THE UNIVERSITY
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An Evaluation of Integration Strategies Based on New Technologies in High-Volume Supply Chains.

Thesis submitted in accordance with the requirements of the University of Liverpool
for the degree of Doctor of Philosophy
By

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ABSTRACT

'The success of United Kingdom manufacturing is crucial to our country's prosperity, now and in the future. It generates around 3.5 million jobs directly and is the source for approximately two-thirds of all UK exports' (DTI, 2004).

Manufacturing is fundamental to the affluence of the UK economy. Thus, in 1999, Manufacturing 2020 was formed with the aim of bringing together the voices of business, government, the science base and others to identify threats and opportunities we are likely to face over the next ten to twenty years (Wright, 2000). Focusing on manufacturing supply chains, Wright (2000) identified technology as being the driver for improvements across all areas of the supply chain, taking out cost and reducing lead times. Within the broad category of technology the author acknowledged the 'Internet' along with 'advanced communication systems' as being central to the sharing of information. Information sharing and more significantly the benefits of information sharing have been well documented (Zhao *et al*, 2002 and Mason-Jones & Towill, 1997). Lee and Whang (2000) stated that recent advances in cost-effective information technologies (IT) has made the cost-benefit trade-off favourable toward well coordinated supply chain management (SCM).

This thesis considered and evaluated three supply chain integration architectures to facilitate next generation manufacturing. The three architectures were developed on the basis of a pre-determined framework. The formation of the framework was driven by the large body of literature supporting the three distinct architectures. Identifying the supply network environments to which the architectures should be applied was determined via a classification framework. This represented a core element of the research methodology. Having the generic integration architecture templates in place along with specific supply scenarios permitted the case studies to commence. The supply chain integration case methodology (SCICM) acted as a roadmap through each of the cases. The analysis highlighted the inadequacies in both the operating practices and information systems in operation. Where appropriate a prototype was developed to support the principle of a specific integration architecture. Finally, the key points to emerge from each case were drawn together and conclusions were formed.

The results of each case combined to conclusively respond to the research questions initiated at the outset. The Enterprise Application (EA) and Internet systems and technologies that support supply chain strategies were identified along with the components required to support the integration of these systems. The most appropriate supply chain information architectures were found to be very much dependent on the company's position within the supply chain along with its inherent attributes. Positive effects were on the whole experienced through introducing the architectures to the particular scenarios. However, it could only be decided on a case-by-case basis as to whether the benefits would outweigh the potential costs of an improved integration architecture. The classification (type) of the supply chain helps to determine the configuration of the proposed integration architecture. The key factors that helped identify the most appropriate configuration of the integration architectures were found to be the sector the companies operate within, their position within the supply chain and whether or not there is a specific supply chain strategy in operation. Finally it was found that the previous methods of communication seldom become redundant as a result of presenting an innovative integration architecture unless the business case to invest in such an architecture is sufficient.

Acknowledgements

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1 INTRODUCTION

1.1 Introduction

'The success of United Kingdom manufacturing is crucial to our country's prosperity, now and in the future. It Generates around 3.5 million jobs directly and is the source for approximately two-thirds of all UK exports' (DTI, 2004).

It is evident from the statement above that the manufacturing sector is fundamental to the affluence of the UK economy. Thus, in 1999, Manufacturing 2020 was formed with the aim of bringing together the voices of business, government, the science base and others to identify threats and opportunities we are likely to face over the next ten to twenty years (Wright, 2000). Gregory (2000) considered a number of key drivers that he believed along with other 2020 panel members would shape the manufacturing sector in the future. 'Mass customisation', 'shrinking supply chains', 'make-to-order' and 'simultaneous processes' represent a selection of characteristics proposed for future manufacturing excellence.

The Manufacturing 2020 report (Wright, 2000) focusing on manufacturing supply chains identified technology as being the driver for improvements across all areas of the supply chain, taking out cost and reducing lead times. Within the broad category of technology the author acknowledged the 'Internet' along with 'advanced communication systems' as being central to the sharing of information. Information sharing and more significantly the benefits of information sharing have been well documented (Mason-Jones & Towill, 1997 and Zhao *et al*, 2002). Lee and Whang (2000) stated that recent advances in cost effective information technologies (IT) have made the cost-benefit trade-off favourable towards well coordinated supply chain management (SCM). Examples of such technologies include client-server architecture, TCP/IP, relational DBMS (database management systems), ERP (enterprise resource planning) systems, EDI (electronic data interchange), object orientated programming environments, wireless communications and the Internet. Cronin (1995) stated that the Internet has been widely acknowledged as a technology that can make a considerable contribution to supply chain communication. The Economist Intelligence Unit and Meritus Consulting Services (E.I.U, 2000) confirm that the Internet holds the key to supply-chain excellence.

Taking the latter into consideration, the research presented herein considers the integration architectures to facilitate next generation manufacturing. In recognition of the various technologies available (Lee and Whang, 2000), three integration strategies are introduced based upon a pre-determined framework. Empirical evidence of the applications and architectures that have been applied to actual supply chain scenarios are presented to substantiate the proposed hypotheses. In essence it is hoped that this research will enable companies to, above all, understand the real benefits of information sharing, and secondly realise the opportunities in terms of technologies and configurations that are available.

In terms of the structure of this chapter, the following section further develops the background to this research, highlighting in greater detail the main drivers identified by leading industrialists and academics. Following this, the research questions, hypotheses and objectives are presented. The penultimate section considers briefly the contents of each chapter within this document, in order to provide the reader with a basic roadmap. The chapter concludes with a summary of the key points.

1.2 Background

The Foresight programme was launched in 1993 following a major review of different sectors within the UK. The main purpose of the programme was to: '*develop visions of the future; build bridges between business, science and government and increase national wealth and quality of life*' (Wright, 2000). In 1999, the structure of the Foresight Programme was revised and the outcome was three 'Thematic' panels and ten 'Sector' panels. The panels combined representatives from a range of sectors including the government. They were asked to consider the future and make recommendations for action. One of the three 'Thematic' panels was the 'Manufacturing 2020' panel, which was principally set up with the aim '*to stimulate now the action necessary to sustain a strong and globally competitive UK manufacturing sector in 2020 and beyond*' (Briggs, 2000).

The manufacturing sector is critical to the UK as this sector alone represents over 60% of all exports. Employment, wealth creation and quality of life all depend to a large extent, on this manufacturing base, as is demonstrated by Briggs (2000) in the report on global manufacturing trends. Within the many reports that have been published over recent years a number of areas have been identified as to where we are now and where we should be by the year 2020. Specifically the terms 'Mass Production', 'Long Pipeline', 'Sell From Stock', 'Sequential Processes', 'Cost of Inventory' and 'Wait in Line' were all acknowledged by Gregory (2000) as being the characteristics of modern day manufacturing. However, Gregory (2000) along with

'Manufacturing 2020' expect that the characteristics listed above will be replaced in future years by paradigms such as 'Mass Customisation', 'Shrinking Supply Chains', 'Make-To-Order' and 'Simultaneous Processes'.

It is this vision and its relationship to supply chain management that has provided the motivation for this research. Mason-Jones & Towill (1997) identified 'information' to be the driving force for all supply chains. This is also a view supported by Kehoe and Lyons (2000) (see figure 1.1). Next generation manufacturing will demand the individual entities of a supply chain to become increasingly more integrated.

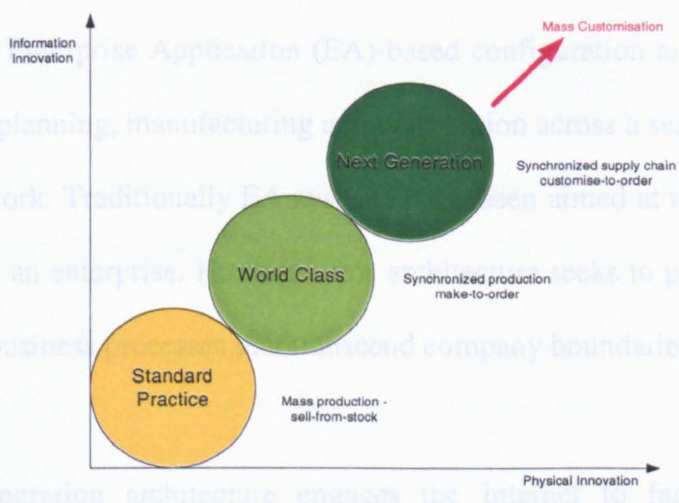


Figure 1.1 – FUSION (Kehoe and Lyons, 2000)

There are many opportunities to facilitate integration. Leading industry ERP companies such as SAP and i2 provide a rich set of integration technologies to seamlessly integrate their products with software installations residing elsewhere, SAP or otherwise. In addition, the rapid evolution of the Internet has eliminated many of the inefficiencies present within supply by reducing transaction costs and providing the ability for lower-tier suppliers to integrate with suppliers downstream (Yucesan & Wassenhove, 2002).

The next generation of manufacturing will be characterised by a far higher level of supply chain integration than exists today (Kehoe and Lyons, 2000). If the UK is going to remain a primary contributor to manufacturing innovation and success then a considerable amount of research and future thinking will have to follow in the area of information integration.

1.3 Research Questions

This study identifies and applies three generic integration architectures to a selection of supply chain environments (case studies). The integration architectures were formulated through an extensive review of the literature. The first integration architecture, the Enterprise Application (EA)-based configuration aims to seamlessly connect supply, planning, manufacturing and distribution across a series of companies in a supply network. Traditionally EA systems have been aimed at tightly integrating processes within an enterprise. However, this architecture seeks to provide the means to integrate the business processes that transcend company boundaries.

The second integration architecture engages the Internet to facilitate improved information integration. The Internet's status as a viable communication medium has been strengthened by the substantial selection of Internet tools and technologies that have emerged in recent years. Thirdly, a hybrid-based integration architecture is considered. This is one which seeks to improve the information communications of a particular company via methods and resources that the company already has in place. It is expected that the first two architectures will both contribute towards the outcome of this configuration.

A classification framework was developed to identify the supply network environments to which the architectures should be applied. The performance of each network was closely monitored prior to and following one of the integration strategies being prototyped. In summary, this research provides an empirical evaluation of integration strategies based upon a range of technologies in an array of diverse environments. With all these factors in mind, this research sought to answer the following questions:

1. Which Enterprise Application (EA) and Internet systems and technologies are available to support supply chain strategies between trading partners situated at different levels of a supply chain?

2. Which components are required to support the integration of these systems?

3. Based upon the identified technologies and systems, what would be the most appropriate supply chain information architectures?

4. What are the effects on the supply chain of implementing systems to support these strategies? i.e. what are the benefits? Do the benefits outweigh the potential costs?

5. Does the classification (type) of the supply chain alter the configuration of the proposed integration architectures?

6. Do the previous methods of communication become redundant as a result of presenting a innovative integration architecture?

1.4 Hypotheses

The hypotheses supporting this research are:

1. *The Internet is an efficient, cost effective and viable means of integrating the activities of business units operating upstream of an Original Equipment Manufacturer (OEM).*
2. *Modern day Enterprise Applications can integrate to such an extent that simultaneous processes can take place.*
3. *Modern day supply chains are hindered by the lack of, and quality of valuable information.*

1.5 Research Objectives

Having defined the research questions it is necessary to demonstrate how satisfactory outcomes to each of the questions listed in section 1.3 are to be achieved. Therefore, at the outset of this research a set of objectives were formulated to target each of the research questions. The research objectives were as follows:

- **Objective 1**

To review the relevant literature concerning supply chains (SC), supply chain management (SCM), supply chain challenges, supply chain structures and solutions and supply chain systems (linked with Objective 3).

- **Objective 2**

To develop a comprehensive classification framework to help identify and distinguish each of the case studies to be undertaken.

- **Objective 3**

To critique the specific literature and evaluate contemporary developments in both academic circles and by commercial bodies in terms of supply chain information systems to facilitate integration.

- **Objective 4**

To design, develop and apply three generic integration architectures to each of the case scenarios identified within the classification framework.

- **Objective 5**

Complete a series of cross-sectoral case studies via the application of a structured methodology.

- **Objective 6**

To prototype an integration application or modify an existing system based upon one of the three integration architectures designed to support the specific supply chain strategy of the company(s) involved.

- **Objective 7**

To evaluate the performance of applications/proposals implemented as part of this research, particularly with regards to the performance of the particular chain under analysis.

- **Objective 8**

The final objective of this project is to consider if a relationship can be forged between the classification of the supply chain and the appropriate integration architecture. This encompasses an evaluation of the proposed integration architectures.

1.6 Thesis Contents Overview

This section briefly describes the contents and structure of this research. Figure 1.2 illustrates the research framework that was adhered to throughout the duration of this study.

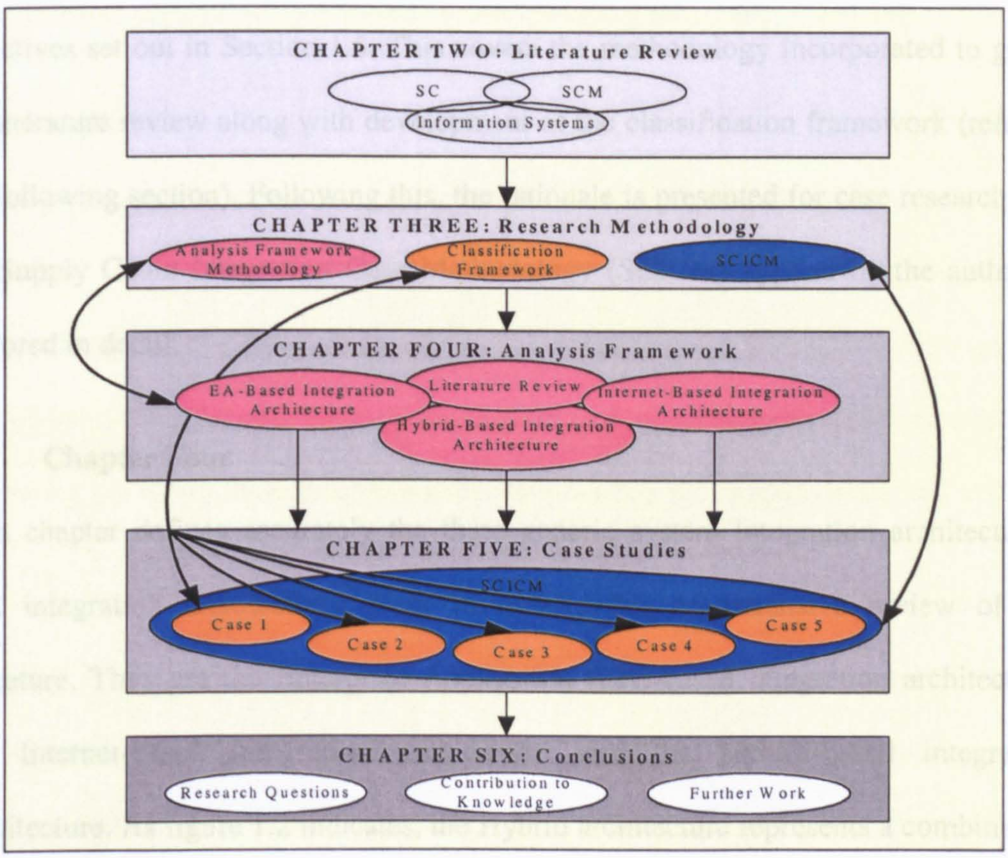


Figure 1.2 – Research Framework

Discussing each chapter briefly:

- **Chapter Two**

This chapter has been divided into two primary sections, covering each of the topics on which this research is based. The first section discusses the core concepts of supply chains and supply chain management (SCM). The second section explores the systems that function within supply chains. Both communication media (EDI, web, fax, telephone) and also specific planning systems (MRP, ERP MRPII, SCM) are examined. As figure 1.2 illustrates a considerable overlap exists between the topics discussed.

- **Chapter Three**

This chapter describes the research approach that was used to achieve the research objectives set out in Section 1.5. This covers the methodology incorporated to guide the literature review along with development of the classification framework (refer to the following section). Following this, the rationale is presented for case research and the Supply Chain Integration Case Methodology (SCICM) applied by the author is explored in detail.

