required with mathematical models (Anderson et al., 1998). Many researchers support the use of simulation to effectively analyse supply chain configurations and provide indicators of supply chain system performance (Wyland et al., 2000). The systems adopted for supply chain modelling commonly use industrial dynamics or systems dynamics modelling techniques, like Forrester (1958, 1961) used. These have been used successfully to explore how the Forrester effect, which can generate boom-and-bust inventory scenarios, can be reduced through various redesign strategies (Towill and Naim, 1993).

The weaknesses of simulation experiments include the computer resources difficulties in developing models, in some cases a computer specialist is required (Wisniewski, 1997). It has to be noted that when looking at complex systems, like supply chains, the process of developing, verifying, and validating a simulation model can be time-consuming and expensive (Anderson et al., 1998). Simulations only provide a sample of how real system would operate, fraught with estimation and approximation expensive (Anderson et al., 1998). Simulation has to simplify reality to a certain extent and can, therefore, result in context stripping. Despite these weaknesses, simulation does provide quantitative analysis of a scenario and hence, could lead to a more detailed and precise business case. There are a number of commercially available software packages for simulation including iThink ™, Simul8 ™, Witness ™ and Process ™.

## 4.3 Conclusion

This chapter focused on how supply system architectures are designed and selected. Successful characteristics of manufacturing strategy formulation processes are drawn upon (Platts, 1994, Platts et al., 1996) to evaluate existing frameworks. A number of frameworks and methodologies do exist in the literature, but none of these fulfilled the requirements discussed in 4.1. Therefore, this chapter strengthens the conclusion that a process framework is required to guide the design and selection of supply system architectures, which was purported in chapter 2. Moreover, the required structure for a process framework to select supply system architecture has been clarified, including not only the required procedures and project management (from chapter 2), but also the necessity of participation and clarity of point of entry. The chapter also highlights that different decision-making techniques can be employed, including AHP, QFD and simulation.

# Chapter 5 - Stage 2: Archival Case Study Analysis

Design and selection of supply systems architecture is an area that requires further research (c.f. chapter 2). This chapter reports on the archival case study analysis conducted on six cases of the design and selection of supply system architecture. The analysis explores how organisations have selected supply system architectures and although the process is not well-documented, there is some support that business case; change management; existing system management; good communications; process management; project management and software selection were key elements. The lack of documentation means it is difficult to say "how" supply system architectures are designed and selected. The process is often conducted by consultants; hence, it is not made transparent as the consultancy business depends on being able to deliver these processes.

## 5.1 Justification for the archival case study research approach

Case studies were analysed to further address the research question Q2 b) How have supply system architectures been selected? (from table 1.1 in section 1.2). A case study research strategy is highly appropriate for addressing this question, because as Yin (2003) states this strategy has a distinct advantage when:

> "a "how" and "why" question is being asked about a contemporary set of events, over which the investigator has little or no control." (Yin, 2003, pg. 9)

The selection of supply chain architecture is a contemporary event and the investigator has no control over how it has been conducted in the past. Although, it should be noted that action research would allow the investigator to have some control over future supply system architecture selections.

This analysis relies on the use of archival case studies, which Yin (2003) states can be valid and high quality. Archival case studies utilise secondary sources which can be defined as the published summarises of the raw data obtained in various studies, which may or may not be related to the original purpose for which the data was collected

(Stewart, 1984). Within the field of OM, Lewis (1998) advocates greater use of existing case studies as an effective and efficient means for comparing complex and disparate operations settings (Lewis, 1998). Jarvenpaa (1991) recognised that secondary data in the IS field can provide a potential 'gold mine' of empirical research. Sachan and Datta (2005) also state that innovative application of secondary data is lacking in supply chain and logistics research.

## 5.2 Research design: unit of analysis and case selection

ERP and other supply system architecture implementations were regarded as interesting phenomenon for study, because success was so variable and hence, the causes of diabolical failure led to many revelatory cases being written. The previous studies of the implementation process were revealed to include pre-implementation issues in the design and selection process (c.f. section 2.4). Hence, the unit of analysis for this archival case study research can be considered as "supply system design and selection process in manufacturing supply chains". Depending on the research paradigm, case study research can be based on a single-case, providing it can be justified based on one of five rationales: that is critical; extreme/unique; representative/typical; revelatory or longitudinal (Yin, 2003). However, in this instance these rationales do not apply and hence, an embedded multiple-case study design (Yin, 2003) was used. Multiple cases were required to find out how the design/selection process was conducted in different supply chains/networks. It is considered "embedded" as although multiple units of analysis were used, the cases were conducted independently (as opposed to pooling the data, which would be a holistic unit of analysis).

There has been considerable debate surrounding selecting the right number of cases in case study research (e.g. Eisenhardt, 1989, Yin, 2003). The debate is fuelled by the misunderstanding of the difference between analytical and statistical generalisation and by epistemological and ontological perspectives. Eisenhardt (1991) and Stake (1995) to a degree acknowledge that the sample size hinges on maximising the learning effect, i.e. how much is known and how much new information can be gained from further case studies (Eisenhardt, 1991, Stake, 1995). Based on experience, Yin (2003) states around 6-10 cases is appropriate within a multiple-case study design, whereby 2 or 3 cases are required for literal replication (prediction of similar results) and a further 4 to 6 for theoretical replication (predicts contrasting results but for predictable reasons). Eisenhardt (1989) states between 4 and 10 cases usually works well, with fewer than 4 cases having limited complexity and unconvincing empirical grounding, unless there are mini-cases within the work. Hence, it can be concluded that a minimum of six cases would satisfy both Yin (2003) and Eisenhardt's (1989) views and utilise sufficient replication logic (Eisenhardt, 1989, Yin, 2003) and consequently improve the analytical generalisation of the findings.

Initially, cases that explored ERP or other supply chain systems implementations were located via Business Source Premier; Emerald; Science Direct; Proquest and several practitioner magazines. These cases were then reviewed to ensure:

- the objective of the system implementation was supply chain/network focused
- that companies involved were fundamentally in the manufacturing industry
- that the data was reliable
- reporting of the case included reflection on the design/selection process

Unfortunately, the third and fourth bullet points led to the exclusion of many of famous examples of problematic implementations. For example, the following cases had to be excluded: Fox Meyer Drug, whose ERP implementation led to bankruptcy (Jesitus, 1997); Hershey, who experienced severe inventory management problems after implementing ERP (Stedman, 1999, Vogt, 2002) and also, Nike, who blamed an i2 technologies solution for shortages in trainers, despite surpluses in Asian plants (Dignan, 2002, Kary, 2001, Koch, 2004, Luening, 2002, Wilson, 2001). These cases were reported in a journalistic style and hence, it was difficult to ascertain the reliability of the data, versus sensationalism. The depth of the reporting focused on revealing interesting facts; figures and anecdotes from the cases, with some reflection on rushed implementation (e.g. Stedman, 1999), but considerably more focus on apportioning blame (Dignan, 2002, Kary, 2001, Luening, 2002). Hence, there is no real consideration of the selection process, let alone in sufficient detail. Hence, the resulting six case studies were chosen for analysis:

- Geneva Pharmaceuticals (Bhattacherjee, 2000)
- Manco (Al-Mashari and Al-Mudimigh, 2003, Al-Mashari and Zairi, 2000b)
- Paper Co (Koh et al., 2006)

- Rolls Royce (Yusuf et al., 2004)
- Texas Instruments (Sarkis and Sundarraj, 2003)
- Wine Co (Mandal and Gunasekaran, 2002)

Table 5.1 summarises how the three cases met the selection criteria previously stated. There were some similarities in the supply chain objectives across cases, mostly focusing on improving the internal supply chain (Geneva Pharmaceuticals; Manco; Rolls Royce; Texas Instruments and Wine Co). Two cases also focused their objectives on improving dyadic links, one focusing on downstream to customers (Manco emphasised customer-responsiveness) and the other upstream to suppliers (Paper Co focusing on strategic purchasing). Half of the cases considered improving the overall external chain or network of customers and suppliers (Texas Instruments and Wine Co), and extending this to also include partners (Rolls Royce). The specific objectives are detailed in table 5.1. All of the companies were directly involved in the manufacturing industry, as shown in table 5.1; however, the particular manufacturing industry was not specified in the Manco case. The data reliability was the most problematic aspect to verify, with some cases not giving details of the data collection methods (Rolls Royce and Wine Co). Hence, the reliability of the data had to be inferred by considering the depth and detail of the analysis. Only the Manco case made the actual process of data analysis explicit. All cases included some reporting on the process of design or selection, the most detailed account provided by the Manco case.

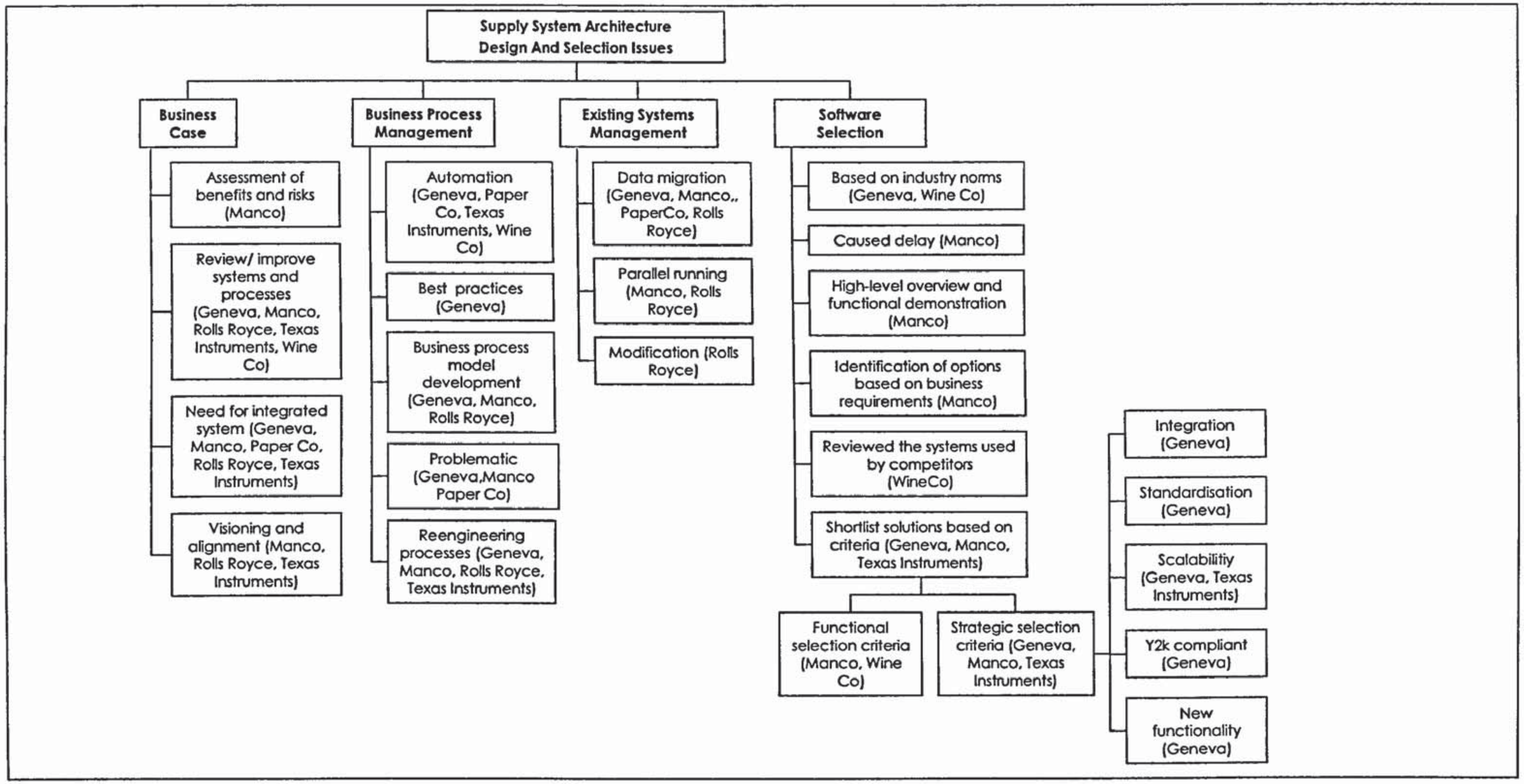
**Table 5. 1 Selected archival case studies**

| | **Geneva Pharmaceuticals** (Bhattacherjee, 2000) | **Manco Group** (Al-Mashari and Zairi, 2000b) | **Paper Co** (Koh et al., 2006) | **Rolls Royce** (Yusuf et al., 2004) | **Texas Instruments** (Sarkis and Sundarraj, 2003) | **Wine Co** (Mandal and Gunasekaran, 2002) |
|---|---|---|---|---|---|---|
| **Supply chain/ network focus** | Improve internal supply chain | Improve internal supply chain and improve demand-side dyadic links through customer responsiveness | Improve supply-side dyadic links, through strategic purchasing | Improve internal and external supply chain and other partnerships | Improve internal and external supply chain | Improve internal and external supply chain |
| **Industry** | Generic pharmaceuticals (pg. 5) | "major manufacturer" (pg. 297) – anonymity | Paper (pg. 458) | Aerospace and defence (pg. 255) | Transistors, chips and circuits (pg. 433) | Wine (other products mentioned) |
| **Process type** | Batch (pg.8) | Unknown | Continuous | Jobbing and batch | Batch and mass | Batch |
| **Data collection methods** | Not described explicitly: 1. Quotes from employees (interviews) 2. Project documentation | 1. Semi-structured interviews 2. Observations 3. Documentation | 1. Telephone interviews 2. In-depth interviews 3. Open-ended questionnaire | Not described explicitly: 1. Quotes from employees (interviews) 2. Project documents 3. Intranet | 1. Structured interviews 2. Telephone and e-mail 3."Snowballing" interviews with consultants 4. Archival information | Not described explicitly: 1. Screen shots of actual system (observation) 2. Specific quantitative data (documentation) |
| **Reporting of design and selection** | Some discussion of business process mapping to software | Follows entire process, including selection | Some discussion of system match to process manufacturing | Some discussion of business process mapping to software | Some discussion of tailoring to business process | Some discussion of reviewing systems |

# 5.3 Data analysis method

These case studies were analysed following Miles and Huberman's (1994) guidelines. Hence, firstly the data was tabulated into a summary of the design and selection processes in each individual case (considering the cases independently). The design and selection aspects were considered: business case; BPR and process management; existing systems management and software selection (c.f. chapter 2, section 2.4). The overarching aspects were also considered: change management; good communications and project management (c.f. chapter 2, section 2.4). Appendix 2 shows the summary information for each case. The data was then coded to enable a cross-comparative analysis, which led to the development of two coding diagrams shown in figure 5.1 for design and selection issues and figure 5.2 for the overarching issues. The final stage was to interpret the analysis and hence, the interpretation follows (Miles and Huberman, 1994).

**Figure 5. 1 Design and selection issues coding diagram**



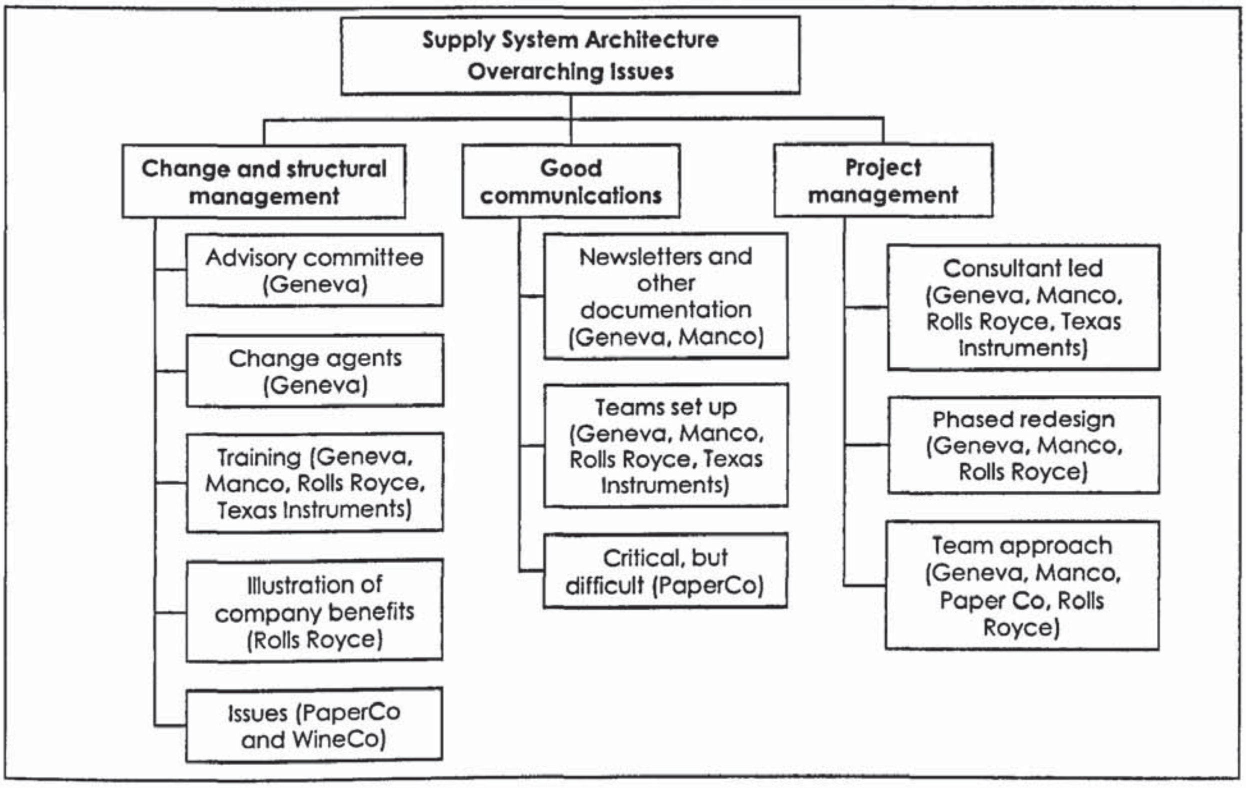
## 5.4 Interpretation of supply system architecture selection approaches

The design and selection approaches and overarching issues analysed in the cases are summarised in appendix 2. The discussion starts by considering the design and selection issues and then turns to the overarching issues. The design and selection issues are summarised in the coding diagram, shown in figure 5.1. There were some similarities in the business case for changing supply system architecture. In all cases the business cases were stated quite generically, specifying, in general, what was required (e.g. integrated systems, review or change current systems), but the business cases could articulate scope and target more clearly, to be able to measure success. The process framework would need to be flexible to allow for different reasons for selecting supply system architecture to be catered for. At the same time, the process framework will need to create a more specific structure for considering and developing a clear business case.

Business process management was a key theme discussed in all the cases. Some cases mentioned utilising process mapping techniques. There was also one reference to adopting best practices, however, in several cases the supply system architecture did not appropriately support the business processes. In many cases the business processes aspect was particularly problematic. Therefore, the process framework will need to consider business processes and explore those processes involved fully to enable clearer alignment of the supply system architecture. Many of the cases had numerous existing systems in place. Therefore, the issue of migration was a prevalent theme in the cases. One case had to modify the existing systems to enable them to be used during the parallel running phases. Parallel running was a common theme. The process framework will need to consider and include analysis of the existing systems.

The software selection processes were not well formulised in many of the cases; some of the cases did not discuss the process in any depth. Two of the cases explicitly stated that the selection of software was down to the norms of the industry, rather than a thorough appraisal of the options. The process caused delay in one of the cases and varied across the cases. There was a need to highlight strategic and functional criteria. The process framework will need to analyse the scenario in more depth to facilitate the software selection process. Specifically, the functionality requirements and the strategic aims of the project need to be clear, including target performance.

**Figure 5. 2 Overarching issues coding diagram**




The overarching issues were analysed, as summarised in figure 5.2. The cases demonstrated some evidence of considering change and structural management issues. However, this was quite variable across the cases, with most cases relying solely on training. There are some linkages of change and structural management to having a clear business case. Providing a clear business case and related documentation would make the necessary changes clearer. Therefore, the process framework will need to ensure analysis is conducted that produces the necessary documentation to assist change management during the design and selection phase, but also during the eventual implementation phase (which is not part of the process framework). Change management is also linked to good communications, whereby a team approach is important as well as providing sufficient documentation. The process framework will need to facilitate good communication by the use of documentation and workshops.

The majority of cases utilised project phases in some way to clarify the order of the tasks. However, in two of the cases the specific phases were not stated. All cases discussed to varying degrees the need for a team-based project structure, utilising experts, in one case expatriating key individuals into the team. In the majority of cases the project was managed by external consultants, therefore there is an indication of the need for experts. However, using consultants has led to little detailed information on how to conduct the process. Only one case really discussed in any depth what happened. Therefore, some of the aspects of what should be done in the process have been derived, but the specifics of how to conduct the analysis are not clearly disseminated.

## 5.5 Conclusion

The archival case study analysis highlighted that the process is not well documented, which is largely due to the fact that consultants facilitate the process. Platts et al (1993) highlight the need to interview consultants to formalize their "craft skills." This was not part of the research design, however, the cases gave some indication of "what" the consultants did (particularly the Manco case), but not "how" they did it. This is not surprising as knowing "how" to do the analysis is core to the nature of the consultancy business. Despite this, the archival case studies did support some of the established ideas (Platts, 1994, Platts et al., 1996). Particularly, in the procedural section the archival case studies did provide considerable support for the need for a business case; software selection; and systems and process management. Furthermore, evidence to support the need for change management; good communications; project management and resourcing were supported.

The critical review of existing frameworks and tools and the archival case study analysis can be used to draw up a list of requirements for developing the process framework (see table 5.2). Table 5.2 shows the general and specific requirements of a process framework for selecting supply system architecture and the supporting evidence for the inclusion of the different requirements, be it from literature; the critical review or the archival case study analysis.

**Table 5. 2 Process framework for selecting supply system architecture: structure and requirements**

| | Supporting literature | Evidence in other frameworks | Evidenced in archival case study analysis |
|---|---|---|---|
| **1. Procedure, specifically:** | Platts, 1994, Platts et al., 1996 | | |
| Gathering information: | | | |
| Business process management | section 2.4 | section 4.1.1 | ✓ |
| Existing systems management | section 2.4 | section 4.1.1 | ✓ |
| Analysing information: | | | |
| Functionality of different software systems and e-business systems | sections 2.2 and 2.3 | section 4.1.1 | ✓ |
| Compatibility with strategy | section 2.5 | section 4.1.1 | |
| Compatibility with supply chain/network | section 2.6 | section 4.1.1 | |
| Software selection | section 2.4 | section 4.1.1 | ✓ |
| Identifying improvements | section 2.4 | section 4.1.1 | |
| Written record: Business case | section 2.4 | section 4.1.1 | ✓ |
| Tools and techniques | Platts, 1994, Platts et al., 1996; and section 2.4 | sections 4.1.1 and 4.2 | |
| **2. Participation, including:** | Platts, 1994, Platts et al., 1996 and section 2.4 | section 4.1.2 | |
| Groups | Platts, 1994, Platts et al., 1996 and section 2.4 | section 4.1.2 | |
| Workshop style | Platts, 1994, Platts et al., 1996 and sections 2.4 | section 4.1.2 | |
| Change management | sections 2.4 | section 4.1.2 | ✓ |
| Good communications | sections 2.4 | section 4.1.2 | ✓ |
| Decision-making forum that utilises the appropriate technique according to the constraints and analysis needs | Platts, 1994, Platts et al., 1996 | section 4.2 | |
| **3. Project management, including:** | Platts, 1994, Platts et al., 1996 and section 2.4 | section 4.1.2 | ✓ |
| Resourcing | Platts, 1994, Platts et al., 1996 and section 2.4 | section 4.1.2 | ✓ |
| Timescales | Platts, 1994, Platts et al., 1996; | | |
| **4. Point of Entry** | | | |
| Expectations; understanding and commitment | Platts, 1994, Platts et al., 1996; | | |

# Chapter 6 - Stage 3: Development of a Process Framework to Select Supply System Architecture

The process framework developed to guide the design and selection of supply system architecture process is presented in this chapter. The process framework consists of three phases: 1) Scope the supply chain/network; 2) Identify options for supply system architecture and 3) Select supply system architecture. Phase one focuses on clearly defining the boundary of the supply chain/network, indicating which organisations or departments are involved in the analysis (Step 1a). Once the boundary has been drawn the characteristics of that supply chain/network are agreed upon (Step 1b) and the constraints; enablers and risks specified (Step 1c). The final step in phase one is to clarify the goal(s) that the supply system architecture needs to realise (Step 1d). If the goal(s) are deemed too fundamental to be met by implementing new supply system architecture, then strategic analysis may need to be undertaken, e.g. by utilising the quick-scan method.

Phase two focuses on identifying the different options available and starts by mapping out the supply processes that the supply system architecture will focus on, existing systems are also mapped (Step 2a). Once the supply chain/network map has been created, the orientation of the supply chain/network is agreed upon (Step 2b), specifically whether the supply chain/network needs to be integrated; partially integrated; co-ordinated or independent. Once the processes and orientation have been identified, a list of functionality that the supply system architecture needs to provide is drawn up (Step 2c). The final step in phase two is to bring together the goal(s) (Step 1d); enablers; constraints and risks (Step 1c); processes (Step 2a); orientation (Step 2b) and the functionality to develop the business case (Step 2d). The business case will also involve setting the key performance indicators that the supply system architecture will need to deliver.

Once the business case has been clearly documented, phase three focuses on selecting the supply system architecture. The first step utilises an appropriate decision-making technique to identify the options available, including the current system, depending on the time; budget and type of analysis required (Step 3a). The analysis may conclude that the existing system is the best option or needs improving, which will lead to another project. Otherwise, the analysis enables the identification of vendors and these vendors will make presentations and be questioned focusing on ensuring the solution will meet the business case needs (Step 3b). Depending on the vendor presentations are more detailed analysis of the options may be carried out, to enable the software or e-business solution to be chosen (Step 3c). Once selected the process framework is completed and the implementation of the software can begin.

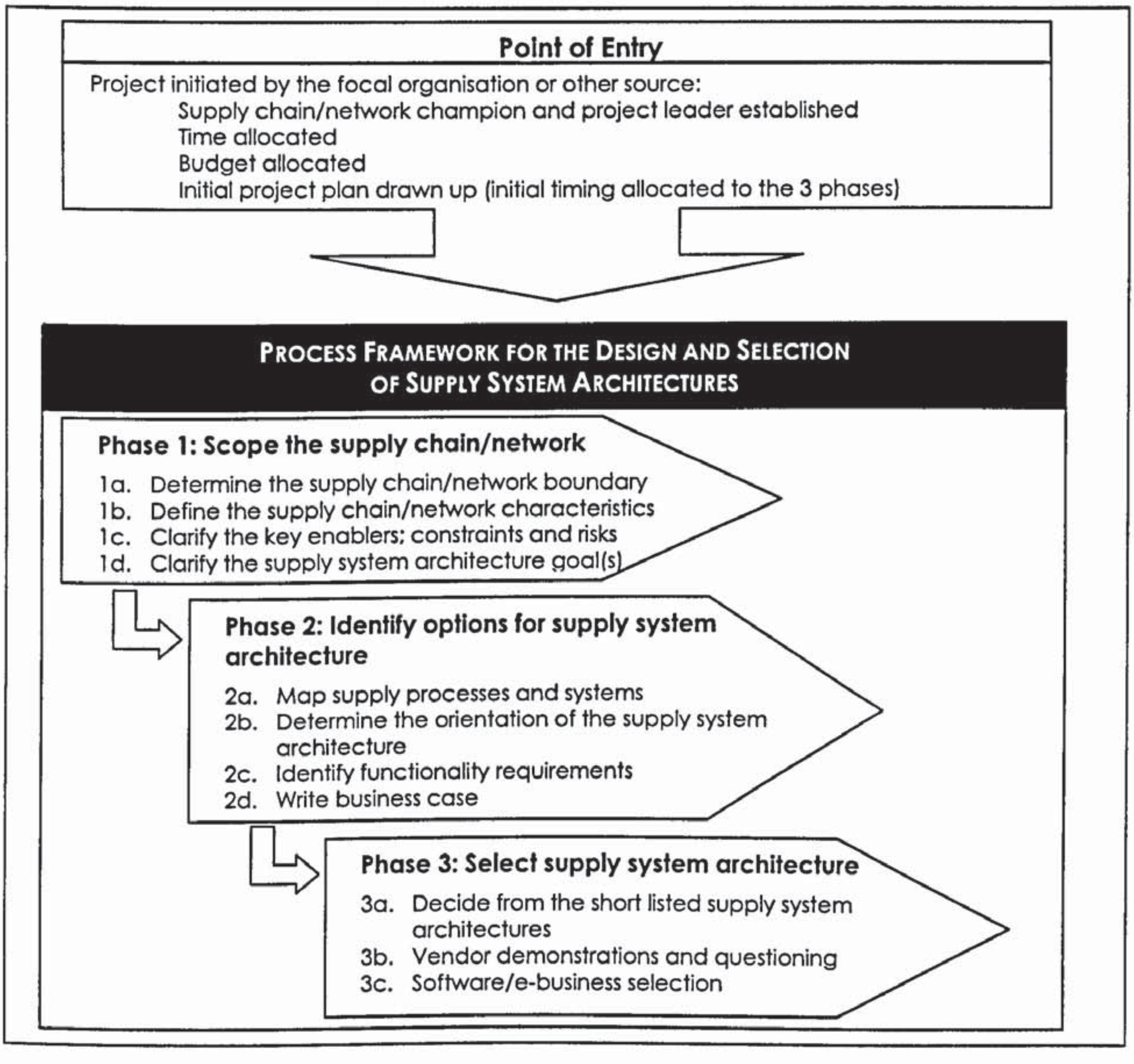
## 6.1 The Process Framework

The process framework focuses on designing and selecting supply system architecture, which was identified as a research gap in chapter 2. The proposed process framework was derived from a critical review of existing frameworks and tools (presented in chapter 4) and the archival case study analysis (presented in chapter 5). In summary, the explicit list of requirements in the conclusion section of chapter 5 (table 5.2) was realised. Hence, the process framework is based on considering supply system architectures within the context of the supply chain/network characteristics (chapter 2). The process framework's structure was designed to focus on achieving Platt's four P's: procedure; participation; project management and point of entry (discussed in chapter 4).

The learning from reviewing the existing frameworks (particularly Biehl and Kim, 2003, Blackwell et al., 2006, Ho, 2002, McGarrie, 1993); and mathematical and conceptual frameworks developed for supply chains/networks was also a vital contribution to the design of the process framework (chapter 4). The process framework, thus, contains three phases: 1) scope the supply chain/network; 2) identify options for supply systems architecture and 3) select supply system architecture (see figure 6.1). There are 11 underlying steps in the process framework which are supported by simple tools and techniques (Platts, 1996) for conducting the relevant analysis. The simple tools and techniques were identified in chapter 4. The actual implementation would follow the design and selection process, but is not covered as it has already been researched (e.g. Al-Mashari and Zairi, 2000a) (c.f. chapter 2), and is outside of the scope of the thesis (c.f.

chapter 1, section 1.6). Despite the presentation of the process framework as a sequential set of steps, the relationships between the steps are made explicit to enable revision of the steps, and even, use of different frameworks or methodologies, as necessary. An explanation of the phases and steps of the process framework follows, using the beer game (Sterman, 1989) for illustration purposes. Each phase and each step is explained in turn.

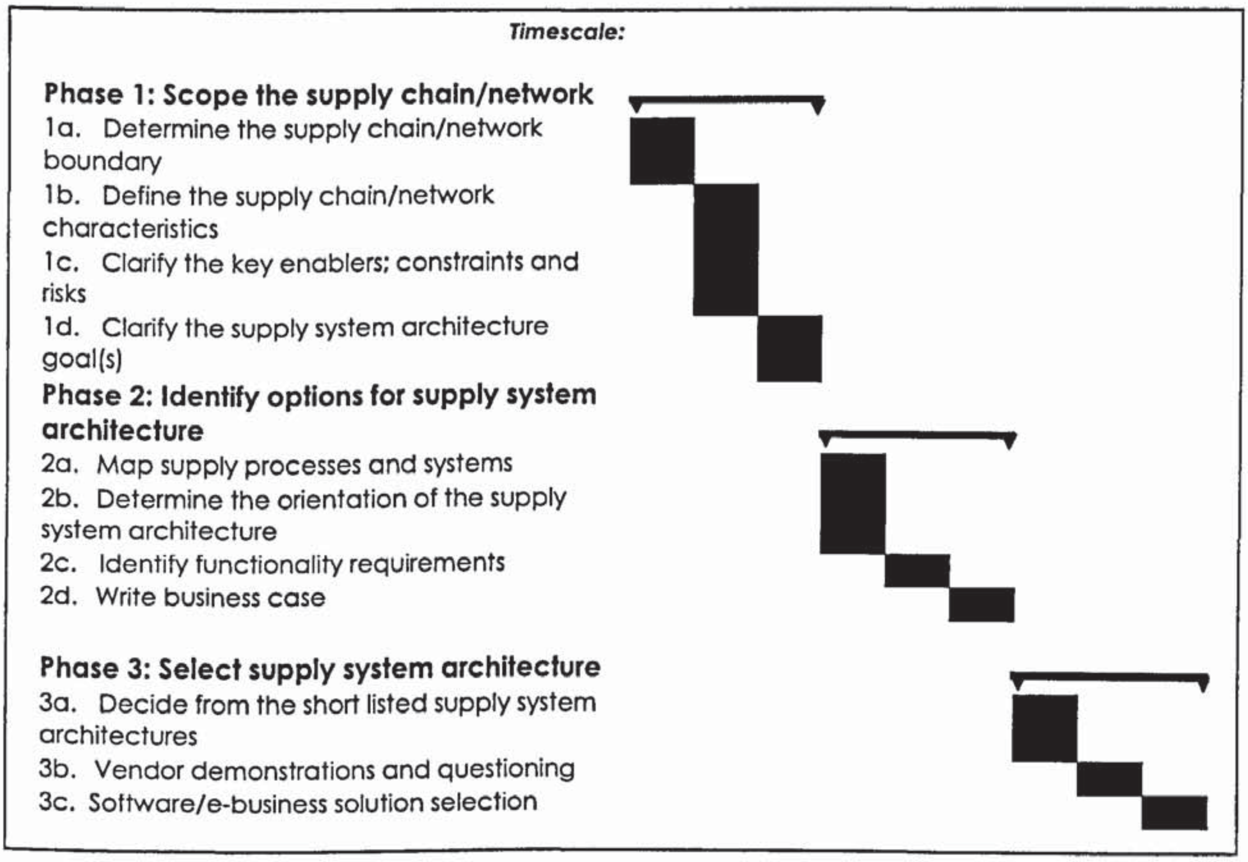
**Figure 6. 1 Supply Systems Architecture Design and Selection Process Framework**



## 6.2 Point of Entry to the Process Framework

Before the process framework can be applied, the managerial, organisational and financial constraints have to be clarified. Specifically, at the point of entry, the supply chain/network champion will need to be established, who will advocate the design and selection of the supply system architecture, and ideally this person will see the process through beyond the process framework, into the entire implementation. The budget for the design and selection processes will need to be set. Time will need to be allocated to the project, and specified on an initial project plan, as shown in figure 6.2. The project plan will need to set the specific timescales for the design and selection process.

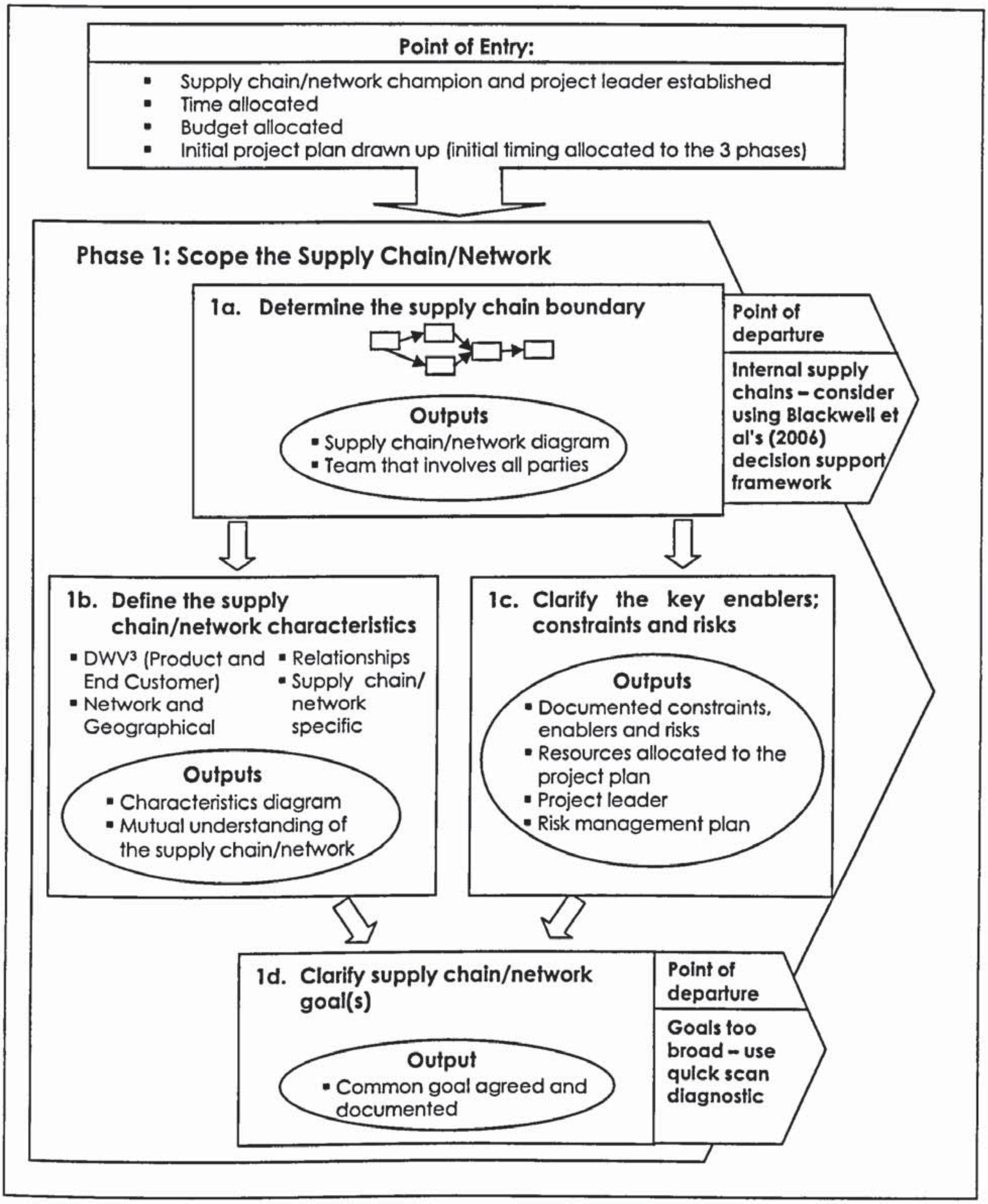
**Figure 6. 2 Gantt chart illustration**



## 6.3 Phase 1: Scope the Supply Chain/Network

The focus of the first phase is to decide who will be involved in using the new supply system architecture (Step 1a. Determine the supply chain/network boundary) and the establishment of a team to represent those parties. Then the team will need to reach a mutual understanding of the characteristics of the supply chain (Step 1b. Define supply chain /network characteristics), within that boundary. The team (from Step 1a) will then review the characteristics of the supply chain/network (from Step 1b) to determine key enablers; constraints and risks (Step 1c Clarify the key enablers; constraints and risks) involved in implementing a new supply system architecture. Step 1c will also include further clarification of the project plan; budget and time available. A team leader will need to be given responsibility to manage the design and selection process. A team leader will need to have the necessary resources allocated, including a budget for the decision-making process (separate to the budget allocated for the purchase and implementation of the system selected). The overall goal for changing or reviewing the supply chain system will then need to be clarified by the team (Step 1d. Clarify supply chain/network goal(s)), paying due consideration to the financial and time constraints. The steps within phase 1 are depicted in figure 6.3.

**Figure 6. 3 Phase 1: Scope the Supply Chain/Network**



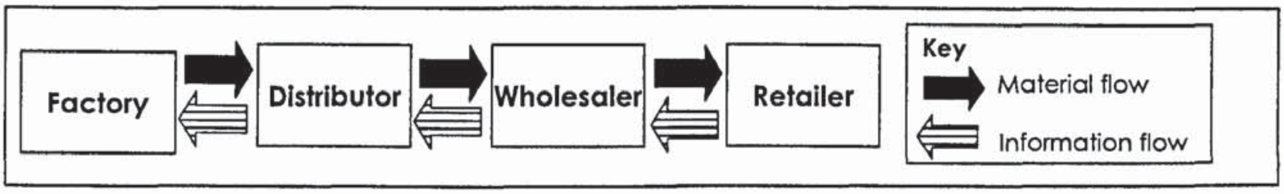
### 6.3.1 Step 1a. Determine the supply chain/network boundary

The first step involves setting the boundary of the supply chain/network (Step 1a. Determine the supply chain/network boundary), i.e. determining which suppliers and/or which parts of the organisation will be involved. The analyst can determine the boundary of a supply chain/network depending on the investigation (Harland et al., 2004). The drawing of the boundary will be driven by the focal organisation (i.e. the organisation that initiated the need to change or review supply system architecture). The boundary can be defined according to Harland's four system levels: internal; dyadic; external chain or network (Harland, 1997). Hence, the focal organisation needs to address the following questions:

- Is it an internal supply chain (within one organisation/enterprise)?
- Is it a dyadic relationship with customer/customers?
- Is it a dyadic relationship with supplier/suppliers?
- Is it a linear chain from suppliers to customers?
- Is it network of organisations, including customers and suppliers?

In an internal supply chain scenario, Blackwell's (2006) decision support methodology could be applied; hence this would be a point of departure. In a network scenario, some organisations may be considered directly involved by the focal organisation, while others considered partially involved. When the boundary has been established the team must be established to ensure that those parties are represented. The output will be a supply chain/network diagram; the beer game example can be classified as an external chain of activities. An assumption has been made that this is an established brand of ale, rather than a lager, where variations on a brand are evident, e.g. Lite or Super chilled, see figure 6.4, as an illustration. All organisations are considered to be directly involved in the process.

**Figure 6. 4 Supply chain/network diagram for the beer game**

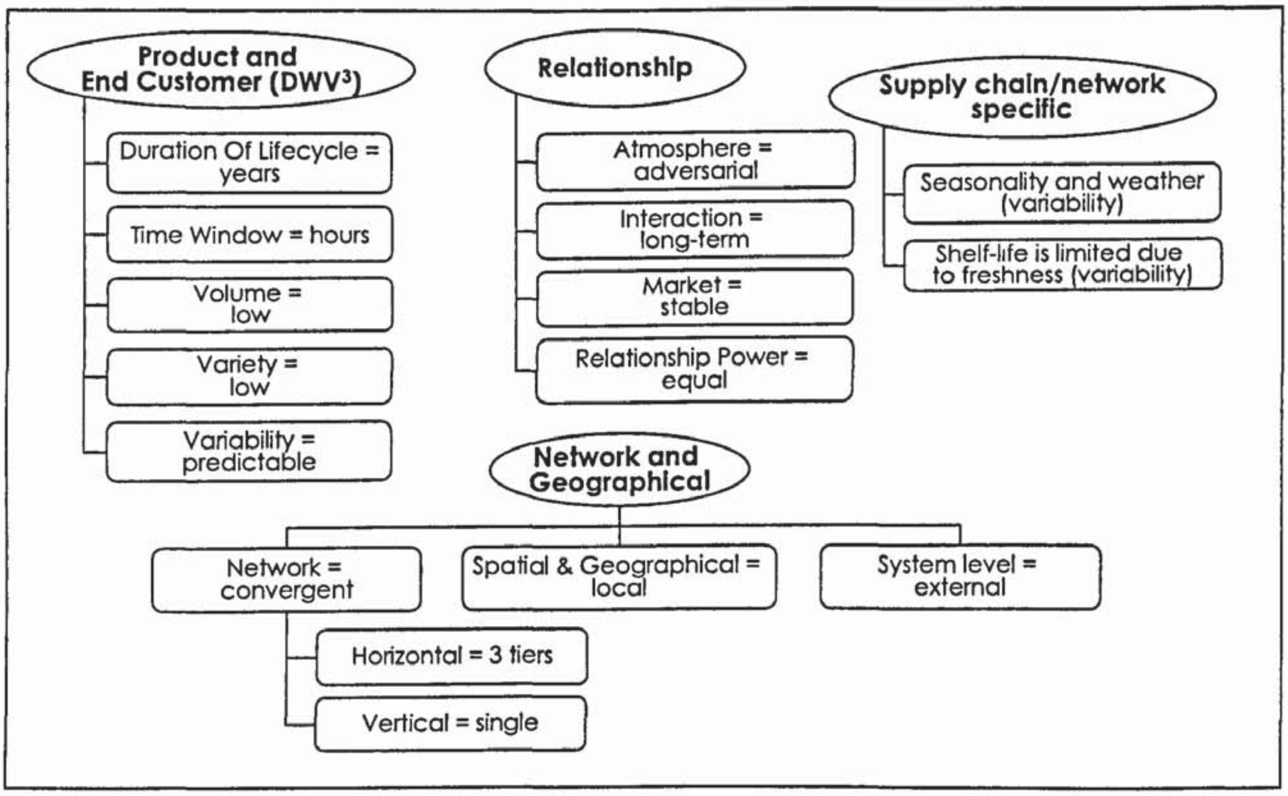



## 6.3.2 Step 1b. Define supply chain/network characteristics

The team will need to acknowledge and agree on the characteristics of the supply chain/network (Step 1b. Define supply chain/network characteristics). Reaching a mutual understanding of the supply chain/network is imperative to the process. The different parties involved will have different perspectives and may also be involved in more than one supply chain/network. Hence, the focus will be on understanding the characteristics of the supply chain/network within the identified boundary (output from Step 1a). Therefore, the supply chain/network characteristics diagram, shown in figure 2.11 and discussed in section 2.6 is populated during this step. Scoring and voting techniques within a group support system can be used to create a decision making forum. The scoring and voting techniques will draw out differences of opinion for discussion, in order to reach a mutual understanding of the supply chain/network.

Figure 6.5 shows the populated diagram for the beer game. There is low variety as the focus is on only one well-established beer brand and hence, has a long product lifecycle. The volume at the retailer is low volume (4 barrels a day). The actual demand is predictable, ranging from 4 to 8 barrels. To avoid the associated costs of not meeting demand, the time window for delivery is 1 day. The local supply network is based on single sourcing and involves multiple tiers. Generally, large retailers have high power over suppliers, but in this case, an assumption has been made that each organisation supplies only the organisations depicted in figure 6.4, hence, it is indicated as equal. The interaction is considered long-term, due to the long-established brand and the market is considered fairly stable, although micro-breweries could have an impact. The atmosphere between the participants is somewhat adversarial, due to the bullwhip effect. Two supply chain specific characteristics have been identified. Firstly, the shelf life of the beer at the retailer is weeks, to ensure the beer is fresh and secondly, it is acknowledged that weather and seasonality could effect the production of ingredients, e.g. hops and barley, as well as demand. The shelf life has an effect on the time window for delivery and the weather affects the variability.

**Figure 6. 5 Characteristics diagram for the beer game**

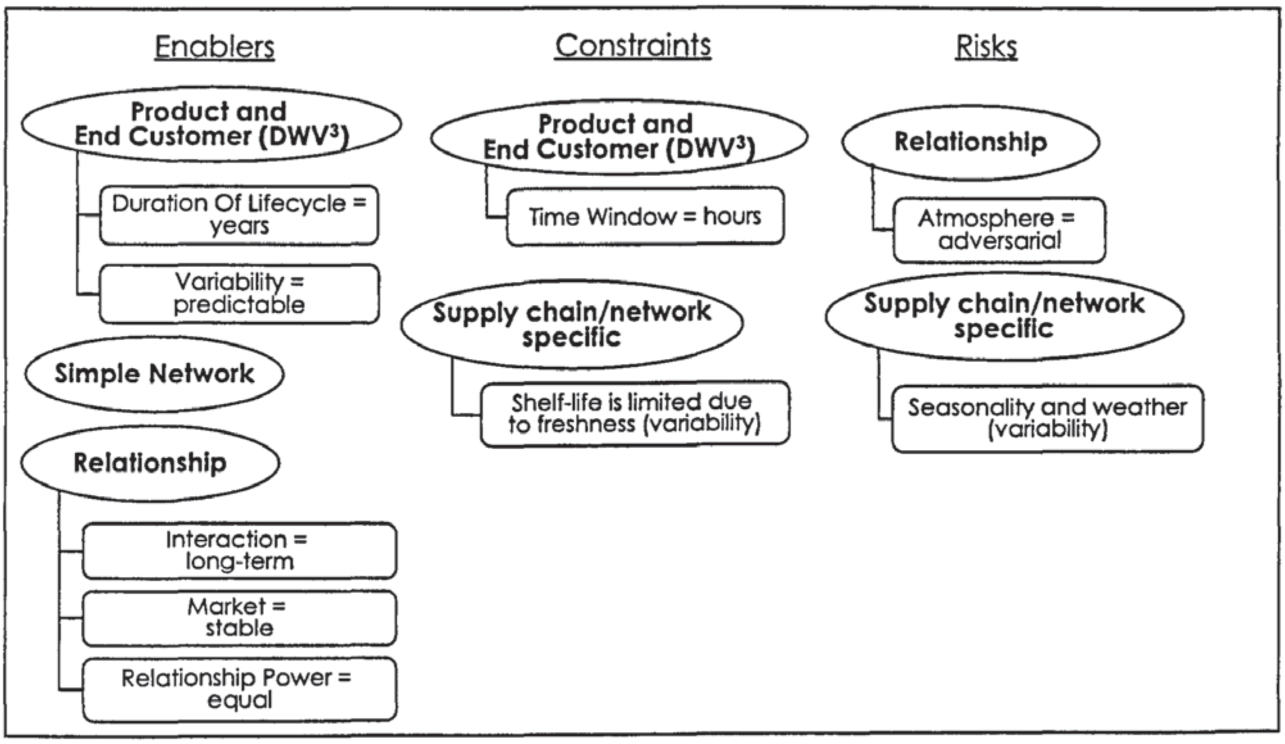



## 6.3.3 Step 1c. Identify key enablers; constraints and risks

The characteristics diagram (from Step 1b) helps articulate the context and difficulties that the supply system architecture must operate within. Hence, the team (from Step 1a) will review the characteristics diagram to determine key enablers; constraints and risks in the adoption of supply system architectures. Key enablers are those characteristics which will aid the eventual implementation of supply system architecture. Primarily, the constraints are the aspects that the eventual system must cope with and also, any characteristics that could impede progress through the process framework steps and eventual implementation. The risks involve any characteristics that could put the new supply system architecture under jeopardy and will need to be identified and risk management plans made. Voting and scoring techniques can be utilised again in this step to enable a decision making forum. The budget and time available will also be reviewed in this step and incorporated into the constraints; risks and risk management plan. Resources will be allocated to the project plan, which may result in adjustments to the timings. During this step, the problems within the supply chain/network may be considered too difficult to resolve by deploying supply system architecture. If this occurs, then it is not a suitable time for a new supply system architecture, hence, it would be necessary to use quick scan (Childerhouse et al., 1999). The quick scan diagnostic method is designed as a change management process for supply chains and should be conducted before information communication technology is implemented (Naim et al., 2002); quick scan is outlined in section 6.6.2. Once the quick scan has been completed, this process framework can be applied.

Using the beer game as an illustration, the key enablers, yet also one of the constraints, falls in the relationships category, see figure 6.6. The long-term interaction in stable market will enable smoother implementation of supply system architecture. However, the adversarial atmosphere between the organisations, caused by the Forrester (1961) and Houlihan (1985) effects is a risk that must be managed. A constraint that needs careful consideration is the relatively short time window for delivery, which is further acerbated by the short shelf life and seasonality/weather is a key risk that can influence quality and quantity of raw materials (e.g. hops and barley).

**Figure 6. 6 Summary of key enablers; constraints and risks (beer game illustration)**




An example of part of a risk management plan is summarised in table 6.1. Risk management must consider the risks, whether there are acceptable or not, the impact and how likely they are. Mitigation plans must also be made to reduce the impact of the risk.

**Table 6. 1 Risk management example**

| | Risk | Acceptable | Impact | Likelihood | Mitigation |
|---|---|---|---|---|---|
| 1 | Adversarial atmosphere | No | High | Medium | ▪ Project leader and supply chain champion to encourage participation<br>▪ Ensure involvement of all parties during the design and selection process to encourage buy-in.<br>▪ Etc. |
| ... | | | | | |
| n | | | | | |

## 6.3.4 Step 1d. Clarify supply chain/network goal(s)

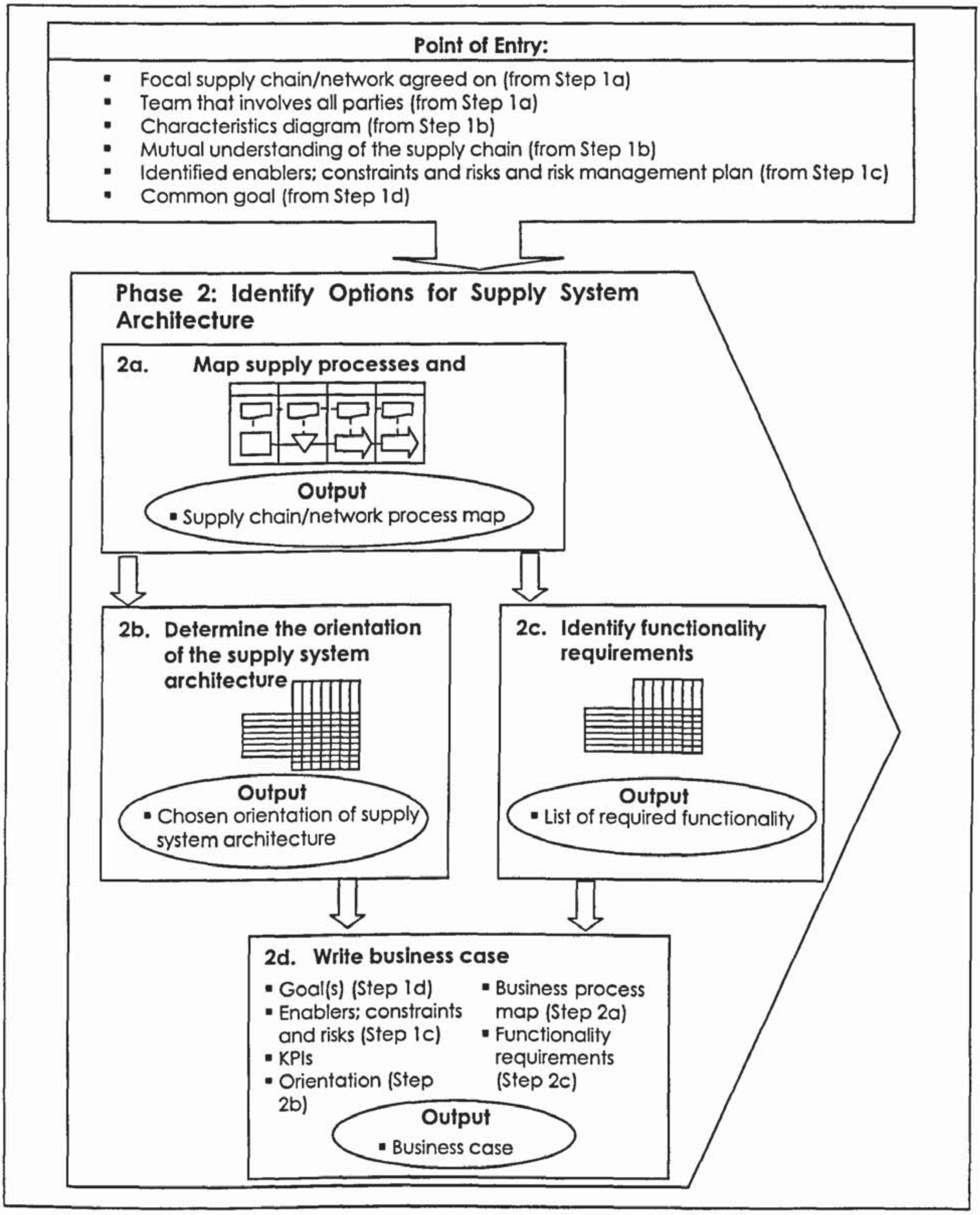
Once the enablers; constraints and risks have been agreed upon, the next step is to clarify the supply chain goals, i.e. what the new supply system architecture will deliver for the supply chain/network. The process will involve negotiation between the different parties in the team (from Step 1a) and will need to consider the characteristics of the supply chain (from Step 1b) and the key enablers; constraints and risks (from Step 1c). Differences of opinion will need to be handled here by using voting and scoring techniques, to create a decision making forum. Using the beer game as an illustration, the review of supply system architecture was motivated by the "boom" and "bust" inventory scenarios. Therefore, the goals are:

3. Improve inventory management and avoid boom and bust inventory scenarios
4. Improve information flow across the supply chain/network
5. Reduce the cost associated with stock-outs

## 6.4 Phase 2: Identify Options for Supply System Architecture

The supply chain/network processes and systems effected by the new supply system architecture will need to be mapped (Step 2a. Map supply processes and systems). During the mapping process, decisions will be made on how much detail needs to be included, hence, further clarifying the boundary (from Step 1a). The mapping process will result in the team (from Step 1a) having a much clearer appreciation of the whole supply chain/network. The clearly drawn boundary will facilitate the debate and discourse about whether to integrate; partially integrate or co-ordinate the supply processes (Step 2b. Determine the orientation of the supply system architecture). The debate and discourse may result in new boundaries being drawn, and hence, for example, a dyadic link may become integrated, but co-ordination employed elsewhere in the network. The next step is to identify the functionality required by the supply system architecture (Step 2c. Identify functionality requirements). The functionality needs to be made clear to enable the options available to be evaluated. The final step in this phase is to write up the business case (Step 2d. Write business case) this will include the enablers; constraints and risks (from Step 1c); the orientation of the supply chain/network (from Step 2b); the business process map (from Step 2a) and the required functionality (from Step 2c). It will also refocus on the supply system architecture goals (Step 1d); these will be translated into key performance indicators that the chosen system will be evaluated against. All four steps in phase 2 are summarised in Figure 6.7.

**Figure 6. 7 Phase 2: Identify Options for Supply Systems Architecture**

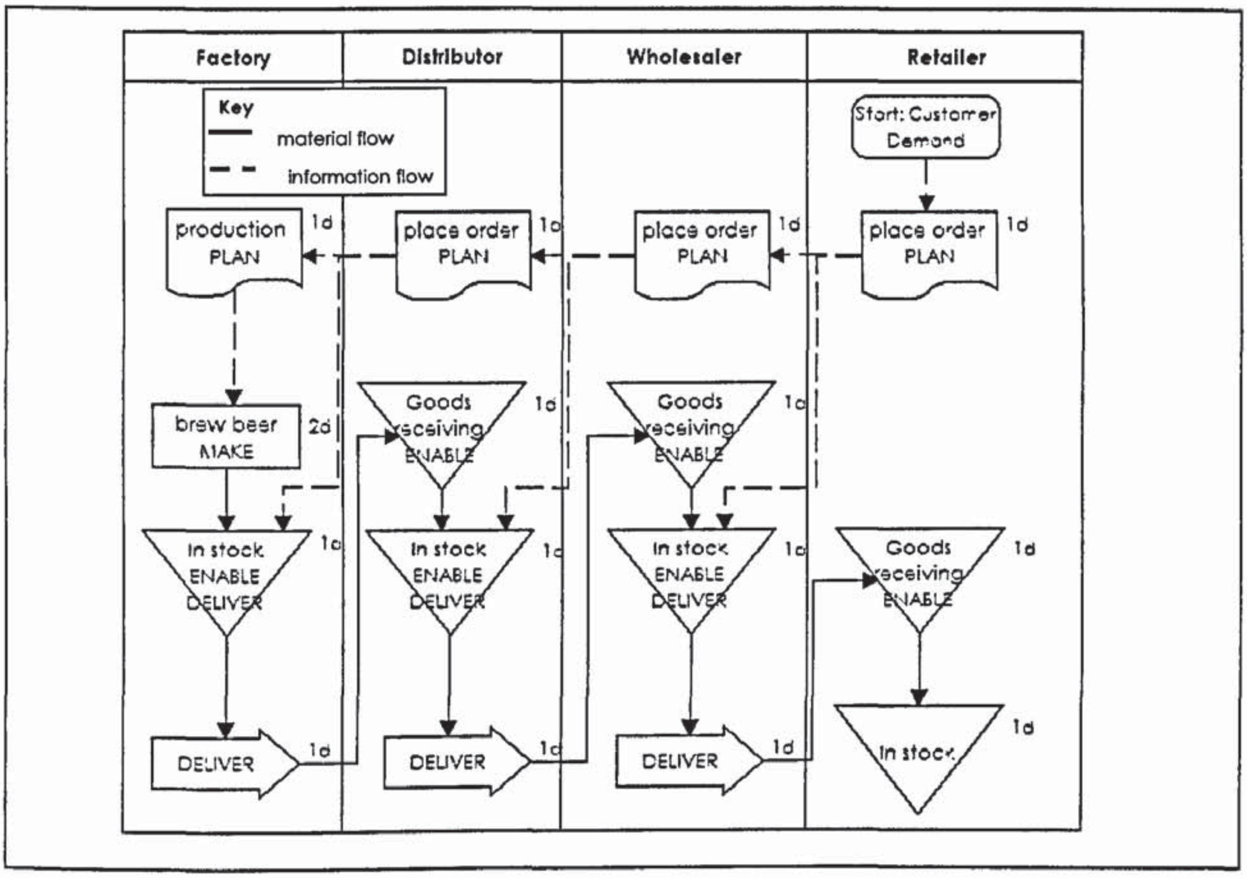


### 6.4.1 Step 2a. Map supply processes and systems

The effected supply chain/network processes and systems are mapped to create a supply chain/network map. The map shows the processes that would be directly affected by the new supply system architecture and the systems that are currently used. Therefore, the supply processes map could show different levels of detail of the different organisations, depending on their role in the supply chain/network. The processes within the focal organisation and those considered to be directly involved (identified in Step 1a) will be mapped in more depth than those considered partially involved (identified in Step 1a). This distinction ensures the focus of investigation is on the core supply processes. The Supply Chain Operations Reference (SCOR) model (Supply Chain Council, 2006) was used to distinguish types of processes, although other processes can included as required by the supply chain/network in focus, due to the fact that the Supply Chain Council excludes customer processes as discussed in section 1.6.

Figure 6.8 illustrates the supply processes considered in the beer game, produced by using the iGrafx Process™ tool. In the beer game, the four different organisations are represented at the same level of detail. The key supply processes of planning (e.g. ordering); delivering and making (e.g. brewing) are included, as well as the enabling storage processes. The duration of the processes is also indicated to the top right of the shape. Figure 6.8 highlights how the current systems pass the information, in the form of orders, echelon by echelon.

**Figure 6. 8 Process map for the beer game**




## 6.4.2 Step 2b. Determine the orientation of the supply system architecture

Mapping the processes is imperative for this step, where the team must decide how to orientate the supply system architecture. The process map is in focus as the team consider how the supply system architecture should be orientated to meet the goals (from Step 1d) whilst utilising the enablers; consider the constraints and reduce the risks (from Step 1c). Quality function deployment (QFD) is used in this step as it aligns this requirements (or "whats") with "how" the supply system architecture must be orientated to fulfil them. Therefore, this describes "what" is required from the supply system architecture and is entered into the left of the QFD matrix, see table 6.2. The individuals from the team (Step 1a) must rate the importance of the goals; enablers; constraints and risks, in terms of their impact on the choice of supply system architecture. Group support systems can be used to facilitate this process until an agreement is reached, the agreed figures are entered into the impact column, see table 6.2.

The next step is to determine "how" the supply system architecture will deal with the needs. Therefore, the seven different processes or efforts from Wong and Boon-itt's (2006) definitions (as discussed in section 2.3) make up the "how" in the right-hand grid in table 6.2. The seven processes are: 1) physical flow; 2) process and activity 3) sharing of information; risk; goal; revenue and rewards; 4) cooperation and coordination of activities; 5) planning and ordering decisions; 6) interaction and collaboration, trust and commitment for collaboration and 7) network integration. Each goal; enabler; constraint and risk is taken in turn and given a value of 1 for weak relationship; 6 for medium relationship and 9 for strong relationship with each of the seven processes, depending on the emphasis from the process mapping exercise, see table 6.2. This indicates whether the process can met the goal; strengthen the enabler; consider the constraint or mitigate the risk. Group support system technology will be vital in determining the score given in the final matrix, shown in table 6.2.

The next step is to computate the matrix to work out the absolute and relative importance of the seven different processes, see bottom portion of table 6.2. These seven processes align to whether the supply system architecture should be integrated; partially integrated; co-ordinated or independent, as shown in table 2.3 and indicated in the bottom portion of table 6.2. The beer game requires all the processes in the matrix, except for network integration; therefore, partial integration is the required orientation of the new supply system architecture.

## Table 6. 2 QFD orientation matrix for the beer game

| **WHATs** vs **HOWs**<br>Strong relationship = 9<br>Medium relationship = 3<br>Weak relationship = 1<br><br>**WHATs** | | Impact | HOWs (from table 2.3): Physical flow | Process and activity | Sharing of information; risk; goal; revenue and rewards | Cooperation and coordination of activities | Planning and ordering decisions | Interaction and collaboration, trust and commitment for collaboration | Network integration |
|---|---|---|---|---|---|---|---|---|---|
| **Goals (from Step 1d):** | | | | | | | | | |
| Improve inventory management to avoid boom and bust inventory scenarios | | 13 | | 3 | 9 | 9 | 9 | | |
| Improve information flow across the supply chain/network | | 12 | | 3 | 9 | 3 | 9 | | |
| Reduce the cost associated with stock-outs | | 11 | 9 | | 9 | 3 | 9 | | |
| **Enablers (from Step 1c):** | | | | | | | | | |
| Duration of Lifecycle | years | 2 | | | 9 | | | 9 | |
| Variability | predictable | 3 | 3 | | | | 3 | | |
| Vertical | single | 4 | | | 9 | 9 | 3 | 9 | |
| Interaction | long-term | 5 | | | 9 | | | 9 | |
| Market | stable | 1 | 3 | | | | | | |
| Power | equal | 8 | | | 3 | | | 3 | |
| **Constraints (from Step 1c):** | | | | | | | | | |
| Time Window | hours | 10 | 9 | | 3 | 3 | 3 | | |
| Shelf-life | limited | 6 | | | | | 3 | | |
| **Risks (from Step 1c):** | | | | | | | | | |
| Atmosphere | adversarial | 9 | | | 1 | | | 1 | |
| Seasonality | seasonal | 7 | 9 | | 3 | | 3 | | |
| | **Absolute Importance** | | 264 | 75 | 507 | 252 | 414 | 132 | 0 |
| | **Relative Importance** | | 3rd | 6th | 1st | 4th | 2nd | 5th | 7th |
| **From table 2.3:** | Integration | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Partial integration | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Co-ordination | | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| | Independence | | | ✓ | | | ✓ | | |

### 6.4.3 Step 2c. Identify functionality requirements

The next step is to identify the functionality requirements of the new supply system architecture; these can be identified through considering the functionality table (table 2.2). The team (from Step 1a) will need to consider each of the functionality elements and decide whether the functionality is required or not to achieve the processes or efforts identified in the QFD analysis (from Step 2b). The group support system technology can be used to facilitate the process, drawing out the functionality list by allowing team members to score the importance of the different functionality requirements. The functionality requirements with the highest votes will then be included; those where there is a difference of opinion can be discussed. Particular attention is paid to those systems which provide partial integration, as indicated in figure 2.10. Partial integration of an external supply chain/network can be achieved by either integrated systems, which is a combination of enterprise systems and best of breed systems (APS; WMS; TMS; CRM and SRM) or CPFR. The supply chain/network utilises single sourcing, so therefore the supply planning and operations functionality was not really necessary, e.g. they would not need to hold reverse auctions. Evaluating the functionality from table 2.2 for the beer game led to the identification of the following required functionality:

- Production Planning and Management
  - Materials/Inventory planning and management
- Demand Planning and Management
  - Collaboration and collaborative planning
  - Forecasting

### 6.4.4 Step 2d. Write business case

The team (from Step 1a) will then need to write up the business case. This step will involve pulling together the goal(s) (from Step 1d); the enablers; constraints and risks (from Step 1c); the required orientation (from Step 2b); the business process map (from Step 2a); and the functionality list (from Step 2c). This step will also need to determine the metrics or key performance indicators (KPIs) that the new system will need to achieve, identified as important by Bolstroff and Rosenbaum (2003) and Supply Chain Council

(2006). The key performance indicators will be derived from the common goals (from Step 1d) and the constraints and risks (from Step 1c). A table of key performance indicators will be drawn up, as illustrated using the beer game example in table 6.3. The KPIs will form the basis of the evaluation of the eventual success of the selected supply system architecture.

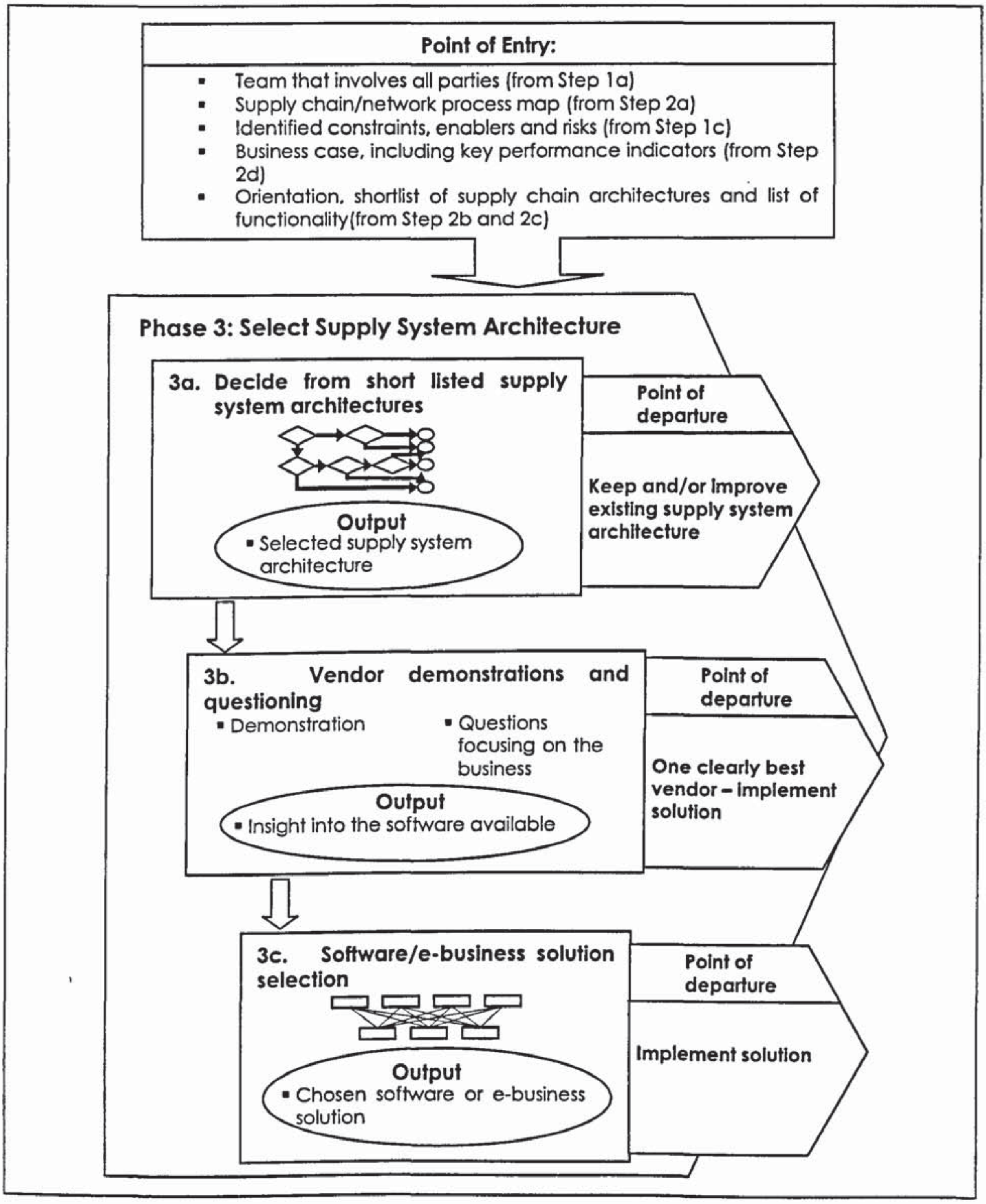
**Table 6. 3 Key Performance Indicators (KPIs) for the beer game supply system architecture**

| Characteristic | Key Performance Indictor | Criteria for Evaluation | Actual performance | Desired performance | Gap Desired-actual |
|---|---|---|---|---|---|
| Goal | 1. Improve inventory management and avoid boom and bust inventory scenarios | Stock outs | > twice a year | < 1 a year | significant |
| (includes risks: adversarial atmosphere and seasonality and weather) | 2. Improve information flow across the supply chain/network | Visibility of actual demand | Echelon-by-echelon | Supply chain | significant |
| | 3. Reduce the cost associated with stock-outs | Average cost per day | $2 a day | $1 a day | significant |
| Constraints | | | | | |
| Time Window of hours and limited shelf-life | 4. On time delivery | Late delivery | >4 barrels a day | 0 | significant |

## 6.5 Phase 3: Select Supply System Architecture

The third phase is the actual selection process (see figure 6.9); firstly the supply system architecture(s) need to be decided upon, using an appropriate decision-making technique (Step 3a. Decide from short listed supply system architectures). This step will also consider the existing system(s) as an alternative. The conclusion could be to stay with or improve the existing system. When the conclusion is the selection of new supply system architecture(s), then the next step is to have vendor demonstrations of the software available (3b. Vendor demonstrations and questioning). The vendor demonstrations are an important part of the process and will gather extra information on the software to enable the software selection process. The final step will reach a decision on which software to purchase (Step 3c. Software selection). The software selection step will vary depending on the results of the vendor demonstrations, detailed analysis will be required if there is more than one viable vendor.