- **Chapter Four**

This chapter defines accurately the three generic system integration architectures. The integration architectures were formulated via an extensive review of the literature. They are the Enterprise Application (EA)-based integration architecture, the Internet-based integration architecture and the Hybrid-based integration architecture. As figure 1.2 indicates, the Hybrid architecture represents a combination of the EA-based and the Internet-based integration architectures.

- **Chapter Five**

This chapter presents the case studies undertaken within this research. The case studies presented examine a selection of different companies operating in a range of different supply networks. Each of the companies studied was selected for its inherent attributes identified within the classification framework (refer to the following section). The constant that was evident in all the cases presented below is that they were all situated in high-volume (HV) environments:

Case 1 – **HV Process Manufacturing Study**; this study involved two companies, a manufacturer, and a supply chain solutions provider (SCSP). The brief here was to analyse information flow between the two companies. Following the initial analysis the three generic architectures were applied to the scenario. Determining the impact of a prototyped application represented the final stage of this case.

Case 2 – **HV FMCG Study**; in total there were three companies directly involved in this project, a manufacturer, a distributor and a retailer. This investigation involved the analysis of both the operational and systems performance of the supply network in which the three companies are positioned with a view to applying the three generic architectures to the mapped structure. A series of glass pipeline (GP) experiments simulating the effect of an information communication prototype represented the final stage of this case.

Case 3 – **HV Retail Study**; two companies, one of which could be split into two supply network participants formed the basis of this study. This investigation analyses the operational performance of the current vendor managed inventory (VMI) procedure along with a detailed examination of information systems infrastructure currently in place. Alternative generic architectures were designed and applied and a prototyped application was evaluated.

Case 4 – **HV Automotive Remanufacturing Study**; This study concerned two companies involved in the manufacture and assembly of automotive transmissions. Both companies sought a more flexible information system. Hence the three generic architectures were designed based on the initial structure. The Internet-based architecture was implemented and the final stages involved assessing the impact of this prototype.

Case 5 – **HV Automotive Study**; This project involved a total of five companies and represents the largest case study within this research. The study involved an extensive performance evaluation along with rigorous systems analysis to permit alternative architectures to be presented. An ISP assisted with the implementation of the Internet-based architecture and five glass pipeline (GP) experiments simulated the impact of the architecture based upon different parameters.

- **Chapter 6**

Chapter six represents the final Chapter within this thesis. This chapter considers the key themes that have emerged as a result of the research undertaken. The contribution to knowledge is put forward along with further work that can be carried out in this field of research.

1.7 Chapter Summary

This chapter has provided a clear and definitive introduction to this thesis. The vision of Manufacturing 2020 along with the Government initiatives and foresight that inspired this research, have all been introduced. The research questions have been considered, and the research hypotheses and questions established.

The work undertaken seeks to provide empirical evidence that will enable companies to understand the real benefits of information integration based upon the adoption of new technologies. The components necessary to ensure the success of this research have been introduced to provide a foundation from which to move forward.

2 LITERATURE REVIEW

2.1 Introduction

This chapter has been divided into two primary sections covering each of the topics upon which this research is based.

The first section discusses the core concepts of supply chains and supply chain management (SCM). The introduction to supply chains is accompanied by a review of the literature on modern day high-volume SCM. This is of particular significance to this research as each of the case studies discussed in Chapter 5 involves a high-volume supply scenario. The field of SCM is based very much around the challenges associated with supply chains. Following a brief introduction and history, a series of fundamental issues currently affecting SCM are examined. The final part of this section looks closely a selection of the supply chain structures that have emerged as policies to counteract the challenges identified earlier.

Part two concerns the systems that function within supply chains. Mason-Jones and Towill (1997) consider information enriched supply chains advocating technology as being significant in facilitating this vision. Thus, a historical development of supply chain information systems provides the foundations for this section. Both communication media (EDI, web, fax, telephone) and also specific planning systems (MRP, ERP MRPII, SCM) are examined. This systems review provided a suitable platform for the Analysis Framework Chapter (Chapter 4) to further investigate and consider the integration architectures and techniques that have been developed both in the literature and within academic circles.

2.2 Part One: The Supply Chain & Supply Chain Management

2.2.1 Introduction

The supply chain and the associated concept of supply chain management (SCM) form the basis of section 2.2 and this thesis as a whole. The supply chain and its various configurations represent the core of this research and so there was a necessity to comprehensively investigate the literature within this field. Having discussed supply chains in their most basic form the emphasis of this review moves towards high-volume supply chains. High-volume supply within different sectors is a central theme to this research, and each of the case studies presented in this thesis concerns a high-volume scenario.

Supply chains are notorious for their high levels of inventory, high costs and general instability. Numerous authors (Forrester, 1958; Burbidge, 1961,1984; Sterman, 1989; Towill and Naim, 1993; Towill, 1996; Lee *et al*, 1997a, 1997b) have documented their perceptions of the causes. Consequently it was important to review the literature concerning demand amplification and its associated origins. Supply chain management evolved in order to confront the problems of excessive inventories, high costs and general dissatisfaction within operational supply chains. It is appropriate, therefore, that the evolution of SCM and its modern day structures should be investigated.

The final part of this section looks closely at the supply chain structures that have emerged as policies to counteract challenges such as demand amplification. This section will examine the current schools of thought and in what context they are used. A summary concludes the first part of this literature review.

2.2.2 The Supply Chain

2.2.2.1 Introduction

The 'Supply Chain' (SC) has for many years been the focus of considerable research. Its value is deemed to be so great that numerous organisations invest large sums of money for SC development each year. The topic is vast, and subsequently, authors have approached the area from a number of different angles. The simplified view taken by a number of the authors can lead many to take the perspective that the supply chain has a linear structure (figure 2.1), conveying goods from suppliers to manufacturers, wholesalers, retailers and finally to the customer.

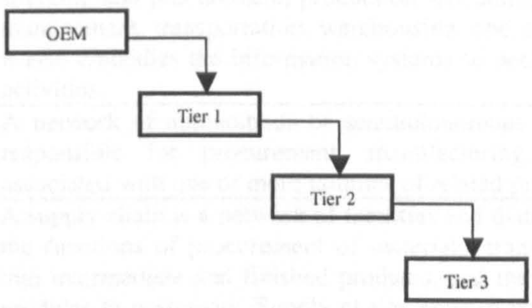


Figure 2.1 - A Linear Supply Chain Structure

However, in reality this notion is over simplistic. Modern day supply chains are supply webs or networks, rather than chains, with multiple customers and multiple suppliers as depicted in figure 2.2, (Wright, 2000; Chandra & Kumar, 2000).

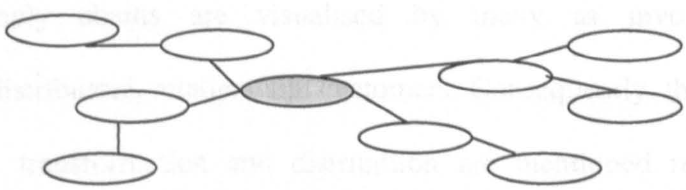


Figure 2.2 - A Network of Suppliers and Customers

2.2.2.2 Definitions

A myriad of supply chain definitions have been proposed over the years, and a selection are displayed in table 2.1.

Author	Definition
Stevens, J. **(1989)**	A system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via the feed forward flow of materials and the feedback flow of information.
Lee, H.L. & Billington, C. **(1995)**	A network of production and distribution facilities that procures raw materials, transforms these materials into intermediate and finished goods and distributes the finished goods to customers.
Cox, J.F., Blackstone, J.H. & Spencer, M.S. **(1995)**	1. the process from the initial raw materials to the ultimate consumption of the finished product linking across supplier-user companies; and 2. the functions within and outside a company that enable the value chain to make products and provide services to the customer
Quinn, F.J. **(1997)**	The supply chain encompasses all of those activities associated with moving goods from the raw-materials stage through to the end user. This includes sourcing and procurement, production scheduling, order processing, inventory management, transportation, warehousing, and customer service. Importantly, it also embodies the information systems so necessary to monitor all of these activities.
Swaminathan, J.M., Smith, S.F. & Sadeh, N.M. **(1998)**	A network of autonomous or semiautonomous business entities collectively responsible for procurement, manufacturing and distribution activities associated with one or more families of related products
Ganeshan, R. & Harrison, T.P. **(1996)**	A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. Supply chains exist in both service and manufacturing organizations, although the complexity of the chain may vary greatly from industry to industry and firm to firm.
Gunasekaren, A., Macbeth, D.K. & Lamming, R. **(2000)**	A worldwide network of suppliers, factories, warehouses, distribution centers, and retailers through which raw materials are acquired, transformed, and delivered to customers

Table 2.1 - Supply Chain Definitions

It is true to say that a number of common themes arise in each of the above definitions. Supply chains are visualised by many as involving suppliers, manufacturers, distributors, retailers and customers. Consequently, the principal areas of procurement, transformation and distribution are mentioned repeatedly in the definitions above.

Stevens (1989) takes a systematic view of the supply chain in which there is a forward flow of materials and backward flow of information. Quinn's definition extends that of Stevens and includes processes such as production scheduling, order processing and inventory management. Lee and Billington (1995) do not tackle the information flow theme and take the more simplistic view where raw materials are transformed to finished goods and subsequently distributed. This is a stance taken by each of the other definitions in the table. For the purpose of this thesis, the definition proposed by Quinn (1997) is used as it incorporates all of the processes mentioned earlier, whilst also citing the systems required to monitor all of these processes.

2.2.2.3 High-Volume Environments

Having introduced the supply chain, the motivation behind the decision to pursue high-volume configurations and more specifically the automotive, process and FMCG sectors is now considered. The introduction to this research recognised the key characteristics of mass customisation and make to order as being the future of manufacturing in the UK. Bovet and Sheffi (1998), Briggs (2000) along with Kehoe and Lyons (2000) all stated that future manufacturers would be required to mass customise, that is produce high-volumes of individualised products. Kehoe and Lyons (2000) continue, referring to a selection of high-volume manufacturers such as Dell that have actually managed to achieve mass customisation, albeit in relatively low-level of both product and supply chain complexity. Hence, the true challenge clearly lies in the ability to integrate the supply networks of the more complex, economy-driving high-value manufacturing sectors.

With this in mind the following sections consider the automotive, process and fast moving consumer goods (FMCG) sectors. The classification framework (Chapter 3) along with the attributes inherent to each of these sectors led to the selections of the three sectors. Being the most complex the automotive sector is considered first and foremost. Following this process industry supply chains are examined as they encompass a broad range of products (steel, aluminium, pharmaceuticals). Finally FMCG supply chains are scrutinised. The FMCG sector consists of shallow supply chains often involving highly perishable products.

2.2.2.4 High-Volume Automotive Manufacturing Supply Chains

A considerable amount has been written about the automotive sector over the years for two principal reasons. Economists have looked to the automotive sector when trying to gauge the wealth of the economy (GDP), whilst others (academia, industry analysts) study the sector for the extensive complexity and variability of its supply network. The automotive sector represents possibly the most complex of supply networks, (Baumgaertel *et al*, 1998). The authors rationalise its complexity by stating that the final product is extremely complex and highly customisable, produced in high volume, and from start to completion, starting with the raw material, takes a long time.

The AUTOCHAIN project (AUTOCHAIN, 2001), which came to end in late 2000, provided an in-depth analysis from which considerable information could be extracted for the purpose of this literature review. The current automotive landscape is being determined by a number of strategies brought about via industry leaders and particular economic climates. Globalisation is becoming increasingly apparent as OEM's with well established markets in developed countries are now looking to the future markets of South and Central America, Eastern Europe, Asia-Pacific, and eventually Africa where demand is expected to increase (Bovet and Sheffi, 1998). Hand in hand with the theme of globalisation is the movement towards consolidation within the automotive sector. The automotive components industry has been among the most active sectors in terms of mergers and acquisitions, as well as joint ventures and co-operation agreements.

Platforms are another area in which changes are being witnessed as manufacturers are looking to reduce the number of basic platforms underlying their model range. The benefits of this are a reduction in development time and cost of new models and also limited duplication of engineering and components. Partnerships are arising in previously hostile buyer-supplier relationships. New long-term partnerships are now being encouraged between key component suppliers. The benefits can range from having an exclusive long-term deal to supply components to suppliers being invited to participate early in the development of a new vehicle or concept.

Modularisation is a concept that has grown considerably in popularity in recent years. OEM's no longer want the trouble of initiating partnerships with hundreds of suppliers so increasingly they are sourcing complete modules to their first tier suppliers. This provides them with the opportunity to simplify their own production facility by transferring responsibilities to selected suppliers.

Setting the scene for the modern day automotive sector now permits us to move forward and look at the structure of the actual supply chain. In reference to research undertaken by Parunak *et al* (1998), supply networks, in general take the form of an hourglass, with an OEM at the centre. Figure 2.3 is oversimplified, but does represent the general pattern of a supply network where raw materials, parts and subassemblies move in the lower half of the hourglass towards the OEM, and finished goods move from OEM to customers.

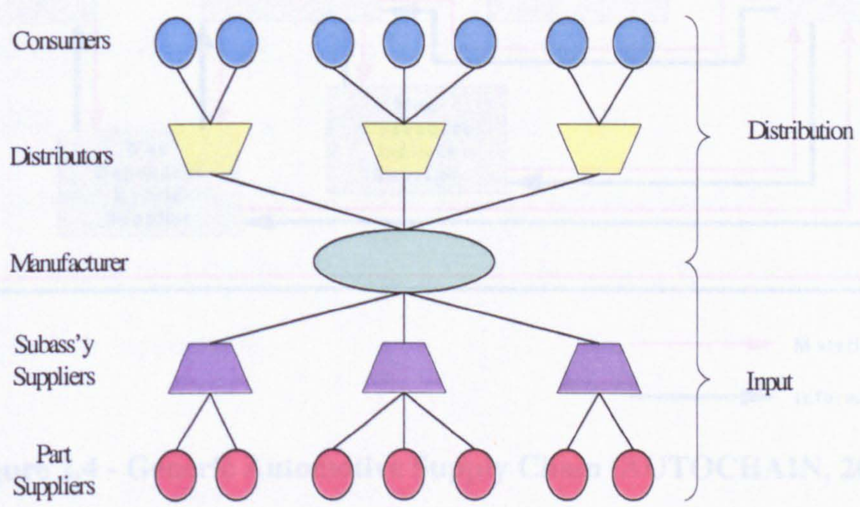


Figure 2.3 - Supply Network Hourglass (Parunak *et al*, 1998)

Whilst the simplified hourglass model is useful in understanding some basic supply chain principles, it does not really reveal much about the unique characteristics of the automotive supply chain. Referring back to the AUTOCHAIN research once again, figure 2.4 shows the essential topology of the European automotive supply chain.

Figure 2.4 exemplifies the key types of organisations (9 blue boxes) involved and the nature of their relationships in the supply chain (AUTOCHAIN, 2001). As mentioned earlier, the notion of having tiers in a supply chain is dated and over simplistic and in fact there is a complex members network involving multiple relationships (Baumgaertel *et al*, 1998).