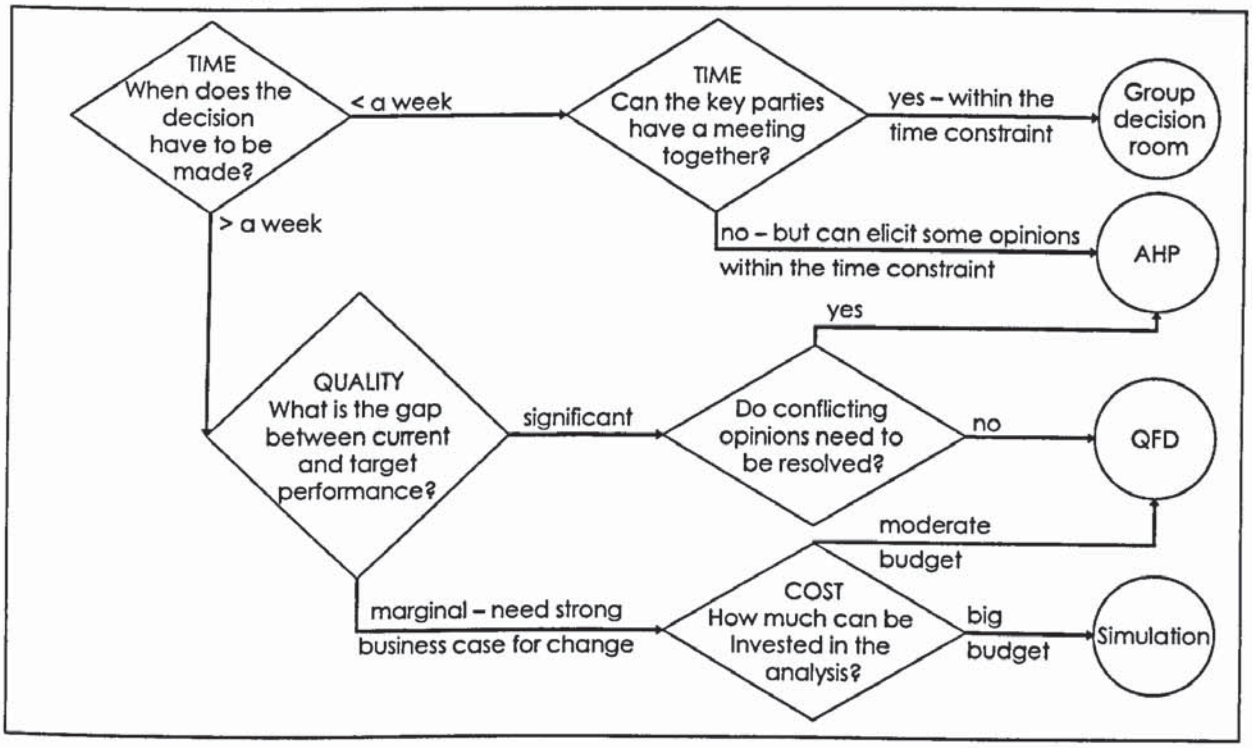
**Figure 6. 9 Phase 3: Select Supply System Architecture**



### 6.5.1 Step 3a. Decide from short listed supply system architectures

There are different decision-making techniques available to select the appropriate supply system architecture. A flowchart was designed to identify which decision technique is appropriate, depending on the time available to make the choice, the quality required and the budget, as shown in figure 6.10. If there is not much time available to make the decision and the team (from Step 1a) can get together for a workshop then the group decision room is the best option. Within a group decision room either QFD or AHP can be used to select the supply system architecture. Whether QFD or AHP is used, they both consider the functionality requirements against the supply systems architecture available, keeping the goals; enablers; constraints and risks in mind. There is not a direct mapping of the functionality from the table 2.2, because the functionality is handled differently and needs to consider the goals etc. AHP is preferable if there is conflict within the team. If it is not possible to get the team (from Step 1a) together AHP could be used over the distance and aggregated.

**Figure 6. 10 Flowchart to guide the choice of decision making technique, depending on time; quality and budget**



However, if there is more time available to make the decision then the KPIs need to be reviewed to determine if there is significant difference between current and target performance. If this is the case, either QFD or AHP can be used, AHP is preferable if there is likely to be conflicting opinions. If however, there is only marginal difference between the current and target performance, then ideally simulation will be used as it allows for quantitative evaluation of the options. However, if there is not sufficient budget available QFD should be used to determine which supply system architecture is appropriate. The different decision-making techniques will guide the analysis and selection of supply system architecture in different ways. A summary of how to utilise each technique: AHP; QFD and simulation follows.

#### 6.5.1.1 Group decision room and AHP

The group decision room can utilise the AHP or the AHP can be facilitated over a distance. The AHP will be used in the group decision room if there is likely to be a conflict of opinions. The AHP can be used to select supply system architecture as it enables decisions to be made by setting criteria and then evaluating the alternatives according to the criteria, as discussed in section 4.2.1. Expert Choice ™ is a commercially available software package that utilises the AHP that can facilitate the process. Expert Choice ™ has group decision support facilities to enable groups to make the decision, this requires a facilitator. The process of using Expert Choice ™ to make the group decision will be as follows:

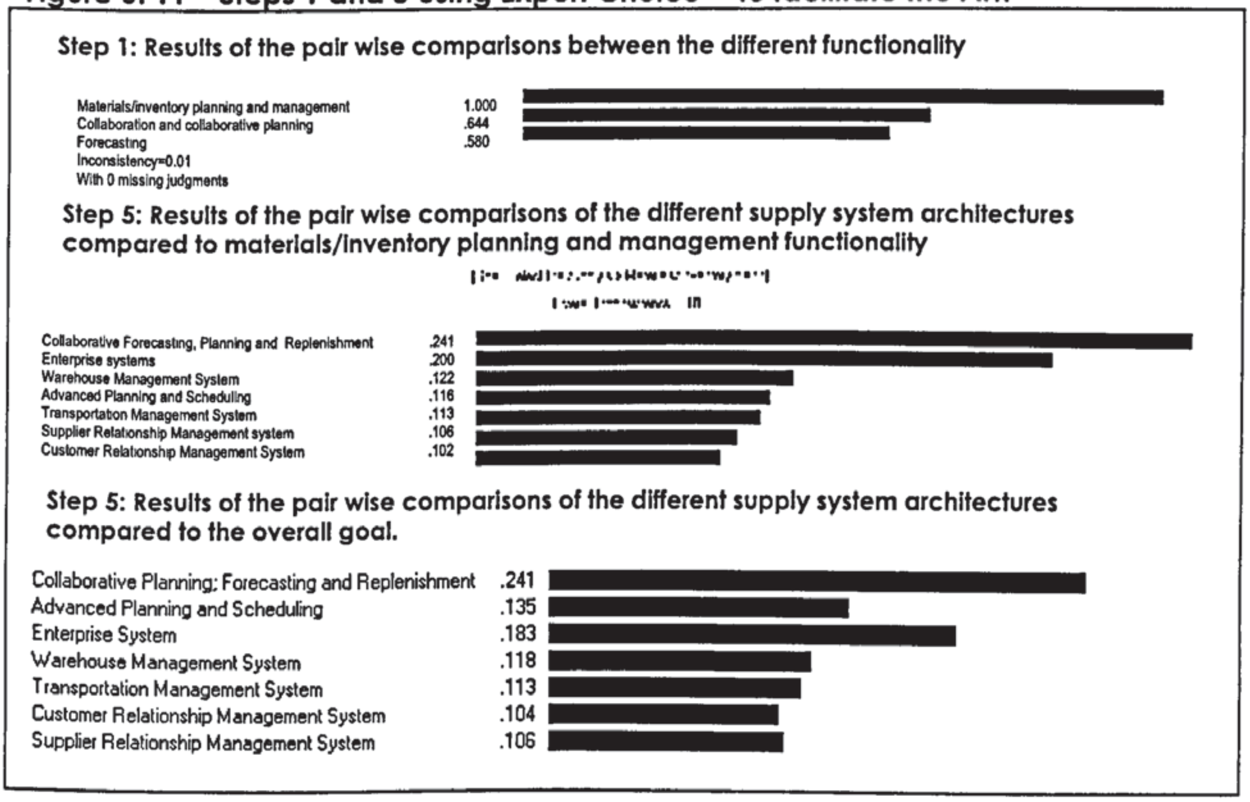
1. The individuals will make pair-wise comparisons between the different types of functionality (identified in Step 2c), focusing on the business case (from Step 2d).
2. The facilitator will combine the judgements of how important the functionality is and share the combined figures with the group, along with sensitivity analysis.
3. The facilitator will then lead the discussion to reach a consensus.
4. The facilitator will explain the different supply system architectures available that fit the orientation (decided upon in Step 2b), using section 2.2's descriptions and table 2.2.
5. The individuals will make pair-wise comparisons between the different supply system architectures and the existing system and how well they provide the functionality against each other.

6. The facilitator will combine the judgements of how well the supply system architectures met the functionality requirements and share the combined figures with the group, along with sensitivity analysis.

7. The facilitator will then lead the discussion to reach a consensus.

Using the beer game as an example, the AHP, using Expert Choice ™ resulted in the selection of CPFR as the appropriate supply system architecture. The pair wise comparisons diagrams and analysis are shown in figure . Graphs can be created to show the comparisons between each functionality aspect and the supply system architectures, as well as the overall alignment to the goal. Debate between the group members will be more focused using the different graphs produced. In a case where supply system architectures perform similarly well the individual graphs of the different functionality requirements can be utilised to facilitate discussion on which supply system architecture to adopt, or whether to adopt a combination of supply system architectures. Sensitivity analysis can also be conducted where the functionality priorities can be altered to determine the impact.

Figure 6. 11 Steps 1 and 5 using Expert Choice™ to facilitate the AHP



### 6.5.1.2 Group decision room and QFD

The group decision room can utilise QFD or QFD can be facilitated over a distance. QFD will be used in the decision room if there is not likely to be great conflict of opinions. QFD will be implemented in a similar way to section 6.4.2, however the "whats" will be the functionality requirements (listed in Step 2c) and the "hows" will be the supply system architectures (identified in Step 2b). If scoring was used to rank the importance of the different functionality, these scores can be transferred into the importance column of the QFD matrix. Using the beer game as an example, table 6.4 shows the functionality required by the beer game in the left hand portion of the matrix. Step 2b indicated that the beer game should strive for partial integration, therefore either CPFR or a combination of best of breed solutions should be integrated, shown in the top section of the QFD matrix, in table 6.4. The relationship between the functionality and the supply system architectures is then scored depending on the strength of the relationship, shown in the middle section of the QFD matrix. The QFD analysis reveals that CPFR is the best option for the beer game, see table 6.4.

**Table 6. 4 Supply system architecture QFD matrix**

| | | Supply system architectures (from Step 2c) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **WHATs vs HOWs**<br>Strong relationship = 9<br>Medium relationship = 3<br>Weak relationship = 1<br><br>**WHATs** | **Importance** | Collaborative Planning; Forecasting and Replenishment | Advanced Planning and Scheduling | Enterprise System | Warehouse Management System | Transportation Management System | Customer Relationship Management System | Supplier Relationship Management System |
| **Functionality (from Step 2c):** | | | | | | | | |
| Production Planning and Management | | | | | | | | |
| Materials/Inventory planning and management | 3 | 9 | | 9 | 3 | 1 | | |
| Demand Planning and Management | | | | | | | | |
| Collaboration and collaborative planning | 2 | 9 | 3 | 9 | | | | |
| Forecasting | 1 | 9 | | 3 | | | | |
| **Absolute Importance** | | 54 | 6 | 48 | 9 | 3 | 0 | 0 |
| **Relative Importance** | | 1st | 4th | 2nd | 3rd | 5th | | |

### 6.5.1.3 Simulation

Simulation will develop a model of the supply chain/network and allow for "what if" experimentation of the different supplies system architectures. The results can give an indication of how the different supply system architectures will perform against the KPIs. Simulation models can be developed that will model the functionality of the different supply system architectures, although some assumptions and abstractions of the actual systems will need to be made. The production of simulation models will involve a computer expert. The results of the simulation experiments can be compared to decide which supply system architecture performs the best. There are seven main steps in a simulation project:

i. Objective/Problem definition
ii. Model conceptualisation
iii. Model build
iv. Verification and Validation
v. Experimentation
vi. Results analysis and conclusion

Abridged from Pidd (1998) and Robinson (1994)

The first two steps have already been conducted in the preceding steps in the process framework. Specifically, the business case, produced in Step 2d defines the objectives of the simulation (step i). The process map created in Step 2a forms the conceptualisation of the model (step ii). However, the map will need to have the dynamic capabilities added to it during model building (step iii).

Building the model can be an extension of the iGrafx Process™ based process map created in Step 2a. The manufacturing and delivery processes can be modelled using the functionality already present in the iGrafx Process™ elements in the dialog box that is behind each of the different shapes on the process map. The processes need to have resources assigned to them, iGrafx Process ™ has an in-built resources functionality. iGrafx Process ™ allows the user to specify the type of resource; how many there are; the cost and the shift pattern. The manufacturing and delivery processes also need a timing element;

which is contained in the Task area of the dialog box. Manufacturing and delivery processes where the time is consistent across product types are easily modelled, these have already been inputted into the process map in figure 6.8, indicated to the top right hand of each shape. The timing of manufacturing and delivery can be adapted to reflect the quantity of products made, by adding a quantity attribute, similarly if time varying according to product type an attribute called can be set up to represent the product types.

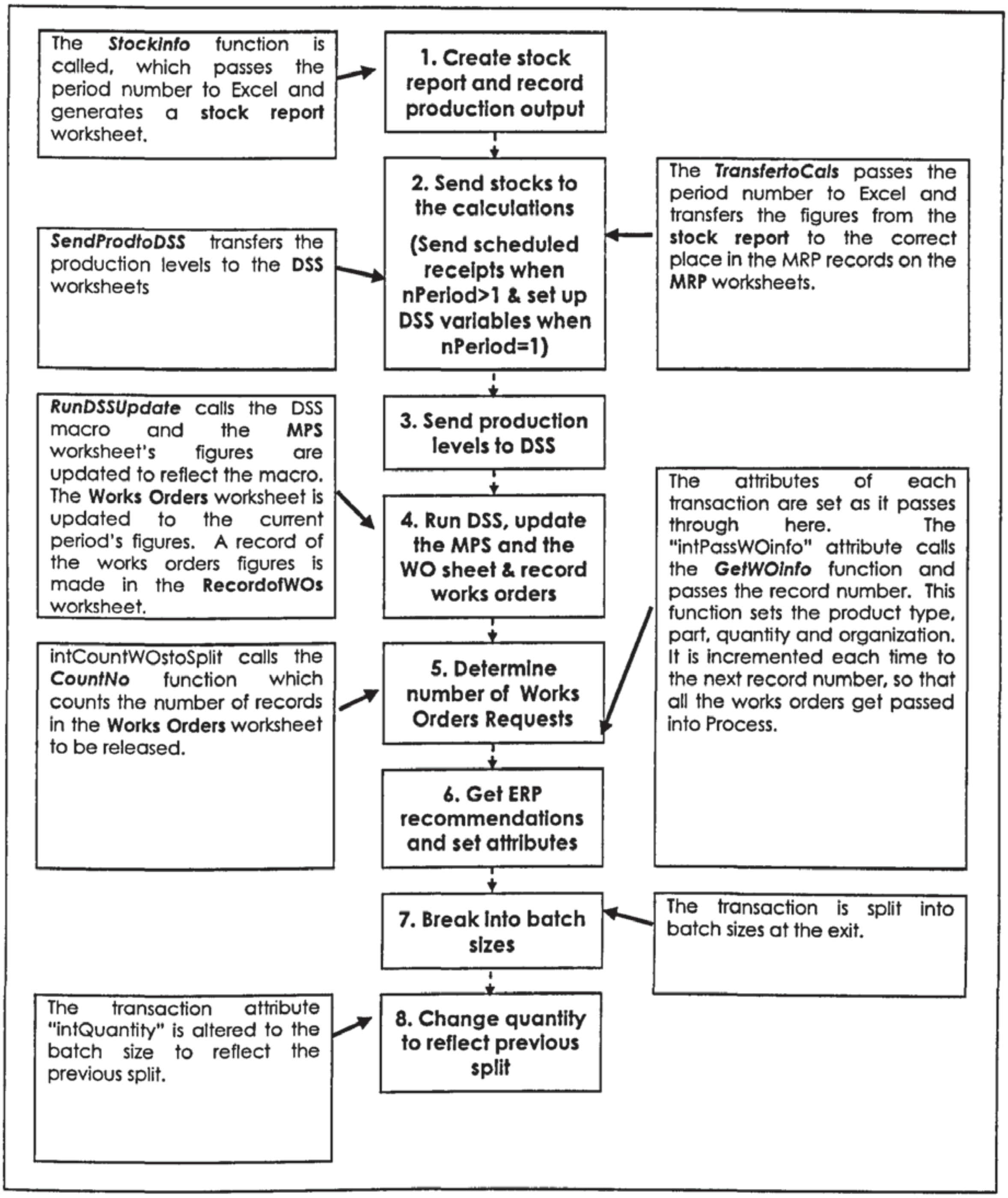
Modelling the planning activities is more complex as the functionality of different supply system architectures will require the use of Excel and Visual Basic for Applications (VBA). An application programming interface (API) exists in iGrafx Process™ which enables VBA functions to be called during the simulation. In order to conduct MRP/ERP calculations, six VBA functions are required, as shown in table 6.5 and indicated in ***Bold Italics*** in figure 6.12. These functions are the bridging mechanism between the model and the Excel worksheet used to conduct all the MRP calculations to govern the model. These interactions between the iGrafx Process ™ model and Excel which conducts these periodic calculations are summarised in figure 6.12. The central boxes are the activities in the iGrafx Process ™ model. The boxes to the left and right explain what happens at each stage and the VBA functions that are called.

**Table 6. 5 The planning functions**

| Function name in iGrafx Process™ | Function name in the VBA | Sub-functions called by the VBA function |
|---|---|---|
| ***Stockinfo***(S.Period) | GetStockLevel(DoubleArgument) | RecordOutput |
| ***Transfertocals***(S.Period) | CalsUpdate(DoubleArgument) | XLSchReceiptsMRP<br>SetupDSSinputs<br>StocksToCals<br>CalOnhand |
| ***SendProdtoDSS***(S.Period) | ProdtoDSS(DoubleArgument) | InsertProdintoDSS<br>XLOnhandDSS<br>XLWeekProdToActiveDSS |
| ***RunDSSUpdate***(S.Period) | DSSAndUpdate(DoubleArgument) | DSSMacro<br>UpdateMPS<br>UpdateWOsheetAndRecordWOs |
| ***CountNo*** | CountWOsforRelease(nRows) | |
| ***GetWOinfo*** | SettingWOattributes(ExcelLine) | |

The first activity transfers the output figures (how much has been made) and generates a stock report. The second activity updates the scheduled receipts figures and sets the Decision Support System (DSS) inputs and always transfers the stock levels to the MRP calculations. The third activity sends the production figures to the DSS. The fourth activity runs the Automatic Pipeline, Inventory and Order Based Production Control System (APIOBPCS) calculation. The APIOBPCS calculations are based on the work of Disney (2001). The fifth activity determines how many works orders there are to be released and splits the transaction into this number. The sixth activity sets the attributes according to the works orders produced by the MRP calculations. The seventh activity separates these works orders into batch sizes. The eighth activity resets the quantity attribute to reflect the batch size. After the planning sub process is completed the works order is sent to the relevant organisation.

**Figure 6. 12 The iGrafx Process and VBA functions for Planning**




The first activity creates a stock report based on the levels of stocks in the model. It calls Stockinfo in the before attributes using the following text: Send_Stock = Stockinfo( S.Period). The Stockinfo function then triggers the GetStockLevel function, it passes the period in order to number the stock report accordingly. Figure 6.13 shows how the stock report is generated, as an example of the VBA required. Firstly, the output is recorded into the Excel worksheet by calling the RecordOutput function, see figure 6.13. Then the stock report is generated, a new worksheet is opened, this sheet is named to reflect the current period. Then the generic stock report is copied and pasted into the new worksheet. The planning diagram is then activated to enable the transfer of scenario attribute values from the Process model to the stock report sheet.

**Figure 6. 13 Code for the GetStockLevel Function**

```
Function GetStockLevel(nStock As Double)
   Dim nExcelRow As Integer
   Dim rngCopyStockRep As Range
   Dim rngFormulaCopy As Range
   Dim rngStocksHome As Range
   Dim rngStockCurrentArray As Range
   Dim nStockExcelCountRows As Integer
   Dim sFormulaCopy As String
   Dim sFGAttributeName As String
   Dim sStoresAttributeName As String
   Dim sWiPAttributeName As String

Call RecordOutput(nStock)

'Add a new worksheet to hold this period's stock information
      pb_wkbPlanning.Sheets.Add
      pb_wkbPlanning.ActiveSheet.Select
      Set pb_wksStocks = pb_wkbPlanning.ActiveSheet

'Name the sheet Stocks_nPeriod
      pb_wksStocks.Name = "Stocks_" & nStock

'Get the generic stock report and add to the new stock report the data required
'(i.e. Copy and Paste)
      Set pb_wksStockReport = pb_wkbPlanning.Worksheets("Stocks")
      pb_wksStockReport.Activate
      Set rngStocksHome = pb_wksStockReport.Cells(1, 1)
      rngStocksHome.Activate
      Set rngCopyStockRep = rngStocksHome.CurrentRegion
      rngCopyStockRep.Copy
      pb_wksStocks.Activate
      pb_wkbPlanning.ActiveSheet.Paste

'Find out how many rows of stock information data need to be filled in
   Set rngStocksHome = pb_wksStocks.Cells(1, 1)
   Set rngStockCurrentArray = rngStocksHome.CurrentRegion
   nStockExcelCountRows = rngStockCurrentArray.Rows.Count

'Get the Planning Diagram
    Set pb_igxDiagram = pb_igxDiagrams.Item(pb_nPlanningItem)
    pb_igxDiagram.ActivateDiagram

'Work through the stock report array and fill in the stock figures for each SKU
'into the relevant cell in the Stock_nPeriod sheet
   For Each pb_dobj In ActiveDiagram.DiagramObjects
         If pb_dobj.ID = "8107" Then
             Set pb_a = pb_dobj.AsType("igrafx.activity")

             For nExcelRow = conpb_nlLineHeader + 1 To nStockExcelCountRows
             sStoresAttributeName = pb_wksStocks.Cells(nExcelRow, _
             conpb_nStoresNameColumn).Value
             pb_wksStocks.Cells(nExcelRow, conpb_nStoresQuantityColumn) _
```

```
            .Value = pb_a.CurrentScenario.Simulator.Simulation. _
            AttributeValue(sStoresAttributeName)
            Next nExcelRow

            nExcelRow = 1

            For nExcelRow = conpb_nlLineHeader + 1 To nStockExcelCountRows
            sWiPAttributeName = pb_wksStocks.Cells(nExcelRow, _
            conpb_nWiPNameColumn).Value
            pb_wksStocks.Cells(nExcelRow, conpb_nWiPQuantityColumn).Value = _
            pb_a.CurrentScenario.Simulator.Simulation.AttributeValue _
            (sWiPAttributeName)
            Next nExcelRow

            nExcelRow = 1

            For nExcelRow = conpb_nlLineHeader + 1 To nStockExcelCountRows
            sFGAttributeName = pb_wksStocks.Cells(nExcelRow, _
            conpb_nFGNameColumn).Value
            pb_wksStocks.Cells(nExcelRow, conpb_nFGQuantityColumn).Value = _
            pb_a.CurrentScenario.Simulator.Simulation.AttributeValue _
            (sFGAttributeName)
            Next nExcelRow

            nExcelRow = 1
        End If
    Next pb_dobj

'Copy the formula that calculates the totals into the stock report sheet
    sFormulaCopy = "M2:M" & nStockExcelCountRows
    Set rngFormulaCopy = pb_wksStocks.Range(sFormulaCopy)
    rngFormulaCopy.FormulaR1C1 = "=RC[-3]+RC[-6]"

    pb_wksStocks.Calculate

End Function
```

The different VBA functions can be created to mimic MRP/ERP calculations and therefore, the potential exists to use simulation to model different supply system architectures.

Each model produced will need to be verified and validated. Robinson sees "the purpose of verification is to guarantee the correct behaviour of each element in the model." (Robinson, 1994, pp. 136). Robinson goes on to pinpoint the verification specifics as being:

- "Timings, e.g. cycle times, repair times, travel times
- Control of elements, e.g. breakdown frequency, shift patterns
- Control of flows, e.g. routing
- Control logic, e.g. scheduling rules, stock replenishment
- Distribution sampling, e.g. gamma input data gives gamma samples"

(Robinson, 1994, pg. 136)

A variety of techniques exist for validation of the model (Hermann, 1967, Sargent, 2003), these include:

- Hypothesis validity (Hermann, 1967, Sargent, 2003);
- Comparison to Other Models (Sargent, 2003)
- Fixed Values (Sargent, 2003)
- Face Validity (Hermann, 1967, Sargent, 2003)
- Internal Validity (Hermann, 1967 and Sargent, 2003)
- Animation (Operational Graphics) (Sargent, 2003)
- Traces (Sargent, 2003)
- Compare to theory (Hermann, 1967, Sargent, 2003)
- Sensitivity testing (Hermann, 1967, Sargent, 2003)
- Event validity (Hermann, 1967 and Sargent, 2003)
- Historical Data Validation (Sargent, 2003)
- Predictive Validation (Sargent, 2003)
- Extreme-Condition Tests (Sargent, 2003)
- Degenerate Tests (Sargent, 2003)

The verification and validation activities can be time-consuming, but are utilised to ensure the results from the experimentation can be relied upon.

There is potential to use simulation to decide upon supply system architecture. The supply system architectures can be modelled using a combination of iGrafx Process ™; VBA and Excel, as explained in figure 6.12 and the example of VBA code example given in figure 6.13. Utilising simulation is a far more time-consuming method of decision making. However, the depth and precision of analysis are greater and there is more objectivity in the analysis. The group decision scenario may rule out the use of simulation as many of the steps in simulation are not interactive, for example the build; verification; and experimentation steps do not involve the group. The validation step only involves the group during the face validity testing part. However, in a scenario where a detailed business case for change is required, simulation provides the necessary detailed analysis.

### 6.5.2 Step 3b. Vendor demonstrations and questioning

Software vendors and e-business solutions providers will then be invited to demonstrate their solution to the team (from Step 1a). The team (from Step 1a) will utilise the business case (from Step 2d) to question the vendors and ensure that the solution has go the right functionality. Therefore the questioning will focus on:

- Determining the fit with the goal(s) (from Step 1d and in the business case);
- Establishing if the constraints can be dealt with (from Step 1c and in the business case);
- Establishing if risks can be mitigated (from Step 1c and in the business case);
- Checking that the functionality is provided (from Step 2c and in the business case);
- Evidencing whether the solution will perform based on the key performance indicators (KPIs) (from Step 2d and in the business case)
- Obtaining costs and other solution specific information

The vendor demonstrations may result in one clearly best vendor, in which case, the process framework is completed and the process of implementation can begin. Otherwise, more detailed software selection processes are required, therefore, continue to Step 3c. The vendor demonstrations will vary depending on the software vendor and therefore, it is not possible to give an example for the beer game.

### 6.5.3 Step 3c. Software selection

The software selection process will depend on the results of the vendor demonstrations; it could be a simple discussion of the pros and cons. However, AHP based software evaluation can be conducted (Sarkis and Sundarraj, 2001, Wei et al., 2005, Wei and Wang, 2004).

## 6.6 Points of Departure

The process framework focuses on designing and selecting supply system architecture for supply chains/networks. Therefore, other tools and methodologies may be discovered to be important on the route through the process framework. For example, in step 1a when the boundary is drawn, internal supply chains may wish to adopt Blackwell's (2003) methodology. The process framework will not be suitable for larger change management activities, which may be identified at step 1d when the goals are set, therefore the quick scan diagnostics method (Childerhouse et al., 1999, Naim et al., 2002) could be utilised. The process framework does not guide the eventual implementation process either. Therefore, if the existing system is going to be improved upon (Step 3a); or when a software/e-business solution vendor is selected (Step 3b or 3c) the process framework is completed and the implementation process starts. The methodologies that can be used after departing the process framework at the various steps are now outlined: Blackwell's (2003); quick scan diagnostic method (Childerhouse et al., 1999, Naim et al., 2002) and eventual implementation.

### 6.6.1 Blackwell's (2003) decision-making methodology

Blackwell (2003) presents an 11 step decision-making methodology for integrating enterprise systems, shown in figure 6.14. His methodology was designed for single enterprises to enable them to determine how integrated their information systems need to be (steps 1 and 2). His methodology uses a team with clearly defined roles and responsibilities (step 3) and considers resource allocation (step 4). The methodology highlights that certain factors are likely to have an impact on resources as the level of integration increased. Blackwell (2003) states these factors as the flexibility/obsolescence of current systems; the need for business process re-engineering (BPR) and/or software customization; change management issues; software compatibility; risk of implementing a system that adversely affects the business and the need to develop interfaces. The methodology focuses on creating a sound business cases (steps 5 and 10). The enterprise determine how much integration is required (step 6) and assess their legacy IS (step 7), to determine if the systems have the desired functionality and/ or flexibility, to be integrated. Otherwise, the enterprise can purchase an integrated system and the methodology outlines how any potential software vendors could be assessed, thereby helping to identify the one(s) most likely to supply a suitable system (step 8). The different integration options available (single system single vendor and best of breed) can then be purchased or developed using the existing IS (step 9). Therefore, a sound business case results (step 10), which the project can be evaluated against (step 11). Throughout Blackwell's (2003) methodology the enterprise can re-evaluate, re-structure or even abandon an integrated systems project as necessary by using the gates, shown in figure 6.14.

**Figure 6. 14 Blackwell's (2003) decision making methodology**

Aston University

Illustration removed for copyright restrictions

Source: Blackwell (2003) and Blackwell et al (2006)

## 6.6.2 Quick scan diagnostic method

The quick scan diagnostic method was developed at Cardiff University, it is a two-week endeavour that seeks to quickly identify change management opportunities in a supply chain/network, shown in figure 6.15. Quick scan utilises a variety of data collection techniques to evaluate a supply chain/network. Questionnaires are used to identify issues; processes are mapped; data is collected, e.g. MRP; scrap reports; forecasting accuracy, etc. to pinpoint any uncertainties. Uncertainties can be classified as supply; demand; process or control uncertainties. The data is analysed to highlight the strengths and weaknesses of the supply chain/network. Weaknesses are further explored using cause and effect diagramming techniques. This analysis reveals a number of improvement opportunities which are evaluated, using economic value-added (EVA) and by considering the time and cost to implement. The results are presented to the management team to enable an action plan to be agreed.

**Figure 6. 15 Childerhouse et al's (1999) quick scan diagnostic method**

Aston University

Illustration removed for copyright restrictions

Source: Childerhouse et al (1999)

## 6.6.3 Implementation

The eventual implementation should follow existing guidelines and frameworks, discussed in section 2.4. An implementation strategy (Al-Mashari and Zairi, 2000b, Mandal and Gunasekaran, 2003) will need to be used, this could mean that the system is implemented using immediate cutover; parallel running; phased implementation or piloting (Bocij et al., 2003). The processes of systems installation, integration and testing will also need to be managed (Al-Mashari and Zairi, 2000b, Al-Mashari et al., 2003), which will need to be accompanied by training and education (Al-Mashari et al., 2003). Benchmarking (Al-Mashari and Zairi, 2000b) will need to be conducted during the process to enable learning to take place. The whole process will need to include: change management (Al-Mashari and Zairi, 2000b, Al-Mashari et al., 2003); good communications (Al-Mashari et al., 2003, Mandal and Gunasekaran, 2003) and project management (Al-Mashari and Zairi, 2000b, Al-Mashari et al., 2003, Cliffe, 1999, Mandal and Gunasekaran, 2003). Post-implementation evaluation will also need to be conducted (Al-Mashari, 2002, Al-Mashari et al., 2003, Al-Mudimigh et al., 2001 and Laughlin, 1999).

## 6.7 Review of the Process Framework: Requirements Alignment

The process framework was developed by focusing on the requirements that were discussed in chapters 4 and 5 and summarised in table 5.2. Therefore, the process framework meets the requirements, as explored fully in table 6.6. Each of the steps was carefully considered to ensure that the procedure; participation; project management and point of entry requirements were explicitly realised in the process framework. The process framework focused on utilising a procedure that gathered information relevant to the selection of supply system architecture (e.g. the supply chain/network characteristics in Step 1b and the supply processes and systems map in Step 2a) and that the information was analysed to enable the selection of supply system architecture, paying due attention to functionality (Steps 2c and 3a) as well as, compatibility with the supply chain/network (Steps 1a; 1b; 1c; 1d; 2b; and 3a). Throughout the process framework a written record is created and tools and techniques utilised. Participation is encouraged by identifying a team (Step 1a) and harnessing group support system technologies (exploited (Steps 1b; 1c; 1d; 2b; 2c; 3a and 3c). This level of participation and the written record aid change management and improve communications. Project management tools are utilised at the outset and timing revised in Step 1c and again in the analysis (Step 3a). The point of entry is explicit before the process framework (figure 6.1) and at each phase (figure 6.3; 6.7 and 6.9).

**Table 6. 6 Summary aligning the process framework to the requirements derived from the literature, critical review and archival case study analysis**

| Requirements (from table 5.2) | Realised in the process framework |
|---|---|
| **1. Procedure:** | |
| ***Gathering information:*** | |
| Business process management | Step 2a focuses on mapping the supply processes to enable the orientation to be determined (Step 2b) and the functionality listed (Step 2c). |
| Existing systems management | Step 2a maps the existing systems and these are utilised when deciding on the supply system architecture in Step 3a. |
| ***Analysing information:*** | |
| Functionality of different software e-business systems | The functionality requirements are listed in Step 2c; included in the business case (Step 2d) and used in the supply system architecture decision-making (Step 3a). |
| Compatibility with strategy | Step 1b considers the key characteristics of the supply chain/network and Step 1d clarifies the goal. |
| Compatibility with supply chain/network | Considered when the boundary is drawn in Step 1a; forms part of the definition of characteristics (Step 1b) and is therefore carried through in the analysis. |
| Software selection | Software selection is first considered when the orientation of the supply system architecture is determined (Step 2b) and when the functionality requirements are identified (Step 2c). The actual supply system architecture is decided upon in Step 3a. Vendor demonstrations and questions may result in software selection (in Step 3b), or more detailed software selection in Step 3c. |
| ***Identifying Improvements*** | The articulation of KPIs when the business case is being written (Step 2d) demonstrates the improvement gap. The comparative analysis in Step 3a seeks to identify an improvement in supply system architecture to meet the gap. |
| Written record, including business case | Throughout the process framework there is a written record of the analysis, in Phase one as follows: supply chain/network diagram (Step 1a); supply chain/network characteristics diagram (Step 1b); list of key enablers; constraints and risks (Step 1c); clarified supply system architecture goal (Step 1d). In Phase two a written record is provided by: the supply processes and systems map (Step 2a); the QFD analysis that indicated the orientation of the supply chain/network (Step 2b); the list of functionality requirements (Step 2c) and the eventual business case which is the culmination of the two phases and includes KPIs (Step 2d). In phase 3, whichever decision-making technique is utilised in Step 3a, the results can be formed into a written record as follows: a QFD matrix; an AHP synthesis graph or comparative simulation results. Step 3b will need to be summarised and then if the final step (3c) is undertaken the AHP will again provide a synthesis graph. |
| Tools and techniques | The following tools and techniques are utilised in the process framework: supply chain/network diagram (Step 1a); group support system technology (Steps 1b; 1c; 1d; 2b; 2c; 3a and 3c); supply chain/network characteristics diagram (Step 1b); the supply processes and systems map (Step 2a); QFD analysis (Step 2b and 3a); AHP (Step 3a and 3c) and simulation (Step 3a). |

| Requirements (from table 5.2) | Realised in the process framework |
|---|---|
| **2. Participation:** | |
| Groups | The team is decided in Step 1a which provides the basis for the group work throughout the process framework. |
| Workshop style | Several meetings and four workshops are included in the process framework: 1) Defining supply chain/network and goal setting; 2) Agreeing process map and supply system architecture functionality; 3) Deciding on supply system architecture and 4) Software selection. Although there is an option to conduct the analysis over a distance, the workshop approach is preferred. |
| Change management | Ownership of the problem and eventual supply system architecture should be ensured through the group processes during each step of the framework. The different steps facilitate the evaluation of the current supply system architecture creating a business case (Step 1d) that fully justifies the change required. |
| Good communications | Will be enabled by the production of written records in many of the steps, as well as the workshop style. |
| Decision-making forum that utilises the appropriate technique according to the constraints and analysis needs | Throughout the process framework group support system technology is exploited (Steps 1b; 1c; 1d; 2b; 2c; 3a and 3c). QFD analysis (Step 2b and 3a) is incorporated, as well as AHP (Step 3a and 3c) and simulation (Step 3a), depending on the project constraints. |
| **3. Project management:** | |
| Resourcing | Initial project plan at point of entry, which is further clarified when the enablers; constraints and risks are identified (Step 1c). |
| Timescales | As above, and Step 3a considers timing to ensure that the decision can be made effectively given the time available. |
| **4. Point of Entry** | |
| Expectations; understanding and commitment | Clarified through the establishment of a team in Step 1a and ensured by explaining the required point of entry before the process framework is applied (figure 6.1) and at the start of each phase (shown in figures 6.3; 6.7 and 6.9). |

## 6.8 Conclusion

The process framework was developed from a critical review of existing frameworks and tools (chapter 4) and the archival case study analysis (chapter 5) and, therefore, is the realisation of a detailed list of requirements (table 5.2). These requirements were not met by the other frameworks or methodologies reviewed in section 4.1. Specifically, in terms of procedure, the framework is unique in the scope of supply system architectures considered and the compatibility and contextual issues are covered more coherently. The other key difference is that the process framework utilises different decision-making tools dependent on the time constraint. Therefore, the process framework also embraces the need for project management; it also focuses participation and clear points of entry. These requirements were met in three phases: 1) Scope the supply chain/network; 2) Identify options for supply system architecture and 3) Select supply system architecture. The extensive review of the existing literature enabled the process framework to be developed, ready for testing in the three case studies described in section 3.6.

# Chapter 7 - Stage 4: Application of the Process Framework to Three Cases

The process framework for selecting supply system architecture was applied to three cases: a snack manufacturer maize supply chain; a luxury automobile seat set supply chain and a drill manufacturer network. The three case applications demonstrate that it is feasible to apply the process framework. The process framework was revealed to be applicable to the different contexts that the three cases operate in. The process framework's focus on generating outputs for building a clear business case is fully illustrated in this chapter, each step in phases 1 and 2 is clearly focused on collecting the necessary information to build a clear business case for supply system architecture selection. Only Step 3a of Phase 3 was applied, which is the supply system architecture decision, based on the business case. The other two steps in phase 3: Step 3b. Vendor demonstrations and questioning and Step 3c. Software/e-business selection, require active participation with software vendors, which is not possible during the initial testing stage.

The first phase which scopes and defines the supply chain/network proved to be clear and simple to follow. This first phase consists of Step 1a, drawing a boundary; Step 1b, defining characteristics within that boundary; Step 1c, identifying the enablers; constraints and risks and Step 1d, clarifying the goals. The different contexts within the case studies can be clearly defined and clarified using the tools and techniques that support the steps. The characteristics diagram tool proved useful in all three cases for defining the supply chain/network and considering the enablers; constraints and risks. The second phase was also applied to the three cases; the focus of this phase is on identifying the options for supply system architecture. Step 2a utilised process mapping techniques, which in all three cases revealed the processes that the supply system architecture would need to support in a clear format. The process map focused the analysis in Step 2b, which involved determining the orientation of the supply system architecture. All of the supply chains/networks involved long-term interaction and single sourcing, therefore, in each scenario, partial integration was revealed to be the most appropriate orientation. Despite the similarity in orientation, Step 2c revealed that each supply chain/network had different functionality requirements. The final step in phase 2, Step 2d, finalises the business case by drawing together the different outputs from the previous steps in phases 1 and 2 and clearly articulating the key performance indicators that the supply system architectures will be need to meet. The third phase focuses on the actual decision of which supply system architecture or combination best meets the needs stipulated by the business case, here comparative analysis is conducted, and using QFD in the snack manufacturer maize supply chain and drill manufacturer network and using AHP in the luxury automobile seat set supply chain.

## 7.1 Presentation of the cases

Illustration of the feasibility of the framework is provided in this chapter. It details the application of the framework to the following three supply chain/network cases: snack manufacturer maize supply chain; luxury automobile seat set supply chain and drill manufacturer supply network. The remainder of the chapter consists of three main sections, one for each case. It provides the how the three phases of the process framework were applied and overviews the analysis produced from applying the process framework.

## 7.2 Case 1: Snack manufacturer maize supply chain

The snack manufacturer maize supply chain was selected because it had external chain scope and data was available (a more detailed justification of the case studies is provided in section 3.6). The data was available from Ho's (2002) PhD thesis, which was collected by the DOMAIN research group. The DOMAIN research group were working specifically with the maize supplier on the use of internet technologies to improve supply chain. The focus on internet technologies meant that the supply chain was reviewing their supply systems. The framework was applied, using the data from Ho's (2002) thesis, as detailed in the following sections.

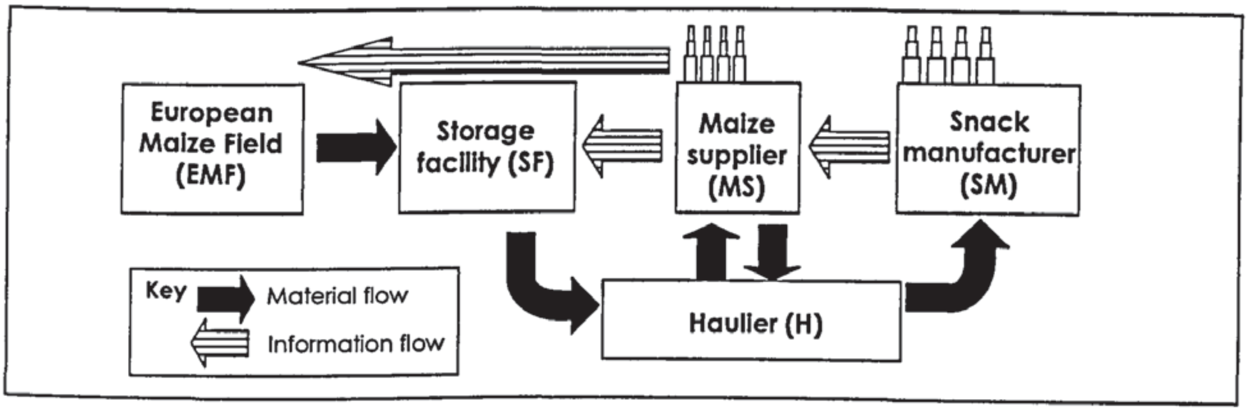
## 7.2.1 Phase 1: Scope the supply chain/network

The maize supplier was the focal organisation and it had already decided to focus on the supply of one of two types of maize. It should be noted therefore, that the term "maize" refers to this one type of maize, which is supplied to the snack manufacturer by the maize supplier. Thus, completing phase 1 was fairly straight-forward, as the scope of investigation (hence the boundary) had been determined – the maize fields in Europe; transportation; cleaning and milling maize.

### 7.2.1.1 Step 1a. Determine the supply chain/network boundary

The snack manufacturer maize supply chain is focused on the organisations involved in supplying the maize to the snack manufacturer. The supply chain boundary was drawn around five participants: snack manufacturer (SM); maize supplier (MS); haulier (H); storage facility (SF) and the European maize field (EMF), as shown in figure 7.1. Hence, the supply chain under review considers the full upstream organisations, right up to raw materials; however, the downstream retailers are not included. Maize is sourced from European maize fields (EMF) and delivered to a UK-based storage facility (SF); the maize is then delivered to the maize supplier (MS) by a haulier (H). The maize supplier (MS) cleans and processes the maize, before the haulier (H) delivers it to the snack manufacturer (SM).

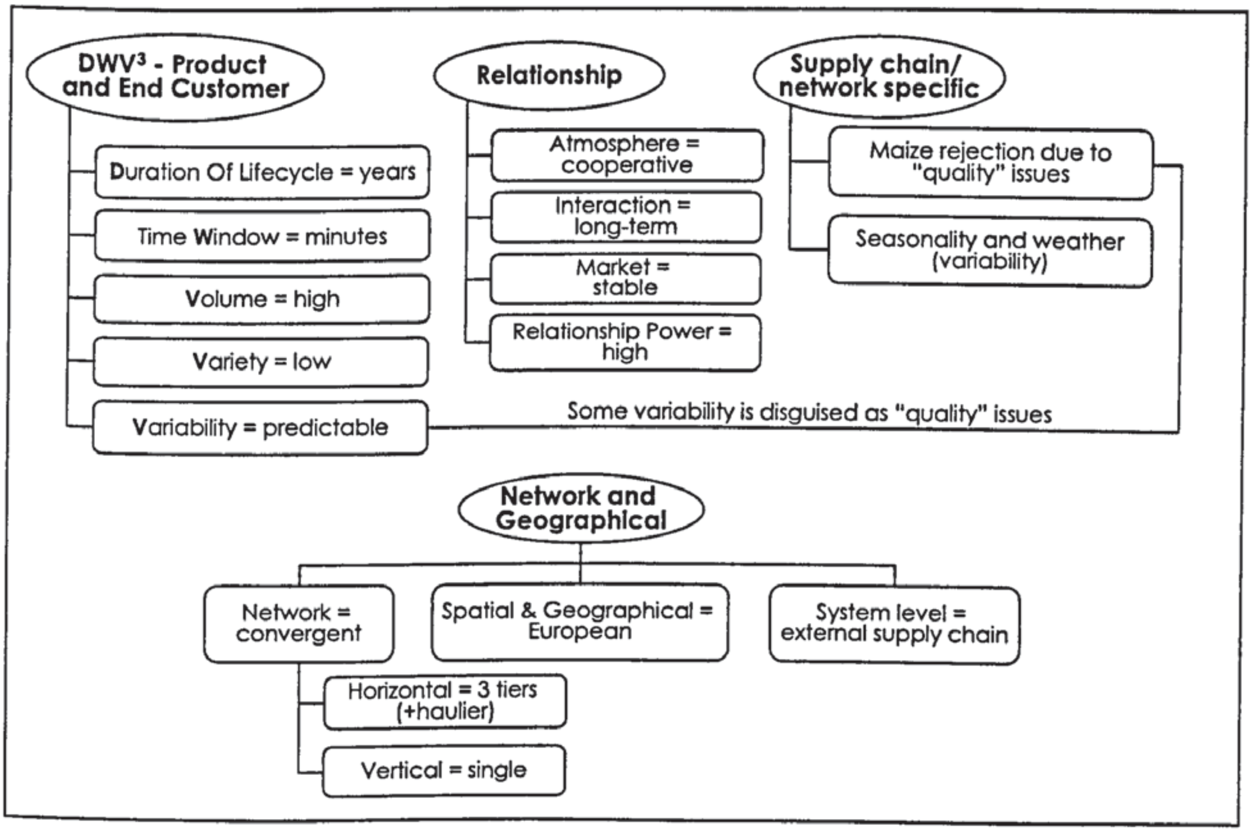
**Figure 7. 1 The snack manufacturer maize supply chain boundary**




### 7.2.1.2 Step 1b. Define the supply chain/network characteristics

The snack manufacturer maize supply chain is clearly focused on low variety as only one type of maize is considered; however, the volume is high, as 175 tonnes a week are supplied to the snack manufacturer, see Figure 7.2. The actual demand is predictable, as the orders from the snack manufacturer are consistent, 100 tonnes on a Thursday and 75 tonnes on a Friday and maize has a long product lifecycle. The maize has to be unloaded at the snack manufacturer at 12 noon; therefore the time window for delivery is in minutes. The supply network is European, including the maize fields and is based on single sourcing and involves multiple tiers. The relationship power is high as the maize supplier relies on the snack manufacturer's business, however, the interaction is a long-term one and the market is considered fairly stable due to the popular brand of snacks that the snack manufacturer makes. Two supply chain specific characteristics have been identified. Firstly, the snack manufacturer sometimes rejects the maize, stating quality issues, however, the real reason is considered to be when forecasted demand is not met. The snack manufacturer would state poor quality to avoid haulage charges. Therefore, there is some variability in demand. Secondly, it is acknowledged that weather and seasonality could effect the production of maize, which can affect the variability.

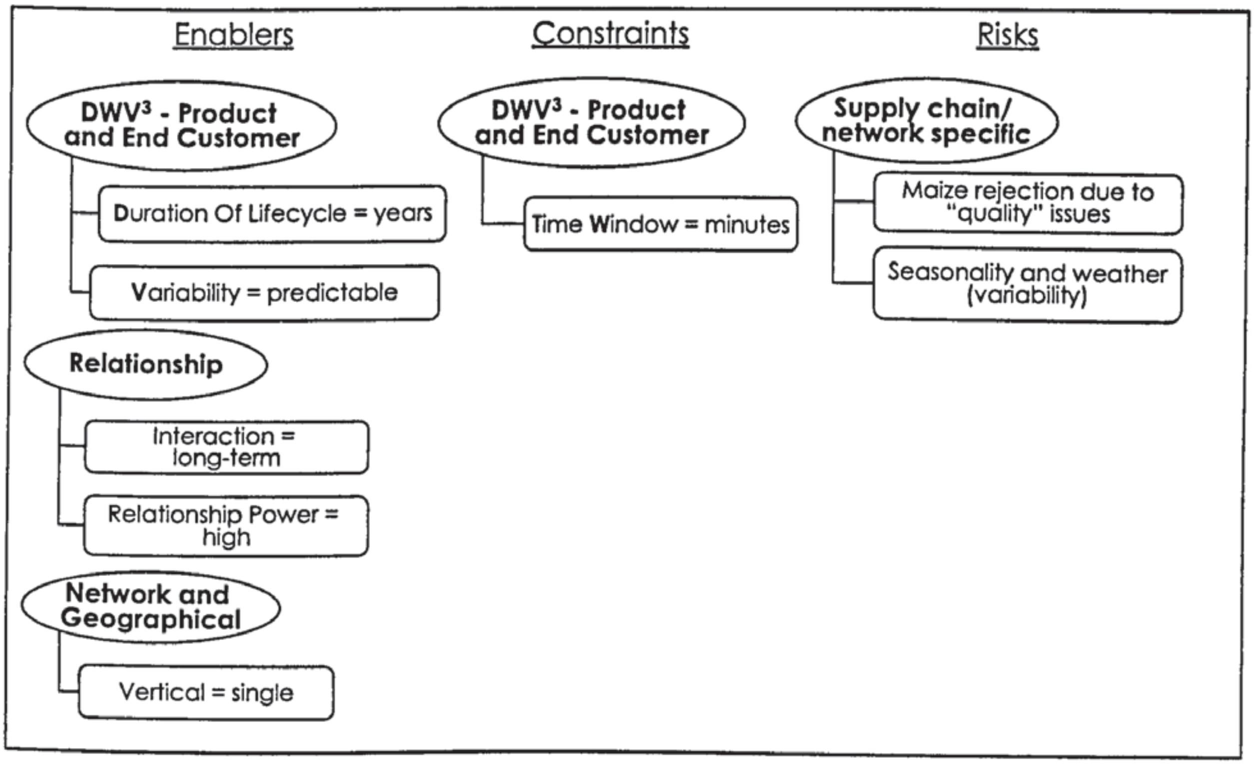
**Figure 7. 2 The characteristics of the snack manufacturer maize supply chain**



### 7.2.1.3 Step 1c. Clarify the key enablers; constraints and risks

The enablers; constraints and risks are identified, as shown in figure 7.3. Two of the key enablers, yet also one of the constraints, lie in the DWV[3], or product and end customer category. Specifically, the long product lifecycle and predictable demand should enable easier supply system planning. The long-term interaction; high relationship power and single sourcing all ease the implementation of supply system architecture. The end customer constraint that the supply system architecture will need to cope with is the relatively short time window for delivery. The effect of the short time window for delivery can be worsened by the seasonality/weather risk that can influence quality and quantity of maize production in the European maize fields. Another risk that needs to be contained is the current rejection of maize by the snack manufacturer that masks when forecasts are not met by actual demand.

**Figure 7. 3 Summary diagram of the key enablers; constraints and risks for the snack manufacturer maize supply chain**



#### 7.2.1.4 Step 1d. Clarify supply system architecture goals

The major motivation for reviewing supply system architecture is the snack manufacturer's current practice of rejecting maize due to "quality" issues, when their forecasts do not match demands, in order to avoid haulage charges. Currently, demand requirements are transmitted once a week, sometimes supplemented by facsimile or telephone if more co-ordination is needed or in the case of an emergency. Therefore, the supply system architecture goals are:

- Improve information flow;
- Communicate changes in demand upstream;
- Reduce transportation costs by preventing over-delivery of maize.

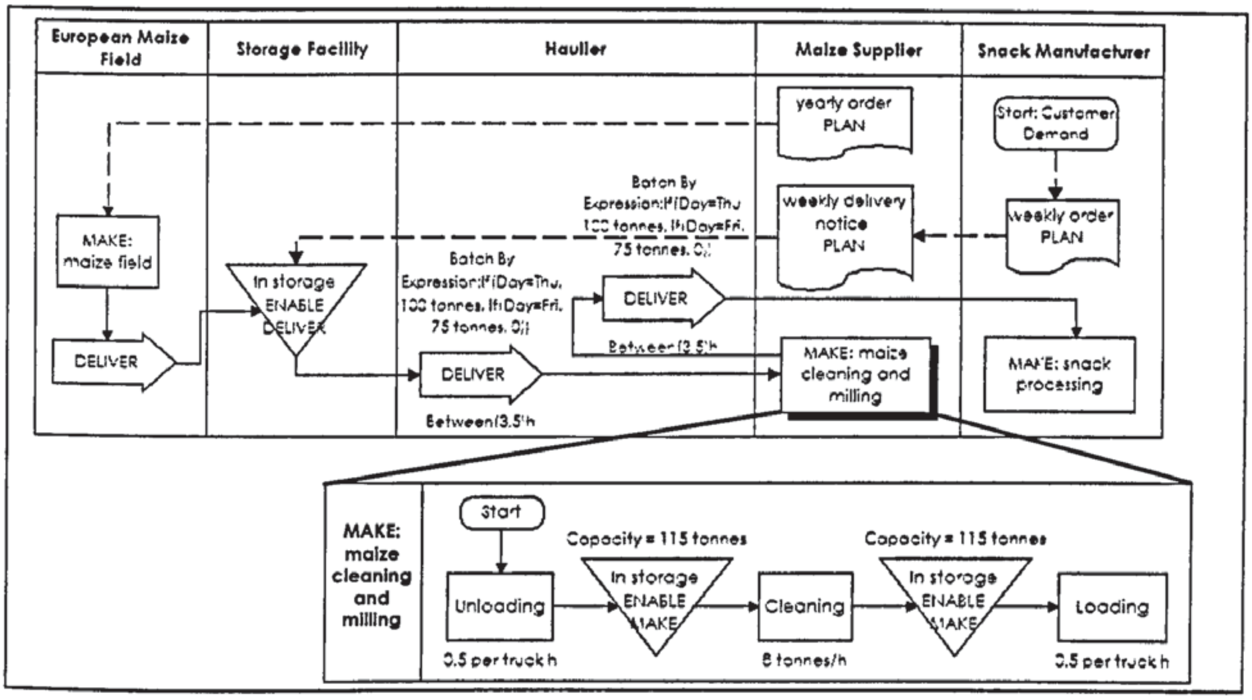
### 7.2.2 Phase 2: Identify options for supply systems architecture

Phase 2 involved further clarifying the processes and systems in the snack manufacturer maize supply chain; determining the orientation of the supply system architecture and identifying the required functionality. The final output was the business case, which draws together all the supply system architecture needs.

#### 7.2.2.1 Step 2a. Map supply processes and systems

A process and systems map for the snack manufacturer maize supply chain was produced using the iGrafx Process™ tool, shown in figure 7.4. In the snack manufacturer maize supply chain, the five different organisations are represented: European maize field (EMF); storage facility (SF); haulier (H); maize supplier (MS) and snack manufacturer (SM). The key supply processes of planning (e.g. ordering); delivering and making (e.g. cleaning) are indicated, as well as the enabling storage processes. The duration of the processes is also shown underneath the shape. The black shadow on the make processes conducted by MS indicates that it is shown in more depth in a sub-process diagram, see figure 7.4. Figure 7.4 shows the current ordering systems, e.g. the weekly orders from the SM to the MS and from the MS to the SF and a yearly order form the MS to the EMF.

Figure 7. 4 Snack manufacturer maize supply chain process maps




## 7.2.2.2 Step 2b. Determine the orientation of the supply system architecture

The orientation of the snack manufacturer maize supply chain was determined to be partial integration from the QFD analysis, shown in table 7.1. The most important aspect was the co-ordination of activities, followed by sharing of information; risk; goal; revenue and rewards. Interaction and collaboration was the lowest scoring functionality, therefore, co-ordination could also be considered.

**Table 7. 1 QFD orientation matrix for the snack manufacturer maize supply chain**

| WHATs vs HOWs<br>Strong relationship = 9<br>Medium relationship = 3<br>Weak relationship = 1<br><br>WHATs | Impact | HOWs from table 2.3<br>Physical flow | Process and activity | Sharing of information; risk; goal; revenue and rewards | Cooperation and coordination of activities | Planning and ordering decisions | Interaction and collaboration, trust and commitment for collaboration | Network integration |
|---|---|---|---|---|---|---|---|---|
| **Goals (from Step 1d):** | | | | | | | | |
| Improve information flow | 9 | | | 3 | | 9 | 9 | |
| Communicate changes in demand upstream | 10 | | | 9 | 9 | | | |
| Reduce transportation costs by preventing over-delivery of maize | 11 | | 9 | | 9 | | | |
| **Enablers (from Step 1c):** | | | | | | | | |
| Duration of Lifecycle years | 6 | | 3 | 3 | 3 | 3 | | |
| Variability predictable | 5 | | | | 3 | 9 | | |
| Interaction long-term | 4 | | | 9 | 9 | | 3 | |
| Power high | 3 | | | 9 | 9 | | 3 | |
| Vertical single | 2 | | | | 9 | | | |
| **Constraints (from Step 1c):** | | | | | | | | |
| Time Window hours | 7 | | | 9 | | 9 | | |
| **Risks (from Step 1c):** | | | | | | | | |
| Maize rejection due to "quality" issues | 8 | | | 9 | 9 | | | |
| Seasonality and weather (variability) | 1 | | | | 9 | | | |
| **Absolute Importance** | | 0 | 117 | 333 | 384 | 207 | 102 | 0 |
| **Relative Importance** | | | 4th | 2nd | 1st | 3rd | 5th | |
| **From table 2.3:** Integration | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Partial integration | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Co-ordination | | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| Independence | | | ✓ | | | ✓ | | |

### 7.2.2.3 Step 2c. Identify functionality requirements

The functionality requirements were articulated by paying attention to those systems which provide partial integration, as indicated in figure 2.10. Partial integration of an external supply chain/network can be achieved by either integrated systems, which is a combination of enterprise systems and best of breed systems (APS; WMS; TMS; CRM and

SRM) or CPFR. Due to the single sourcing, no supply planning and operations functionality was required, however, the following functionality requirements were identified:

- Production Planning and Management
  - Materials/Inventory planning and management
  - Production planning, scheduling and control
- Demand Planning and Management
  - Collaboration and collaborative planning
  - Forecasting
  - Distribution planning and management
  - Shipment

#### 7.2.2.4 Step 2d. Write business case

The business case can be put together using the goal(s) (from Step 1d); the enablers; constraints and risks (from Step 1c); the required orientation (from Step 2b); the business process map (from Step 2a) and the functionality list (from Step 2c). The metrics or key performance indicators (KPIs) were also identified in this step, see table 7.2. The KPIs reveal that in many cases the snack manufacturer maize supply chain is on target using the existing supply system architecture. However, there are still improvements to be made in improving information flow and reducing transportation costs by preventing over delivery.

**Table 7. 2 Key Performance Indicators (KPIs) for the snack manufacturer maize supply system architecture**

| Characteristic | Key Performance Indictor | Criteria for Evaluation | Actual performance | Desired performance | Gap Desired-actual |
|---|---|---|---|---|---|
| Goals | 1. Improve information flow<br>2. Communicate changes in demand upstream | Forecasts shared | never | frequently | significant |
| (includes risk: maize rejection due to "quality" issues) | 3. Reduce transportation costs by preventing over-delivery of maize | Deliveries returned | often | never | significant |
| Constraint | | | | | |
| Time Window of minutes | 4. On time delivery | Late delivery | nil | nil | no gap |
| Risk | | | | | |
| Seasonality and weather (variability) | 5. Cope with weather effects | Interrupted supply | nil | nil | no gap |

## 7.2.3 Phase 3: Select supply system architecture

The previous phase identified the requirements for the snack manufacturer's maize supply system architecture. The focus is now on deciding on appropriate supply system architectures that provide partial integration.

### 7.2.3.1 Step 3a. Decide from the short listed supply system architectures

QFD was utilised in this step as the snack manufacturer maize supply chain was not in any particular conflict. Although it is clear that there is some disagreement about the return of maize, for bogus quality reasons, the organisations can be considered to be working together to stop doing this. Reviewing the QFD analysis shown in table 7.3, transportation management system was the option with the highest priority, the TMS will enable costing analysis to be made on the deliveries and to schedule them more carefully. Due to the small difference in scoring, the TMS could be integrated with the existing systems, or additional investment could be made into Collaborative Planning Forecasting and Replenishment or an enterprise system.

**Table 7. 3 Supply system architecture QFD matrix**

| | | Supply system architectures | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **WHATs vs HOWs**<br>Strong relationship = 9<br>Medium relationship = 3<br>Weak relationship = 1<br><br>**WHATs** | **Importance** | Existing ordering system | Collaborative Planning: Forecasting and Replenishment | Advanced Planning and Scheduling | Enterprise System | Warehouse Management System | Transportation Management System | Customer Relationship Management System | Supplier Relationship Management System |
| **Functionality (from Step 2c):** | | | | | | | | | |
| **Production Planning and Management** | | | | | | | | | |
| Materials/Inventory planning and management | 3 | 9 | 3 | 1 | 3 | 3 | | | |
| Production planning, scheduling and control | 1 | 9 | | 1 | 3 | 3 | | | |
| **Demand Planning and Management** | | | | | | | | | |
| Collaboration and collaborative planning | 4 | | 9 | | | | | 1 | |
| Forecasting | 2 | | 9 | 1 | 3 | | | 1 | |
| Distribution planning and management | 6 | | | 3 | 3 | | 9 | | |
| Shipment | 5 | | | 1 | 3 | 3 | 9 | 1 | |
| **Absolute importance** | | 36 | 63 | 29 | 51 | 27 | 99 | 11 | 0 |
| **Relative importance** | | 4th | 2nd | 5th | 3rd | 6th | 1st | 7th | |

### 7.2.3.2 Step 3b. Vendor demonstrations and questioning and Step 3c. Software/e-business selection

These two steps could not be tested in the snack manufacturer maize supply chain.

## 7.3 Case 3: Luxury automobile seat set supply chain

The luxury automobile seat set supply chain case was selected for exploration because it had external chain scope (a more detailed justification of the case studies is provided in section 3.6). The data was available through collaboration with the FUSION (Future Supply Innovations) research group from the University of Liverpool. The FUSION research group was working with the luxury automobile manufacturer on a number of supply chain issues. One of these issues was supply chain planning; hence, it was an ideal case for applying the framework. It should be noted that the term "luxury automobile" refers to a particular model of automobile for a large manufacturer. The framework was applied, using the data from the case, as follows:

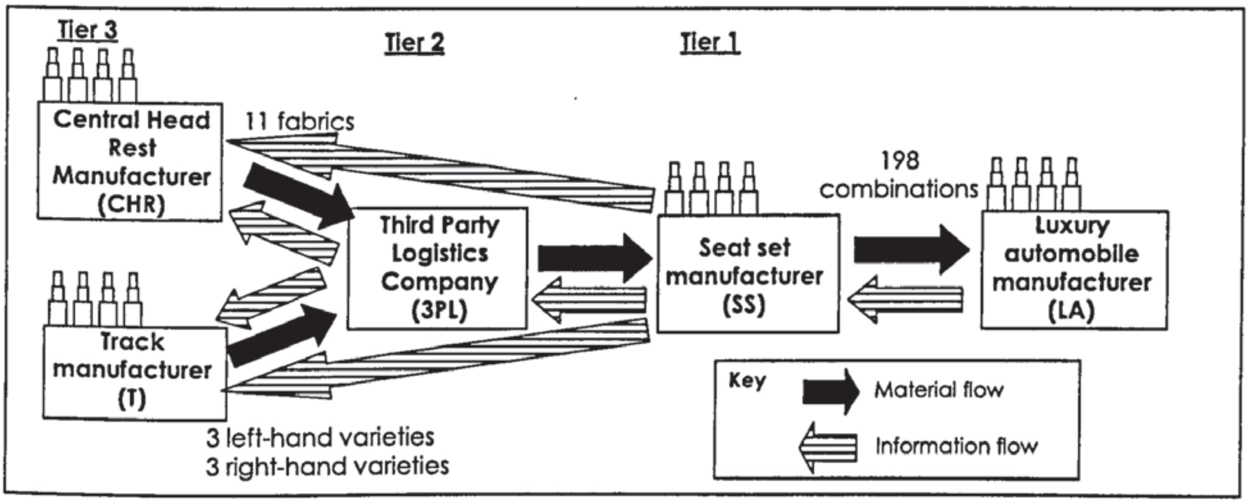
### 7.3.1 Phase 1: Scope the supply chain/network

The luxury automobile manufacturer had already determined which part of their supply network needed more analysis and had potential for improvement. Thus, completing phase 1 was fairly straight-forward, as the scope of investigation had been determined – the seat set. Seat sets consisting of front and rear seats are delivered as a module to the luxury automobile manufacturer, in the fabric specified by the end customer. The following sections describe how phase 1 was applied to the luxury automobile seat set supply chain.

#### 7.3.1.1 Step 1a. Determine the supply chain/network boundary

The supply chain boundary was drawn around five organisations: luxury automobile manufacturer (LA); seat set manufacturer (SS); third-party logistics company (3PL); central head rest manufacturer (CHR) and track manufacturer (T). Hence, the supply chain under review does not include other car parts or go further upstream of tier three for the seat set. The dealer network and the end customer are also not included. The connections between the five organisations are depicted in figure 7.5. LA is supplied seat sets from the seat set manufacturer; there are eleven different fabric finishes available. A third-party logistics company supplies the seat set manufacturer with optional central head rest and tracks. The central head rest and the tracks are supplied to the 3PL by two separate organisations: CHR and the T, respectively. A track is the runner the front seat sits on to determine how much the seat can be adjusted forwards/ backwards and upwards/downwards and there are three varieties available for the left-hand and right hand seat. Hence, the choice available to the eventual end customer leads to a variety of 198 different combinations (based on the choice of fabric of the seat set, whether or not to have a central head rest and the tracks required on the front seats).

**Figure 7. 5 The luxury automobile seat set supply chain boundary**

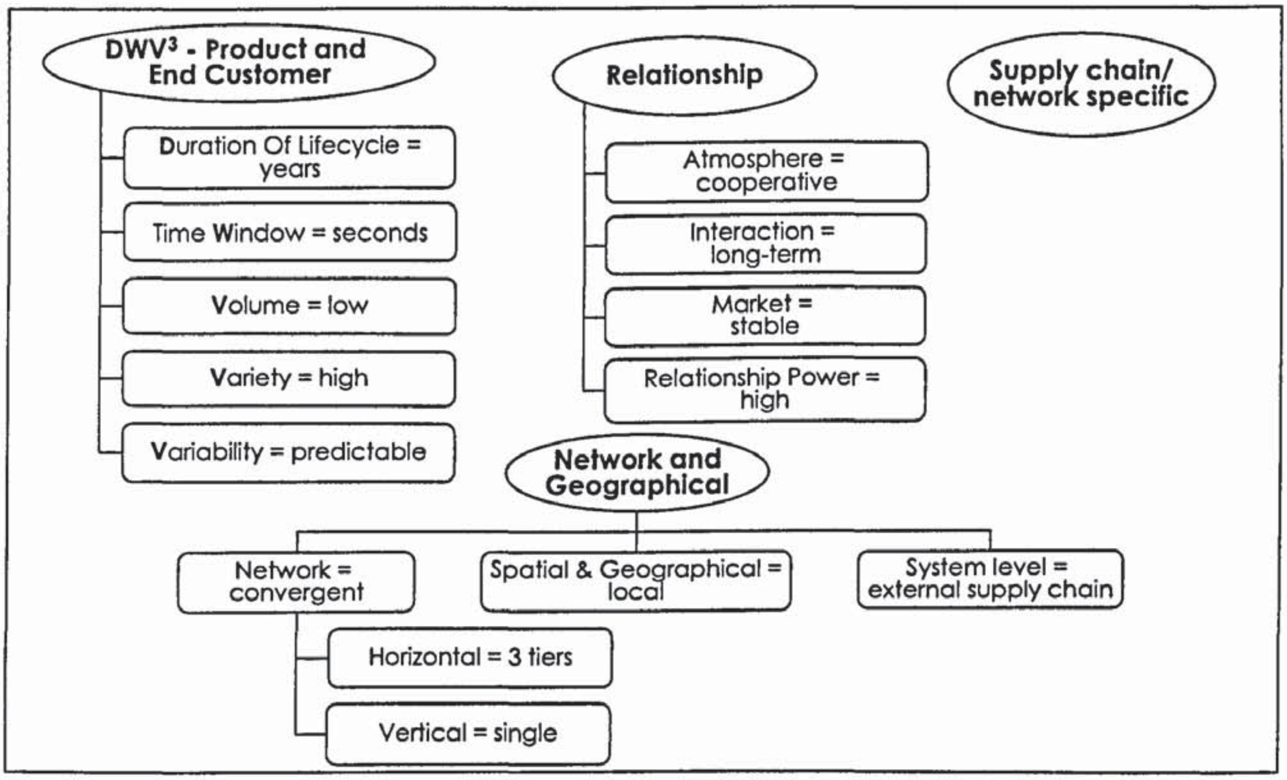



### 7.3.1.2 Step 1b. Define the supply chain/network characteristics

A key aspect for this supply chain was to define these from the perspective of the seat set, not the wider network of the luxury automobile, as shown in figure 7.6. The end customer of the entire luxury automobile supply chain is prepared to wait several weeks for delivery of their luxury automobile. However, the time window for delivery of seat sets is seconds; other wise LA will exert a penalty on SS. The duration of the lifecycle is years; once a model has been designed it is manufactured several years, although some changes may be made to the design. There is a high variety of seat set mix, with 198 combinations. These 198 combinations are considered to be particularly high in comparison with the volume of production being 430 automobiles per day Monday-Thursday and 350 per day on Friday. The demand is fairly predictable, with some seasonality based on the release dates of new car registrations; however, seasonality is smoothed with a level schedule. LA has a high relationship power over SS, which fosters long-term cooperation within a fairly stable market. The external supply chain for the seat set is single sourced; convergent; contains three tiers and is local due to the boundary previously drawn in step

1a. Although the actual luxury automobiles are delivered to global customers, again it is important to note that is the seat set under focus.

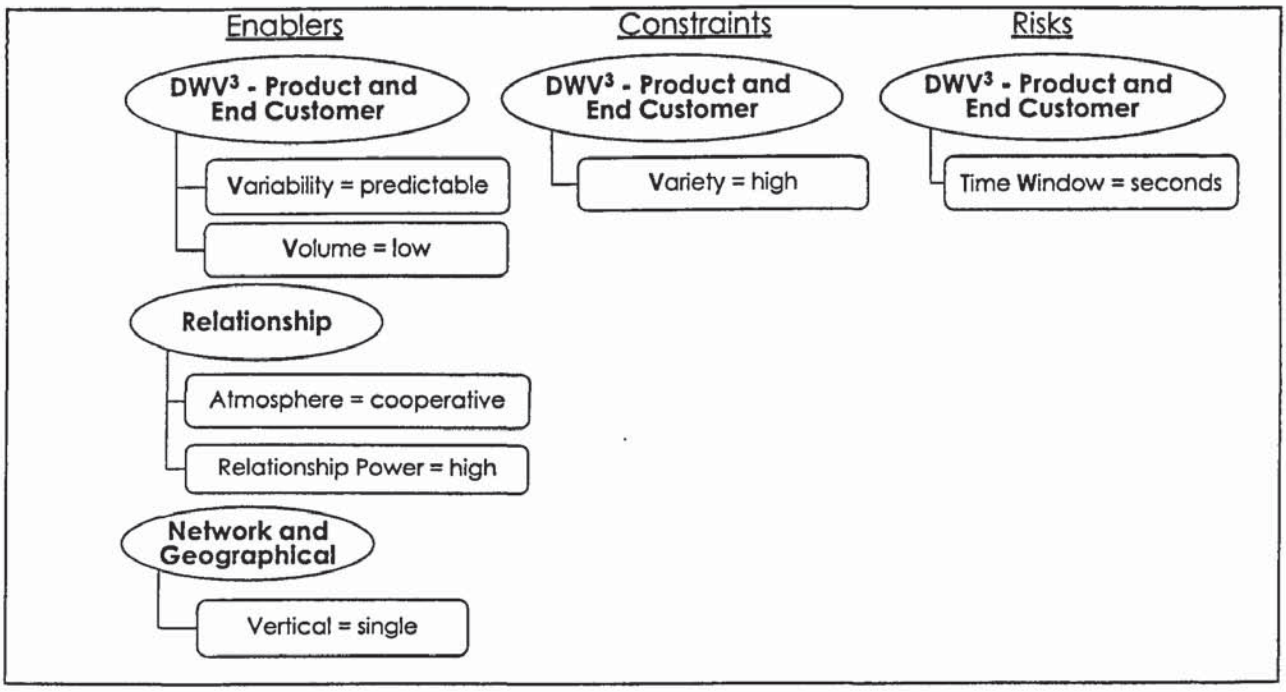
**Figure 7. 6 The characteristics of the luxury automobile seat set supply chain**




### 7.3.1.3 Step 1c. Clarify the key enablers; constraints and risks

The characteristics identified in Step 1b were reviewed to clarify which characteristics would: enable; constrain or endanger a change in supply chain systems, as shown in figure 7.7. Different characteristics from DWV³, the product and end customer category are enablers; constraints and risks for the luxury automobile seat set supply chain. The predictable variability and low volume will aid the implementation of supply system architecture. Other strong enablers lie in the power and atmosphere of the relationships in the chain, LA dominates and can drive change easily, single sourcing further reinforces this. The major constraint is that the supply system architecture must have the ability to accommodate the high variety of product mix and the risk is not delivering this variety in the tight time window for delivery.

Figure 7. 7 **Summary diagram of the key enablers; constraints and risks for the luxury automobile seat set supply chain**




### 7.3.1.4 Step 1d. Clarify supply system architecture goals

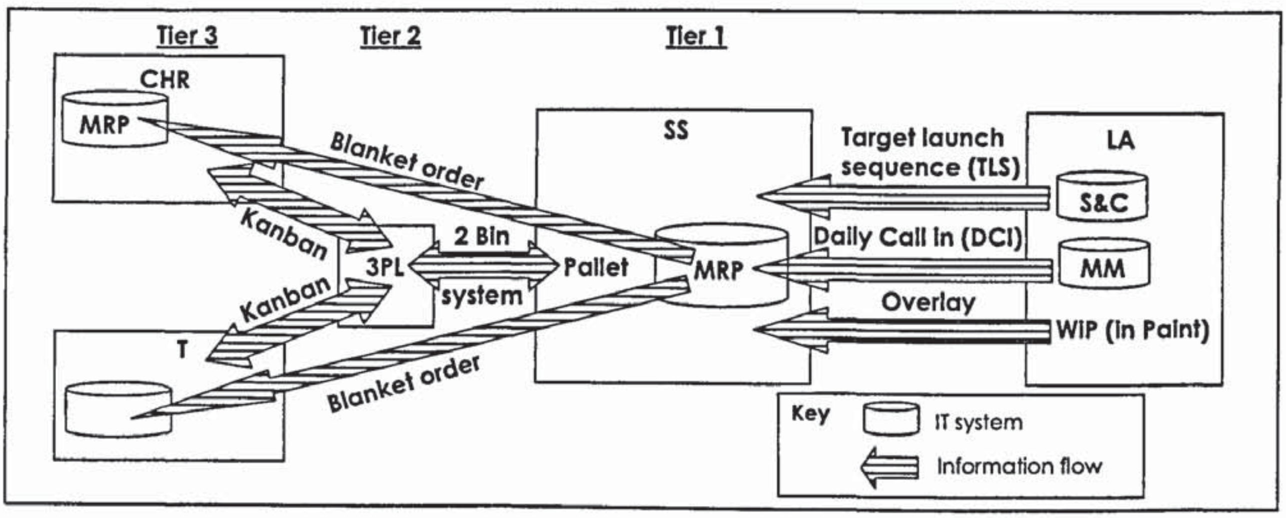
The goal was to improve the visibility of demand to enable a more effective and efficient supply chain. LA has to be supplied seat sets on time, as line stoppage is unacceptable. To achieve this, both the supply chain design and the information flow have evolved over time, rather than being designed. Hence, a 3PL was added upstream, in close proximity to SS to create a buffer between SS and their suppliers: T and CHR. Multiple and contradictory information is being produced by different planning systems, as shown in figure 7.8. Informal planning is relied upon to accomplish on-time delivery. Hence, the more specific goals were to:

- Improve the coherence of the information flow
- Minimise the impact of contradictions in planning data due to the multiple signals of demand
- *Longer term:* Consider the potential to remove the 3PL layer, due to improvements

SS currently receive 3 sets of contradictory planning data from LA which makes planning difficult. LA supply SS with a daily call in (DCI), which gives a 10 day horizon of daily requirements and also provide tentative weekly and monthly forecasts. The DCI is generated from LA's materials management (MM) system. The DCI is considered inaccurate and contradicts dramatically with the continuous broadcast of the target launch sequence (TLS). The TLS is the actual daily demand in production line sequence (this is generated by a different system that stores and controls (S&C) the sequence for the painted car bodies). SS faces a large penalty if they do not supply the seat sets in time, according to the TLS. Hence, to aid SS's planning, LA also supply them with an overlay. The overlay is "informal" data, based on recording the work in process (WiP) quantities at the end of a shift in the painting facility at LA (paint is the process proceeding the car body being put into S&C). Hence, the overlay is the number of car bodies that will at some point appear on the TLS. The problem is compounded due to the fact that it is the inaccurate DCI that is fed into both CHR's and T's MRP system.