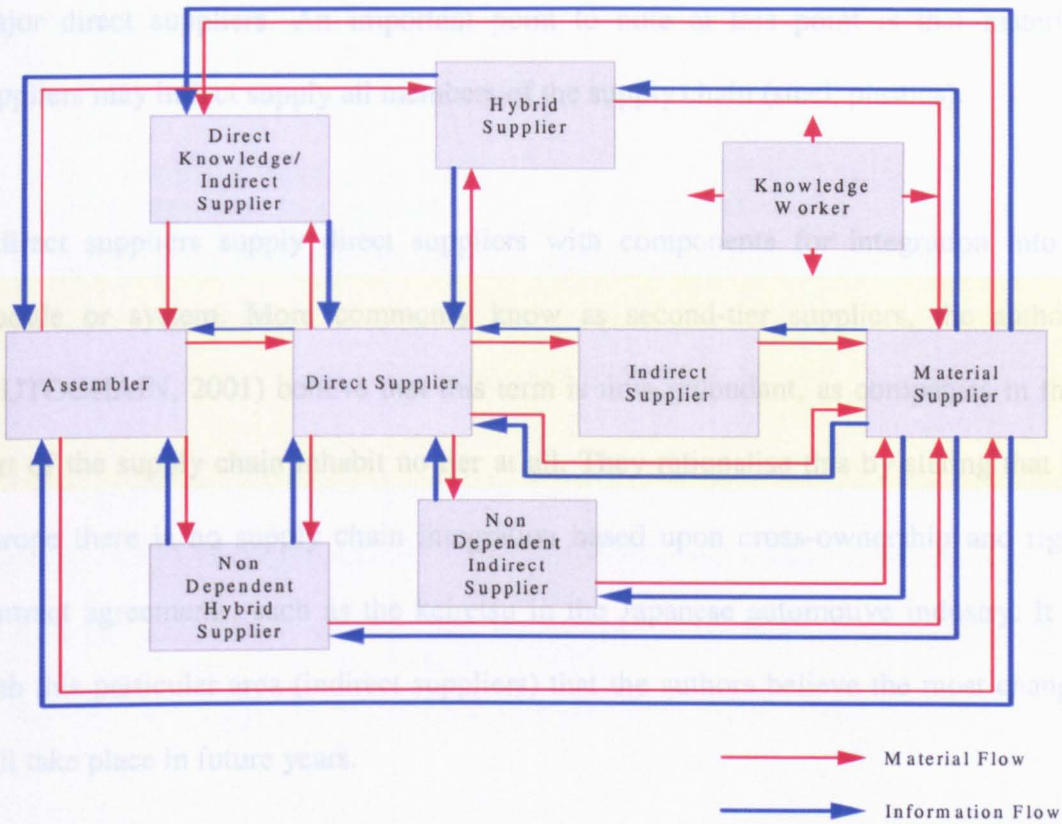


Figure 2.4 - Generic Automotive Supply Chain (AUTOCHAIN, 2001)

It is possible for organisations to hold multiple positions within the chain depicted in figure 2.4, and clearly the diagram indicates product and information flows moving in opposite directions. Briefly discussing each of the nine organisational positions: Assemblers (otherwise known as the OEMs) are located in the most 'down stream' position in the automotive supply chain and suppliers situated at all tiers move their products and services towards the assemblers.

Direct Suppliers (first-tier suppliers) are going through a period of significant change in the automotive sector. Often very large multinationals in their own right, direct suppliers are increasingly undertaking more responsibility for the smooth operations of their Assemblers. The AUTOCHAIN report (2001) expects that the ever-increasing global consolidation amongst assemblers will consequently diminish the number of major direct suppliers. An important point to note at this point is that material suppliers may in fact supply all members of the supply chain (steel, plastics).

Indirect suppliers supply direct suppliers with components for integration into a module or system. More commonly know as second-tier suppliers, the authors (AUTOCHAIN, 2001) believe that this term is now redundant, as companies in this part of the supply chain inhabit no tier at all. They rationalise this by stating that in Europe there is no supply chain integration based upon cross-ownership and rigid contract agreements, such as the keiretsu in the Japanese automotive industry. It is with this particular area (indirect suppliers) that the authors believe the most change will take place in future years.

Hybrid suppliers, situated at the summit of figure 2.4, are those suppliers which manage supply relationships to both assemblers and direct suppliers. Effectively, they may supply similar products to both the assembler and direct supplier. Direct Knowledge/Indirect Suppliers involve companies that provide specialised products, i.e. innovative devices such as engine management systems, parktronic etc. Increasingly these companies are working indirectly as product suppliers by feeding their products into direct suppliers for incorporation within their particular module. Collaboration with the assembler is also necessary due to the often mission critical nature of the components.

Non-dependent suppliers are charaterised by the fact that the automotive sector does not represent their core business. Being situated in this position gives these particular companies the advantage of being very selective over the contracts they take on. The authors recognise there to be two types of non-dependent suppliers:

- Non-dependent indirect suppliers - not obliged to align themselves with a direct supplier in order to survive as they have a choice.
- Non-dependent hybrid suppliers - operational characteristics of the dependent hybrid but significantly lower exposure to the auto industry.

The final organisational position in figure 2.4 is that of the Knowledge worker. More widely known as management consultants, advertising and marketing agencies and IT consultants, knowledge workers inhabit all locations within figure 2.4. They infrequently have a product to supply, but do offer their expertise and guidance.

Now a model of the supply chain has been introduced, it is appropriate to present a selection of real word examples from the literature. Starting with the least complex, the work of Parunak *et al* (1998), (figure 2.5) illustrates a simple supply network.

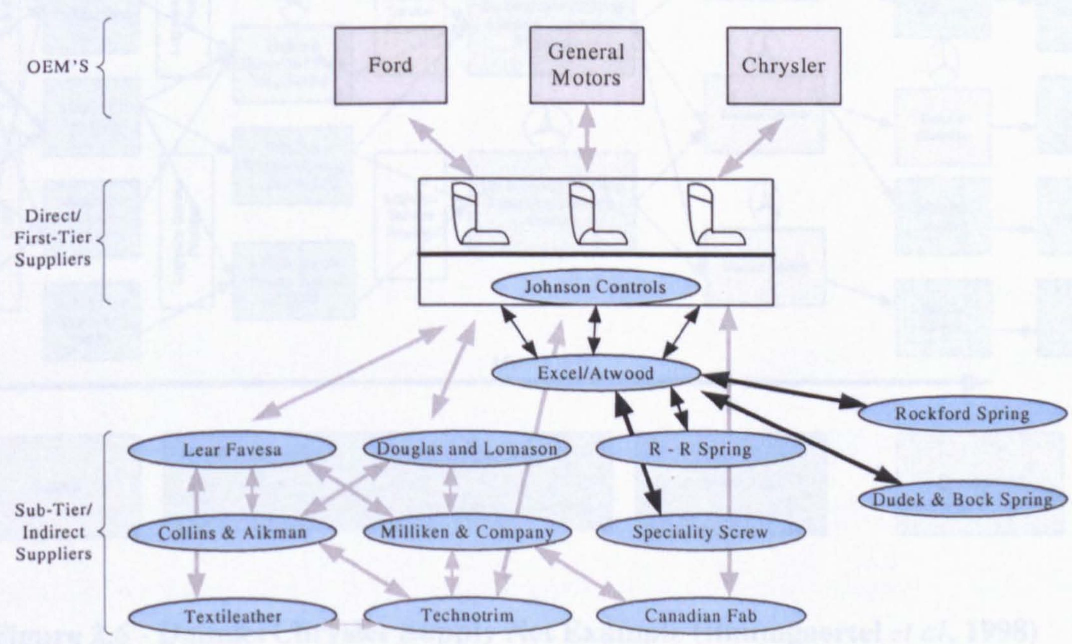


Figure 2.5 - A Simple Automotive Supplier Network (Parunak *et al*, 1998)

Johnson Controls supplies seating systems to Ford, General Motors, and Chrysler, and purchases the components and subassemblies of seats either directly or indirectly from over one hundred and fifty other companies, some of which also supply one another. The labels situated on the left-hand side of the diagram highlight how this supply chain would be perceived under the explanation provided by the AUTOCHAIN project (2001).

A more comprehensive view of an automotive supply arrangement is presented by Baumgaertel *et al* (1998) in their paper looking at agent models of supply network dynamics. Figure 2.6 represents an example of the Daimler-Chrysler supply network.

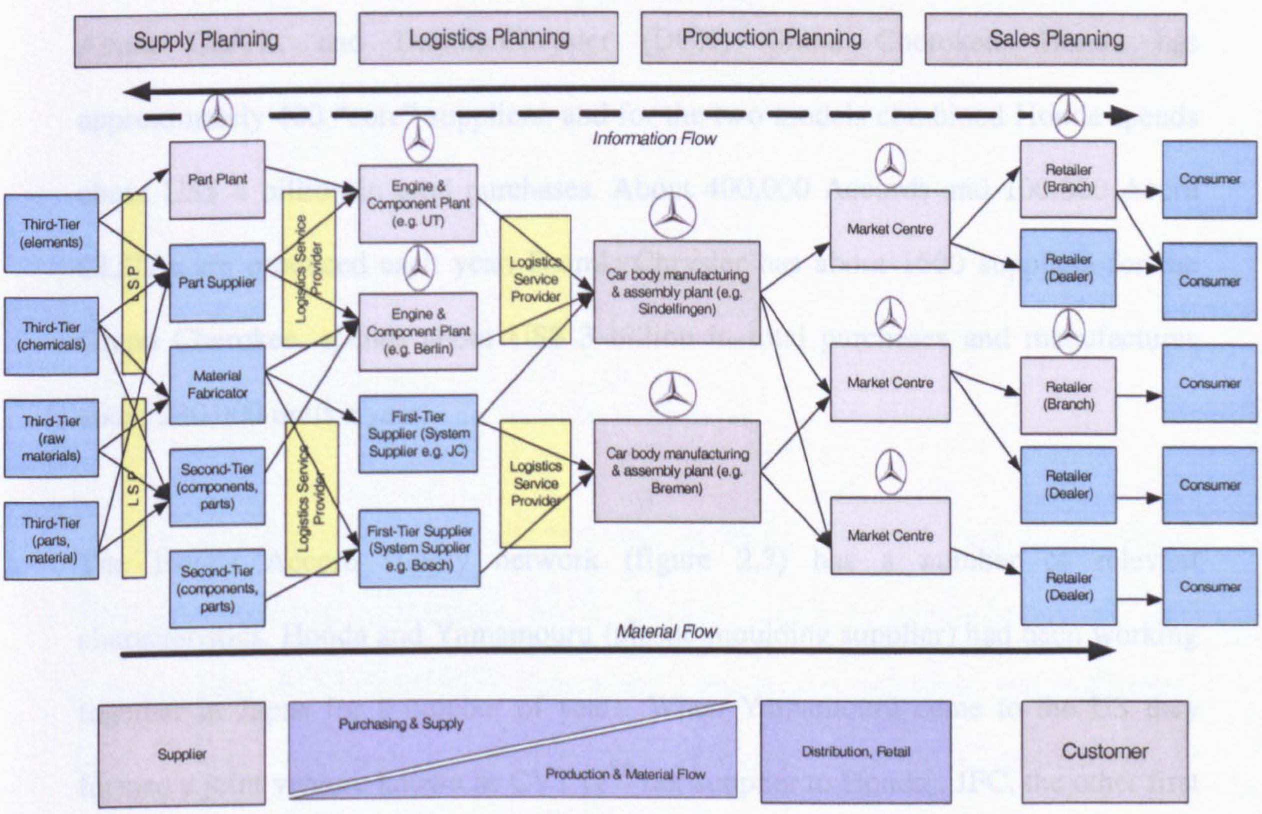


Figure 2.6 - DaimlerChrysler Supply Net Example (Baumgaertel *et al*, 1998)

In reference to the figure 2.3, the supply network above has identical characteristics to those in the 'hourglass' model. Baumgaertel *et al* (1998) retain the idea of tiers, but it is clear to see that there are numerous 'one-to-many' relationships, which would confirm the ideas presented in the AUTOCHAIN project (2001). It is also relevant to mention that the Mercedes emblems represent ownership. Within this supply scenario a number of first-tier/direct suppliers and second-tier/indirect suppliers fall under this category.

One of the most recent analyses of the automotive supply chain is provided by Choi & Hong (2002). In their paper on the structure of supply networks, they concentrate on three case studies, focusing on the centre console assembly for the Honda Accord, Acura CL/TL, and DaimlerChrysler (DCX) Grand Cherokee. Honda has approximately 400 "core" suppliers, and for the two models combined Honda spends about US$ 4 billion in total purchases. About 400,000 Accords and 100,000 Acura CL/TLs are produced each year. DaimlerChrysler has about 1500 suppliers for the Grand Cherokee, spends about US$ 3 billion in total purchases and manufactures about 230,000 units a year.

The Honda Accord supply network (figure 2.7) has a number of relevant characteristics. Honda and Yamamouru (plastic moulding supplier) had been working together in Japan for a number of years. When Yamamouru came to the US they formed a joint venture known as CVT (1ST tier supplier to Honda). JFC, the other first tier supplier to Honda (figure 2.7) owns the patent on a particular mechanism with the cup holder. Thus Honda works closely with JFC engineers to develop the cup holder assembly. The two companies mentioned appear as top tier suppliers in figure 2.7.

Several second tier suppliers, although selected by CVT, come from Honda's core suppliers' list. These core suppliers typically rely heavily on Honda's business. Although Honda is involved with second tier selection at the outset, once mass production begins, the responsibility of managing then moves to CVT. An important point to mention here relates to the authors stating that suppliers situated in the second and third tiers, supply to each other as well as the tiers above. In terms of complexity, there are about 50 entities in this supply network: 2 first tier, 21 second tier, 18 third tier, 7 fourth tier and 2 fifth-tier suppliers.

The second of the supply networks discussed involves another model produced under the umbrella of the Honda Corporation, known as the Acura CL/TL. In contrast to the Accord, one top-tier supplier (Intek) is the complete integrator of the console assembly. By comparing the two supply networks (figures 2.7 and 2.8), it is clear to see a number of the same suppliers are present in both. This would more than likely be due to the cost saving benefits gained through carry-over items. In this particular supply network, there are 76 entities in total: 1 first tier, 20 second tier, 28 third tier, 17 fourth tier, 9 fifth tier and 1 sixth-tier supplier.

The final supply chain examined by Choi & Hong (2002) is that of the Grand Cherokee, produced by DaimlerChrysler (DCX). The relationship between DCX and Textron dates back to the 1960s. Leon Plastics has similar operations and capabilities to Textron and used to be a top-tier supplier. However, following the restructuring of DCX's supply base they were demoted to a second-tier position. Clearly, figure 2.9 shows that Textron is the sole first-tier supplier that integrates parts and subassemblies together.

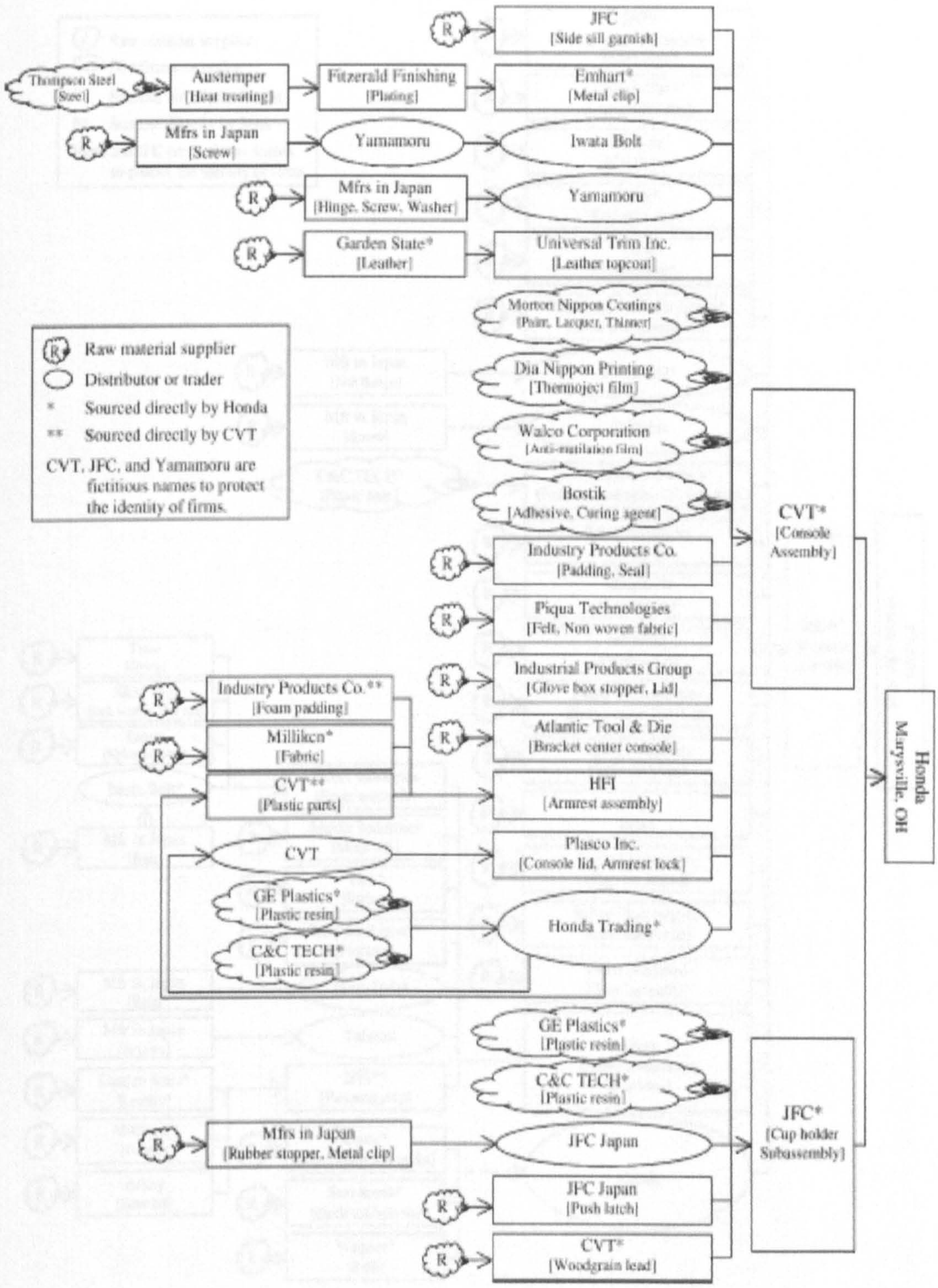


Figure 2.7 - Supply Network of Accord Centre Console (Choi & Hong, 2002)