The DCI uses blanket ordering of central head rests and tracks from CHR and T respectively. A pallet based 2 bin system is used between the 3PL and the SS, due to the close proximity of the 3PL to SS. The inaccuracy of data means the MRP system in SS is not suitable for organising the daily delivery of central head rests or the every two day delivery of tracks to the 3PL. Here, kanbans are used between the 3PL and both CHR and T, there is a greater distance here so electronic kanbans are used. In summary, the complexity and inaccuracy in the systems need further analysis. The supply system architecture could be redesigned to improve the accuracy of the data and information flow. Improved information could enable the removal of the 3PL from the chain.

**Figure 7. 8 The conflicting systems used in the luxury automobile seat set supply chain**



## 7.3.2 Phase 2: Identify options for supply system architecture

Phase 2 involved further clarifying the processes and systems in the luxury automobile seat set supply chain; determining how the supply system architecture should be orientated and identifying the functionality requirements. The final output was the business case, which culminates the supply system architecture needs of the luxury automobile seat set supply chain.

### 7.3.2.1 Step 2a. Map supply processes and systems

A high level process map of the supply chain/network processes was created in iGrafx Process ™ focusing on the boundary set in Step 1a, which is shown in figure 7.9. The level of detail of the processes was a careful consideration here. The make processes in LA are not considered in detail, simply represented as a delay, however, the three sources of planning data are mapped. The TLS is shown in detail in the high-level process map, as this is very important as it must be met within the 12 hour limit, which is also indicated in the bottom right of the map. The source processes are not included as the supply chain is single-sourced (defined in Step 1b). Storage (or enable make/enable deliver) are emphasised as inventory levels are an important aspect for consideration. The return process is not being considered in the map as returns are rare and the focus is to improve planning materials movement down stream (clarified in Step 1d).

Some processes are modelled in more detail; these are indicated with a black shadow in figure 7.9. More detail is included in separate process maps, to emphasis priorities and in order to make the high-level map easier to read. More detailed process maps were required for the other two sources of planning data from LA: the DCI and the overlay (see appendix 3). The operating production processes conducted by SS are shown in an individual map and so is the initiation of the kanbans (see appendix 3), the actual loops are shown on the high-level process map as they are part of the evaluation. SS operated two separate lines, one for the front seat, where the tracks are fitted and one for the rear seat, where the central head rest is fitted (if requested). The joining of the front and rear set is depicted on the high-level process map in figure 7.9. The joining is of particular important as getting the combinations correct for delivery to LA is essential. The different processes are also summarised in table 7.4.

## Table 7. 4 Luxury automobile seat set supply chain process table

| Process (**SCOR process in bold**) | Time | Frequency | Enable source | Enable make | Make | Enable deliver | Deliver |
|---|---|---|---|---|---|---|---|
| **LA** | | | | | | | |
| Waiting time prior to fit | 1 hour 48 mins[3] | | ◗ | E ● | | | |
| **Make** (trim and final assembly) | 10 hours | | | | ● | | |
| **SS** | | | | | | | |
| **Deliver** to LA | 10 mins | 5 deliveries per 8 hour shift (48 seat sets per wagon) | | | | | ➔ |
| **Enable Deliver** Finished Goods Stock | 5 hours 12 minutes[4] | | | | | ▼ | |
| **Make** Seat set | 41 mins 51 secs[5] | Cycle time 123 secs | | | ● | | |
| **Enable Source** Raw material stock | 80 hours | | ▼ | | | | |
| **Deliver** to LA | 2 hours 30 mins | Daily | | | | | ➔ |
| **3PL** | | | | | | | |
| **Deliver** pick up from CHR and T | 1 hour | Daily | | | | | ➔ |
| **CHR** | | | | | | | |
| **Enable Deliver** Finished Goods Stock | 24 hours[6] | | | | | ▼ | |
| **Make** (CHR assembly) | 1 hour 30 mins | Continuous | | | ● | | |
| **Enable Source** Raw material stock | 32 hours[7] | | ▼ | | | | |
| **T** | | | | | | | |
| **Make** Track assembly | | Continuous | | | ● | | |
| **Enable Deliver** Finished Goods Stock | | | | | | ▼ | |

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[3] 96 seat sets

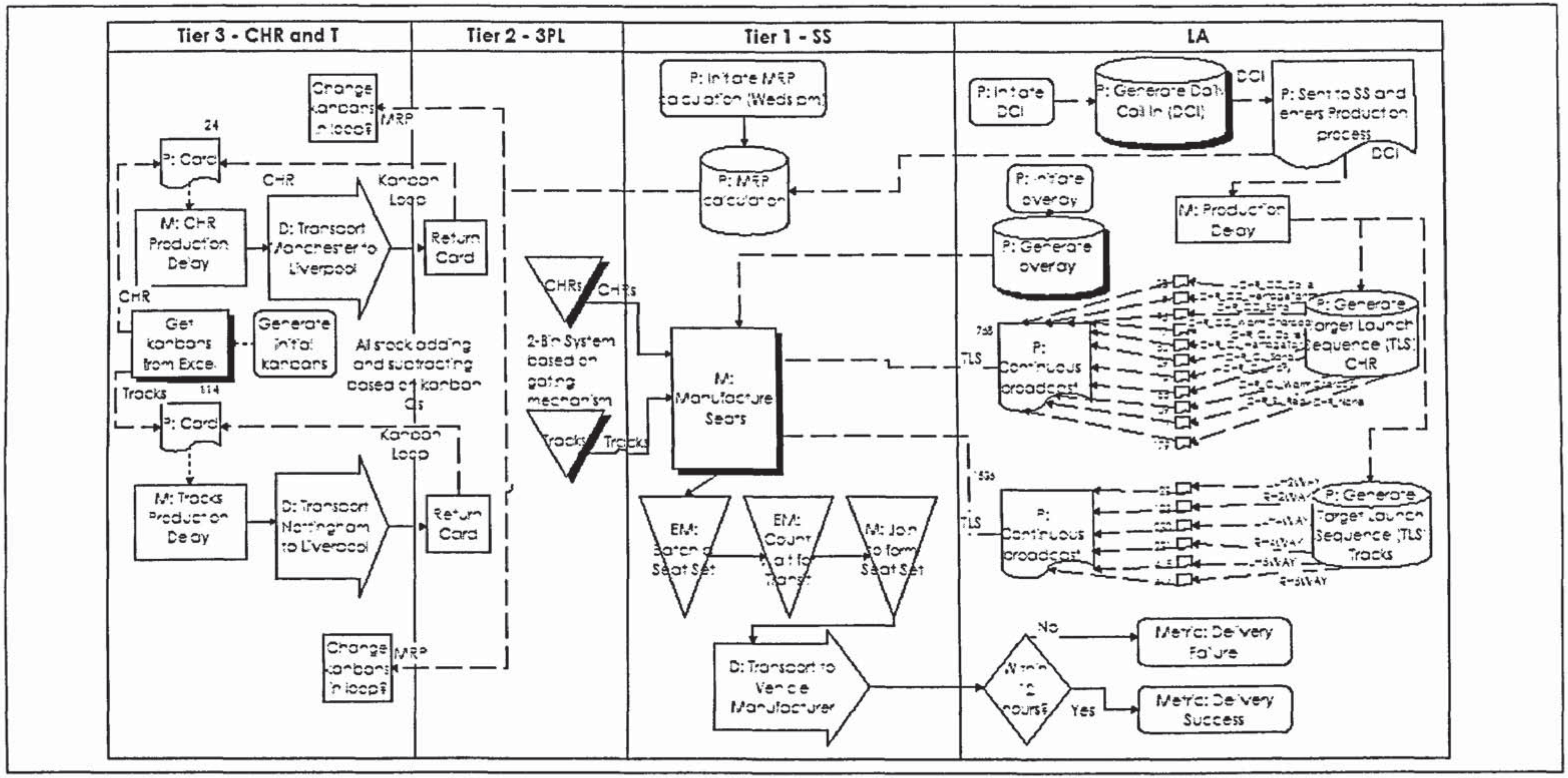
[4] Average seat sets in Finished Good inventory = *130.*
Average production rate per shift = *200.*
Therefore, average waiting time = 130/200 of a shift = *5 hours 12 minutes.*

[5] Front seat = 12 workstations + 3 test stations + 1 labelling station and 1 transport to FG station.
CT = 123 seconds, therefore total time = *34 minutes 51 seconds.*
Rear seat = 8 workstations + 1 right first time station + 1 transport to FG station
CT = 123 seconds, therefore *20 minutes 30 seconds.*
*Therefore, "Seat Set" process time = 34 minutes 51 seconds + 6 minutes = 40 minutes 51 seconds.*

[6] 1.5 days (each of 2 X 8 hour shift)

[7] 2 days (each of 2 X 8 hour shift)

**Figure 7. 9 Top level - Luxury automobile seat set supply chain process map**



#### 7.3.2.2 Step 2b. Determine the orientation of the supply system architecture

A mutual understanding of the processes imperative to the seat set luxury automobile supply chain facilitates the consideration of the co-ordination and integration processes. Hence, the QFD analysis revealed partial integration to be the most suitable orientation for the luxury automobile seat set supply chain, as shown in table 7.5. The most important aspect was cooperation and coordination of activities. Partial integration would be required as the second most important aspect was interaction; trust and commitment, which rules out co-ordination.

**Table 7. 5 QFD orientation matrix for the luxury automobile seat set supply chain**

| | | | HOWs (from table 2.3) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **WHATs vs HOWs**<br>Strong relationship = 9<br>Medium relationship = 3<br>Weak relationship = 1<br><br>**WHATs** | | **Impact** | Physical flow | Process and activity | Sharing of information; risk; goal; revenue and rewards | Cooperation and coordination of activities | Planning and ordering decisions | Interaction and collaboration, trust and commitment for collaboration | Network integration |
| **Goals (from Step 1d):** | | | | | | | | | |
| Improve the coherence of the information flow | | 8 | | | 9 | | 9 | 9 | |
| Minimise the impact of contradictions in planning data due to the multiple signals of demand | | 7 | | | 9 | 9 | 9 | 9 | |
| **Enablers (from Step 1c):** | | | | | | | | | |
| Variability | predictable | 5 | | | | 3 | 3 | | |
| Volume | low | 3 | | | | | | | |
| Atmosphere | cooperative | 2 | | | 9 | | | 9 | |
| Power | high | 4 | | | | 9 | | 9 | |
| Vertical | single | 1 | | | 3 | 3 | | 3 | |
| **Constraints (from Step 1c):** | | | | | | | | | |
| Variety | high | 6 | | 9 | | 9 | | 9 | |
| **Risks (from Step 1c):** | | | | | | | | | |
| Time window | seconds | 9 | 9 | 9 | | 9 | | | |
| | | | 81 | 135 | 156 | 252 | 150 | 246 | 0 |
| | | | 6th | 5th | 3rd | 1st | 4th | 2nd | |
| **From table 2.3:** | Integration | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Partial integration | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Co-ordination | | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| | Independence | | | ✓ | | | ✓ | | |

#### 7.3.2.3 Step 2c. Identify functionality requirements

The functionality requirements were articulated, single sourcing meant that no supply planning and operations functionality was required; however, the following functionality requirements were identified:

- Production Planning and Management
  - Materials/Inventory planning and management
  - Operational performance
  - Production planning, scheduling and control
- Demand Planning and Management
  - Collaboration and collaborative planning
  - Forecasting
  - Logistics management

#### 7.3.2.4 Step 2d. Write business case

The preceding steps form the business case, specifically: the goal(s) (from Step 1d); the enablers; constraints and risks (from Step 1c); the required orientation (from Step 2b); the business process map (from Step 2a) and the functionality list (from Step 2c). The specific metrics or key performance indicators (KPIs) were identified, see table 7.6.

**Table 7. 6 Key Performance Indicators (KPIs) for the luxury automobile seat set supply system architecture**

| Characteristic | Key Performance Indictor | Criteria for Evaluation | Actual performance | Desired performance | Gap Desired-actual |
|---|---|---|---|---|---|
| Goals | 1. Improve the coherence of the information flow | Sharing of actual demand further upstream | Infrequent | Weekly | significant |
| | 2. Minimise the impact of contradictions in planning data due to the multiple signals of demand | Collaboration and reconciliation of TLS; DCI and overlay | Never | Daily | significant |
| Constraint | | | | | |
| High variety | 3. Maintain appropriate mix of cloth upstream | Variance (Target-actual stock levels) | Variable performance (under and over stocked) | Closer alignment to target (cloth specific tolerances) | moderate |
| Risk | | | | | |
| Seconds delivery time window | 4. Seat sets delivered within 12 hours of the TLS | Late delivery | nil | nil | no gap |

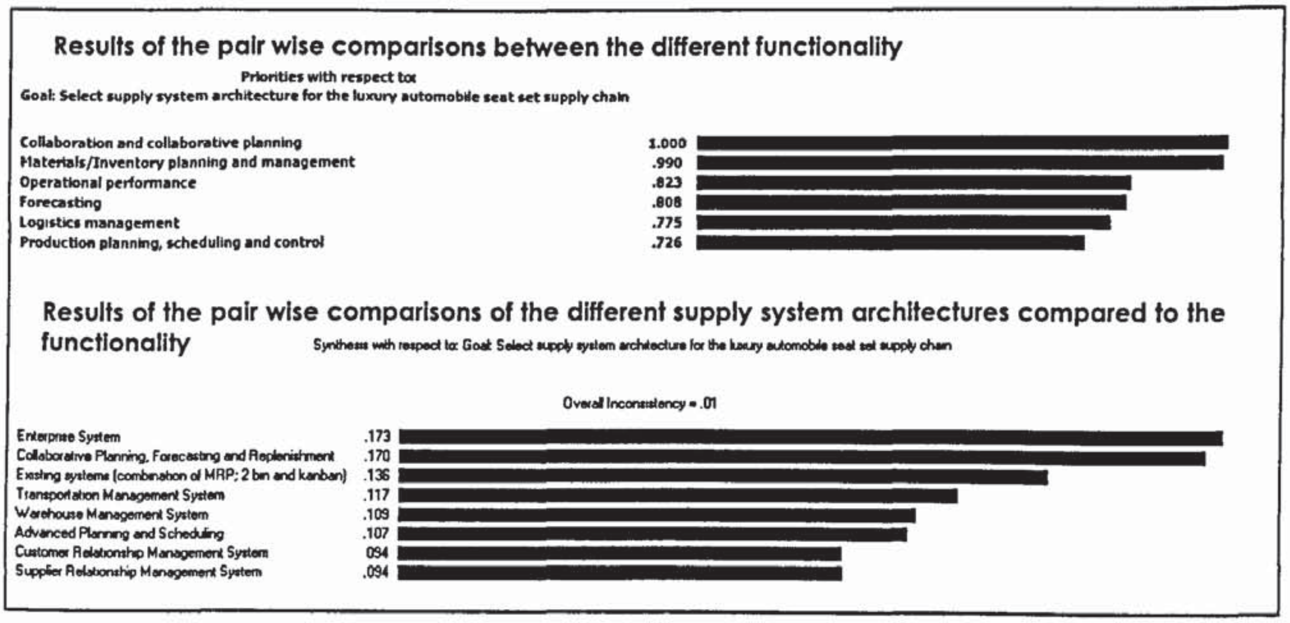
## 7.3.3 Phase 3: Select supply system architecture

The previous phase formalised the business case for selecting supply system architecture for the seat set luxury automobile supply chain, which articulates the business requirement for partial integration.

### 7.3.3.1 Step 3a. Decide from the short listed supply system architectures

AHP was utilised in this step, as if the decision was being made in practice, see figure 7.10, there would be conflicts to resolve concerning the third party logistics company. Although the longer term objective of removing the third party logistics company from the luxury automobile seat set supply chain would not be made explicit to the third party logistics company, it could be inferred, and hence, would generate conflict. The AHP analysis reveals collaboration and collaborative planning to be top priority for functionality; flowed by materials/inventory planning and management. Conducting AHP pair wise comparisons of the different supply system architectures puts enterprise systems as the best solution. Enterprise systems are closely followed by Collaborative Planning; Forecasting and Replenishment; followed by the existing systems. Therefore, it is concluded that CPFR could be considered the best option to develop significant improvements, as the existing systems already utilise enterprise systems. The information fed into the existing systems also needs to be improved upon, which was drawn out by the analysis conducts in the previous two phases.

**Figure 7. 10 AHP results for the selection of supply system architecture for the luxury automobile seat set supply chain**




## 7.3.3.2 Step 3b. Vendor demonstrations and questioning and Step 3c. Software/e-business selection

These two steps were not tested in the luxury automobile seat set supply chain.

## 7.4 Case 4: Drill manufacturer upstream network

The drill manufacturer supply chain case was selected for exploration because it had network scope and the data was available as it had been used as a teaching case at Aston University (a more detailed justification of the selection of case studies is provided in section 3.6). The nature of the case study is to provide a problematic scenario for students to pro-actively tackle a variety of issues. Although the case does not specifically use problematic systems, the nature of the case provides a complex context to test the framework.

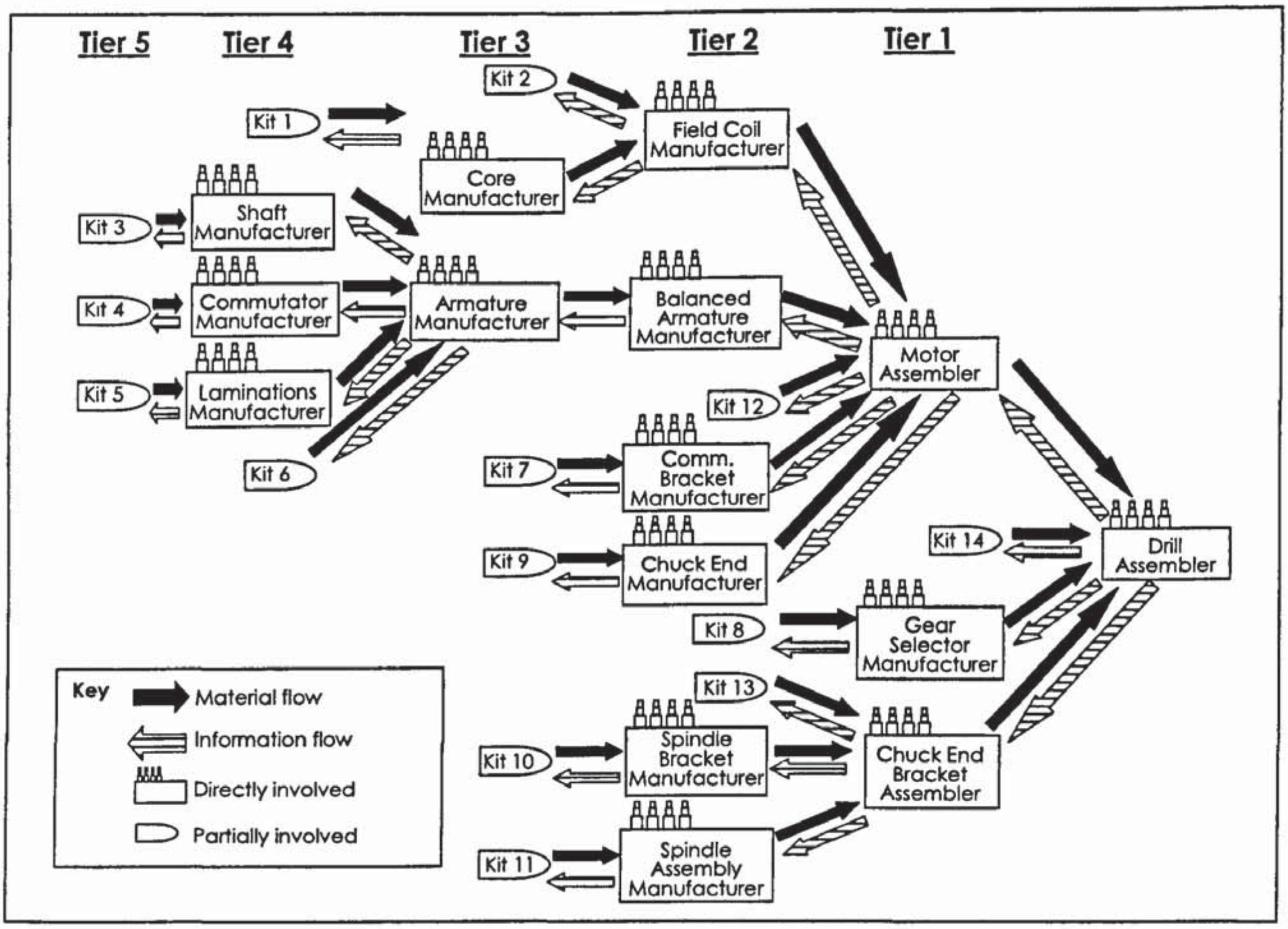
### 7.4.1 Phase 1: Scope the supply chain/network

The scope and depth of the information on the drill manufacturer teaching case make it a rich test bed for exploration. The major operating problems lie in the upstream network, rather than the downstream network. The drill supply chain is considerably more complex than many of supply chain models in the literature; consisting of twenty-nine organisations in total across five supply chain tiers. The following sections describe how phase 1 was applied to the drill manufacturer upstream network.

#### 7.4.1.1 Step 1a. Determine the supply chain/network boundary

The supply chain boundary was drawn around the upstream network, considering fifteen organisations as directly involved in selecting the new supply system architecture, with a further fourteen organisations partially involved, as indicated in figure 7.11. In total, the boundary spanned five supply chain tiers; the number of organisations at each tier varies from four in the tier one to nine in the second tier. There are four different sized drill products manufactured by the supply chain, which are assembled in the same, however, the variation in sizes means that standard time varies and changes in setups can be required. Each organisation manufacturers or assembles specific parts/components and delivers them to the downstream tier. The parts that each organisation supplies are indicated in figure 7.11, for example in tier four the shaft; commutator and laminations are produced by three separate organisations, as well as kit 6. The considered organisations, indicated on figure 7.11, all supply kits of parts that their customers use to build components of the drill. Each kit provides the smaller parts for one drill, for example, kit 14 contains: power lead assembly; body mouldings; leads; hammer switch; sleeve; felt washers; screws; labels and chuck. The drill manufacturer uses the parts in kit 14 to assemble the motor; gear selector and chuck end bracket into a complete drill.

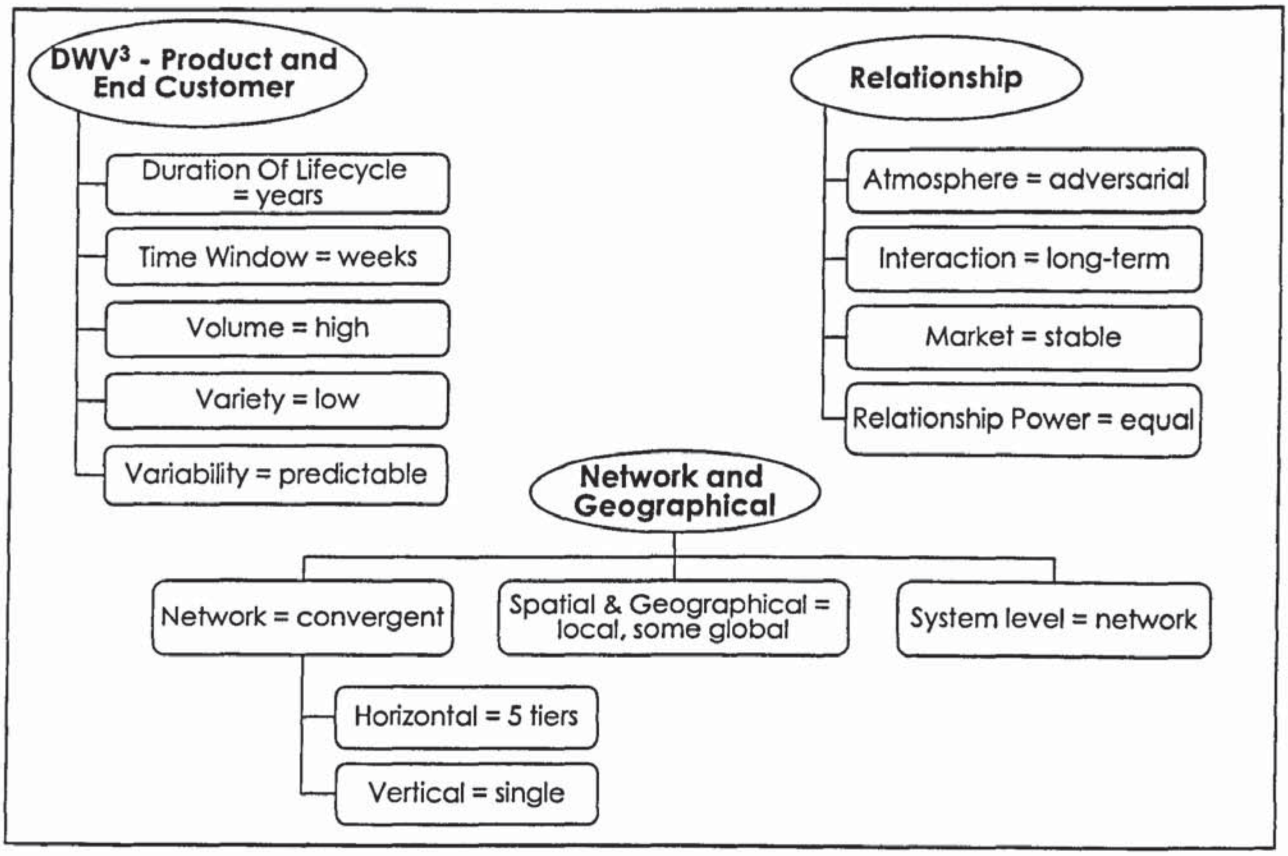
**Figure 7. 11 The drill manufacturer upstream network boundary**




### 7.4.1.2 Step 1b. Define the supply chain/network characteristics

The characteristics of the drill manufacturer upstream network were defined, as shown in figure 7.12. The perspective of the directly involved organisations was given the priority, whilst considering the partially involved organisations to a lesser extent. The product demand is predictable, further supported by long duration of the lifecycle; no new products or models will be manufactured in the foreseeable future. There is low variety four types of drill are made, the volume of production is high in comparison with approximately 32,000 drills being manufactured each week. The time window for delivery is in weeks to months and is not pressing, with all organisations carrying buffer stocks to protect against late deliveries. Although there is a long-term interaction between the organisations, they are adversarial towards each other due to problems with deliveries and quality issues in the past. However, they have equal power in a stable market, which is partially due to the single sourcing and also their dependence on each other. The convergent network for the drill; contains three tiers and is the directly involved organisations are local, however the partially involved organisations are global, thus delivery lead times are longer.

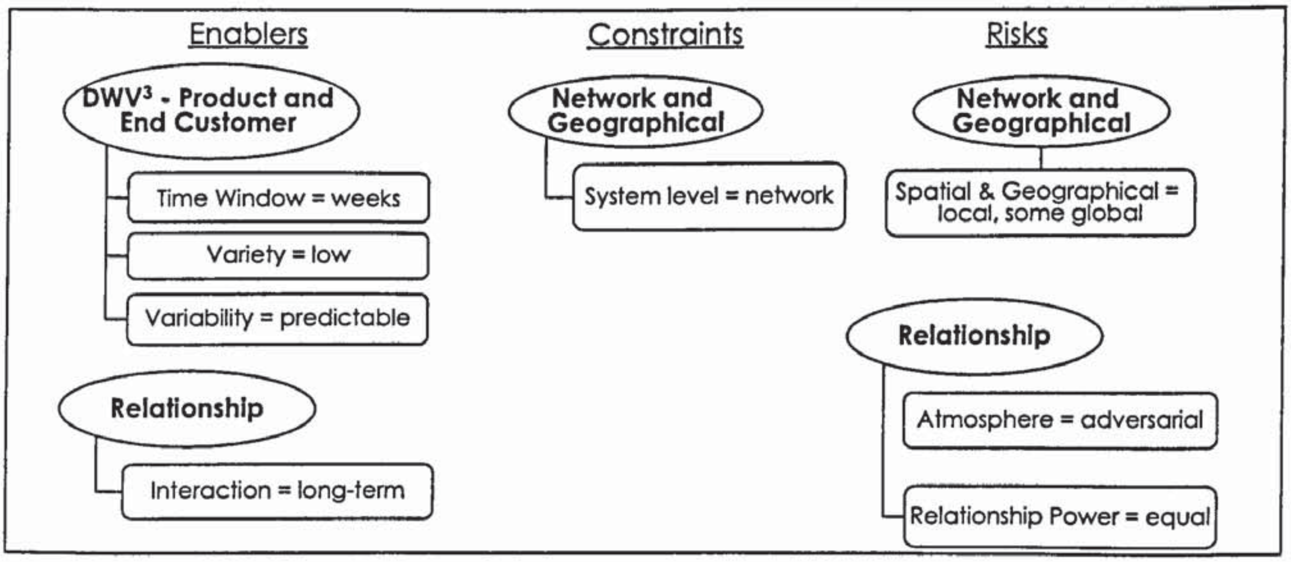
**Figure 7. 12 The characteristics of the drill manufacturer upstream network**




### 7.4.1.3 Step 1c. Clarify the key enablers; constraints and risks

Figure 7.13 summarises those characteristics in the drill manufacturer network that would enable; constrain or are a risk to consider when selecting the new supply system architecture. The $DWV^3$ or product and end customer characteristics are supportive to the change, specifically the predictability of demand; low variation and long time window for delivery. The long-term interaction relationship characteristic was considered to be an enabler. The major constraint is to manage the complexity of the network across the 5 tiers. One of the risks is the global location of partially involved organisations, which lengthens logistical lags. Difficulties arise in the relationships category, equal power across so many organisations will make it difficult to reach a consensus and coupling that with adversarial atmosphere creates a substantial risk to changing the supply system architecture.

**Figure 7. 13 Summary diagram of the key enablers; constraints and risks for changing the planning system in the drill manufacturer supply chain**




### 7.4.1.4 Step 1d. Clarify supply system architecture goals

The main supply system architecture goal for the drill manufacturer network was to reduce the amount of inventory across the organisations within the network. All organisations were carrying considerable buffer stocks of raw materials and work in process to protect themselves against late deliveries or quality problems. For example, the motor assembler was keeping 31,109 armatures in their warehouse, despite their close proximity to the balanced armature manufacturer. Furthermore, despite the buffer stocks, delivery to the end customers was often late; in general, arrears or back orders were not uncommon across the network. Specifically, the drill manufacturer is in arrears by 287 units of one type of drill. The root causes of late deliveries and quality problems are outside the scope of selecting supply system architecture. Quick scan would be able to investigate the issues further as these would be drawn out when the uncertainty sources are investigated, particularly the scrap reports; suppliers schedule adherence and stock reports (full list of data explored during quick scan is provided in table 3, Naim et al., 2002, pp. 143). However, new supply system architecture can be considered concurrently or after the actions identified from the quick scan diagnostics. Appropriate supply system architecture would enable better inventory planning. Therefore, the goals to improve the inventory situation, after the changes are:

- Reduce the inventory levels for components supplied by directly involved organisations
- Improve delivery on schedule performance between directly involved suppliers to their customers
- Co-ordinate production and delivery activities more closely to ensure fulfilment of end customer demand

## 7.4.2 Phase 2: Identify options for supply system architecture

Phase 2 involved further clarifying the different processes and systems in the drill manufacturer supply chain; determining the orientation of the supply system architecture and identifying the functionality requirements. The result of the two phases is the clear articulation of the business case.

### 7.4.2.1 Step 2a. Map supply processes and systems

Figure 7.14 shows the high level process map of the drill manufacturer network processes; this was created in iGrafx Process ™ focusing on the directly and partially involved organisations, to follow the boundary shown in figure 7.11. The end customer is represented and the timeliness of the delivery to the end customer is indicated as an important metric in the bottom right hand section of figure 7.14. The planning processes are depicted in the high-level process map by showing the purchase orders. All the directly involved organisations were mapped in greater detail, including their production and planning processes, as indicated by the black shadow in figure 7.14. The process map for the balanced armature manufacturer is shown as an example in figure 7.15.

The detailed process maps indicate the inventory and storage locations, for example, in figure 7.15, the warehousing section of the balanced armature process map

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individuals will also indicate how well they feel that the different supply system architectures will provide the functionality by making pair wise comparisons (Step 3a, section 6.5.1.1). Breaking the decision down in to pair wise comparisons simplifies the process and speeds up the decision making process. It also makes it easier for differences of opinion to be drawn out and discussed. However, making the comparisons between different supply system architectures in Step 3a was quite complex and required careful consideration. Despite the complexity, it was used in the luxury automobile supply chain successfully and with ease. Simulation was not tested in any of the three cases, however section 6.5.1.3 showed that it is a more complex tool to use and therefore, its use in the decision-making process may be necessary in some scenarios.

### 8.3.6 Appropriateness of the process framework

The extensive literature review sought to ensure that the process framework was appropriate to aid the selection of supply system architectures. The application of the process framework further demonstrates its appropriateness for determining suitable supply system architecture. Specifically, through following the steps in the process framework clarification and understanding of the supply chain/network in focus is developed. Working through the steps leads to the development of a clear business case, which was identified as important in the literature review (section 2.4) and archival case study analysis (section 5.4). Furthermore, the process framework addresses the need for analysis and consideration of functionality requirements (in Steps 2c and 3a). Overall, the outputs produced and the structure of the process framework can be considered appropriate for selection supply system architecture.

### 8.3.7 Appropriateness of the tools and techniques

The use of the tools and techniques in previous frameworks focused on similar problems justifies their appropriateness, specifically the use of QFD (Ho, 2002) and AHP (Sarkis and Sundarraj, 2001, Sarkis and Talluri, 2004, Wei et al., 2005) and simulation (Ho, 2002). The outputs generated through the application of the case also demonstrates their appropriateness, as the outputs make recommendations on the relevant usefulness of the different supply system architectures (Step 3a), see table 8.3. For example, in the case of the snack manufacturer, the QFD analysis was appropriate to determine that TMS could be used, and possibly, combined with CPFR. The production of analysis aligned to the problem so clearly, validates the appropriateness of the techniques employed. Simulation was not explored in any of the three cases; therefore, its appropriateness has not been tested in the context of the process framework.

## 8.4 Utility – the usefulness of the process framework

The process framework could be disseminated in industry for practitioners to use and also within academia; hence its relevance to these parties is critiqued. The issue of facilitation of the process framework is also explored.

### 8.4.1 Relevance of the process framework from an industrial and practitioner perspective

Considerable practitioner articles indicate that supply chains/networks continue to struggle with selection of supply system architecture (c.f. section 2.1.3). The process framework has not yet been deployed in practice; therefore, it is difficult to comment insightfully on whether it is considered useful. It can be eluded that it is useful for practitioners given that it provides a clear structure to produce a business case. Furthermore, functionality of different supply system architectures (Steps 2c and 3a); implementation issues (refer to table 2.4) and compatibility to the supply chain/network (Steps 1b, 2b and 3a) are all considered, as derived from the literature review. Further testing and verifying the process framework's usefulness in industry is discussed in section 9.4.1.

## 8.4.2 Usefulness of the process framework for academics

The process framework should prove useful for academics, as evidenced by the presentation of the process framework at two academic conferences (Benton and Love, 2006a, Benton and Love, 2006b). The supply system architecture classification discussed in section 2.3 and illustrated in figure 2.10 maps supply system architecture according to the degree of integration, which is a topical debate in the literature (e.g. Wong and Boon-itt, 2006). The resulting conceptual framework that considers the classification in the context of supply chain/network characteristics (figures 2.11 and 2.12) should also provide academics will some useful insights into the problem of selecting supply system architectures. Although the conceptual framework is not fully tested (see sections 9.4 and 9.5 for further discussion of the limitations and further research, respectively), the case study applications did highlight its usefulness in considering the problem.

## 8.4.3 Facilitation

The use of tools and techniques throughout the process framework eases the facilitation. Step 1a generates a supply chain/network boundary diagram, which can be used throughout to refocus the team on the supply chain/network, as opposed to their specific domain. The complete network of the luxury automobile is vast, hence using this diagram aided the re-focusing the reflection and analysis on the focal seat set supply chain (figure 7.5), rather than the whole network. In the drill manufacturer network it was vital in facilitating the process of determining focal organisations for consideration, versus those to be considered more generally (figure 7.11). Without using such a tool, getting consumed by the particularities of a smaller part of the chain could impede the process. The supply chain/network boundary diagram is expanded upon in Step 2a which generates a supply process and systems map. The process maps facilitate the consideration of the orientation (Step 2b) and the listing of required functionality (Step 2c).

Despite the careful selection and use of a variety of tools and techniques the process framework will still require expert facilitation. Expert facilitation is necessary due to the complexity of the problem and the fact that the decision is a group decision. Understanding and being able to analyse the different supply system architectures requires knowledge of the different functionality and emphasis. The group dynamics could also generate issues when the process framework is followed, these issues would need to be handled expertly to ensure the smooth progress through the steps in the process framework.

## 8.5 Conclusion

The process framework has been critiqued in terms of its feasibility; usability and utility. Although, not fully tested and explored in every aspect, the results of the testing suggest that the process framework is a valid approach for selecting supply system architecture. The analysis; outputs and documentation gained from applying the process framework would support the selection of supply system architecture. The process framework can be considered to be a road map for guiding the selection process. However, careful facilitation would still be required, due to the complexity of evaluating different supply system architectures against each other.

# Chapter 9 - Conclusions and Future Implications of the Process Framework

The development and initial testing of the process framework for selecting supply system architecture are the main contributions of the thesis. Three further advances are also made by the thesis in the areas of supply system architecture and decision-making techniques. Firstly, a spectrum which classifies supply system architectures from integration; through partial integration; co-ordination to independence was developed. Secondly, a conceptual framework and supporting characteristics diagram were developed for exploring the problem of selecting supply system architecture. Thirdly, the thesis adopts the approach of utilising appropriate decision-making techniques depending on the time; cost and type of analysis required.

The main limitations to the research work, the type of industrial contexts the process framework is tested in and the lack of testing of some aspects of the process framework. Specifically, the process framework was tested in fairly mature, and therefore, less dynamic supply chains/networks and reverse logistics scenarios were not explored. The testing was also all focused on manufacturing supply chains/networks, rather than service supply chains/networks. The process framework is designed to exploit the use of group system support technologies, however, these are not tested. Furthermore, the two steps which involve the participation of software vendors have not been tested.

Despite these limitations the contributions and advances that the thesis makes have implications for theory in the areas of supply chain/network strategy development and decision support systems. The characteristics diagram and process mapping techniques could be useful in supply chain/network strategy development. The flowchart for determining the most appropriate decision-making technique, depending on the time; cost and type of analysis required, has implications in decision-support systems. Further work in testing the process framework through expert opinion and action research exists. The process framework could also be developed to predict the suitability of supply system architectures in different industrial settings, over time, with more applications.

Finally, the work could be extended to explore service supply chains/networks which would expand the applicability of the process framework.

This chapter is divided into six sections, the first section (9.1) focuses on the process framework and testing of it as the main original contribution. The focus of the second section (9.2) is on highlighting and discussing the other advances made in the areas of supply system architecture and utilisation of appropriate decision-making tools and techniques. The third section (9.3) summarises how the research objectives and questions set in section 1.2 were addressed in the thesis. The fourth section (9.4) considers the limitations of the contributions expressed in section 9.1 and 9.2. The fifth section (9.5) highlights the implications of the research and the platforms for further study and exploration. The chapter is then concluded with a short summary (section 9.6).

## 9.1 The original contribution – Development and initial testing of a process framework for supply system architecture selection

The main original contribution is the development and initial testing of a process framework for supply system architecture selection. The literature review revealed that there is an abundance of systems proposed for managing supply chains/networks (AMR Research, 1998, Buxmann et al., 2004, Nairn, 2003, Taylor, 2004). However, difficulties arise in selecting supply system architecture due to confusion in functionality (Albright, 2004, Anon, 2006, Biehl, 2005, Buxmann et al., 2004, Nairn, 2003, Taylor, 2004); implementation issues concerning design and selection (Al-Mashari et al., 2003, Al-Mashari and Zairi, 2000b, Bernroider and Koch, 2001, Hecht, 1997, Rao, 2000, Wei and Wang, 2004) and compatibility issues (Benton and Love, 2001, Benton and Love, 2006a, Benton and Love, 2006b, Buxmann et al., 2004). Although guidance on how to select system architecture was located in the literature, it was revealed to be limited in a variety of ways (c.f. section 4.1). In summary, the frameworks that have been developed were limited as follows:

- focused only on internal chains (Blackwell, 2003, Blackwell et al., 2006, Lee, 1998, Light et al., 2001, McGarrie, 1993, Sarkis and Sundarraj, 2001, Wei et al., 2005, Wei and Wang, 2004), rather than all system levels through to supply networks;

- did not cover all the supply system architectures, this was true of all the frameworks, with Ho's (2002) providing the best coverage, but it did not include ERP; many frameworks were focused solely on one type of solutions, e.g. ERP (Blackwell, 2003, Ho and Lin, 2004, Lee, 1998, McGarrie, 1993, McGarrie, 1998, Sarkis and Sundarraj, 2001, Wei et al., 2005, Wei and Wang, 2004) or electronic marketplaces (Sharifi et al., 2006);

- limited in consideration of participation and clear point of entry into the framework (Biehl, 2005, Ho, 2002, Sarkis and Talluri, 2004, Sharifi et al., 2006);

- methodology for development was not clearly justified or explicit (Ho, 2002, Lee, 1998, Sarkis and Sundarraj, 2001, Sarkis and Talluri, 2004, Wei and Wang, 2004);

- limited testing, a number of frameworks did not evidence any testing (Blackwell, 2003, Blackwell et al., 2006, Lee, 1998) or applied it to an illustrative example, not indicating where the data was from (Biehl, 2005, Biehl and Kim, 2003, Sahay and Gupta, 2003, Sarkis and Talluri, 2004), or applied it to a single case study (Ho and Lin, 2004, Light et al., 2001, Sarkis and Sundarraj, 2001, Wei et al., 2005, Wei and Wang, 2004). Only three of the frameworks were tested in more than one case (Ho, 2002, McGarrie, 1993, Sharifi et al., 2006).

The process framework expressly realised the requirements (shown in table 5.2) derived from the critical review (chapter 4) and archival case study analysis (chapter 5) in a three phase process framework, summarised in figure 6.1. The particular uniqueness of the framework is emphasised by the focus on the issues (explored in sections 2.2; 2.4; 2.5; 2.6; 4.1; 4.2 and 5.4), which thus, demonstrates utilisation of both theoretical (chapters 2 and 4) and empirical (chapter 5) analysis.

The process framework focuses on addressing the implementation issues by combining the requirements for successful manufacturing strategy formulation derived from Platts (1994) and Platts et al (1996), with the implementation issues identified in section 2.4 and analysed in the six archival case studies in chapter 5. Specifically, the process framework was designed to consider: procedure; participation; project management and point of entry these are now briefly explained (see table 5.2 for the full requirements list). Firstly, the procedural considerations were addressed to ensure it was logical, from gathering information on processes and existing systems; to analysing the information concerning functionality requirements; compatibility and software selection, through to identifying possible improvements to supply system architecture. The procedural steps in the process framework led to the development of a business case and exploited the use of simple tools and techniques. Secondly, the participation requirements consider the need for group work in a workshop style, which also supports the requirement for good communication. The use of group support systems is presented as a facilitator of improved group work, in conjunction with the simple procedural tools and techniques. Thirdly, project management is considered in terms of resourcing an appropriate team and considering timescales. Timescales are adhered to through project management techniques, combined with alternative analysis techniques that factor in time constraints. Fourthly, the requirements for clarifying the point of entry are designed into the process framework, with clear signposting of the inputs and outputs within each phase and each step. Table 6.6 shows, specifically, how the steps within the process framework address the requirements.

The process framework is empirically tested in three case study applications, previous frameworks were relatively untested (see appendix 1, section: Methodology for developing and testing the framework). The application of previous frameworks to a single case study (Ho and Lin, 2004, Light et al., 2001, Sarkis and Sundarraj, 2001, Wei et al., 2005, Wei and Wang, 2004), or multiple case studies (Ho, 2002, McGarrie, 1993, Sharifi et al., 2006) demonstrates the feasibility of previous frameworks. However, previous frameworks did not expressly consider whether the guidance they provided was usable; useful or valid with the exclusion of some consideration by Blackwell (2003), indicated in table 8.1. The process framework presented in chapter 6 and applied in chapter 7, did discuss and explore these issues and make explicit the limitations in the testing across the criteria of feasibility (section 8.2); usability (section 8.3); utility (section 8.4) and validity (section 8.5).

## 9.2 Other advances made by the thesis

The thesis delivers five main contributions or advances in the area of supply system architecture selection, as summarised in table 9.1. The main original contributions of the thesis are the development of the process framework for selecting supply system architecture (output 1 in table 9.1), as discussed in the previous section and the application testing of the framework (output 2 in table 9.1). The three phase framework harnesses the advance made in de-mystifying the supply system architectures discussed in section 2.2 which resulted in a spectrum, from integrated, through partial integration, co-ordination to dependence, explained in section 2.3 (output 3 in table 9.1). Another advance in the thesis is the development of a conceptual framework of the characteristics for consideration when selecting supply system architecture, discussed in section 2.6 (output 4 in table 9.1). The process framework also makes an advance in the use of decision-making tools and techniques, previous work focused on utilising a particular technique, irrespective of the time and cost constraints and the level of analysis required. The thesis utilises different decision-making techniques, as discussed in section 4.2 and derived a flow chart for determining appropriateness, shown in figure 6.10 (output 5 in table 9.1).

**Table 9. 1 Summary of the contributions made by the thesis**

| Output | Addressed in previous research | Summary of the contribution/advance made | Research objective /questions | Chapter /section |
|---|---|---|---|---|
| 1. Development of a process framework for supply system architecture selection. | To some extent, but existing frameworks were limited in scope; consideration of the supply system architectures available or consideration of the requirements for participation and project management (discussed in section 4.1). | The main contribution of the thesis is the three-phase process framework for selecting supply system architecture:<br>Phase 1: Scope the supply chain/network<br>Phase 2: : Identify options for supply system architecture<br>Phase 3: Select supply system architecture | O2 and Qs 2a; 2b and 2c. | Chapter 6 summarised in figure 6.1. |
| 2. Empirical testing and evaluation of the process framework. | Not addressed, as the process framework was developed in the thesis, hence, only tested in the thesis. | The empirical testing of the process framework in three cases is another contribution. The testing proves analytical generalisability through literal replication, and is presented in chapter 7. Detailed evaluation of the process framework is conducted across the criteria of feasibility; usability; utility and validity, discussed in chapter 8. Testing of alternative existing frameworks was limited, with no evaluation across the criteria identified in section 8.1. | O3 and Qs 3a; 3b; 3c and 3d. | Chapters 7 and 8. |
| 3. Spectrum to show the orientation supply system architecture. | Not specifically addressed, the existing classifications, discussed in section 2.2.6, are not based on the orientation of supply system architectures (excluding previous work by the author explained in section 2.3). | The thesis contributes the articulation of the different systems available on a spectrum from integrated; partially integrated; co-ordinated to independent, shown in figure 2.10. The spectrum aids clarity and understanding of the supply system architectures available. | O1 and Qs 1a and 1b. | Section 2.3 and used in the process framework, see section 6.4.2. |
| 4. Conceptual framework of the characteristics for consideration when selecting supply system architecture. | To some extent, characteristics discussed in the context of supply strategy in section 2.5.1, as opposed to selection of supply system architecture (excluding previous work by the author explained in section 2.3). | The conceptual framework makes an advance by proposing that three categories of characteristics are important in supply system architecture selection: product and customer (DWV[3]); network and geographical and relationship. | O2 and Q2a. | Section 2.6 and used in the process framework, see section 6.3.2. |
| 5. Guidance for exploiting appropriate decision-making techniques for supply system selection, dependent on constraints. | To some extent, the previous work utilised specific decision-making techniques, which validates their usefulness for making the decision. However, they utilise a specific technique, irrespective of the constraints. | An advance is made, whereby a flow chart (figure 6.10) is derived to determine which technique is appropriate for supply system architecture selection. Appropriateness of the technique considers time; cost and the depth of analysis required. | O2 and Q 2c. | Flowchart in the process framework, see section 6.5.1. |

### 9.2.1 Spectrum to show the orientation supply system architecture

The research has made an advance, in the approach taken to classify supply system architectures (output 3 in table 9.1), which is discussed in section 2.3. The focus of the classification is on supply chains/networks, as opposed to previous classifications which were internal chain/single organisation focused (Slack, 1991, Voss and Harrison, 1987). The classifications that were supply chain/network focused considered only ERP and e-marketplaces (Biehl, 2005, Biehl and Kim, 2003) or listed functionality, without mapping supply system architecture to the continuums of time horizon and planning detail stated (AMR Research, 1998). The approach acknowledges that when considering supply system architecture, the nature of the desired orientation of the supply chain/network is important, specifically whether the parties seek to integrate; partially integrate; co-ordinate or remain independent. The use of these terms for considering supply chains/networks is supported by the considerable review undertaken by Wong and Boon-itt (2006) and builds on the previous classification developed by the author (Benton and Love, 2001, Benton and Love, 2006a). The classification proved useful in the realisation of the process framework, utilised in Step 2b (section 6.4.2) and applied to the three case studies in sections 7.2.2.2; 7.3.2.2 and 7.4.2.2. The feasibility of the spectrum that classifies supply system architecture is discussed in 8.2.2, and its appropriateness discussed in section 8.3.7.

### 9.2.2 Conceptual framework of the characteristics for consideration when selecting supply system architecture

Another advance is the development of a conceptual framework for selecting supply system architecture (output 4 in table 9.1), which is shown in figure 2.12. The conceptual framework is derived from existing work that classifies supply chains/networks (reviewed by Childerhouse et al., 2002). It focuses on using the DWV[3] classification which was tested in Childerhouse's (2000) PhD, however, it also considers other categories derived as important in the literature, specifically, network and geographical (Beamon and Chen, 2001, Harland, 1997, Lamming, 1992) and relationship (Cox, 2004b, Håkansson and Snehota, 1995). The conceptual framework is utilised in the process framework in Step 1b (section 6.3.2), through the use of the key characteristics diagram to define the supply chain/network, shown in figure 2.11. The characteristics diagram is applied to the three case studies in sections 7.2.1.2; 7.3.1.2 and 7.4.1.2. The feasibility of the characteristics diagram for defining supply chains/networks is discussed in 8.2.2, and its appropriateness discussed in section 8.3.7.

### 9.2.3 Guidance for exploiting appropriate decision-making techniques for supply system selection

The final advance is the utilisation of different decision-making techniques to suit the scenario (output 5 in table 9.1). Previous frameworks have focused on particular technique(s), without justifying why the technique was chosen in any depth (c.f. section 4.1). The frameworks all also assume that the technique chosen can be applied, regardless of time and cost constraints, and the required analysis. The analysis of the different tools available was then used to form a flowchart to select appropriate decision-making technique in Step 3a (section 6.5.1). The flowchart is applied to the three case studies in sections 7.2.3.1; 7.3.3.1 and 7.4.3.1. The feasibility of the flowchart to select decision-making technique is discussed in 8.2.2, and its appropriateness discussed in section 8.3.7.

## 9.3 Conclusions from the research objectives and questions

The overall aim of the thesis was to develop a process framework to guide the selection of supply system architecture for a supply chain/network. The process framework was derived; developed and tested through exploration of the options and issues in selecting supply system architecture (objective 1); the realisation of the process framework based on the requirements (objective 2) and the empirical testing of the process framework (objective 3). These research objectives were addressed in different parts of the thesis, as shown in table 1.1. This section summarises the conclusions drawn by considering each of the research objectives and their underlying research questions in turn.

### 9.3.1 Objective 1: To identify the options and issues in selecting supply system architecture

The first objective was separated into two research questions: identifying what types of system are available to support supply chains/networks (Q1a) and articulating why the process of selection is difficult (Q1b). The different options available for supply system architecture were identified in section 2.4 as follows: Enterprise Resource Planning (ERP) systems; Advanced Planning Systems; supply chain execution systems: CRM; SRM; WMS and TMS; Collaborative Planning, Forecasting and Replenishment systems and e-business solutions: e-marketplaces and e-purchasing. The functionality of these systems was identified and summarised in table 2.2. These different supply system architectures were also mapped onto a spectrum ranging from integrated through to independent to aid understanding of the orientation of the supply system architecture (shown in figure 2.10).

Three types of difficulties in selecting supply system architecture were identified in chapter 2. The first difficulty explored was the array of different systems available, which is further compounded by the overlap in functionality (section 2.2). The second difficulty exposed was the implementation problems in design and selection, notably: the need for a business case; business process and existing systems management and software selection. These issues are highlighted in section 2.4 and further analysed through archival case studies in chapter 5. The third difficulty was the compatibility of the supply system architecture with the supply chain/network. A conceptual framework was developed to highlight the key characteristics to consider in determining compatibility, shown in figure 2.12.

### 9.3.2 Objective 2: To develop a process framework to support the selection of the overall supply system architecture

The second objective, to develop a process framework is fully realised in chapter six. Chapter six described the three phases of the framework and illustrates each of the steps using the beer game as an example. However, it is chapters 2, 4 and 5 that explore the three research questions that underpin the design of the process framework. The first research question focused on identifying the contextual issues involved in supply system selection. Section 2.6 articulated the conceptual framework of three categories of contextual issues for consideration when selecting supply system architecture. The three categories in the conceptual framework are as follows: those characteristics pertaining to the product and end customer ($DWV^3$); network and geographical characteristics and the characteristics of the relationship.

The second research question sought to find out how supply system architectures have been selected. The question was addressed in the archival case study analysis (chapter 5) and the review of existing frameworks (chapter 4). The archival case study analysis demonstrated that evidence existed on the processes used in supply system architecture selection, but little information on how to conduct the processes. The review of existing frameworks provided depth on how the supply system selection process could be conducted. However, the existing frameworks were unable to fulfil all the requirements, which were identified and used for critiquing the existing frameworks in section 4.1.

The final research question which supported the design of the process framework was to identify the analytical techniques to aid the selection of supply system architecture. These techniques were identified through the review of existing frameworks (section 4.1) and discussed in section 4.2. The analytical techniques to support the selection of supply system architecture were identified as: group support system technologies; AHP; QFD and simulation. These analytical techniques have different strengths and applicability. Hence, the process framework includes a flow chart to determine the most appropriate decision-making technique, depending on the scenario, as shown in figure 6.10.

### 9.3.3 Objective 3: To test the ability of the process framework to support the design of the overall supply system architecture

The process framework was tested through application to three case studies, illustration of these applications is provided in chapter 7. The testing of the process framework was evaluated according to the following four criteria, which form the basis of the research questions: feasibility; usability; utility and validity. The first objective, feasibility, concerns whether the process framework could be followed. The ability to follow the framework is illustrated in chapter 7. The feasibility is reinforced by the discussion of the availability of information; participation and timing in section 8.2. The second objective, usability, considers how easily the process framework can be followed. The ease with which the framework can be followed is discussed in section 8.3, specifically the issues of clarity; ease of use and appropriateness are critiqued. The third objective, utility, focuses on whether the framework is useful. The issues of relevance; usefulness and facilitation are thus discussed in section 8.4. The concluding section reflects on the validity of the process framework (section 8.5).

## 9.4 Discussion of the research limitations

The main limitation is that the process framework has only been initially tested in three case studies. Although this amount of testing compares favourably to the testing conducted on the existing published frameworks (c.f. section 9.1), it is not sufficient to declare the process framework as generalisable. The initial testing does, however, reveal that the process framework is transferable to different industrial contexts. Moreover, the findings are clearly not generalisable from a statistical perspective, as only three supply chains are studied. However, these three case study applications indicate literal replication. However, the framework is designed to be an extendible framework, so further case studies would not only improve the generalisability but also extend the completeness of the framework. Further limitations exist in the testing of the framework, specifically the type of industrial contexts (i.e. the three cases) explored; the lack of actual testing of the group support system technologies and the lack of testing of the two steps that involve software vendor participation. These limitations are now discussed in turn.

### 9.4.1 Industrial context exploration

The process framework has been applied to cases that represent static supply chains/networks, where the organisations are constant. However, in reality, far more dynamic supply chains/networks also exist, which evolve over time and, hence, new supply chains/networks are continually formed (Mills et al., 2004) . The cases explored had long product lifecycles and therefore, relationships were already established, rather than the scenario of shorter product lifecycles, where suppliers and customers may vary over time. Hence, dynamic supply chain structures (Mills et al., 2004) and new product development and commercialisation (Cooper et al., 1997) have not been considered. Therefore, utilising the process framework for selecting of supply system architecture to support these types of supply chain/network has not been explored. The process framework does allow for organisations to be considered at varying levels of detail in Step 1a and Step 2a, which would be important for considering organisations where they is no long term relationship. The process framework also includes the use of simulation in Step 3a, which would enable dynamic scenarios to be tested. Another key aspect of dynamic supply chain/network scenarios is the fact that the parties involved in the supply chain under study could be participating in more than one supply chain. The current framework focuses on achieving a common goal, which may be a misnomer (Cox, 2004a). Identifying a supply chain/network champion will be virtually impossible in a true network. Therefore, more dynamic supply chain infrastructures would need to be investigated.

The framework has been applied to scenarios which focus on the feed-forward of materials. Although the snack manufacturer maize supply chain does includes the return process, the focus is on the rejection of maize based on quality, rather than reverse logistics. There are potential reverse logistics activities within the snack manufacturing supply chain, e.g. reuse of casing. However, the reverse logistics tasks demanded by increasing environmental concerns were not investigated in the snack manufacturer or the other two cases. Therefore, there is no proof that the framework is appropriate for handling the complexity of the two way material flow and processing. Reverse logistics is complex as different materials would need to be handled differently, e.g. disposal, recycling, re-conditioning, etc. Hence, there is scope to consider this aspect in future research.

A final issue concerning industrial context is the focus on manufacturing, discussed in section 1.6., which means that service supply chains/networks are not investigated. Although, there is indication that the process framework may be flexible enough to cope with service supply chains/networks, this needs to be explored in more depth. At this stage, the extendibility of the characteristics diagram in Step 1b, could accommodate service supply chains. The process mapping in Step 2a would be different in service supply chains, but equally possible.

### 9.4.2 Testing of group support system technologies and steps involving software vendor participation

The group support system technologies proposed in Steps 1b; 1c; 1d; 2b; 2c; 3a and 3c are not tested in a group scenario. Although other research indicates that group support system technologies aid the decision making process (reviewed in Turban et al., 2005), it has not been explored and tested in the process framework for selection of supply system architecture. Step 3b and 3c, which involve software vendor participation, have also not been tested. The reason for not testing these two aspects is that the process framework is still in the initial testing stage, whereby the process framework was tested in case study applications, as opposed to in practice. The initial testing did reveal that the process framework could be applied to guide the selection of supply system architectures. The three cases can be used to illustrate how the process framework works when utilising it for actual decision-making in supply chains/networks.

The initial testing is important, prior to using the process framework in real business scenarios, to minimise risk. Alternative approaches to testing the framework, include the use of interviews or action research. However, case study application was considered to be the most appropriate due to the risk involved and to enable depth of exploration of how the process framework would work. The main tools and techniques used in the process framework are deemed to be feasible, but the complexity of facilitating these in a group decision scenario does require further testing. The involvement of software vendors required in Steps 3b and 3c was not possible to enable these steps to be fully tested. However, the outputs generated in the previous steps did indicate that a clear understanding of the business case and requirements would be made, which would aid negotiation and assessment of software vendors.

## 9.5 Implications for theory and further research

The contributions and advances made in the thesis do have implications in related fields, specifically in the area of supply chain/network strategy and decision support systems. Some of the tools and techniques devised and tested within the process framework could be useful in supply chain/network strategy. More specifically, the characteristics diagram, shown in figure 2.11 could be useful for considering the supply chain/network when formulating a strategy. Process mapping is often used for devising tactical and operational strategy; hence testing it within the three case studies could have further implications. The consideration of time; cost and required depth of analysis for selecting decision-making techniques is another advance that the thesis makes which has implications in the theory of decision-support systems.

The development and testing of the process framework has implications for supply chain/network managers and IT managers. Progression through the process framework enables a clear business case to be made for adopting supply system architecture that could provide beneficial for managers. The steps within the process framework facilitate a structured approach for collecting and analysing the supply chain/network to enable selection of supply system architecture. The structured approach facilitates documentation throughout the process, including the development of a supply chain/network diagram; characteristics diagram; identification of enablers; constraints and risks; articulation of key performance indicators

There are several platforms for further research based on the findings in the thesis. The previous section indicates that the process framework requires further testing to improve its validity and generalisability, further research in this area is discussed. There is also considerable potential to enable the process framework to have predictive qualities over time and more applications. The third platform for further research is to develop and apply the process framework in service supply chains/networks.

### 9.5.1 Further testing in the manufacturing supply chain/network arena

The process framework needs further testing to improve its validity and generalisability. Several different options exist for testing the process framework. Specifically, expert opinion could be sought, seeking feedback on the process framework after a presentation an explanation of the process framework using one or more of the case studies for illustration. Using expert opinion would improve the validity of the process framework. The generalisability of could be improved by applying the process framework within an action research methodology. Utilising the process framework in practice would enable further testing and expansion of its potential.

### 9.5.2 Extending the process framework to have predictive qualities over time

The process framework could be extended through more applications and experimentation; this further work could enable the development of predictive qualities over time. Repeated applications and experimentation would enable the characteristics to be studied within in the context of supply system architecture in more depth. Analysing the results of the analysis could enable further supply chain/network diagnostics on the characteristics to enable prediction of the most suitable supply system architecture. Developing the predictive quality of the process framework would speed up the analysis and strengthen its applicability.

### 9.5.3 Application in service supply chains/networks

The process framework has been applied to manufacturing supply chains/networks, therefore its extension into service supply chains/networks would be a natural extension. Service supply chains/networks present new challenges. There are a number of implications for managing queues of people, which can be more difficult than managing queues of materials. The complexities of CRM and customer service would need to be further emphasised and explored.

## 9.6 Conclusion

The thesis has presented a process framework for selecting supply system architecture (chapter 6). The process framework was formulated from the requirements derived through a thorough a critical review of existing frameworks (chapter 4) and archival case study analysis (chapter 5). A case study application research approach was used to test the process framework (chapter 3), within three case study applications (chapters 7 and 8). The testing demonstrated that the process framework has potential for guiding the process of selection of supply system architecture (chapters 7 and 8). Its particular strength is the development of a coherent business case to support vendor selection. The vendor selection steps and the use of group system support technologies within the process framework remain untested. The process framework needs further testing and has potential for development to enable prediction and to be applied within service supply chains/networks.

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# Appendix 1 – Analysis of existing frameworks

## Summary of frameworks

| Framework | Summary |
|---|---|
| 1. Selecting internal and external supply chain functionality, the case of ERP systems versus electronic marketplaces (Biehl, 2005, Biehl and Kim, 2003) | Considers how value can be created through ERP and e-marketplaces, by reviewing their functionality. The decision is made by using a function of costs. The casts are considered to be: opportunity cost; competitive cost; transition cost and maintenance cost. The benefit is considers as salvage value, which is the long-term benefits for the organisation. The decision model runs in Excel. |
| 2. Decision-support framework for implementing enterprise information systems within SMEs (Blackwell, 2003, Blackwell et al., 2006) | A methodology was developed to guide the ERP implementation process, consisting of 11 steps and 4 gates, as follows:<br>Step 1. Identify information systems-related business problems.<br>Step 2. Establish if integrated systems can minimise the problems.<br>Gate 1. Continue/abandon project<br>Step 3. Define roles and responsibilities.<br>Step 4. Understand the need to commit resources.<br>Gate 2. Continue/abandon project<br>Step 5. Outline a preliminary case for integration.<br>Gate 3. Present preliminary case<br>Step 6. Establish an ideal level of integration.<br>Step 7. Assess current information systems.<br>Step 8. Assess software vendors.<br>Step 9. Purchase or develop an integrated system.<br>Step 10. Develop business case.<br>Gate 4. Attain Project approval |
| 3. Methodology for the selection and evaluation of e-business models within supply chains (Ho, 2002) | Consists 2 phases; 18 steps and 2 gates, as follows:<br>Phase 1<br>Step 1: Identify the number of supply chains<br>Step 2: Distinguish the physical structure of each supply chain<br>Step 3: Identify the main financial purpose of deploying e-business to each supply chain<br>Step 4: Ascertain the individual importance of the supply chain (s)<br>Step 5: Use the input matrix to calculate the total weight of each value chain activity in order to identify the important value chain activities<br>Step 6: In the e-business models matrix, ascertain the individual importance weighting of the value chain activities selected<br>Step 7: Use the input matrix to calculate the total weight of each value chain activity in order to identify the important value chain activities<br>Step 8: use the functionality checklist as a checklist to ensure the e-business model (s) identified has most of the functionality required by the organisation<br>Phase 2<br>Step 9: Determine the evaluation objective and performance measurement indicators<br>Step 10: Choose between discrete-event and systems dynamics simulation<br>Step 11: Model conceptualisation and data collection<br>Step 12: 'As-is' model formulation<br>Gate (step 16): Verified and validated? if no return to steps 11 and 12<br>Step 14: Experimentation<br>Step 15: 'To-be' model formulation<br>Gate (step 16) Verified and validated? if no return to step 15<br>Step 17: Compare and evaluate results obtained<br>Step 18: Make recommendation |

| Framework | Summary |
|---|---|
| 4. Design part of the critical success factor framework for the implementation of integrated-enterprise systems in the manufacturing environment (Ho and Lin, 2004) | An integrated-enterprise system implementation critical success factor framework was designed for the whole process, from design; test; realise to improve. The design part considers:<br>The infrastructure: hardware; network and software, including the design compatibility and scalability<br>The design: the integration (within and outside of organisation); process optimisation; architecture and alignment with business goals<br>The implementation plan: managing time; cost and resources; project planning and phased or big bang implementation<br>The organisation: skilled staff; project manager; top management commitment; team and organisational readiness |
| 5. An enterprise decision framework for information system selection (Lee, 1998) | They identify the key considerations and projects involved in designing and implementing ERP using a four step decision making process:<br>Should we replace current systems?<br>What is our future development direction?<br>What solution do we move ahead with?<br>What are the lessons learnt; successes; failures and major issues? |
| 6. ERP and best of breed: a comparative analysis (Light et al., 2001) | Used a case study of the ERP versus best of breed in the entertainment sector, identifies the need for: project management; business process reengineering; IT strategy and implementation process. |
| 7. A framework for the selection and implementation of production planning and control systems for small manufacturing companies (McGarrie, 1993, McGarrie, 1998) | Identifies four phases:<br>1. Current Reality Phase<br>Current reality audit:<br>- Strategic issues<br>- Product issues<br>- Process issues<br>- Capacity issues<br>- Inventory issues<br>- Workforce issues<br>- Quality issues<br>- Supplier relations issues<br>- Customer relations issues<br>2. Way Forward Phase<br>- Organise for change (project teams; education and training and problem identification)<br>- Plan for change (output from current reality; focus improvement and schedule)<br>3. Implementation Phase<br>- Action existing production planning and control system improvements<br>- Select new computer system<br>4. Loop back to current reality |
| 8. Development of software selection criteria for supply chain solutions (Sahay and Gupta, 2003) | Applies a percentage-weight age tree model to different software solutions.<br>The tree identifies primary drivers and secondary drivers. Primary drivers are: technology; cost and pricing; features; customisation and support and services. Secondary drivers are: vendor vision; industry covered; vendor strength and other drivers.<br>The performance ratings are then set.<br>Weight age is assigned to the attributes.<br>The model computates the weightings.<br>A comparative analysis is produced. |

| Framework | Summary |
|---|---|
| 9. A decision model for strategic evaluation of enterprise information technologies (Sarkis and Sundarraj, 2001) | Devises a strategic framework that consists of:<br>Corporate strategic planning<br>Functional strategic planning and design<br>Process and systems engineering<br>Configuration design and functionality requirements<br>Systems evaluation and justification, this step uses analytical hierarchy process (AHP), and indicates 4 steps to this:<br>1. Develop a hierarchy of factors impacting on the final decision. This is known as the AHP decision model.<br>2. Elicit pair wise comparisons between the factors using inputs from users/managers.<br>3. Evaluate relative importance weights at each level of the hierarchy<br>4. Combine relative importance weights to obtain an overall ranking of the candidate alternatives.<br>Systems implementation<br>Post-implementation audit |
| 10. Evaluating and selecting e-commerce software and communications systems for a supply chain (Sarkis and Talluri, 2004) | Uses AHP to compare supply chain and e-commerce communications. Considers software and communication system organisational requirements.<br>Software requirements include: internal adaptability; external adaptability; openness; scalability; security; reliability; ease of use; support; perceived value and costs.<br>Communication requirements include: speed; standards compliance; security; reliability; filtering; service; information access and costs. |
| 11. A classification and selection model of e-marketplaces for better alignment of supply chains (Sharifi et al., 2006) | Classifies e-marketplaces using three matrices for organisations to plot themselves onto.<br>Matrix one considers ownership/level of control (independent; sector coalition and privately owned) versus the type of product (commodities; durables and bespoke).<br>Matrix two considers functionality (anonymous and close relationship) versus type of product (commodities; durables and bespoke).<br>Matrix three considers ownership/level of control (independent; sector coalition and privately owned) versus functionality (anonymous and close relationship) . |
| 12. A comprehensive framework for selecting an ERP system (Wei and Wang, 2004) | Uses a two-dimensional analysis and fuzzy set theory to develop a systematic ERP selection algorithm. They identify 11 steps:<br>Step 1. Form a project team and conduct the business process re-engineering (BPR).<br>Step 2. Collect all possible information about ERP vendors and systems. Filter out unqualified vendors.<br>Step 3. Establish the attribute hierarchy and assign weights to the attributes.<br>Step 4. Interview vendors and collect detailed information.<br>Step 5. Analyze the data obtained from the external professional reports to obtain the objective ERP suitability.<br>Step 6. Assign subjective ratings to the ERP projects on the basis of data acquired in interviews to calculate the subjective ERP suitability.<br>Step 7. Combine the evaluations of both data sources and aggregate the decision-making assessments to determine the final fuzzy ERP suitability.<br>Step 8. Utilize the fuzzy integral value ranking method to obtain the rank of each ERP project.<br>the two kinds of data evaluation for selecting a suitable<br>Step 9. Analyze the results of indices, I and k. Observe the change in the final ERP suitability and the final ranking value.<br>Step 10. Select the ERP project with the maximum ranking value.<br>Step 11. Implement the selected ERP project. |

| Framework | Summary |
|---|---|
| 13. An AHP-based approach to ERP system selection (Wei et al., 2005) | Use AHP to select ERP system, consists of 7 steps (although flowchart indicates intermediary steps):<br>Step 1. Form a project team and collect all possible information about ERP vendors and systems.<br>Step 2. Identify the ERP system characteristics.<br>Step 3. Construct a structure of objectives to develop the fundamental-objective hierarchy and means-objective network.<br>Step 4. Extract the attributes for evaluating ERP systems from the structure of objectives.<br>Step 5. Filter out unqualified vendors by asking specific questions, which are formulated according to the system requirements.<br>Step 6. Evaluate the ERP systems using the AHP method.<br>Step 7. Discuss the results and make the final decision. |

# Methodology for developing and testing the framework

| | Scope: supply chain/network consideration | Industry | Research Methodology for development | Testing of methodology |
|---|---|---|---|---|
| 1. Biehl and Kim, 2003 Biehl, 2005 | internal to dyadic | Not specified | Mathematical modelling. | Illustrative example |
| 2. Blackwell,2003 Blackwell et al., 2006 | internal supply chain (SMEs) | Agricultural | Rigorous: literature review and semi-structured and unstructured interviews; pilot phase; evaluation of pilot; use of expert opinion. | Not tested |
| 3. Ho (2002) | internal to network | Maintenance and repairs, food and automobile | Literature review, pilot, feedback from conferences and journal submissions. | 3 case studies |
| 4. Ho and Lin 2004 | internal | Healthcare | Not specified, potentially experience. | 1 case study |
| 5. Lee, 1998 | internal | Not specified | Not specified, potentially experience. | None specified |
| 6. Light et al, 2001 | internal | Entertainment | Key personnel interviewed every 6 months over 2-3 years, documentary evidence. | 1 case study |
| 7. McGarrie, 1993 | Individual SMEs | Various | Literature review. | 10 case studies |
| 8. Sahay and Gupta (2003) | internal to network | Not specified | Reviewed existing models. | Illustrative example |
| 9. Sarkis and Sundarraj, 2001 | internal | Not specified | Not specified, based on the use of AHP. | 1 case study |
| 10. Sarkis and Talluri (2004) | Internal to network | Not specified | Not specified, based on the use of AHP. | Illustrative 3 company example |
| 11. Sharifi et al (2006) | internal to dyadic | Automobile and global mobile phone manufacturer | Literature review. | 2 case studies |
| 12. Wei and Wang (2004) | internal | Electronics | Not specified, potentially experience. | 1 case study |
| 13. Wei, Chien and Wang (2005) | internal | Electronics | Considers other approaches and selects AHP because other methods are weaken by sophisticated mathematical models or limited attributes to carry out a real-world ERP system selection. | 1 case study |