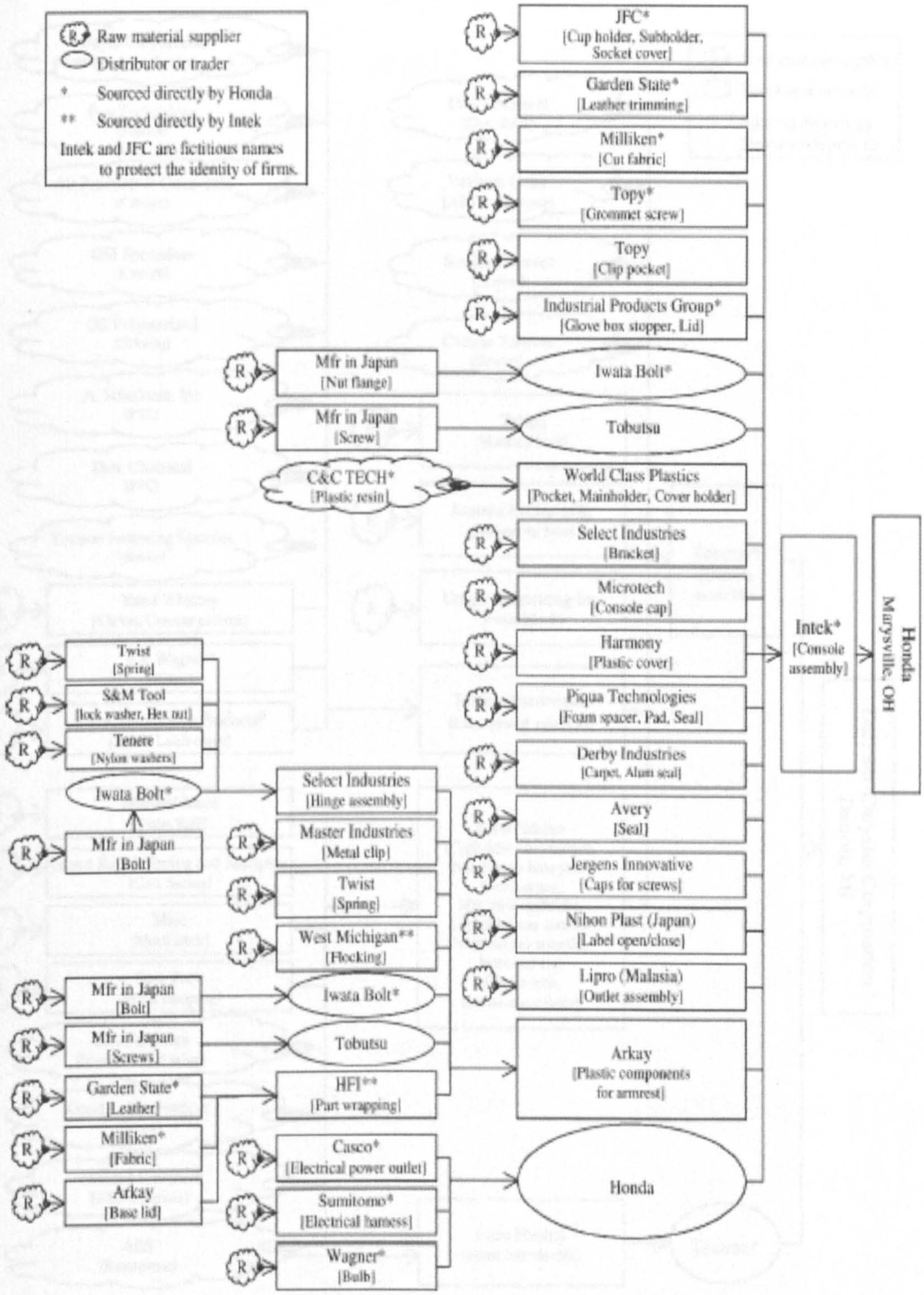


Figure 2.8 - Supply Network of Acura CL/TL Centre Console (Choi & Hong, 2002)

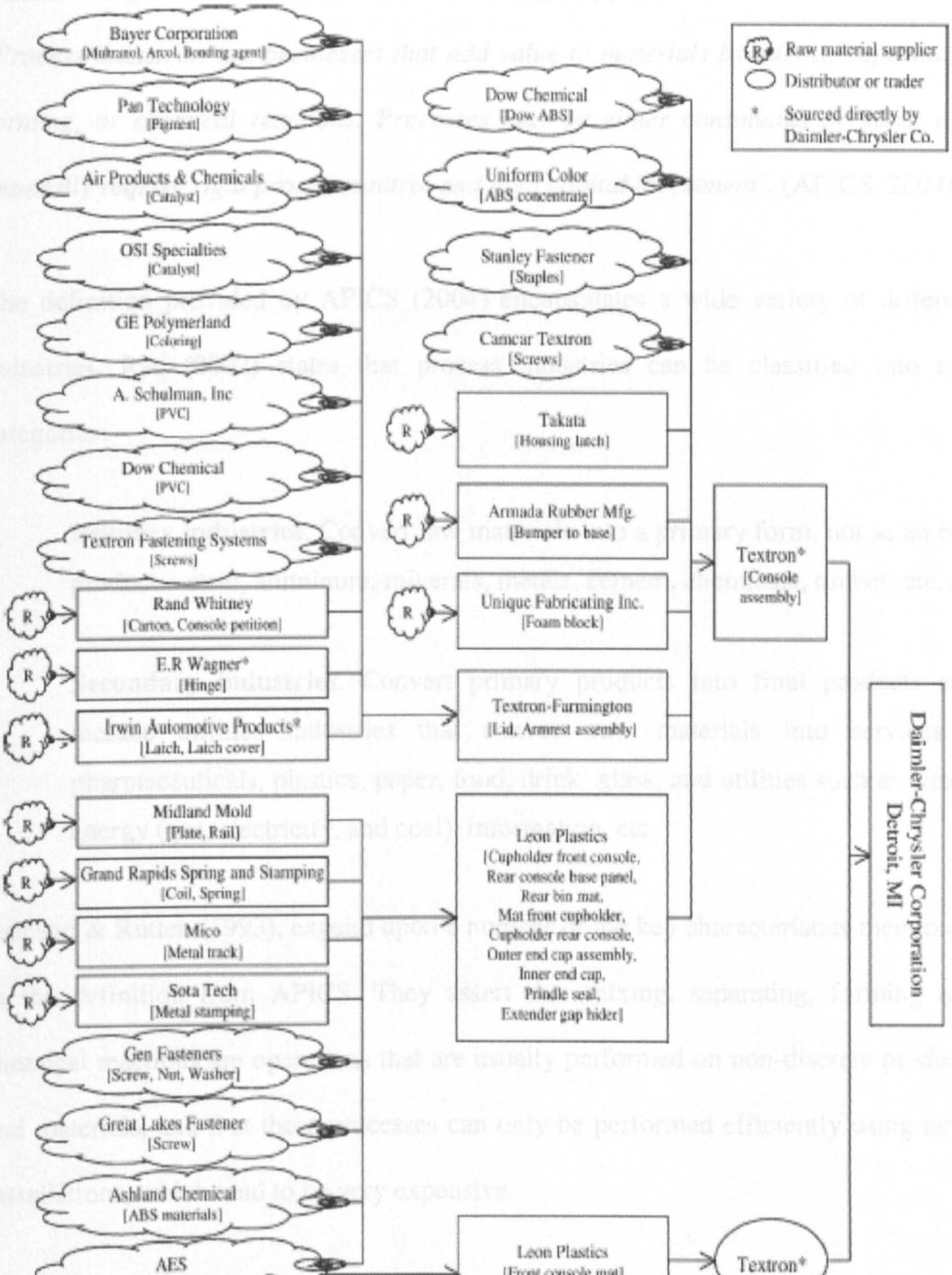


Figure 2.9 - Supply Network of Grand Cherokee Centre Console (Choi & Hong, 2002)

2.2.2.5 High-Volume Process Manufacturing Supply Chains

'Process industries are businesses that add value to materials by mixing, separating, forming, or chemical reactions. Processes may be either continuous or batch and generally require rigid process control and high capital investment'. (APICS, 2004)

The definition provided by APICS (2004) encapsulates a wide variety of different industries. Rao (2002) states that process industries can be classified into two categories:

- **Primary industries.** Convert raw materials into a primary form, not as an end product – steel, aluminum, minerals, metals, cement, chemicals, timber, etc.;

- **Secondary industries.** Convert primary products into final products and include utilities industries that convert raw materials into services – pharmaceuticals, plastics, paper, food, drink, glass, and utilities such as water, energy (gas, electricity, and coal), information, etc.

Fransoo & Rutten (1993), expand upon a number of the key characteristics mentioned in the definition from APICS. They assert that mixing, separating, forming and chemical reactions are operations that are usually performed on non-discrete products and materials, and that these processes can only be performed efficiently using large installations, which tend to be very expensive.

It is widely acknowledged that process industries often obtain their raw materials from mining or agricultural industries. What may not be appreciated is that the raw materials may have natural variations in quality. For example certain raw materials may contain different levels of gases and minerals. Subsequently this can lead to demand variations (for other raw materials) at a production level as the yield or potency is not usually known or measured until the process is started, (Fransoo & Rutten, 1993)

Having searched the literature on high-volume process manufacturing within the different sectors, there appeared to be very little work aimed at modelling the particular supply networks for these industries. However, the few models that have emerged from the literature are now considered. The first model originates from the steel industry. Hafeez *et al* (1996) investigated the supply of reinforced steel bars to the construction industry. Figure 2.10, taken from the paper by Hafeez *et al* (1996), illustrates the material flow in the supply chain. The authors report that the steel market is subject to considerable speculation and consequently the demand for construction products depends not only on the customer/contractor but also on other factors such as steel price, interest rates and delivery times.

The final customer in this supply network is a project management team, which comprises client, consultant and contractors. The stockholders buy and store large quantities of steel, which causes rapid changes in the demand inflicted on the other members of the chain. This supply network under investigation by the authors (figure 2.10) consists of three separately controlled business units: Companies A, B and C. The management structure of the business is decentralised, however, the three companies are highly dependent on one another. Company A is a foundry transforming scrap metal into billets. Companies B and C produce steel products out of steel billets. Company A is sole supplier to Company B and the main supplier (approx. 50%) to Company C. External suppliers make up the shortfalls in raw material for Company C.

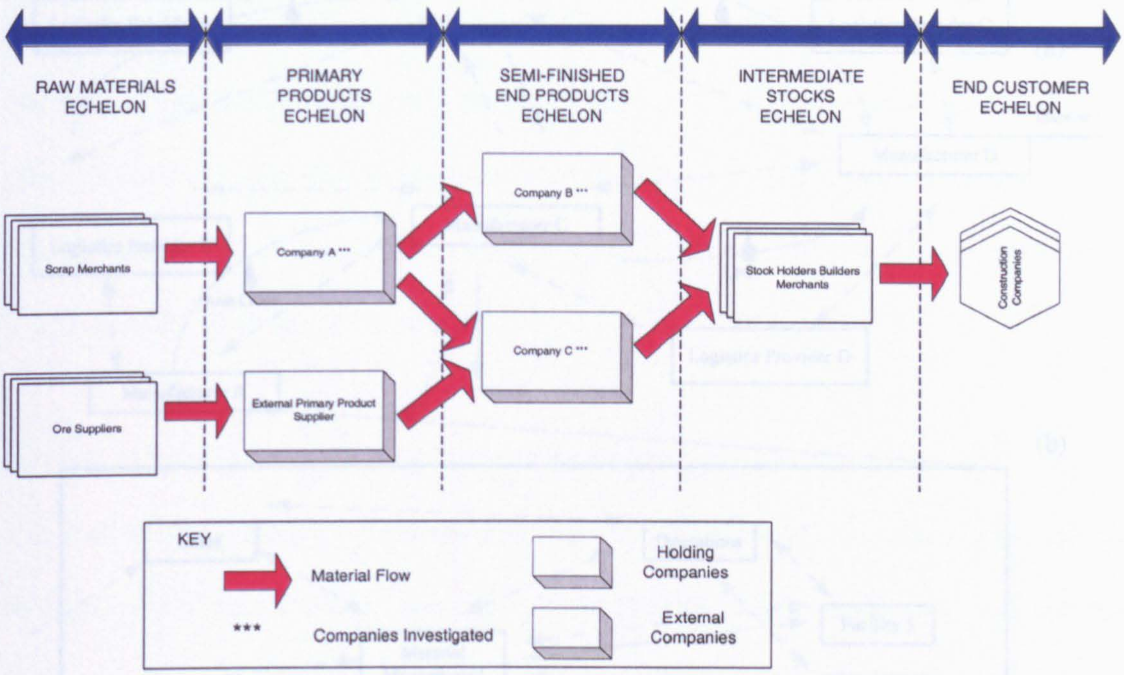


Figure 2.10 - Steel reinforcement industry supply chain (Hafeez *et al*, 1996)

The chemicals industry provides us with the next process manufacturing supply network. Figure 2.11, taken from Julka *et al*, (2002) represents a typical chemical supply chain. The authors maintained that chemical industry supply chains are typically long and plant configurations are rigid. Furthermore, chemical plants are normally their own customers. Thus, supply chain solutions from other industries are not directly applicable in the chemical industry. Garcia-Flores and Wang (2002) believed that compared to other sectors such as the car manufacturing industry, the chemical process industry (CPI) has lagged behind in addressing supply chain issues. Also, different to other sectors is the fact that the supply chain can represent as much as 60-80% of a typical chemical manufacturer's costs.

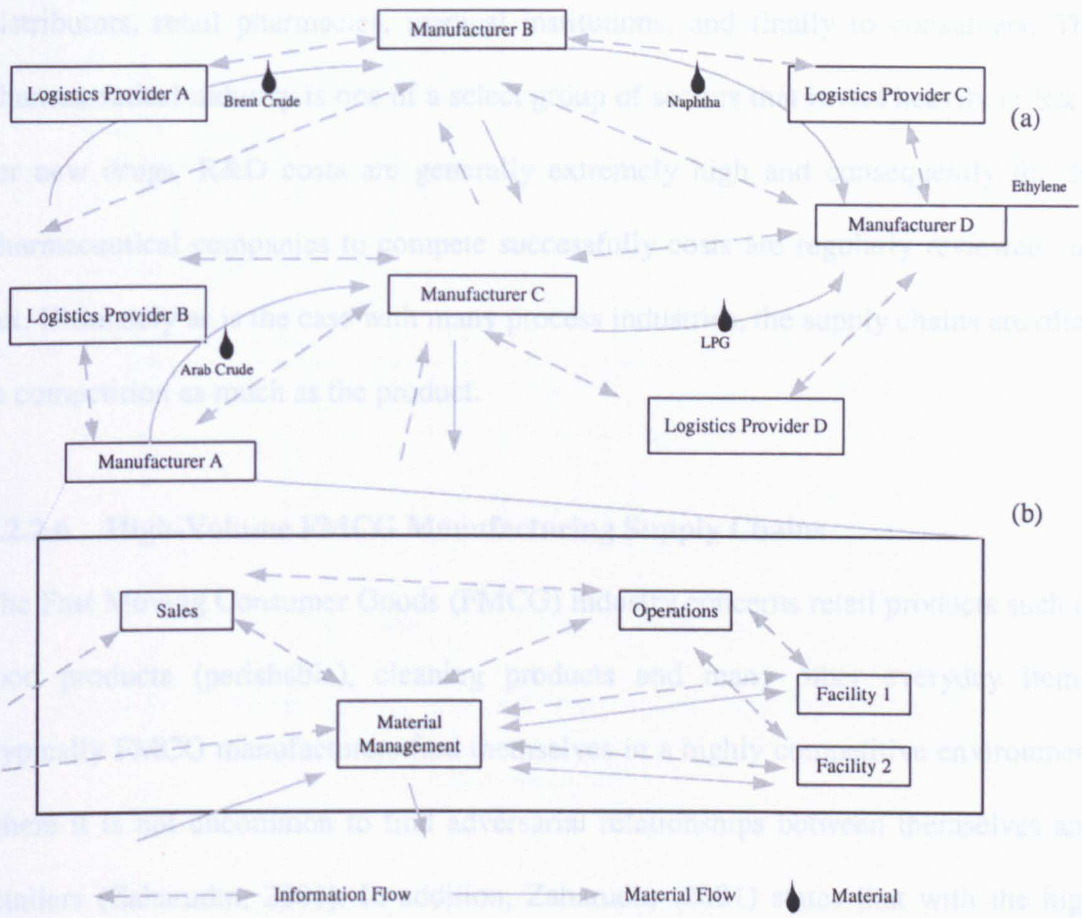


Figure 2.11 - (a) A chemical supply chain; (b) The internal departments of a typical manufacturer. (Julka *et al*, 2002)

Moving on to Pharmaceutical supply chains, there are both similarities and differences with the supply networks dealt with thus far. A number of industry drivers are defining the path of the modern day pharmaceuticals sector. These include a continued growth in drug usage; patent expirations and the anticipated loss of revenue; increased cost and difficulty in bringing new products to market; growing international competition and the increased cost of drug production and distribution.

In many ways the process of producing and distributing pharmaceuticals is similar to that of other industries. Products flow through company warehouses, wholesale distributors, retail pharmacies, medical institutions, and finally to consumers. The pharmaceutical industry is one of a select group of sectors that invest heavily in R&D for new drugs. R&D costs are generally extremely high and consequently for the pharmaceutical companies to compete successfully costs are regularly reviewed and cut. Ultimately as is the case with many process industries, the supply chains are often in competition as much as the product.

2.2.2.6 High-Volume FMCG Manufacturing Supply Chains

The Fast Moving Consumer Goods (FMCG) industry concerns retail products such as food products (perishable), cleaning products and many other everyday items. Typically FMCG manufacturers find themselves in a highly competitive environment where it is not uncommon to find adversarial relationships between themselves and retailers (Zaharudin, 2001). In addition, Zaharudin (2001) states that with the high volumes of products that pass through the supply chain daily, product visibility is usually poor as information becomes choked at various points. Supply chain models within this sector are usually inventory-centric and products are made-to-stock.

Zaharudin's (2001) work on product-driven supply chains provides some constructive analysis of non-meat frozen foods and ice cream supply networks. Figure 2.12 demonstrates the author's vision of a modern day FMCG supply chain. Demand signaling for a product begins with the retailer and is generally based on product history, seasonality and market information. This demand is sent to the supplier/manufacturer, which then examines the incoming orders and adjusts the production plan accordingly. Sourcing is generally undertaken centrally with the main criteria being cost and quality of material. Manufacturing is moving towards single-source products as the benefits from achieving economies of scale in manufacture outweigh additional transportation costs of the finished product. Delivery is usually outsourced to a third party logistics provider.

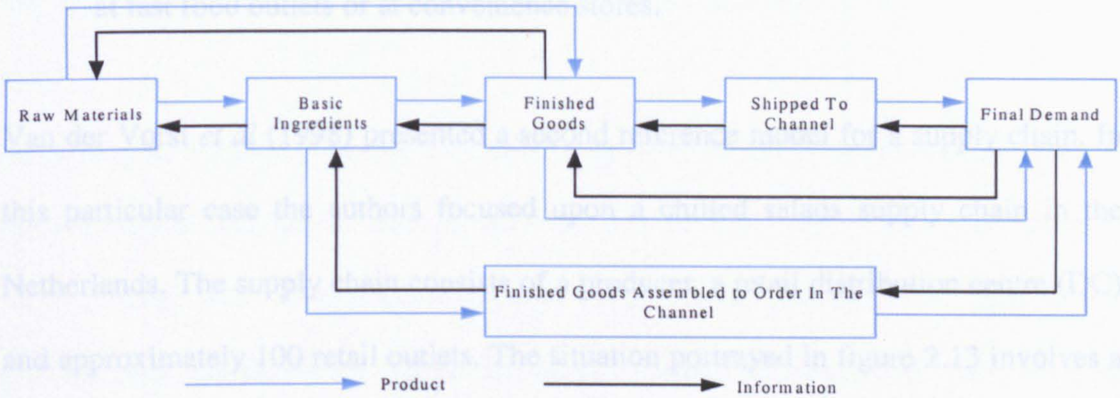


Figure 2.12 - Modern Day Supply Chain Model from the FMCG Sector (Zaharudin, 2001)

Zaharudin's (2001) model describes three main channels that products can take to arrive at the end consumer:

- **Raw Material – Basic Ingredients – Finished Goods – Shipped to Channel – Final Demand.**

  Described by the author as probably the most common supply chain scenario, this model has a make-to-stock strategy and is tied down by high inventory throughout the chain. Finished goods are pushed to the end customer.

- **Raw Material – Basic Ingredients – Finished Goods – Final Demand**

  A make-to-order strategy that would be common for large consumers such as restaurant chains. The number of consumers that buy directly from manufacturers is minimal as they usually buy from wholesalers.

- **Raw Material – Basic Ingredients – Finished Goods Assembled to Order in the Channel – Final Demand**

  A make-to-stock strategy for alternative sales channels. An example given by the author is the purchasing of basic ingredients to produce fresh soft ice cream at fast food outlets or at convenience stores.

Van der Vorst *et al* (1998) presented a second reference model for a supply chain. In this particular case the authors focused upon a chilled salads supply chain in the Netherlands. The supply chain consists of a producer, a retail distribution centre (DC) and approximately 100 retail outlets. The situation portrayed in figure 2.13 involves a producer supplying the DC with approximately 60 different products twice a week, with an order lead-time of 3 days for each delivery.

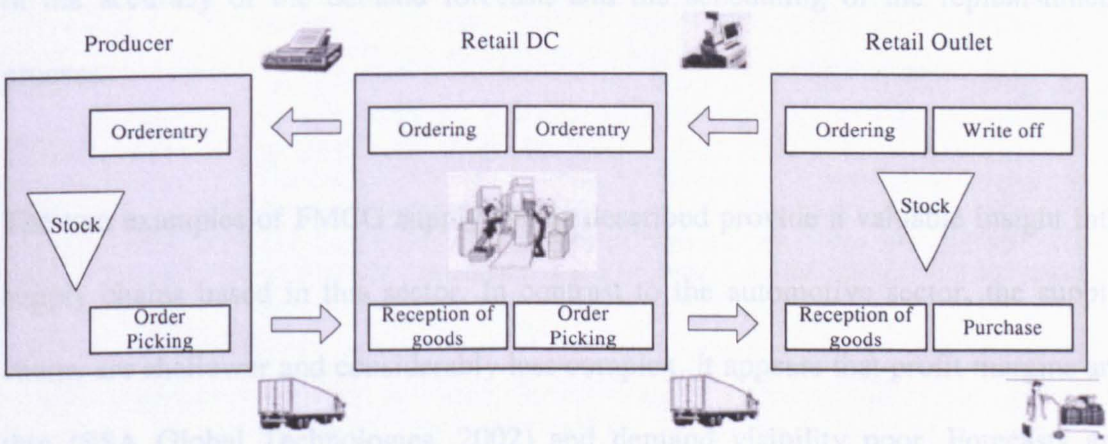


Figure 2.13 - Supply Chain for Chilled Salads with Relevant Processes (Van der Vorst *et al*, 1998)

The DC supplies the retail outlets with chilled salads and simultaneously with other fresh products, three times a week from stock. The average inventory in the DC is 4 days of sales and in the outlets 6.8 days of retail sales. The DC's order policy is based upon actual outlet orders, historical sales patterns and present inventory levels. In the outlet it is reported that managers try to forecast their sales by looking at the sales figures of previous weeks, but basically order to fill available shelf space. It is reported that all stages of the supply chain (figure 2.13) experience high demand uncertainty, due principally to the long order forecast horizons. The highly perishable and seasonal nature of the products only further increases uncertainty.

According to Roussos *et al* (2002), FMCG supply chain inefficiencies can be found in both upstream and downstream directions. The authors believe that the upstream inefficiencies lead to stockouts, inflated return rates and extended lead times. Downstream inefficiencies affect demand forecast accuracy and low on-shelf availability. Supporting the work of Zaharudin (2001), the authors report on the information sharing restrictions between trading partners, which leads to a reduction in the accuracy of the demand forecast, and the scheduling of the replenishment process.

The two examples of FMCG supply chains described provide a valuable insight into supply chains based in this sector. In contrast to the automotive sector, the supply chains are shallower and considerably less complex. It appears that profit margins are thin (SSA Global Technologies, 2002) and demand visibility poor. Forecasts are based on historical information combined with point of sale (POS) data and it is clear that retailers have power and influence over their supply chain partners. Already thin profit margins continue to be pressured by rising costs such as transportation, labeling and packaging (SSA Global Technologies, 2002). With this in mind, it appears the key to future success within the FMCG sector will be closer supply chain relationships stimulating improved communication.

2.2.3 Supply Chain Management and Associated Challenges

2.2.3.1 Introduction

Much has been written about supply chain management (SCM) over past years and a plethora of different areas have been explored. Referring back to table 2.1, a series of definitions were presented in order to obtain a firm understanding of what a supply chain actually is. In contrast, table 2.2 provides some of the most commonly used definitions of supply chain management.

Author	Definition
Oliver, R.K. & Webber, M.D. **(1982)**	The marketing channel should be seen as an integrated single entity.
Houlihan, J. **(1985)**	Covers the flow of goods from supplier through manufacturer and distributor to the end user.
Stevens, G.C. **(1990)**	Controls the flow of material from suppliers, through the value-adding processes and distribution channels, to customers
Ellram, L.M. **(1991)**	An integrative approach to dealing with the planning and control of the materials flow from suppliers to end-users.
Ellram, L.M. & Cooper, M.C. **(1993)**	An approach whereby the entire network, from the supplier through to the ultimate customer, is analysed and managed in order to achieve the best outcome for the whole system.
Christopher, M. **(1998)**	The management of up stream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole.
Lambert, D.M., Cooper, M.C. & Pagh, J.D. **(1998)**	The integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders.
Viswanadham, N. & Srinivasa Raghavan, N.R. **(2000)**	The coordination or integration of the activities of all the companies involved in procuring, producing, delivering and maintaining products and services to customers located in geographically different places.
Mentzer *et al.* **(2001)**	The management of close inter-firm relationships, and that understanding partnering is important in developing successful retail supply chain relationships.

Table 2.2 - Supply Chain Management Definitions

The relatively new concept of supply chain management emerged as the obvious progression from logistics management. Its origins date back to Forrester in 1958 when he wrote, *'Management is on the verge of a major breakthrough in understanding how industrial company success depends on the interaction between* *the flows of information, materials, money, manpower, and capital equipment*'. However, it wasn't until Oliver and Webber (1982) that the term SCM was first introduced. Since then numerous authors (table 2.2) have expanded and increased our understanding of the broad subject matter.

2.2.3.2 Supply Chain Management (SCM) - A Timeline

A widely adopted view is that traditional organisations developed from an environment whereby business functions such as manufacturing, purchasing and delivering, all operated in almost total isolation, (Forrester, 1958; Wright, 2000). Both Forrester (1958) and Wright (2000) also stated that there was a tendency for complete functional independence across organisations' operations, and so often decisions were made in one area of a business with total disregard for the consequential effects on other parts of the business, (figure 2.14).

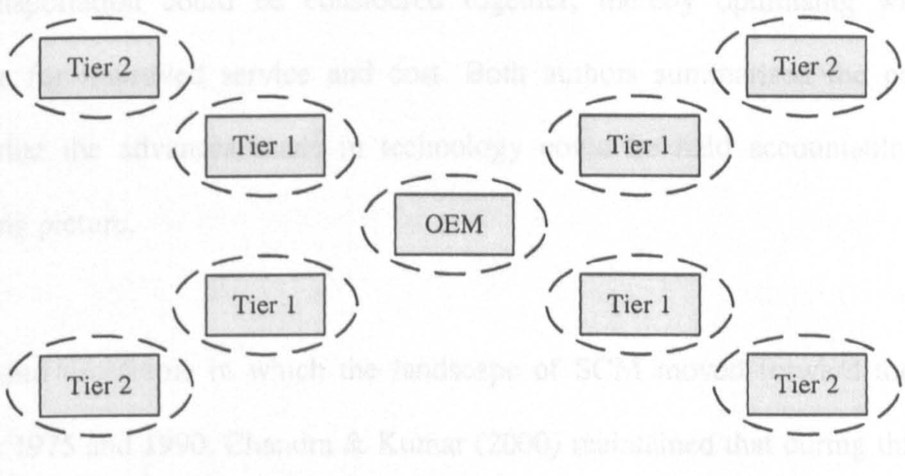


Figure 2.14 - Functional Independence Across Tiers

This lack of co-ordination manifestly exacerbated a number of problems for the organisations concerned. There have been three principal time zones identified in which advances in supply chain initiatives have occurred, as reported by Metz (1998) and Chandra & Kumar (2000). Although each of the authors had different view points of the events that took place during each era, they both provide us with a good grounding for the development of SCM through time.

The first era of significant development in SCM occurred between 1960 and 1975, and both the authors have documented a number of recognisable characteristics from the period. Chandra & Kumar (2000) reported that corporations had vertical organisational structures and optimisation of activities was focussed on functions. Also relationships with vendors were win-lose interactions, and many times adversarial. The view documented by Metz (1998) stated that a relationship between warehousing and transportation was becoming apparent, which he labelled as the 'physical distribution stage'. Combining the functions of transportation and warehousing reportedly provided inventory reduction benefits as forecasting periods could be reduced. Other advantages came about due to the fact that both warehousing and transportation could be considered together, thereby optimising warehouse locations for improved service and cost. Both authors summarised the period by stating that the advances made in technology could be held accountable for the improving picture.

The second timeframe in which the landscape of SCM moved forward took place between 1975 and 1990. Chandra & Kumar (2000) maintained that during this period corporations remained vertically aligned, but the authors also mention that many corporations were involved in process mapping and analysis to evaluate their operations. Metz (1998) stated that EDI and computers to perform analyses were a common theme throughout the period. Clearly the advances in technology were again enabling SCM to move forward.

The third 'present day' period of SCM has a number of common features identified in both the authors' papers. Metz stated that technology has been incorporated into all areas of SCM in order to handle the ever-growing complexity. EDI, electronic funds transfer, higher bandwidth communications, and computerised decision-support systems for planning and execution are all in use. Chandra & Kumar (2000) stated that there has been an increasing trend of strategic alliances among organisations. Along with Metz (1998) they too believed that manufacturing systems in organisations had been enhanced with information technology tools. However, they went on to state that the face of manufacturing was altered by the introduction of concepts such as 'agility', 'modular design', 'mass customisation' and 'process flexibility' as well as many others. Moving away from its evolution, modern day supply chain management is a complex and vast subject. The following section discusses SCM in greater detail.

2.2.3.3 Modern Day Supply Chain Management

Modern day SCM is being shaped by a number of different forces. Figure 2.15 (Bovet & Sheffi, 1998) illustrates three external drivers (consumer demands, globalisation and information/communication) and three additional elements (competition, government regulation and the environment) that the authors believed were critical to future supply chain design.