# Appendix 2 – Summary of the archival case study analysis

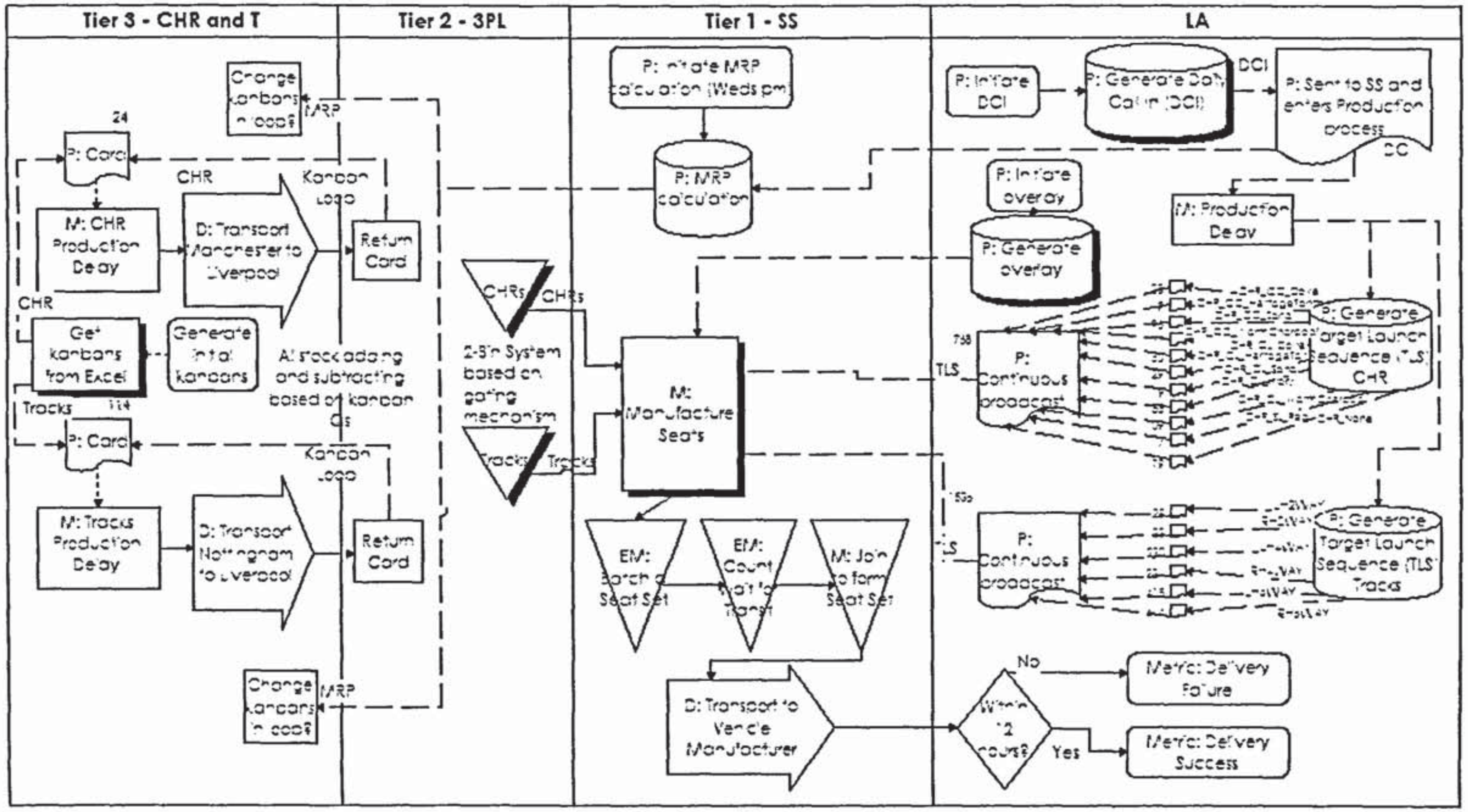
| *Design and selection issues:* | **Geneva Pharmaceuticals** (Bhattacherjee, 2000) | **Manco Group** (Al-Mashari and Zairi, 2000b) | **Paper Co** (Koh et al., 2006) | **Rolls Royce** (Yusuf et al., 2004) | **Texas Instruments** (Sarkis and Sundarraj, 2003) | **Wine Co** (Mandal and Gunasekaran, 2002) |
|---|---|---|---|---|---|---|
| **Business case** | ▪ End-to-end supply chain management through value-added processes that cut across multiple business units (data currently locked in functional silos) (pg. 12)<br>▪ Balance difficult task of manufacturing and purchasing (pg. 9) | ▪ Migrate to a flexible applications system creating an effective customer-responsive supply chain (pg. 299)<br>▪ Evolve from a separated set of business units into a single integrated supply chain (pg. 301) | Involvement in supply chain process to improve competitiveness (pg. 458), focusing on a long-term strategic purchasing vision through:<br>▪ Aggressive review of different cost saving initiatives<br>▪ Productivity improvements<br>▪ Supplier improvements (pg. 459) | Focused on replacing legacy systems which were expensive, difficult to maintain, had Y2k problems (pg. 255) and did not interface well (pg. 256), hence to:<br>▪ Establish direct, online communication with customers, partners and suppliers (pg. 256) | ▪ Evolve standardised business process to support market trends<br>▪ Leverage e-commerce link to customers and suppliers (pg. 432) | ▪ Enhance capabilities in the e-commerce world (part of a strategic alliance with IBM Australia)<br>▪ Tackle inventory problems caused by the variety of production and inventory management systems across the global locations (pg. 50) |
| ***Business process management*** | Reengineer demand and supply processes (pg. 2), using best practices (pg 12). Automate business processes (pg 15) | Manco Operations Re-engineering (MORE) project, deciding to focus first on Manco2.<br>The MORE team used a business model tool to describe how Manco2 conducts business and the user group developed a full list of the business processes. (pg. 302) | Automated the purchasing business process using SAP and e-procurement (pg. 460)<br>Tracking of interactions for process flow (pg. 462)<br>Visibility (pg. 461) | Conducted a four step internal business process reengineering programme: 1) mapping processes; 2) identifying improvements; 3) applying issues to SAP and 4) re-mapping processes aligning to SAP | Massive reengineering effort for global management of inventory and manufacturing processes (pg. 434)<br>Changed business processes, including standardisation (pg. 435) | Automation of the inventory management and tracking processes (pg. 51) |

| | Geneva Pharmaceuticals (Bhattacherjee, 2000) | Manco Group (Al-Mashari and Zairi, 2000b) | Paper Co (Koh et al., 2006) | Rolls Royce (Yusuf et al., 2004) | Texas Instruments (Sarkis and Sundarraj, 2003) | Wine Co (Mandal and Gunasekaran, 2002) |
|---|---|---|---|---|---|---|
| **Existing systems management** | Multiple software programs, pre-dominantly oriented around IBM's technologies. Ad-hoc deployment of systems led to double-booking and re-keying (pg 11-12). | Running systems in parallel, due to irresolvable problems (pg. 306) | Examined to facilitate the roll-out of SAP MM module (pg. 459) | 1500 systems used (pg. 255)<br>Expensive, difficult to maintain and inaccurate and inconsistent (pg. 255)<br>Data migration complex (pg. 257)<br>Parallel running (pg 257) | Thousands of systems in use, many stand-alone (pg. 434) | Reviewed previous systems functionality to ensure replication in SAP (pg. 50) |
| **Software selection** | Chose SAP AG's ERP as it was the industry norm and for best practices; data integration and standardisation; scalability and Y2K compliance (pg. 12 and 14). | Conducted by Bitco and caused a delay.<br>Selected SAP AG's ERP, even though tactically BAAN's package met their needs better (pg. 305). | Chose SAP AG's ERP<br>E-procurement package (pg. 459), despite reservations on its ability to handle process manufacturing (pg. 458) | SAP AG's ERP for aerospace and defence (pg. 257) selected, based on industry norms. | Chose SAP AG's ERP because of scalability.<br>Process involved sending out questionnaires to vendors (pg. 434)<br>i2 planning system<br>SAP AG's ERP | Reviewed the systems used by competitors (pg. 50)<br>Tested the off-the-shelf systems, found that only 35% of functionality was available (pg. 51)<br>Chose to integrate SAP AG's ERP with a bar-coding system (pg. 50) |

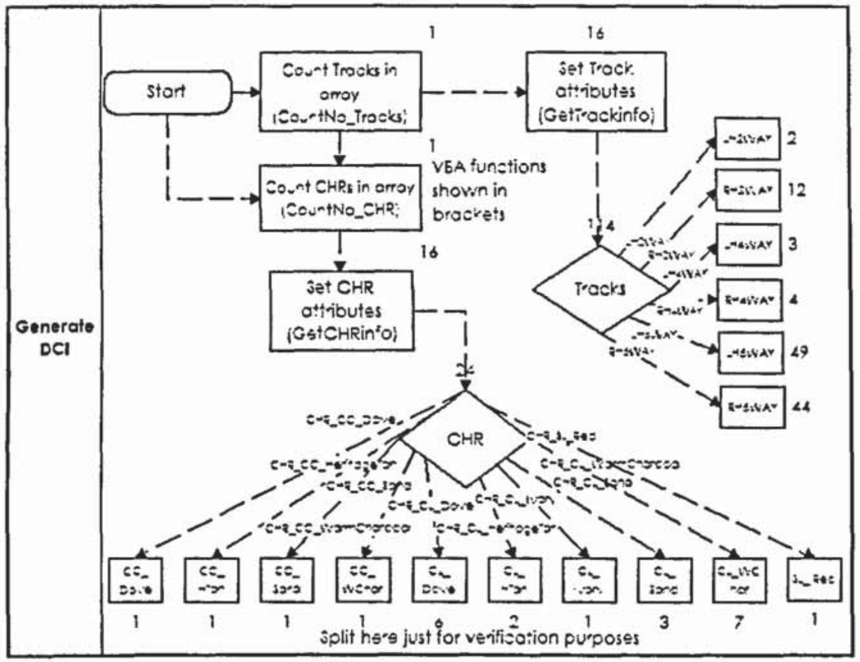
| *Overarching issues:* | **Geneva Pharmaceuticals** (Bhattacherjee, 2000) | **Manco Group** (Al-Mashari and Zairi, 2000b) | **Paper Co** (Koh et al., 2006) | **Rolls Royce** (Yusuf et al., 2004) | **Texas Instruments** (Sarkis and Sundarraj, 2003) | **Wine Co** (Mandal and Gunasekaran, 2002) |
|---|---|---|---|---|---|---|
| **Change and structural management** | Advisory committee formed that reported to the senior vice president level. Training set up. Lunches for discussion. Change agents in business units. (pg. 22-23) | Project teams and business process based (pg. 302) | Existing corporate culture considered to be slow to change to the new technology (pg. 460) | Illustration of the improvements and benefits to the company as a whole (pg. 256) | Team of key personnel expatriated to US (pg. 436)<br>Communications, excluding customer-specific, to be in English (pg. 436) | Employees asked for additional compensation for new duties (pg. 52)<br>Additional on-site training provided for on-going communication (pg. 53) |
| **Good communications** | Communications via newsletters; signs and employee survey (pg. 23) | Training and documentation (pg. 303) | Critical (pg. 462) | Training in seminars for specialists and mass users (pg. 256) | On-site experts, help desk and prioritisation system (pg. 436) | Training required as some personnel had never used a computer before (pg. 52) |
| **Project management** | Three phase implementation plan: phase 1: supply processes (MRP and procurement); phase 2: demand side processes (order management and customer service and phase 3: integration of supply and demand processes.<br>Consultancy teams used: Whitman-Hart (phase 1); Arthur Anderson (phases 2 and 3) and Oliver White (pg 15). | Three phases:<br>1) Visioning and alignment (strategies for operations and IT infrastructure)<br>2) Conceptual detailed design (BPR plans and IT infrastructure)<br>3) Implementation (installation, documentation and training) (pg. 303)<br>MORE team (pg. 301-2) "Bitco" consultants used (pg. 300)<br>4) | Project phases not clear, but:<br>- Some analysis of existing data (pg. 459)<br>- Deployment of SAPs MM module (pg. 459)<br>- Interface with e-purchasing (pg. 459)<br>Purchasing group established (pg. 459) | Project phases:<br>Phase 1: strategy and direction<br>Phase 2: planning, analysis and convergence and early deployment<br>Phase 3: wave 1 – focus on operations and pilot, wave 2 – focus on assembly and spares<br>Rolls Royce steering committee and implementation team (pg. 258) Electronic data services (EDS) and SAP consultants | 3.5 year project plan:<br>1) Strategy formulation<br>2) Process planning and systems design<br>3) System evaluation and justification<br>4) System configuration<br>5) System implementation (pg. 432)<br>Anderson Consulting (now Accenture) (pg. 436) | Project phases not clear, but:<br>- Analysis of competitors solutions (pg. 50)<br>- Testing of solutions (pg. 51)<br>- In-house design and development of a solution (pg. 52)<br>- Training (pg. 52)<br>- Implementation phase (pg. 53) |