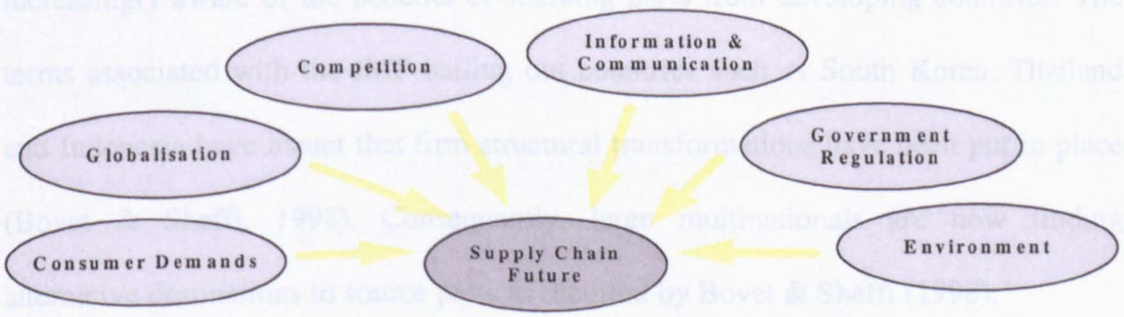


Figure 2.15 - External Drivers Shaping SCM (Bovet & Sheffi, 1998)

Briefly expanding upon each of the external drivers in figure 2.15 will show exactly how complex a concept supply chain management actually is.

- **Consumer Demands**

Traditionally customers have had to select the products they purchased from a pre-defined catalogue. Consequently the products they select often contain features that have no use to the consumer concerned (Wright, 2000). This rigid form of manufacturing the products it is 'believed' customers want not only causes consumer dissatisfaction, but also leaves suppliers vulnerable to a high degree of demand uncertainty.

Supplier power is diminishing as consumers are placing increasingly demanding requirements on the products and services they are being offered. 'Consumer Demands' are becoming evermore important as the days of mass production with limited customisation are clearly numbered as stated by Carson (1998). Customers around the world are now demanding impeccable quality, competitive prices and shorter lead times, (Beaty, 1996).

- **Globalisation**

Increasingly globalisation is having a major impact as organisations are becoming increasingly aware of the benefits of sourcing parts from developing countries. The terms associated with the IMF bailing out countries such as South Korea, Thailand and Indonesia have meant that firm structural transformations have been put in place (Bovet & Sheffi, 1998). Consequently, large multinationals are now finding alternative destinations to source parts as reported by Bovet & Sheffi (1998).

- **Competition**

With the advent of globalisation, and the advances in communications technology competition is as evident as ever. Competition has been made even more intense by the vast quantities of information that have been made available through the Internet. With this intensified level of competition, suppliers are looking to squeeze every last penny out of the supply chain. Effectively this means incorporating best practice techniques in regard to SCM.

- **Information & Communication**

'Key Technologies' according to Metz (1998) have had the most impact on the development of SCM. The evolution of the Internet is causing organisations to re-evaluate their business plans and to embrace e-commerce to sell, market, communicate and trade using alternative methods to those traditionally employed, (Briggs, 2000). Numerous companies (Dell, Cisco, Tesco) have utilised the Internet to market and sell products, whilst others (Amazon, EBay, Play) have built their whole business around it. The Internet allows customers the ability to shop around as direct retailing over the Internet knows no boundaries. The Internet also permits the exchange of critical information between companies. Software companies such as SAP, Oracle and Baan have all integrated the Internet into their products with great success.

Lee & Whang (2000) believed that 'information integration' is the key to the successful running of any supply chain. The technology currently in use within the SCM sector is reviewed in part two of this literature review.

- **Government Regulation**

Governments and government regulation will always have an influential effect on SCM. Trade agreements and trade zones have in the past dictated how countries have done business. Whilst globalisation is fast becoming the norm, it will always be dictated by the individual country's governing bodies.

- **Environment**

'Environmental/Sustainability' issues are steadily having an impact on Supply Chain Design. Hewlett Packard already include envelopes with their new cartridges in order to return the used ones. With product differentiation becoming increasingly difficult, consumers are sure to take other factors such as the environment into account when choosing their merchandise.

Taking into account all of the above, it is not difficult to appreciate the factors that are shaping the immediate future of SCM. However, turning our attention to the challenges facing SCM brings us to demand amplification. Demand Amplification is one challenge that has remained a constant thorn in the side to supply chain theorists for many years. Whilst it is not the only challenge within supply chains, over time it has been a topic that has been focussed upon repeatedly. It is introduced and considered within this literature review, as it is a prominent feature of the scorecard developed for this research.

2.2.3.4 Demand Amplification

'A fundamental problem with supply chains is demand amplification, as initially diagnosed over 30 years ago by Forrester (1958) but it is only recently that the full extent of the problem has been recognized.' (Towill, 1996)

Probably one of the most important concepts within the area of SCM was introduced by Forrester in the 1950s in a series of case studies relating to demand amplification and feedback control loops. By incorporating simulation models, Forrester demonstrated how small variations in final customer demand may be amplified upstream in the supply chain. In his reasonably simple model a sudden 10% increase in retail sales was shown to proliferate factory output by approximately 40% over a 5 month time period. Forrester primarily attributed the effect to the decision rationale of individuals responsible for demand management, (Taylor, 2000). Figure 2.16 depicts a simplistic view of demand amplification.

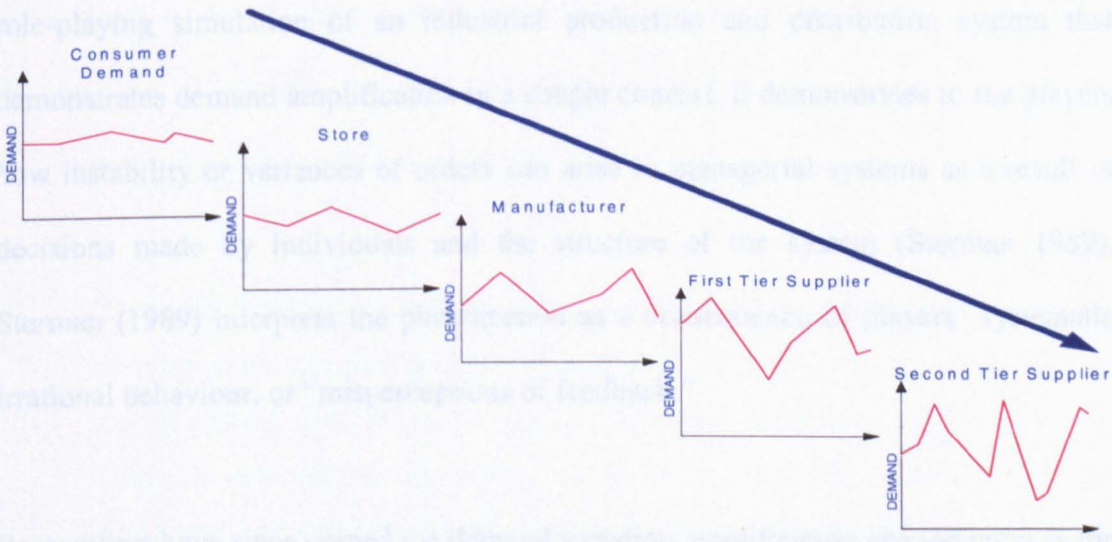


Figure 2.16 - Demand Amplification

Burbidge (1961) stated that natural demand variation is considerably magnified by the time it reaches the manufacturing unit. This magnification is mainly due to the wide use of 'stock control'. Burbidge believed that most production flow was controlled by the method of 'stock control'. Supporting Forrester's research, Burbidge revealed that this type of system always magnifies the demand variation, so that ± 5% natural variation in demand amplitude, after transmission through three inventories (say retailer, distributor and factory stock) can easily be increased into ± 40% variation in the demand on the manufacturing unit. Burbidge (1984) went on to define the 'law of industrial dynamics'; which states that '*if demand for products is transmitted along a series of inventories using stock control ordering, then the demand variation will increase with each transfer*'. Since Forrester's and Burbidge's seminal work in the realm of Industrial Dynamics, numerous other authors have extended the research in this area.

Sterman (1989) discussed the 'Beer Game', and its propensity to create distortion. The "Beer Distribution Game", developed by the Sloan School of Management, is a role-playing simulation of an industrial production and distribution system that demonstrates demand amplification in a simple context. It demonstrates to the players how instability or variances of orders can arise in managerial systems as a result of decisions made by individuals and the structure of the system (Sterman 1989). Sterman (1989) interprets the phenomenon as a consequence of players' systematic irrational behaviour, or "misperceptions of feedback."

Researchers have since coined the demand variation amplification phenomenon as the 'Forrester Effect' or 'Forrester Model' (Angerhofer & Angelides, 2000). Towill and Naim (1993) and Towill (1996) expanded Forrester's work and tested various methods of reducing demand amplification using systems dynamics approaches to develop computer-based simulations of supply chain activity (Taylor, 2000). Disney *et al* (1997) demonstrated that the use of a model of a decision support system coupled with a simulation facility and genetic algorithm optimisation procedure can yield spectacular results when applied to a supply chain.

Lee *et al* (1997a, 1997b) stated that Procter & Gamble (P&G) first coined the term 'bullwhip effect' after noticing that whilst their customers were consuming diapers at a steady state, the demand order variabilities in the supply chain were amplified as they moved up the supply chain. Hewlett-Packard experienced similar findings at one of its major resellers (Lee *et al,* 1997a, 1997b). Sterman's experiments indicated that human behaviour, such as misconceptions about inventory and demand information, leads to demand amplification. Lee *et al* (1997a, 1997b) strongly contended this and show that the players' rational behaviour within the supply chain's infrastructure caused the bullwhip phenomenon. The authors believed that it is actually distorted information in the supply chains that creates the demand variation amplification (Simchi-Levi *et al* 2000; Yu et al 2001; Lau *et al* 2002). Thus, Lee *et al* (1997a, 1997b) declare four major causes of bullwhip:

1. '**Demand forecast updating** – companies in a SC do product forecasting for its production scheduling, capacity planning, inventory control and MRP. In the beer game each player is forecasting based on what he or she observes. When a downstream operation places an order, the upstream manager processes that piece of information as a signal about future product demand and will consequently readjust his/her demand forecast and orders to suppliers'.

2. **'Order Batching** – When demand is made known to a supplier, the company may not immediately place an order with its supplier, as it may want to batch or accumulate demand before issuing an order. Periodic ordering amplifies variability and contributes to the bullwhip effect. Transportation can also have an effect as suppliers may often give their best pricing for Full Truck Load (FLT) orders'.

3. **'Price Fluctuation** - Forward Buying, where customers will take advantage of low price or promotional offers can lead to surges in demand. Such promotions can be costly to the supply chain'.

4. **'Rationing and Shortage Gaming** -When product demand exceeds supply, a manufacturer often rations its product to customers, i.e. often in proportion to amount ordered. Knowing this, customers will often exaggerate their real needs when they order. Later, when demand cools, orders will suddenly disappear and cancellations pour in. The effect of gaming is that customers' orders give the supplier little information on the product's real demand'.

In reference to the work of Forrester and Burbidge, Towill (1997) believed that collectively they provide a comprehensive explanation of the causes of bullwhip (figure 2.17).

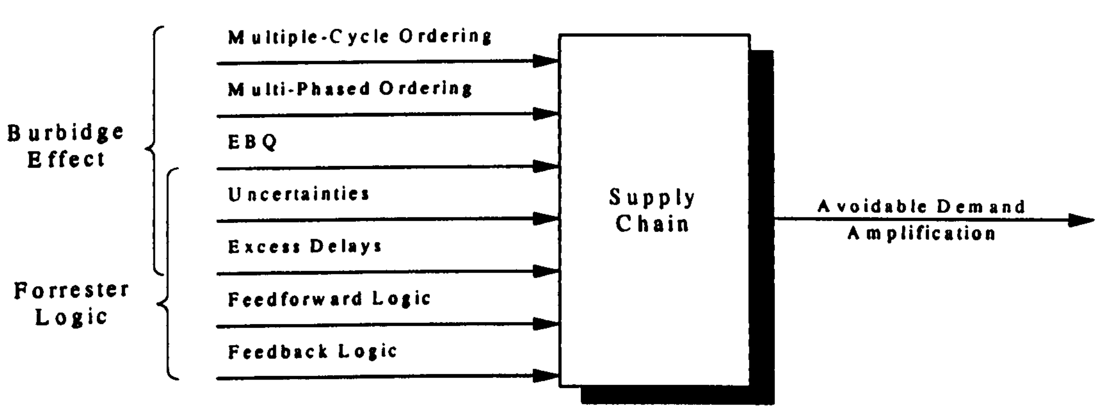


Figure 2.17 – Causes of Bullwhip (Towill, 1997)

From the two analyses above many similarities can be identified. From top to bottom, 'feedback logic' refers to the way in which planning and control systems employ feedback loops to correct inventories. The notion of 'Uncertainties' put forward by Lee *et al* (1997a, 1997b) represents the same theme. The concept of 'Order Batching' (Lee *et al*, 1997a; 1997b) has many similarities to Burbidge's themes of 'Multi-Cycle' and 'Multi-Phased' ordering.

The widely documented causes of the 'Bullwhip' effect that have emerged since the work of Forrester and Burbidge have all been ensued by methodologies to moderate or reduce its effects. As mentioned earlier, Disney *et al* (1997) demonstrated that the use of a model of a decision support system coupled with a simulation facility and genetic algorithm optimisation procedure can yield spectacular results when applied to a supply chain. McCullen & Towill (2002) identified and validated four material flow principles and applied them to the 'Glosuch' supply chain. Using the four principles (Control Systems Principle, Cycle Time Compression Principle, Information Transparency Principle and the Echelon Elimination Principle) McCullen & Towill (2002) showed how bullwhip could be reduced on average by up to 36%. Lau et al (2002) and Yu et al (2001) devised systems to enhance the effects of bullwhip. More recently Disney and Towill (2003a; 2003b) discussed how a vendor-managed inventory (VMI) initiative can have positive results in regards to bullwhip reduction. They investigated each of the causes of Bullwhip as proposed by Lee *et al* (1997a, 1997b) and demonstrated that it is possible to completely avoid two causes of bullwhip altogether (rationing and gaming, order batching).

Many solutions and improvement methodologies have been envisaged from the extensive research carried out on the bullwhip effect. Amongst the most prominent is the sharing of sales and inventory data, the reduction of lead times, batch sizes and delivery frequency. Also it has been shown that by limiting the number and scale of promotional campaigns and established allocation policies based on actual previous sales rather than orders can reduce bullwhip markedly. Narrowing down even further, the assertion that 'information' remains the key to bullwhip reduction can be drawn from the research carried out thus far (Lee *et al*, 1997a, 1997b; Simchi-Levi, 2000; McCullen & Towill, 2001; Lau *et al*, 2002).

In summary, the review thus far has considered supply networks, their ever-growing complexity and how their associated management is going through a period of significant change. Many of the changes are technology-based, whilst others are based upon predetermined strategies. The following section of this literature review examines the different schools of thought that have emerged as solutions to this ever-growing complexity and challenges of SCM.

2.2.4 Supply chain Structures and Solutions

2.2.4.1 Introduction

The operational policies that are to be discussed have emerged to assist in the reduction of uncertainty in supply chains. Manufacturers are being forced to drive out waste and unnecessary cost, reduce lead times and increase responsiveness in order to survive in highly competitive markets. These challenges cannot be met through isolated change to specific organisational units, but instead need to be embraced across entire supply networks.

Many of the policies are inter-related and more often than not, more than one initiative will be in operation at any one time. Selection of the most appropriate initiative depends entirely on the supply scenario and the type of product being produced.

2.2.4.2 Vendor Managed Inventory (VMI) Integration

Vendor managed inventory (VMI) is one of the most widely discussed partnering initiatives for improving multi-firm supply chain efficiency. VMI is a supply chain strategy whereby the vendor or supplier is given the responsibility of managing the customer's stock (Disney and Towill, 2003a; 2003b). Figure 2.18 illustrates a simplistic view of a VMI configuration.

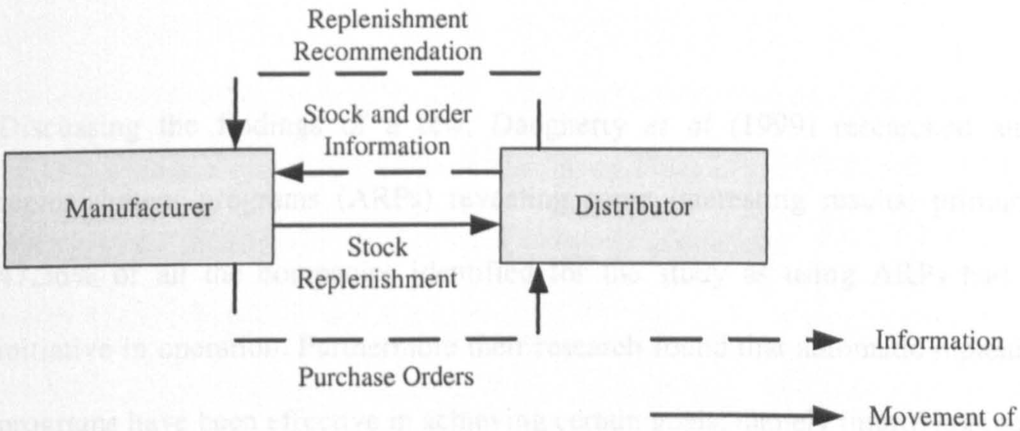


Figure 2.18 – VMI Configuration

Many authors have reported that VMI has grown in popularity over the last 15 years due to retailers such as Wal-Mart incorporating its initiatives (Disney and Towill, 2003a, 2003b; Dong and Xu, 2002; Kuk, 2004; Waller *et al*, 1999;). However, Disney and Towill (2003b) believed VMIs' origins date back to the work of Magee (1958) in a presentation of a conceptual framework for designing a production control system. In the literature, Disney and Towill (2003a, 2003b) revealed that VMI appears in many different forms depending on the author and context they are discussed in. Familiar terminologies include quick response (QR), synchronised consumer response (SCR), continuous replenishment (CR), efficient consumer response (ECR), rapid replenishment (RR), collaborative planning, forecasting and replenishment (CPFR) and inventory management.

In VMI, a relationship is formed where the vendor is given access to its customer's inventory and demand information. The vendor generally compiles this information to generate a recommendation of what and when stocks should be replenished. The benefits of VMI in numerous different scenarios have been widely reported within the literature (Daugherty *et al*, 1999; Waller *et al*, 1999; Achabal *et al*, 2000; Dong & Xu, 2002; Disney & Towill, 2003a, 2003b; Smaros *et al* 2003).

Discussing the findings of a few, Daugherty *et al* (1999) researched automatic replenishment programs (ARPs) revealing some interesting results: primarily that 47.36% of all the companies identified for the study as using ARPs had a VMI initiative in operation. Furthermore their research found that automatic replenishment programs have been effective in achieving certain goals, namely improving/increasing customer service levels, reducing stock outs, improving delivery reliability and speeding up inventory turns.

Waller *et al* (1999) documented how reduced costs and improved service are actually achieved via VMI. In addition, the authors discuss the technological requirements for a VMI system and also investigate the impacts of VMI through simulation. Having created a supply chain model to represent a large variety of industries and using simulations of their ordering rules, the authors found both retailer and manufacturer inventories could be reduced while improving customer service. Achabal *et al* (2000) extend the benefits discussed by Waller *et al* (1999) as they describe the implementation of a VMI decision support system (DSS) for a major apparel manufacturer and over 30 of its retail partners. Separating the two sides, the retailer can achieve (1) more effective inventory management and less uncertainty regarding inventory turnover and customer service levels, and (2) a cost effective method of obtaining sales forecasting and inventory management services. VMI benefits the vendor by (1) providing a method to increase the availability of their brands in stores and still meet retailers' budgetary open-to-buy constraints, (2) eliminating retailers orders which can be misleading in terms of production planning and (3) reducing the opportunity and incentives for gaming.

Moving on to more recent research, Disney &Towill (2003a, 2003b) compared the bullwhip properties of a VMI supply chain with those of a traditional 'serially-linked' supply chain. Their investigations reveal how implementing VMI can eradicate two sources of the bullwhip effect. Looking at VMI from a different perspective Samaros *et al* (2003) incorporated discrete event simulation to examine how a manufacturer can combine traditional order data from non-VMI customers with sales data available from VMI customers. In combining this data the authors assess the impact it has on the manufacturer's operational efficiency. Their work shows that even a relatively small increase in demand visibility can lead to benefits for the manufacturer.

Even though the literature appears saturated with the positive features of VMI, the negatives have also been discussed. Kapia *et al* (2002) discussed the customer's perceived lack of control and how it can hinder VMI implementations. Kuk (2004) listed further limitations: an increased level of details required for planning, high administration costs, ineffective ordering and fulfilment processing, and high incidences of failure on the part of the supplier to harness the customer specific data for planning and manufacturing production. Furthermore, in some cases, priority treatment through reserving finished goods to a few customers has caused a shortage to others. The author reports that these problems have increased the number of cancellations and failures of VMI initiatives.

Samaros *et al* (2003) reported on the results of other research undertaken within this field. They report that research carried out by one group involving 10 companies, concluded that although companies' VMI customers had benefited from improved availability and lower stock levels, only two of the manufacturing companies had been able to realise improvements in their management of production and only one had achieved lower internal inventories.

Form the analysis of VMI it is clear that while negative aspects have emerged, the positive implications of VMI are for all to see. VMI does not require complex systems (Holmstrom, 1998), thus enabling companies of all sizes and capabilities to partake. VMI is an initiative that has evolved and is becoming more widespread as customers are increasingly choosing to delegate responsibility for stock replenishment.

2.2.4.3 Closed Loop Supply Chain (CLSC) Integration

According to Guide (2003), closed loop supply chains are designed to consider the acquisition and return flows of products, re-use activities and the distribution of the recovered products, in addition to traditional forward flows of materials and goods.

With regard to CLSC's, The Erasmus Research Institute of Management (ERIM) along with The Erasmus Econometric Institute has conducted a considerable amount of research on this particular concept (Krikke *et al*, 2001; Kokkinaki *et al*, 2001). Krikke *et al* (2001) have approached the topic from a design perspective, while Kokkinaki *et al* (2001) have tackled the web integration issue of CLSC's. Others, Inderfurth & Teunter (2001) and Guide *et al* (2003) have investigated the production planning and control issues of CLSC's.

A number of key activities make up the skeleton of the overall body of literature on CLSC's: product acquisition, reverse logistics, re-conditioning/re-manufacturing and distribution. Guide (2003) also stated that the choice is often determined by the most profitable alternative between repairing, re-manufacturing or recycling. In terms of this research, 'Reverse Logistics' and 'Re-manufacturing' are key elements.

The concept of 'Reverse Logistics' has, in recent years, gained significant attention from within the realms of academia (Brito *et al*, 2003), and by operations managers and company executives (Dowlatshshi, 2000). Over the past decade the somewhat broad subject matter has been discussed in a number of different contexts. Byrne & Deep (1993) and Wu & Dunn (1995) along with many others have tackled the theme of 'Reverse Logistics' from a purely environmental perspective. Kroon & Vrijens (1995), Pohlen & Farris (1992) and Predergast (1995) have expressed reverse logistics in terms of the recycling issue, whilst many others have focussed their attentions on particular business environments (Tibben-Lembke, 2000; Klausner, & Hendrickson, 2000; Tibben-Lembke & Rogers, 2002; Autry *et al*, 2000).

Focusing on the latter, 'Reverse Logistics' is practised in many different industries: Dowlatshshi (2000) reports that BMW, Delphi, DuPont, General Motors, Hewlett-Packard and TRW all subscribe to this method of business. Thierry *et al* (1995) stated that 'Reverse Logistics' is widely used within the automotive sector. It is becoming evident that firms are using increasingly diverse methods to differentiate themselves or their products from those of their rivals. Many have found incorporating 'reverse-logistics' to recycle or re-manufacture obsolete products can be both cost effective and environmentally friendly.

Re-manufacturing is becoming increasingly popular in a number of different industries (Rogers & Tibben-Lembke, 1999). Re-manufacturing is an integral element of 'Reverse Logistics' and CLSC's. Majumder & Groenevelt (2001) defined it as, *the process of disassembling used items, inspecting and repairing/reworking the components and using these in new product manufacture. A product is considered re-manufactured if its primary components come from a used product.* Statistics compiled in a study by Lund (1998) revealed that there are estimated to be in excess of 73,000 re-manufacturing firms in the United States with a direct employment of 350,000 and total annual sales of $53 billion. Sun Microsystems, Hewlett-Packard, Kodak, Xerox are just a few of the companies that actively participate in re-manufacturing.

From the literature, Guide (2000) identified seven issues within a re-manufacturing context that significantly complicate production planning and control activities:

(1) the uncertain timing and quantity of returns,

(2) the need to balance returns with demands,

(3) the disassembly of returned products,

(4) the uncertainty in materials recovered from returned items,

(5) the requirement for a reverse logistics network,

(6) the complication of materials matching restrictions, and

(7) the problems of stochastic routing for materials for re-manufacturing operations and highly variable processing times.

The issues above along with the research conducted by Guide & Spencer (1997) revealed that there are a number of operational areas that existing information systems fail to adequately address. The system developments that have taken place within this particular area will be discussed within the Analysis Framework Chapter (Chapter 4).

CLSC's emerged as a result of combining the 'forward' and 'reverse' flows that take place in modern day supply chains. Initially CLSC's were envisaged as a way to combine a number of key functions in order to minimise waste and ultimately enhance the environment. However, nowadays they play an integral role in many manufacturing supply chains, and they incorporate all business functions from strategy development and marketing to information systems and operations (Krikke *et al*, 2001).

2.2.4.4 Supply Network Integration

A typical supply chain, or supply network, as discussed in section 2.2.2, consists of either a number of independent enterprises or individual business units within the same company. Many companies have tackled internal inefficiencies though the engineering and reengineering of business practices, and now they are concerning themselves with improving the supply network as a whole (Sauter & Parunak, 1999). Having considered two concepts (VMI and CLSC) that are considered at the cutting edge of supply chain developments (Kehoe and Lyons, 2000), this section examines the more clear-cut notion of supply network integration as a solution.

Common to all manufacturing companies is the need to control the flow of material from suppliers, through the value adding processes and distribution channels, to customers (Stevens, 1989). As Quinn (1997) stated, '*the supply chain encompasses all of those activities associated with moving goods from the raw-materials stage through to the end user. This includes sourcing and procurement, production scheduling, order processing, inventory management, transportation, warehousing, and customer service. Importantly, it also embodies the information systems so necessary to monitor all of these activities.*' Stevens (1989) simplified this stating the scope of the supply chain begins with the source of supply and ends at the point of consumption.

The early work of Stevens (1989) identified customer service as the key output from a supply chain. Customer service is the output of all the functions within a supply system as a whole. Thus, if one function fails, the supply network is disrupted and thereby becomes ineffective. Frohlich & Westbrook (2002) supported this statement by stating that the more integrated the flow of data between customers and suppliers, the easier it becomes to balance supply and demand across the entire network. In order to achieve improved service all of the functions within a supply network must remain stable and therefore trade-offs must be made throughout the chain. Stevens (1989) continued to state that for the benefit of such trade-offs to be achieved it is necessary to think in terms of a single integrated chain. However, the author does recognise the difficulties associated with cross company integration.

In discussing an integrated supply network, Stevens (1989) believed the management of material flow needs to be viewed from three perspectives; strategic, tactical and operational, with the complete coordination of facilities, people, finance and systems. Figure 2.19, taken from Stevens (1989), illustrates a framework for developing an integrated supply chain.

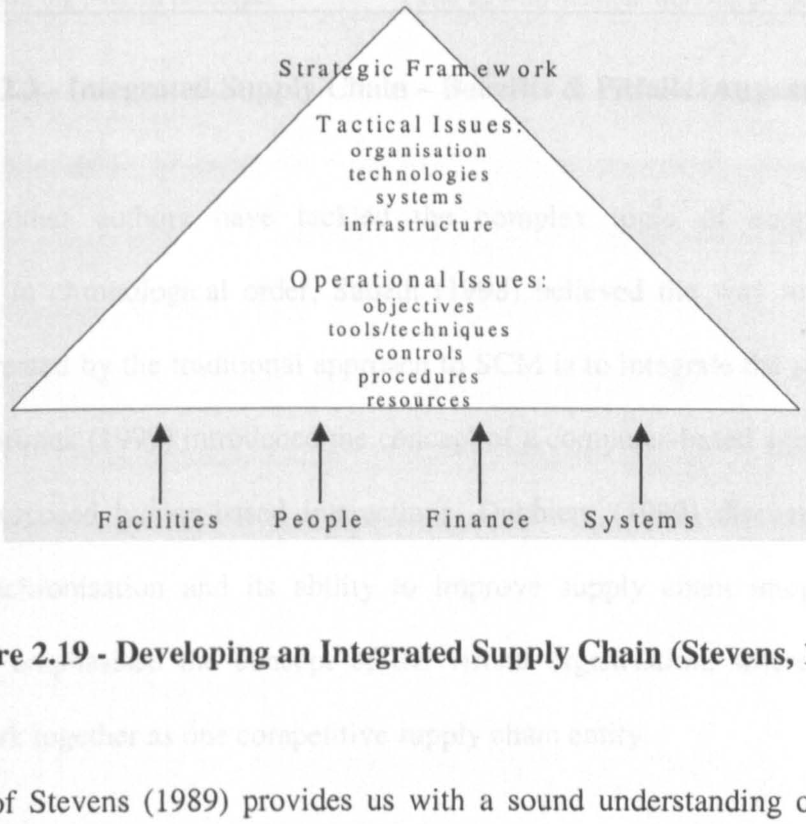


Figure 2.19 - Developing an Integrated Supply Chain (Stevens, 1989)

The work of Stevens (1989) provides us with a sound understanding of some key concepts concerning supply network integration. Moving on to more recent work, August (1999) discussed how integrated supply chains are essential for firms embracing electronic commerce. Steven Cole of Forrester Research says, 'unless a business has integrated its systems with its suppliers, it is going to be very disadvantaged in the Internet economy' (August, 1999). Table 2.3, taken from August (1999), lists the benefits and pitfalls of an integrated supply chain.

Benefits	Pitfalls
Reduces cost by removing manual systems and paperwork	Streamlining suppliers and internal systems is time consuming
Reduces order lead times as suppliers can fulfil in real time	The real value is only realised when suppliers are integrated
Builds relationships with suppliers leading to better order planning, closer working relationships and sometimes better service levels	Requires corporate sponsorship to ensure business goals and objectives are understood, and achieved.
Speeds up payment	Data must be reliable and secure
Improves customer responsiveness	Technology can be complex and expensive
Can achieve return on investment from the first stages – streamlining internal processes	Must standardise with all suppliers so you do not end up with multiple working practices.

Table 2.3 - Integrated Supply Chain – Benefits & Pitfalls (August, 1999)

Numerous other authors have tackled the complex topic of supply network integration. In chronological order, Sabath (1998) believed the way to circumvent problems created by the traditional approach to SCM is to integrate the supply chain. Sauter & Parunak (1999) introduced the concept of a computer-based agent system to assist and succeed human-based interactions. Dabbiere (1999) discussed business process synchronisation and its ability to improve supply chain integration. The author also emphasised the concept of the virtual organisation, where all trading partners work together as one competitive supply chain entity.

Childerhouse *et al* (2002) investigated supply chain integration from within the automotive sector. Having developed a quick scan procedure, the authors analysed 20 European automotive supply chains. Interestingly, only 10 were operating at present day 'best practise'. Frohlich & Westbrook (2002) broke down the concept of integration into demand and supply. In terms of demand-side companies, the authors recognised the major challenges within the supply chain as being improving demand visibility and planning whereas supply-side companies focus upon delivery and cost. Kuo & Smits (2002) incorporated a case study of a high-tech manufacturing company in order to identify factors that improve the performance of integrated supply chains.

The main focus of this paper relates to information technology infrastructures. These are discussed in the Analysis Framework Chapter (Chapter 4).

Supply network integration is clearly a topic of importance. In the real world complete supply network integration is difficult to achieve, especially in sectors with complex supply networks. The key enabler identified within the literature is 'information' and its availability and accuracy. It is fair to say that internal procedures and processes need to be optimised prior to embarking upon an integration strategy. However, the benefits of supply network integration are for all to see with Procter & Gamble incorporating agent-based modelling and ultimately saving $300 million annually. Having identified the key enabler as being 'information' the systems facilitating supply network integration are critical. The development of these systems and future systems are discussed in Chapter 4.

2.2.5 Part One: Summary

In summary, the first section of this literature review has covered a range of topics fundamental to this research. Defining supply chain management and its evolution provides the foundations necessary to move on to the SCM themes more pertinent in today's modern society. The key drivers are recognised as being 'consumer demands', 'globalisation', 'competition', 'government regulation', ' the environment', and the driver most central to this research 'information and communication'.