# Appendix 3 – Process maps of the luxury automobile seat set supply chain

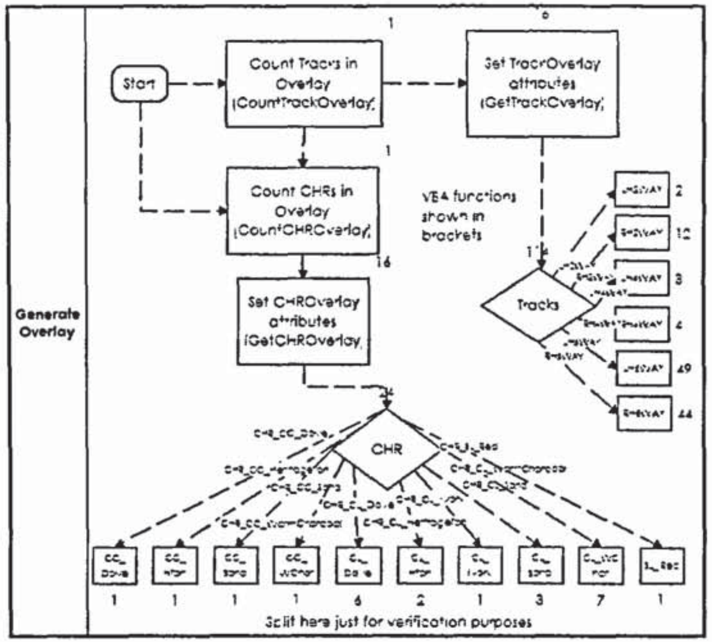
## High-level process map



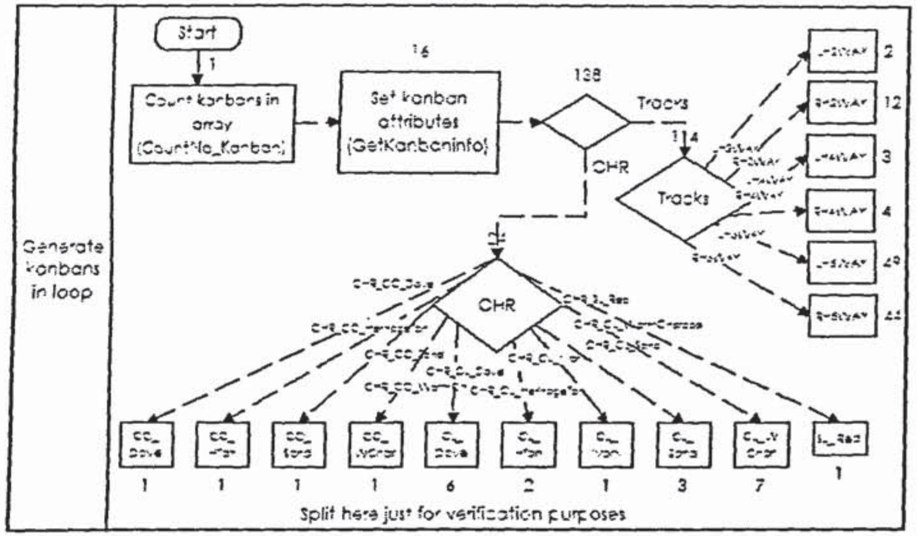
## Generate DCI process map



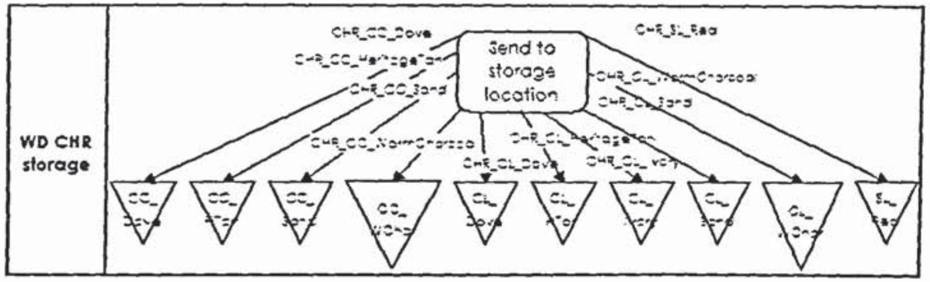

## Generate overlay process map

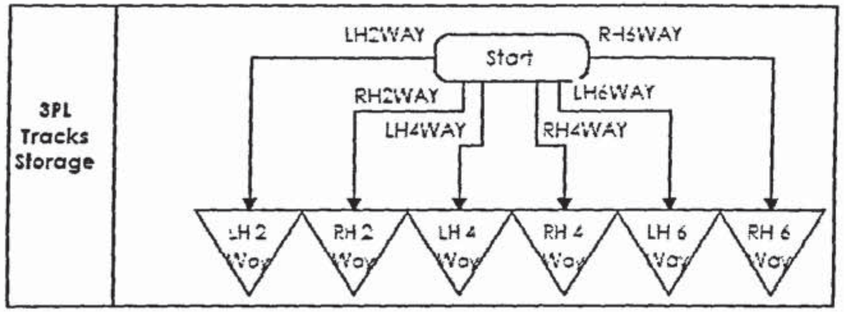


## Get kanbans

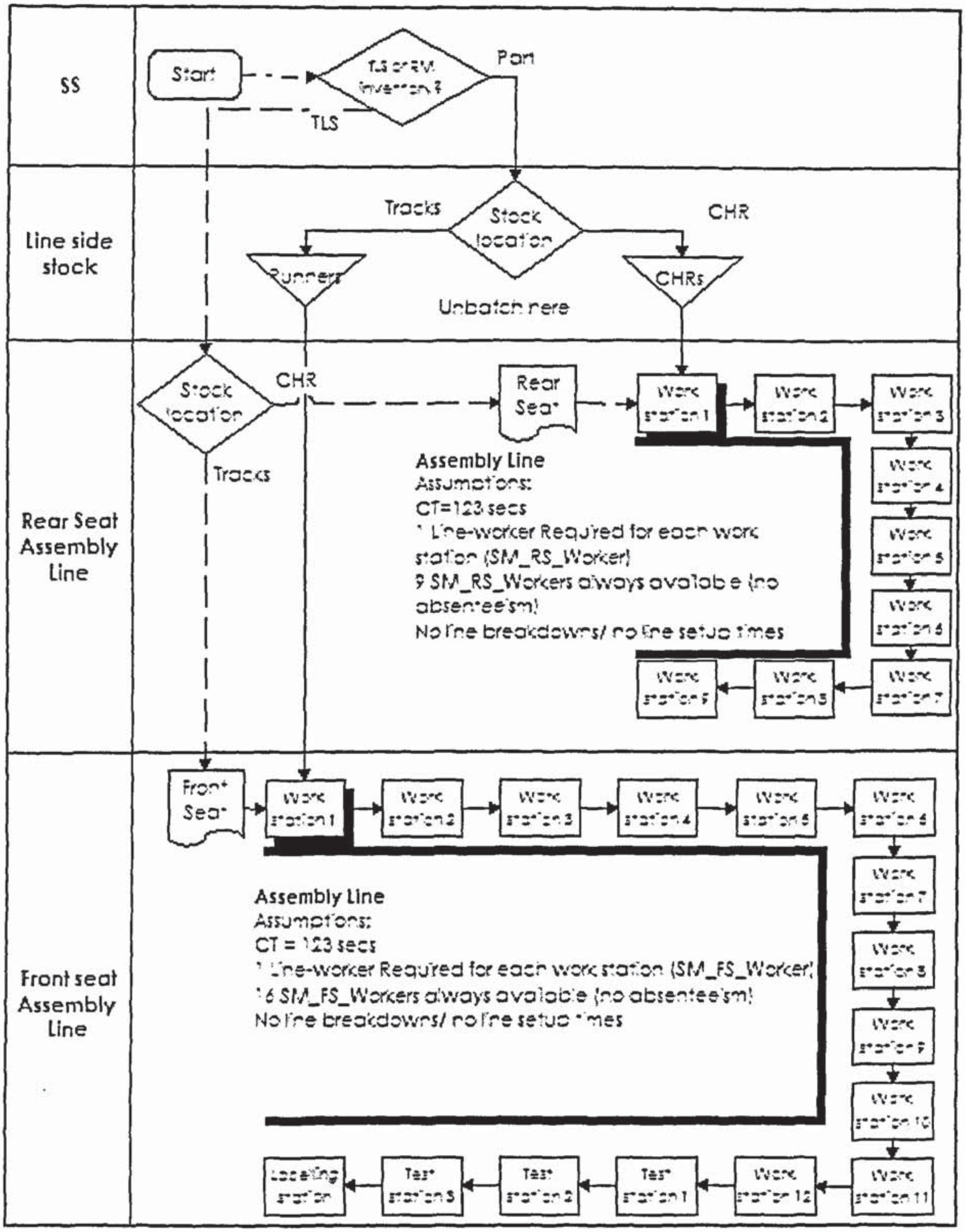



## 3PL central head rest and tracks storage process maps



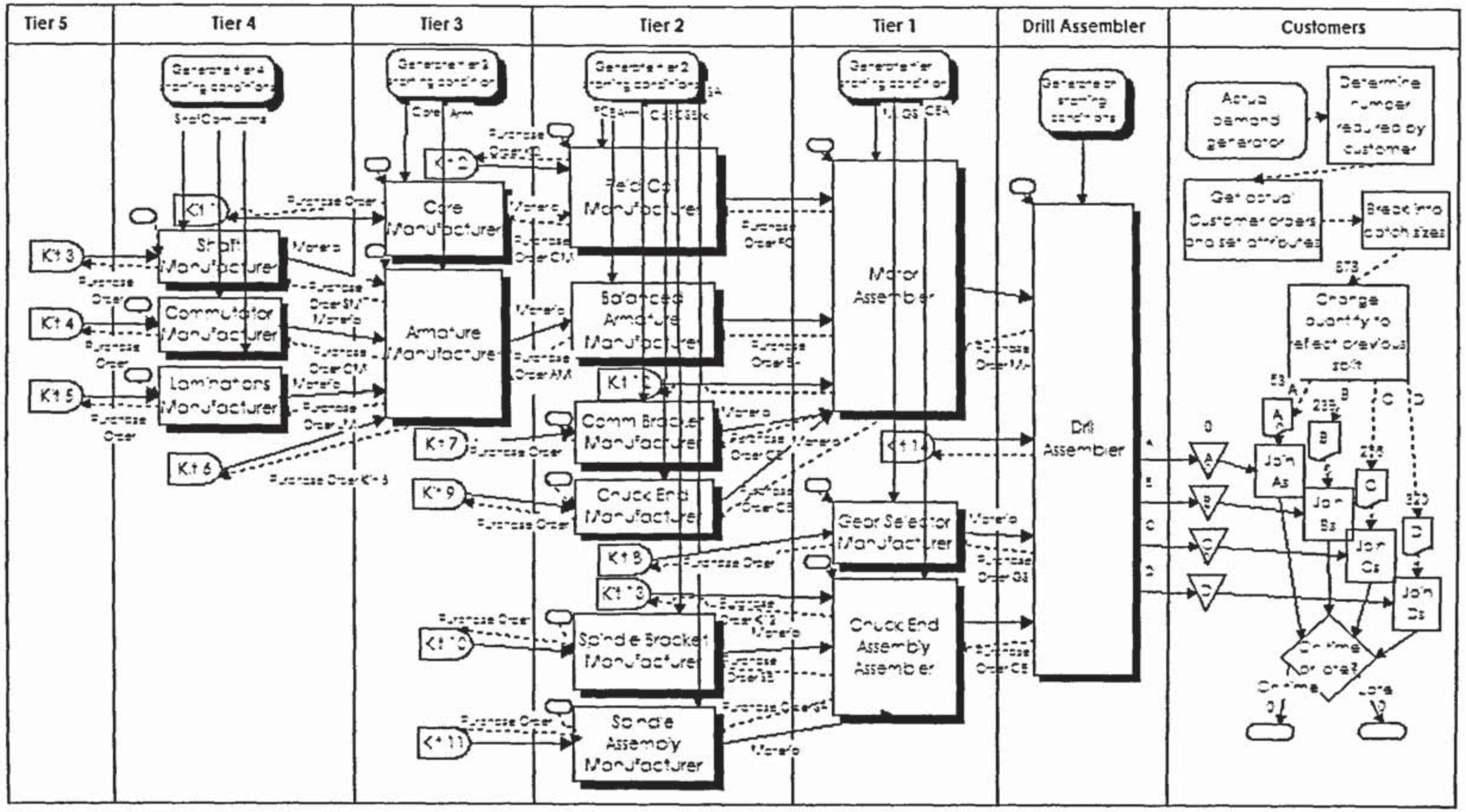



## Seat manufacturer process map

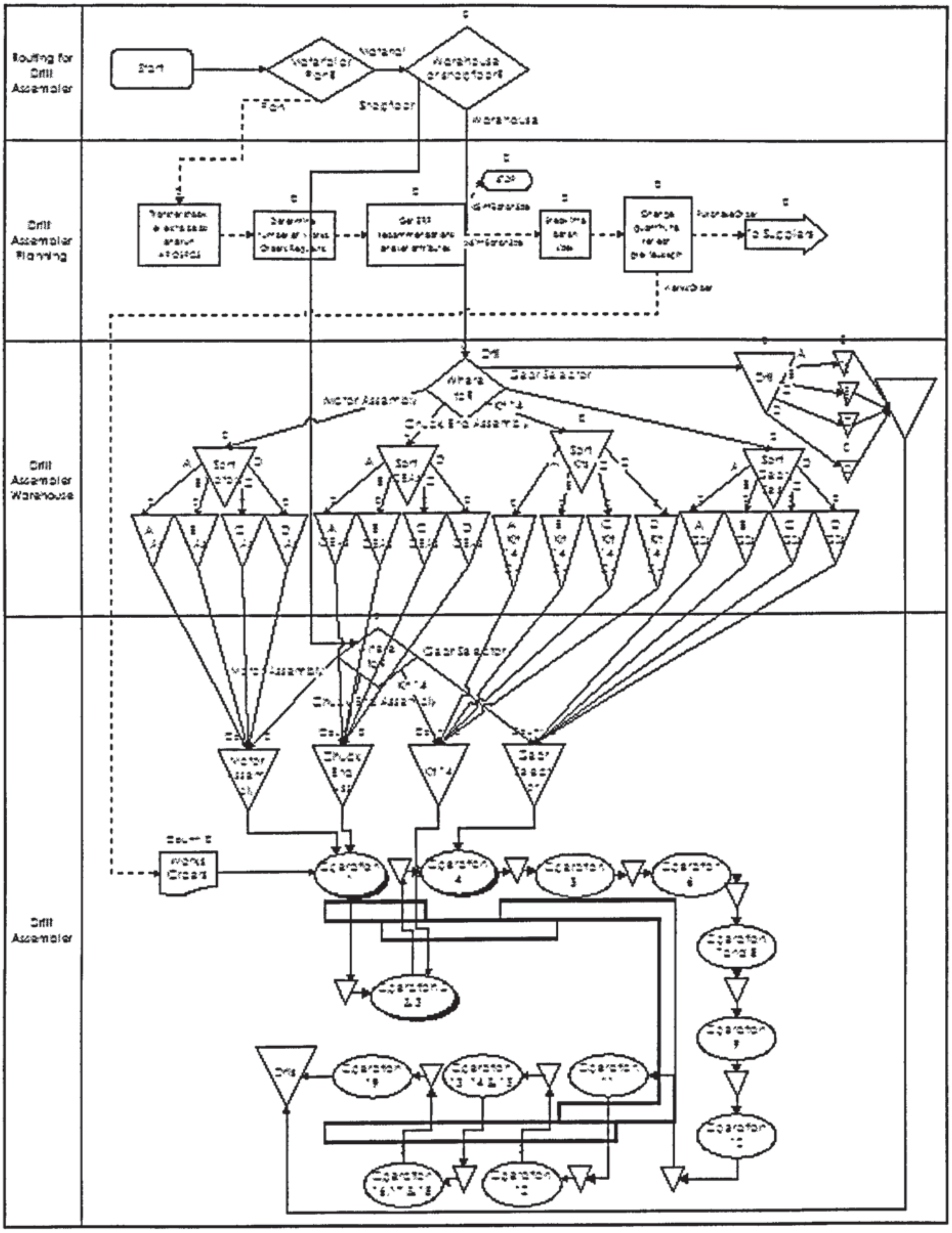


# Appendix 4 – Process maps of the drill manufacturer network

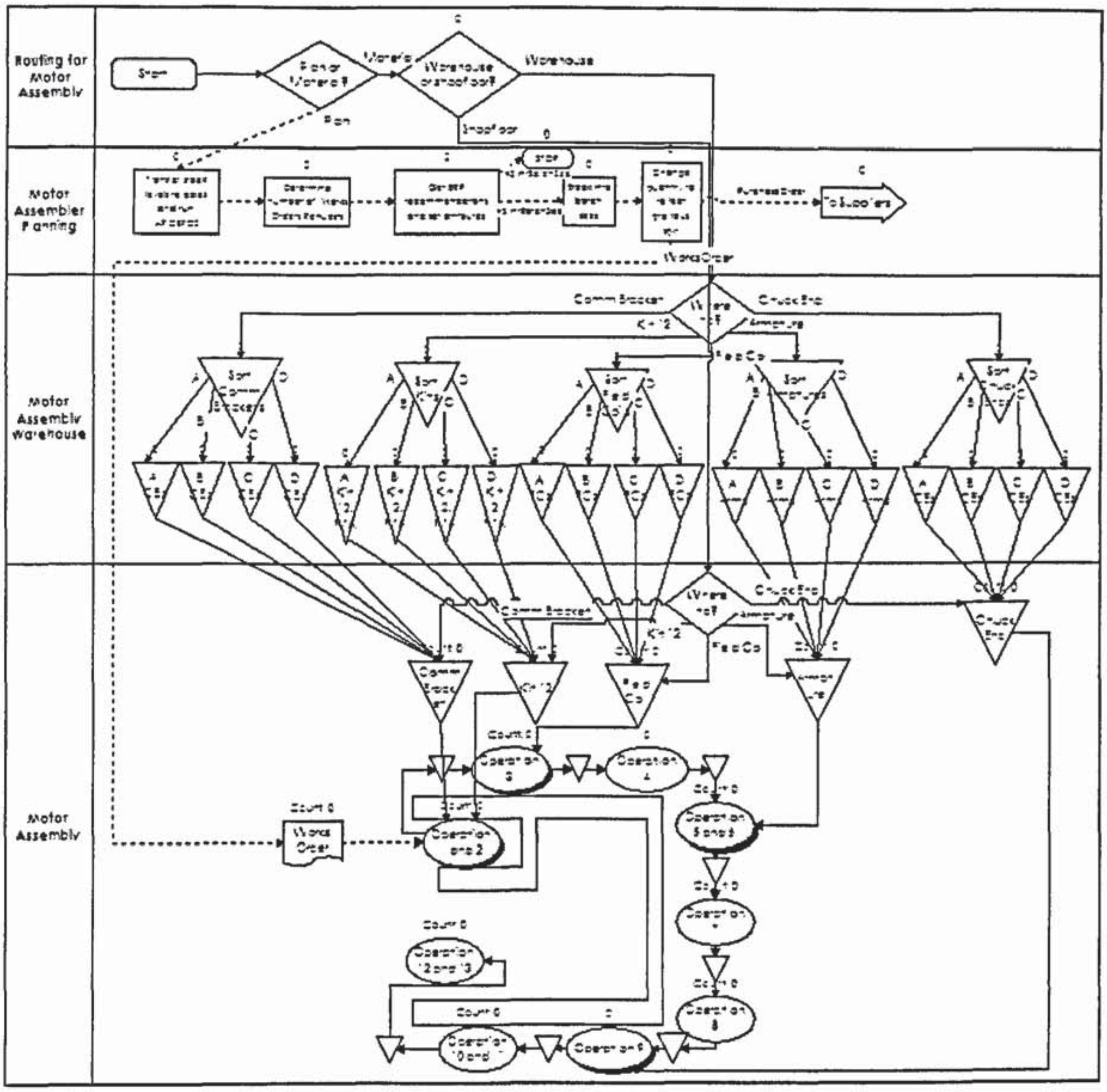
## High-level process map



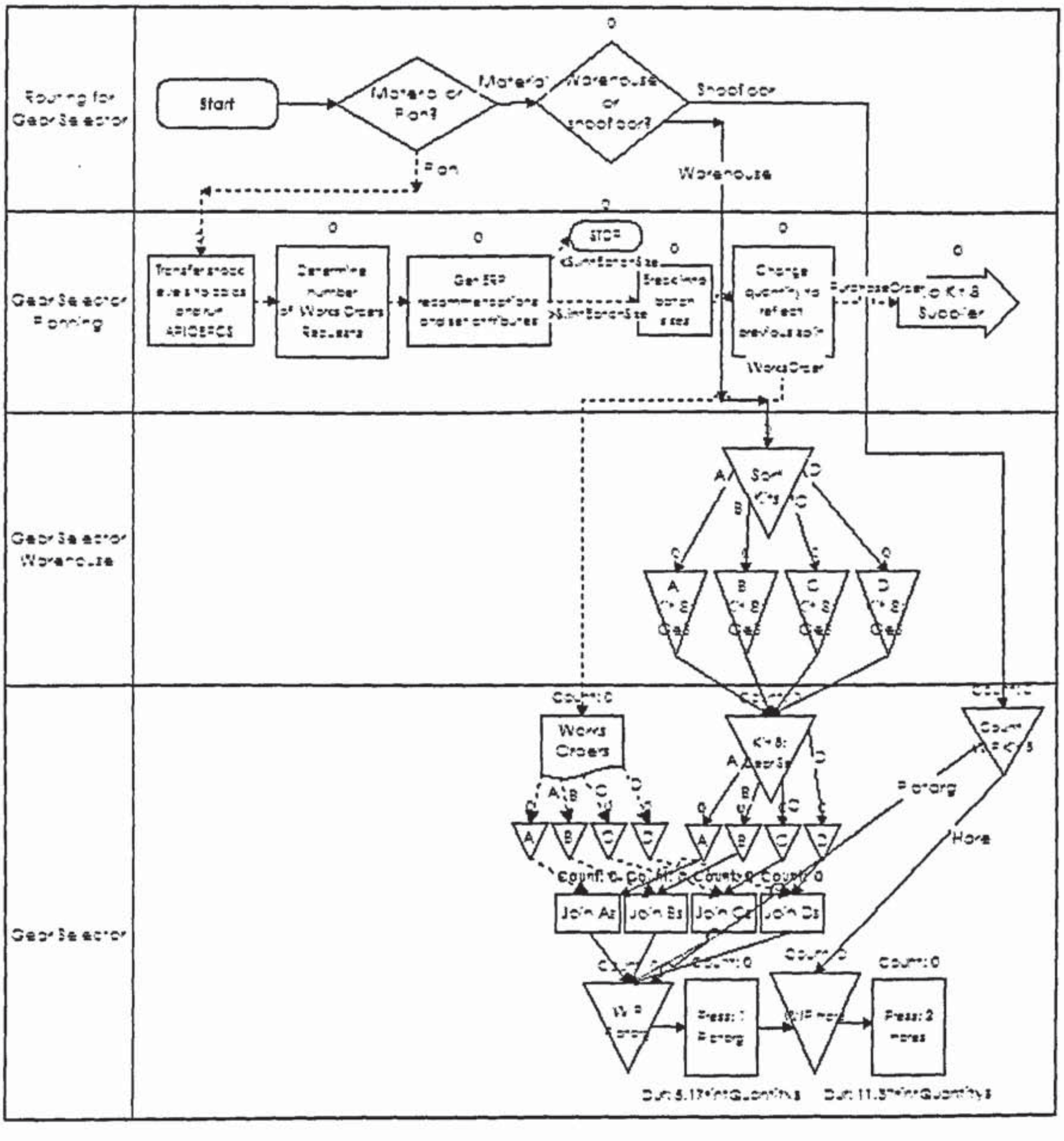
# Drill assembler process map



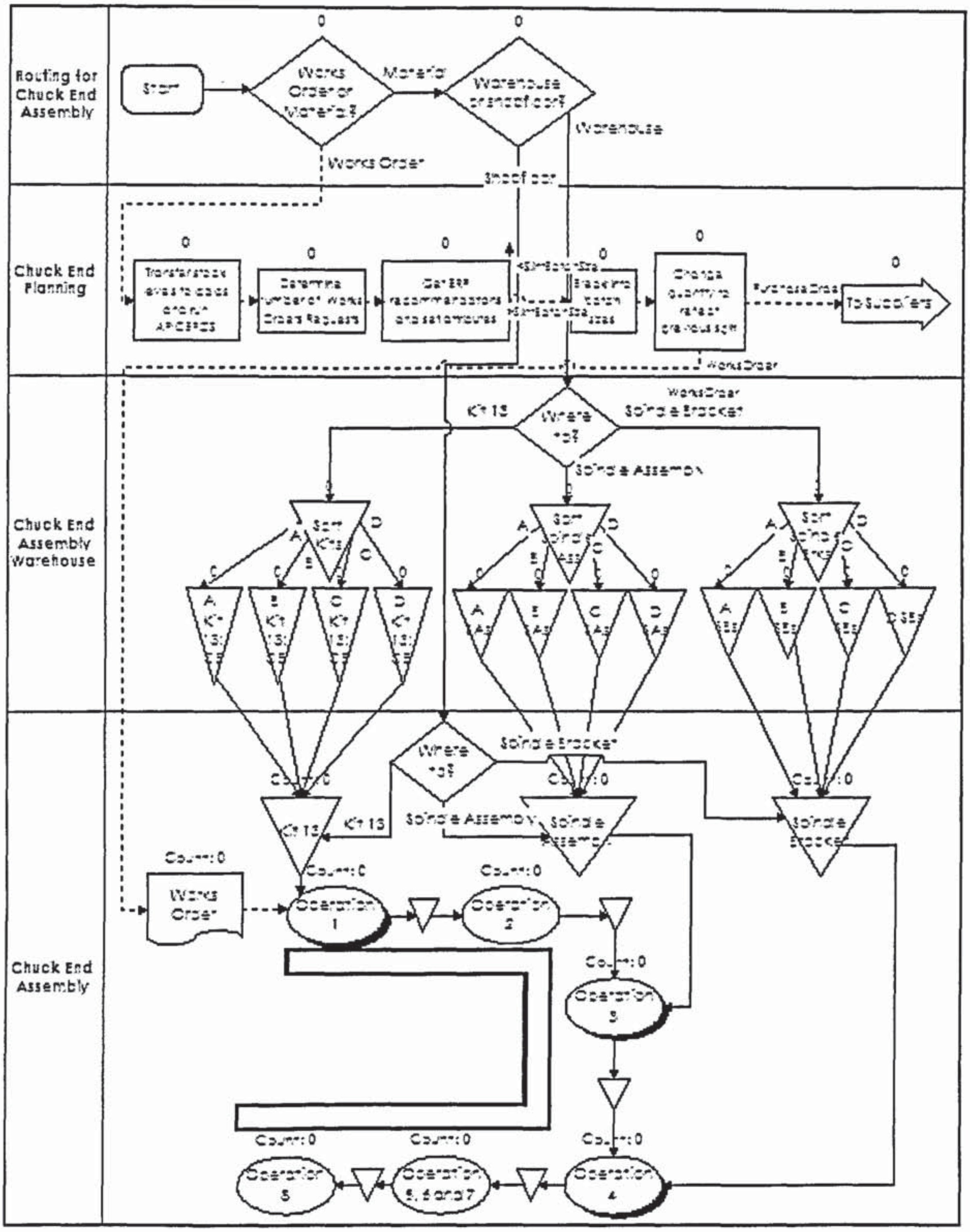
# Motor assembler process map



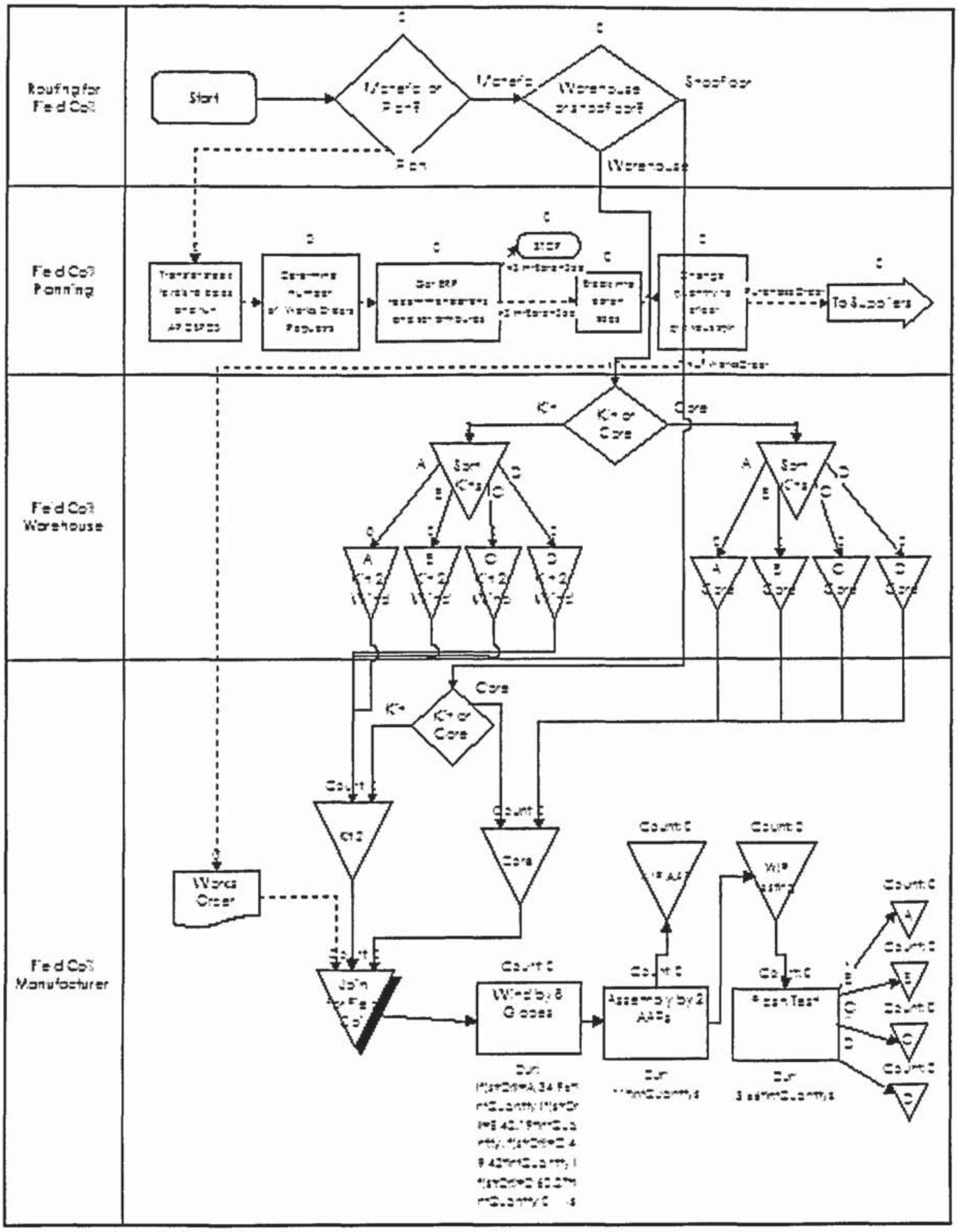
# Gear selector process map



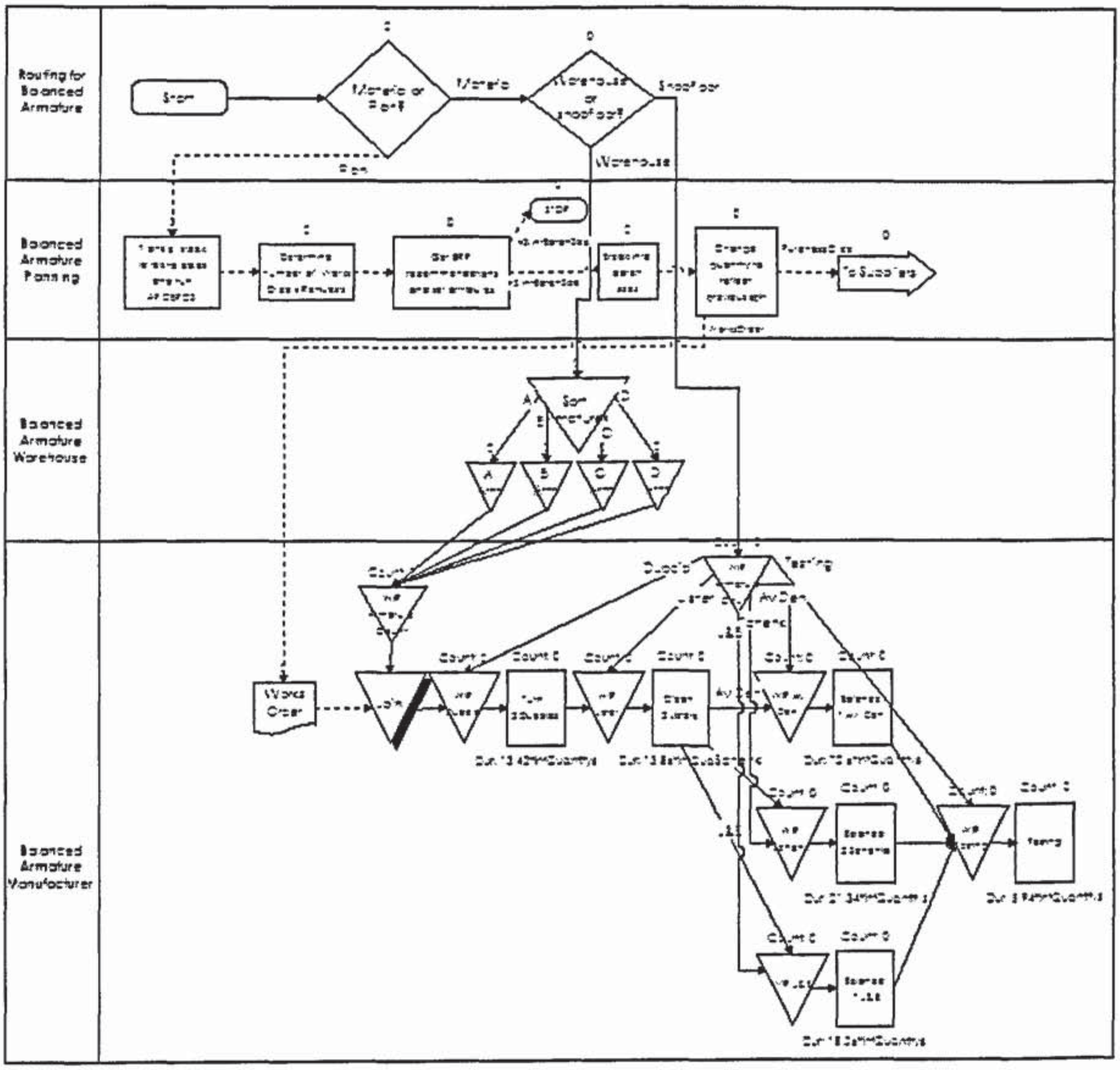
# Chuck end bracket assembler process map



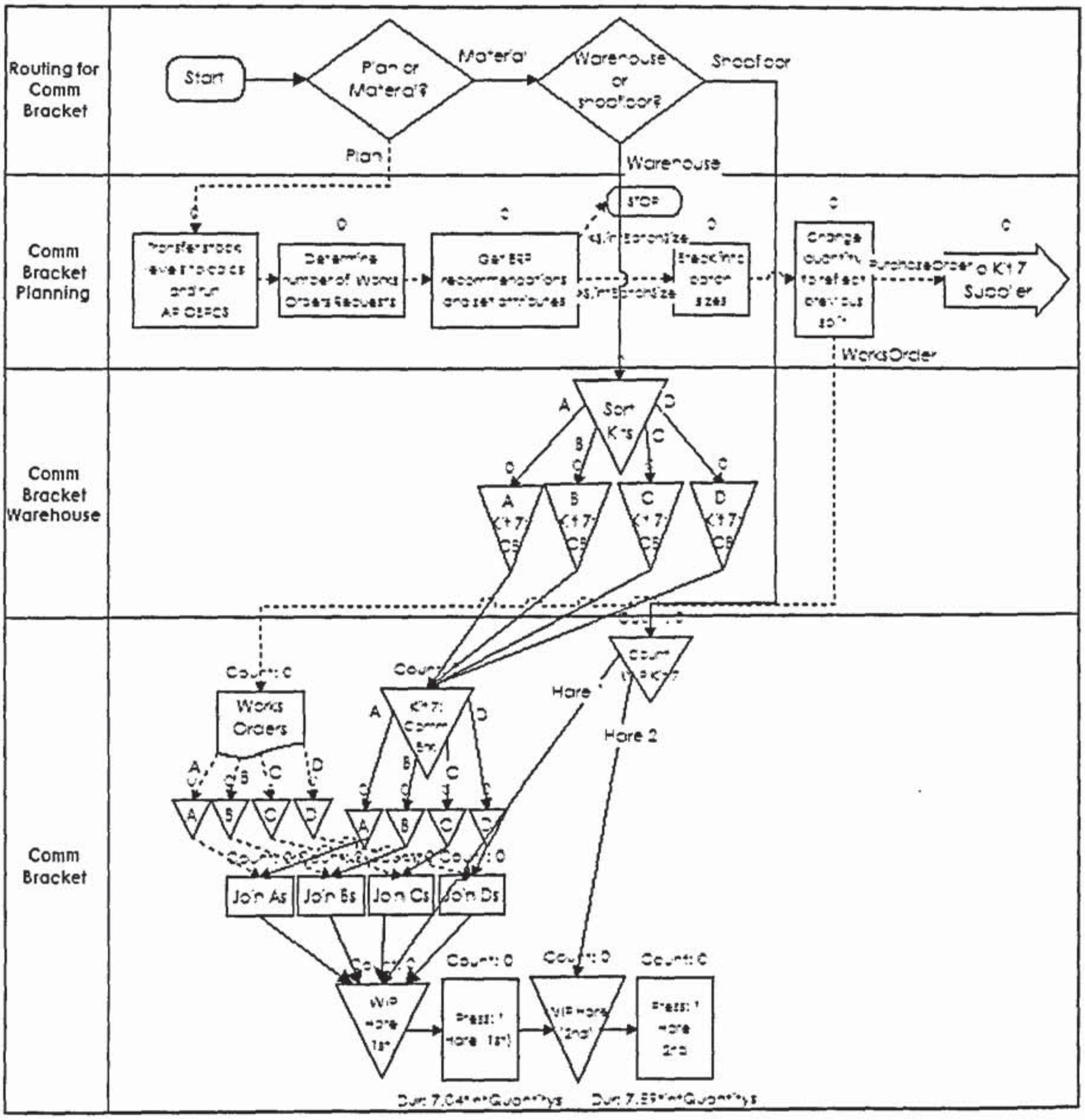
# Field coil manufacturer process map



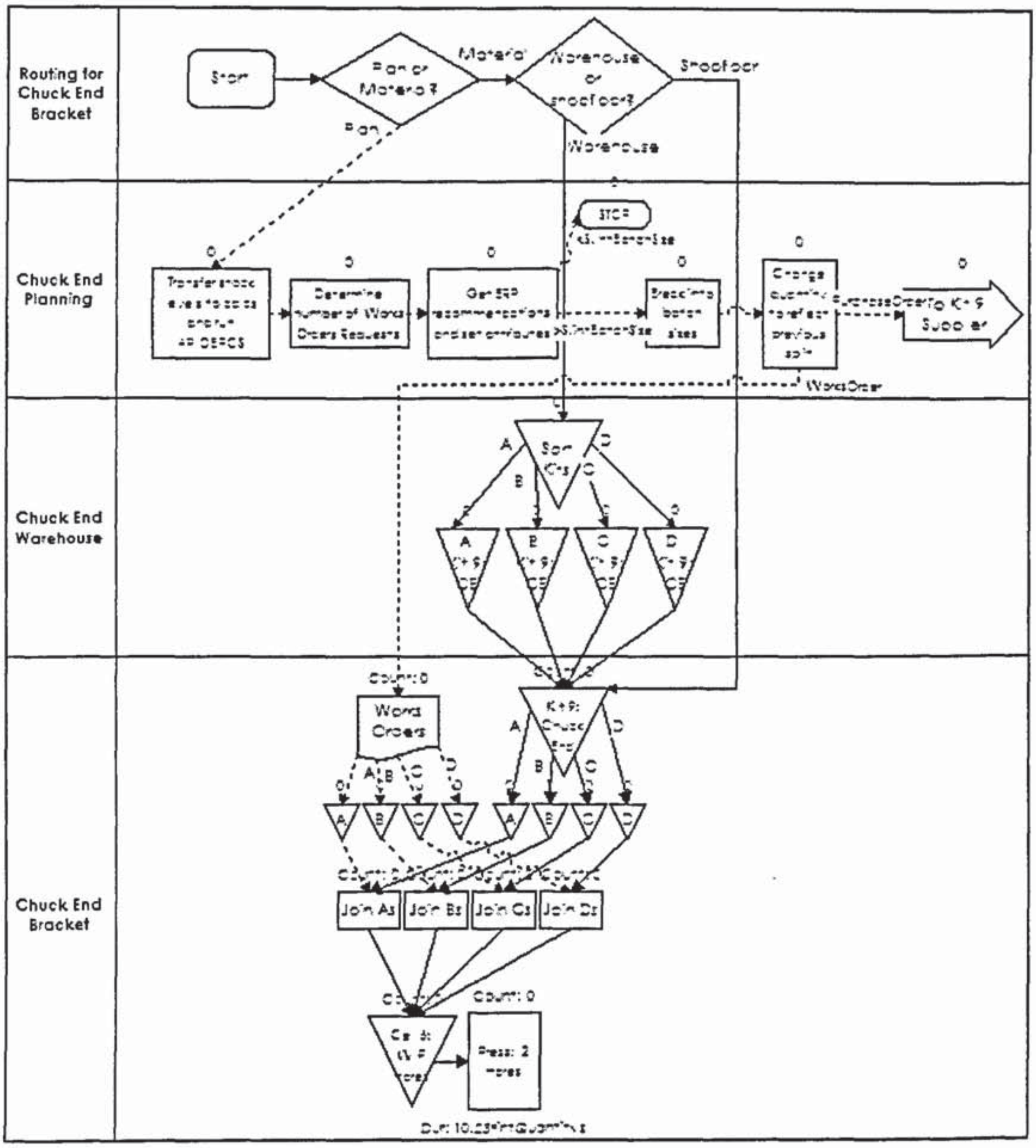
# Balanced armature manufacturer process map



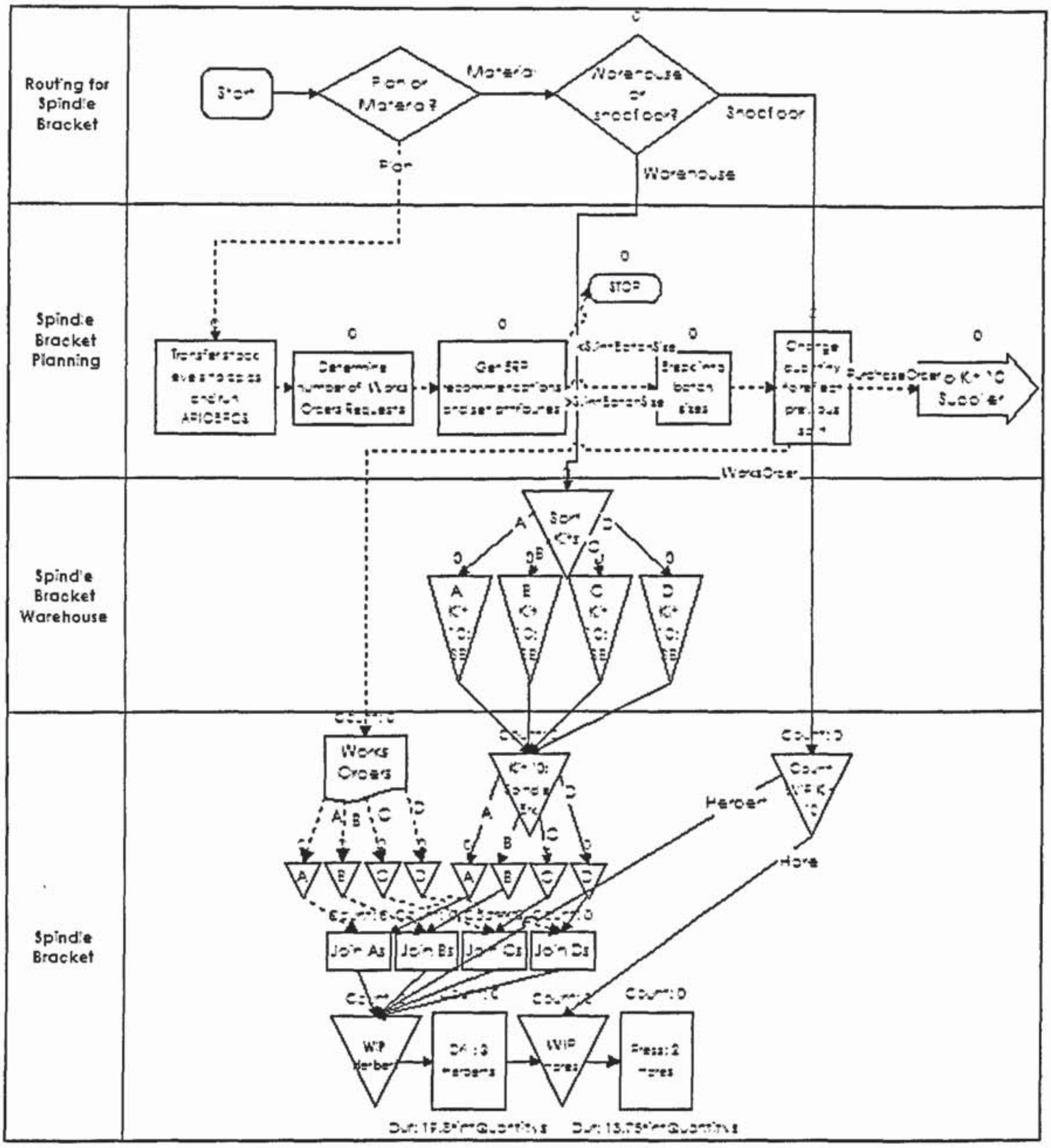
# Comm bracket manufacturer process map



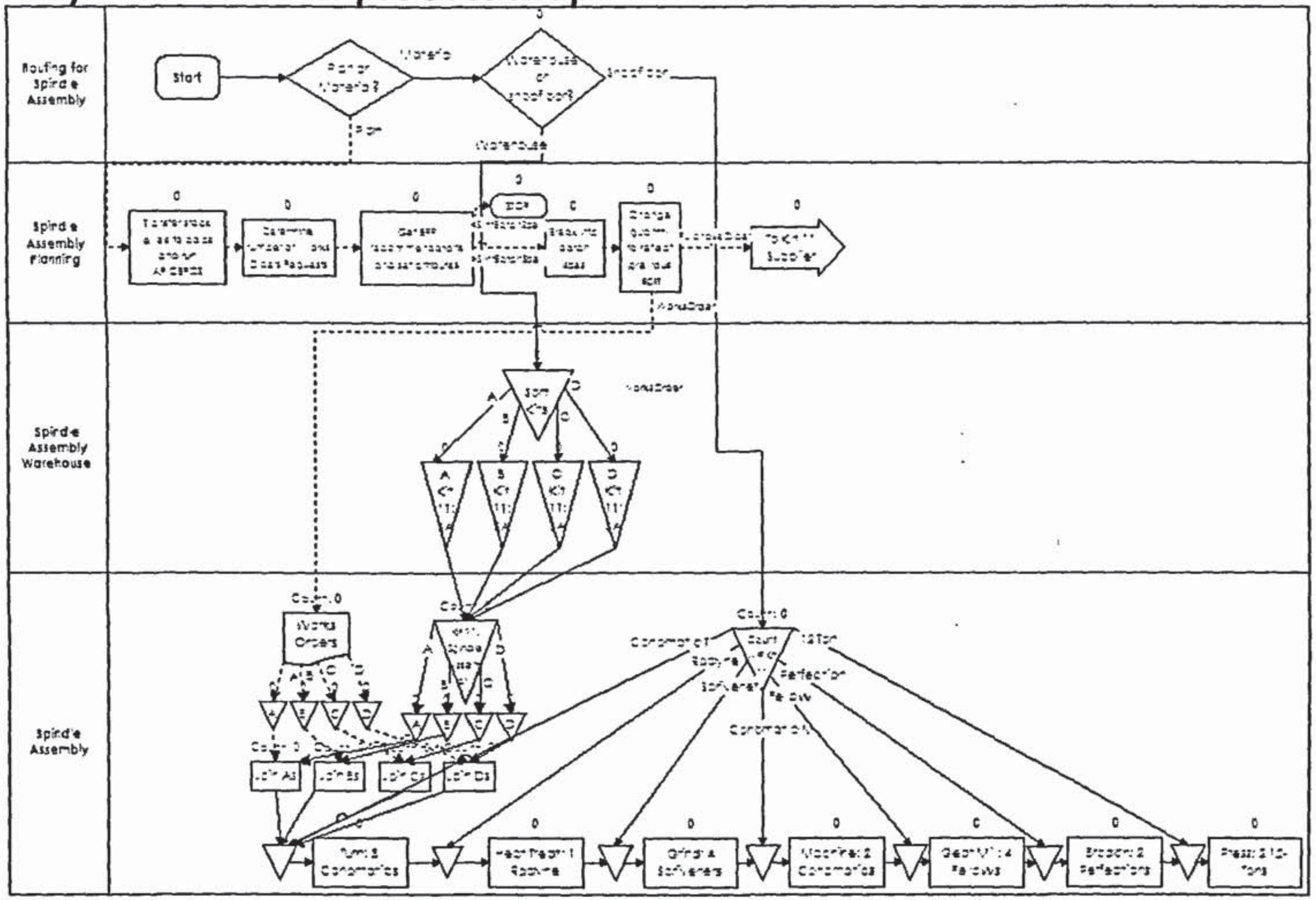
# Chuck end manufacturer process map



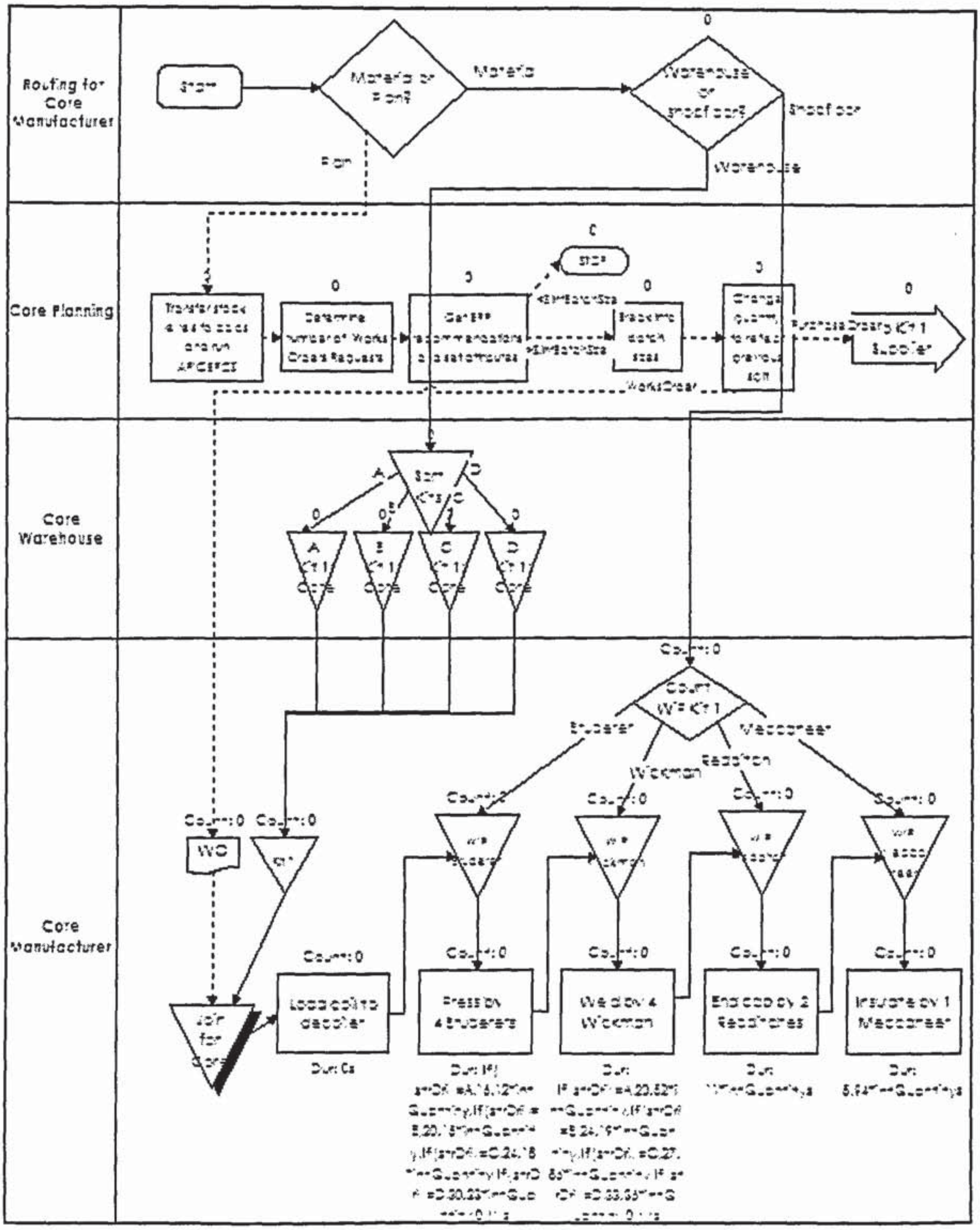
# Spindle bracket manufacturer process map



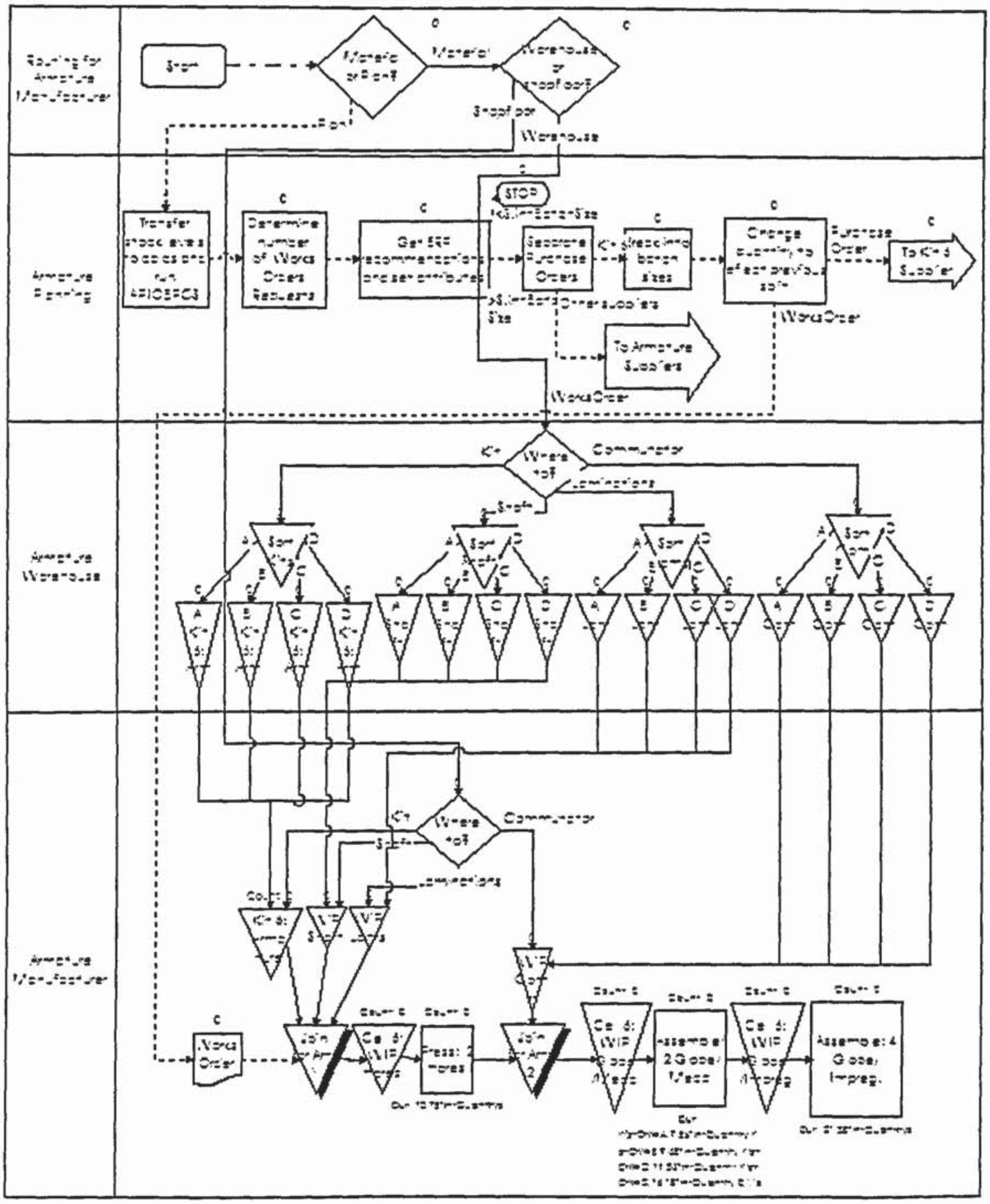
## Spindle assembly manufacturer process map



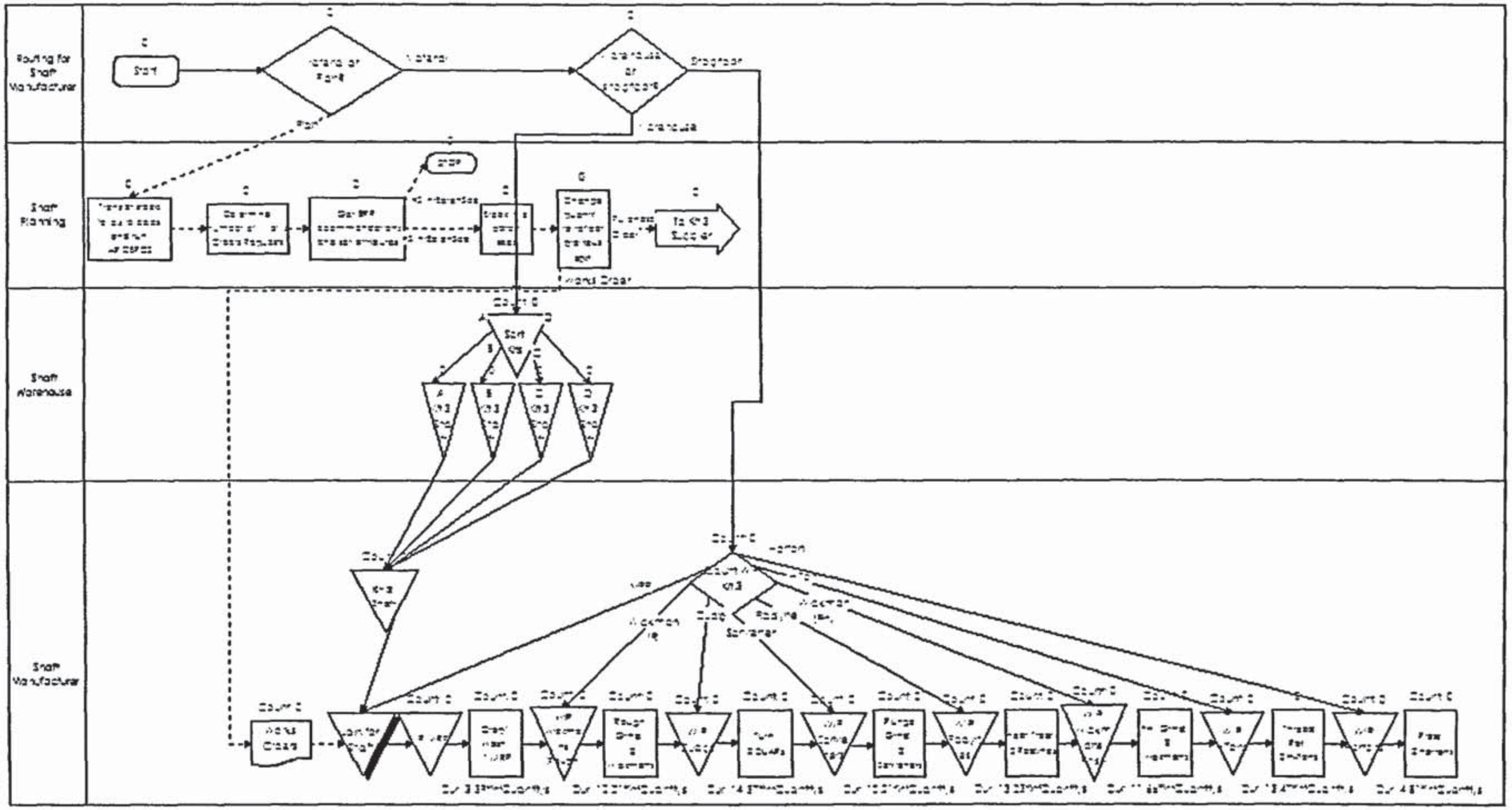
# Core manufacturer process map



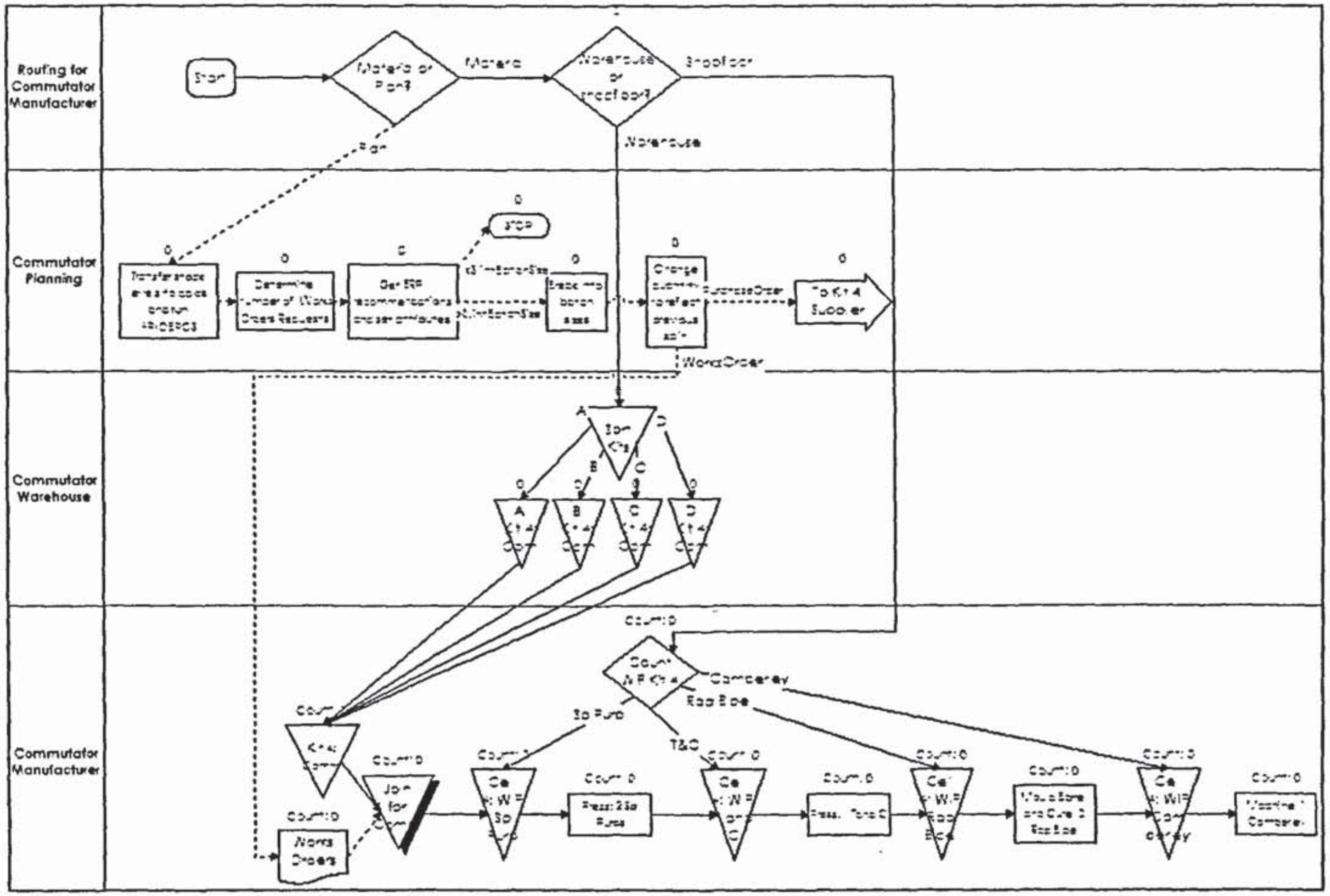
# Armature manufacturer process map



## Shaft manufacturer process map



# Commutator manufacturer process map



# Laminations manufacturer process map