With case research being undertaken within a selection of high volume supply chain scenarios it was important to consider the literature from this field. Real examples enhanced the depth of this section. Moving on, the focus turned to the instrumental work of Forrester (1958), Burbidge (1961 and 1984) and Sterman (1989). The Forrester effect, later described as the bullwhip effect (Lee *et al*, 1997a, 1997b) is inherent within modern day supply chains and ultimately it can be associated to a significant number of the issues and problems that companies are experiencing.

The final part of this section reviewed a selected number of supply chain structures that have emerged in recent years. Whilst it is acknowledged that there are many other supply chain initiatives that could be considered, the theories of vendor-managed inventory, closed loop supply chains and supply network integration were selected at the outset for their growing popularity and influence. The aim of the Analysis Framework Chapter (Chapter 4) investigates the information systems associated with these polices.

2.3 Part Two: Information Systems

2.3.1 Introduction

This part of the literature review concerns the systems and communication media present in supply chains both past and present. An historical development of supply chain information systems provides foundations for this section. This will show the transition from the earliest BOM (Bill of Materials) Processors and MRP (Materials Requirement Planning) systems to the more sophisticated ERP (Enterprise Resource Planning) and SCM (Supply Chain Management) systems.

Moving on from the historical perspective, a more detailed look is taken of the communication media used to transmit data across supply chain networks. This includes the most primitive means of communication at manufacturing companies (phone and fax) to the more advanced communication media of EDI (Electronic data Interchange) and the Internet.

The penultimate part of this section examines the specific planning systems (MRP, ERP MRPII, SCM) discussed briefly in the historical perspective. Whereas the historical review encompasses how the different systems have emerged over the years, this section focuses upon individual systems functionality. An analysis of 12 software applications currently in operation augments the content of this literature review. Furthermore, the problems associated with legacy systems (integration issues) are also touched upon.

2.3.2 Historical Development Of Supply Chain Information Systems

A clear relationship can be noted between technological advancements of the past 30 years and the changes in business processes. Figure 2.20 illustrates the evolution of manufacturing systems over the past 40 years. As section 2.2.3.2 states, three principal time zones can be identified in which advances in supply chain initiatives have occurred, as reported by Metz (1998), Chandra & Kumar (2000). In the first era (1960 to 1975) there was a tendency for all companies within a supply network, and all departments within a company to plan and operate in total isolation. As a result, information systems were rarely used.

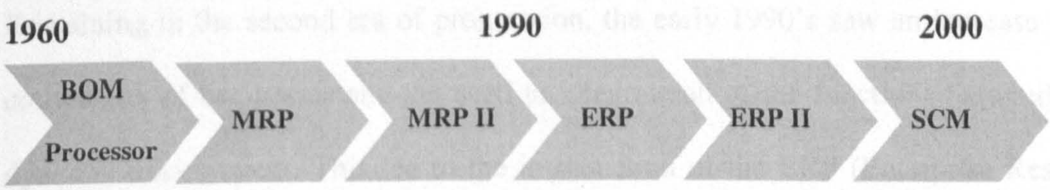


Figure 2.20 - Manufacturing Systems Development Timeline

Incremental changes during the late 1980s and early 1990s represent the second phase of significance within the development of supply chain information systems. BOM (Bill of Materials) processors and then MRP (Materials Requirement Planning) systems were incorporated to calculate production schedules by working backwards from an order due date, utilising fixed production and supplier lead times. Early MRP products were proprietary systems and often required extensive customisation to support diverse manufacturing processes. However, MRP architectures were not renowned for being robust, which created many problems within dynamic business environments. Many of the systems developed during this period continue to remain essential to the successful operations of many manufacturing companies. Often referred to as 'Legacy' systems, they will have been subject to numerous modifications over the years. However, the skeleton of this MRP legacy software remains the backbone of many manufacturing companies.

Technological changes such as client/server architectures, relational databases and object orientated programming impelled the evolution from first-generation MRP systems to second-generation MRP systems. Despite a number of improvements to the core functionality, MRP II systems were still reported to have many of the same limitations as their predecessors.

Remaining in the second era of progression, the early 1990's saw an increase in the complexity of businesses and the need to integrate all of the functions required for a dynamic environment. This led to the introduction of the ERP (Enterprise Resource Planning) tool, which combined MRP II and DRP (Distributed Resource Planning) solutions with a number of enterprise management applications such as financial and human resources. However, a number of problems still existed. The databases behind ERP systems were vast in size, and users hoping to extract information to help with decision-making often became overwhelmed by the sheer volume of content (Allen, 1998; McVey & Cundiff, 2002). The large amounts of historical data held by these databases could not be utilised for business unless advanced analysis tools were used (McVey & Cundiff, 2002). Subsequently, the early ERP solutions did not have the functionality to support important supply chain management decisions.

The mid-1990s begins the final and most recent period of change within this particular sector. A number of software vendors began to approach SCM from a different perspective and addressed many of the limitations intrinsic in traditional ERP systems. Although ERP systems are still being implemented all over the globe, developers of such software are now incorporating capabilities for integration with SCM software. Allen (1998) quoted from research undertaken by the Gartner Group (1997) which stated:

"Through 1999, enterprises with multi-echelon distribution networks that have aggregation, disaggregation, balancing or echelon-skipping requirements within the distribution network will need to augment their existing ERP applications with advanced SCP functionality or risk incurring distribution costs that are at least 10 percent higher due to expediting, low order fill rates and inventory imbalances."

While ERP Systems provide a great deal of planning capabilities, the various material, capacity, and demand constraints are all considered separately, in relative isolation of each other, (Allen, 1998). The author also reported that the more leading edge SCM products are able to consider all the relevant constraints simultaneously, and to perform real time simulations of adjustments in the constraints. McVey & Cundiff (2002), stated that as the SCM market has only emerged in recent years, smaller SCM vendors have benefited from hindsight and have targeted their applications at the gaps in ERP systems

SCM software has been pushed significantly by the phenomenal growth of information technology. McVey & Cundiff (2002) believed that as advances in computing power and data transmission continue, enterprises once thought to be too isolated or dissimilar will rapidly become tractable members of the supply chain community.

2.3.3 Communication Media

'Over the past 30 years organisations have experienced rapid growth in both the number and variety of technologies available to them, particularly those which should aid their communication processes' (Johnson *et al*, 1998).

2.3.3.1 Introduction

Understanding the evolution of modern data communications technologies is useful in understanding why we have arrived at the point we are today. Communication technology has always been central to the operation of a company's supply chain (Pawar & Driva, 2000). The term communication media can be used in many different contexts. For this reason alone it is important to clarify at this stage what exactly is meant by communication media. The communication media discussed in this section encompass all those technologies that have permitted cross company (supply chain) interactions. Thus the telephone, facsimile machine, EDI and the Internet are all discussed.

2.3.3.2 Telephone & Facsimile

The telephone, which converts sound energy to electrical energy and then back to sound, is the world's most widely used means of communication (Gardner & Shortelle, 1997). From the work of two separate groups (Bell and Gray & Edison, 1875), two types of telecommunication were born: analogue and digital (Pawar & Driva, 2000). Since the introduction of the telephone many years ago, information and communication technologies (ICT) have advanced at a phenomenal pace. However, regardless of these innovations, the telephone remains an integral part of industry life. Institutions of all sizes continue to use the telephone in order to convey their data. The financial sector has witnessed an increase in the utilisation of the telephone since the first telephone banking system was introduced by the Nottingham Building Society (NBS) in 1983 (Devlin, 1995).

Many SMEs have remained loyal to the telephone due to the financial implications of incorporating an EDI system (section 2.3.3.3). Consequently many larger corporations ICT infrastructures have been restricted by the number companies willing to invest in their method of communication. Historically, in scenarios such as this, the larger corporation selected one of two paths. They either forced their business partners to invest in communication systems or they continued to use the telephone or the preferred method of their smaller supplier/customer.

Along with the telephone, the fax has been the communication method of choice for smaller companies for many years (Commercenet, 2002). Pawar & Driva (2000) authenticated this with an industry-based case study that reported how a medium-sized UK company used a fax as its main connection to suppliers. A fax machine is a device that scans a document using light and the photoelectric effect. Scanning produces electrical signals that the machine sends via telephone to another fax machine, where signals are used to reproduce a copy of the original document (Gardner & Shortelle, 1997). Since the 1920s, fax machines could be found in virtually every company. For minimal expenditure, companies could send their requirements/orders to their selected suppliers without having to dictate over the telephone. More recently however, the fax machine has had to change in order to compete with the Internet. The introduction of Internet fax machines has prolonged the life span of the fax, however, with the Internet becoming increasingly available the decline in fax machine usage is inevitable.

In conclusion it can be said that technologies such as these are widely used due to their proven historical reliability. Whilst the fax machine maybe slowly nearing retirement, the telephone will remain important for many years to come in terms of manufacturing supply chains. The telephone will retain its status as a critical communication medium until a cheaper, more innovative solution emerges.

2.3.3.3 Electronic Data Interchange (EDI)

The process of 'Electronic Data Interchange' or as it is more widely referred to 'EDI', has been the information transmission backbone of manufacturing companies for many years (Young, 2002). It has allowed business partners to interact via specified message standards, and to this day it is still regarded as a highly innovative business tool that has enhanced business communication infinitely (Robson, 1994). The aim here is to introduce the reader to the concept of EDI and its related areas. First of all, the topics of EDI standards and EDI Carriers (enablers) are reviewed. Following on from this, the impact of the Internet on EDI is investigated. Finally, both the positive and negative implications of EDI recognised in the literature are examined.

2.3.3.3.1 EDI Standards

EDI can be defined as the electronic exchange of standardised business documents over a communications network that links computer systems of various trading partners, (Young, 2002). The long history of EDI combined with its widespread usage across different industries has led to the presence of multiple (often proprietary) standards (Barua & Lee, 1997). The problems started at an early stage when the American National Standards Institute (ANSI) introduced the ANSI X12 standard, which was ensued by various extensions of the language for differing industries. The United Nations then created the EDI for Administration, Commerce and Transport (EDIFACT) standard, which aimed to be a single international language to meet the need of the global economy.

Since the introduction of these standards both ANSI and EDIFACT have evolved to encompass new ideas and technologies. Furthermore, the increasing popularity of the Internet has led to the introduction of Internet-based EDI. Consequently there has been a proliferation of versions of each EDI standard (Young, 2002), making it unattractive to many potential users. However, Barber (1997) is quick to point out that it is not actually the standards that cause the problems with EDI. The author stated that the problem has always been concerned with the structure of a transaction. For example, a document type such as a freight bill with ANSI X12 transaction set 210 is a reflection of the data one trading partner needs from another. The transaction set layout is based on the database or file format necessary to support a specific business application such as a freight bill payment module. Ultimately the origin of the problem lies in the fact that very few trading partners are alike, and therefore it is seldom the case that transaction sets are identical.

2.3.3.3.2 EDI Carriers

Moving away from the contentious issues associated with EDI standards, the next topic for discussion concerns the carriers that enable EDI (Direct Link, VAN, Workstation EDI and Internet EDI). The work of Gudmundsson and Schieveen (2001) provide us with a valuable insight into the EDI carriers identified above. Beginning with the 'Direct Link', the authors describe it as a point-to-point link that is employed to trade among closely affiliated companies. The system avoids any companies situated outside of the specified boundaries due to the added complexity of handling more than one standard. A public telephone line or a leased line can be used to transfer the data. Figure 2.21 illustrates the direct link configuration.

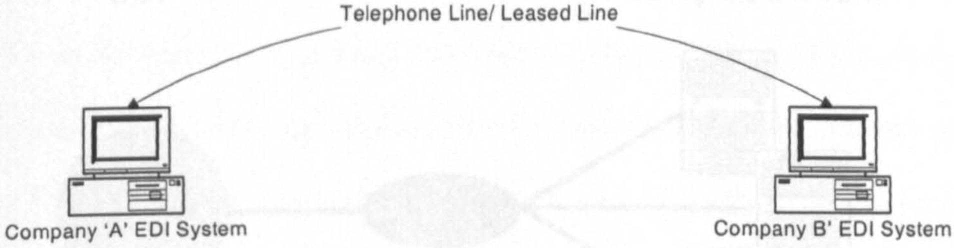


Figure 2.21 - Direct Link Configuration

Companies that have chosen to incorporate a 'Direct Link' configuration, require advanced knowledge of computers, telecommunications and EDI in order to set up communication between trading partners and to integrate the data with in-house applications (Esichaikul and Chaichotiranant, 1999).

The Value Added Network or VAN is the second EDI carrier of interest. A VAN can be described as a privately owned network that manages the connections between participating companies, supplies additional services, similar to trading partner agreements (TPA), and oversees the network. VANs are extremely useful as they allow PUSH and PULL facilities for the sending and receiving of data. The VAN actually serves as a normal post delivery service in which the customer posts a message and its delivery is taken care of (Gudmundsson and Schieveen, 2001). Where other forms of networks fall short in terms of services offered, VANs translate, receive and store messages whilst providing high levels of security (Nelson, 1996). Although the Internet is emerging as a medium to pass data, VANs are still very much the preferred option for data transmission. However, as Ericson (2002) reported, VANs can be expensive. For example, a traditional VAN might be $250,000 for a mainframe installation, plus subscription fees that run as high as 70 cents per transaction. A typical example of a VAN EDI configuration can be observed in figure 2.22.

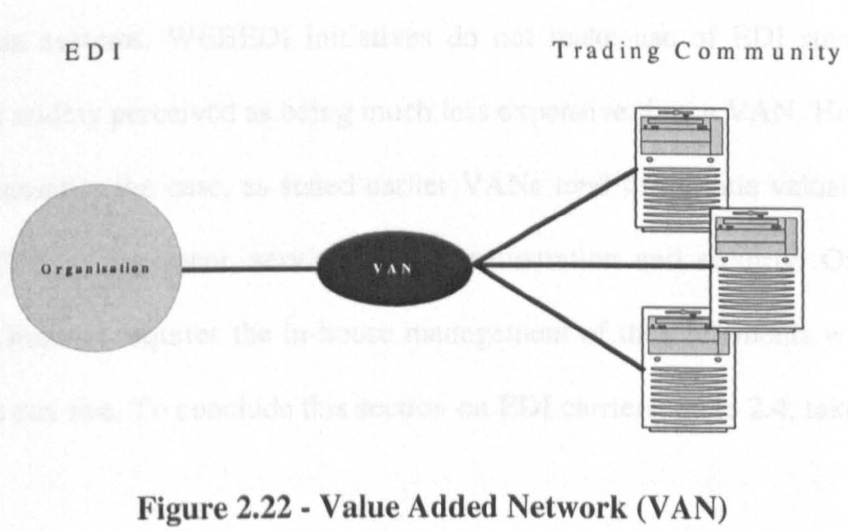


Figure 2.22 - Value Added Network (VAN)

Moving on, 'Workstation EDI' is common in many SMEs, due to their larger trading partners enforcing an EDI-based business environment upon them. Functionality is limited and the system simply allows them to receive an EDI order that can then be printed out and manually entered into their own planning system. There is no integration with internal systems, hence the manual tasks. Esichaikul and Chaichotiranant (1999) reported that this paper-based method is prone to errors. In this case there is clearly no real benefit to EDI as no system integration is achieved (Gudmundsson and Schieveen, 2001).

In terms of the Internet, the two principal methods of conducting EDI are 'Internet EDI' and 'WEBEDI'. 'Internet EDI' incorporates the Internet as a platform for the exchange of transactions only, similar to the VAN and Direct Link scenarios where EDI data is integrated into the internal information systems. E-mail services or file transfer protocol technologies are used for this type of EDI. When e-mail is incorporated, the EDI messages are sent as attachments to the relevant trading partners. Whereas with FTP EDI, entire files of transactions are sent, usually at a specified time. Focusing on WEBEDI, this method of data transfer is more popular where the trading partners are unable to insert data automatically into their internal information systems. WEBEDI initiatives do not make use of EDI standards. The Internet is widely perceived as being much less expensive than a VAN. However, this is not necessarily the case, as stated earlier VANs tend to provide valuable services such as TPA management, service level administration and security. On the other hand, the Internet requires the in-house management of these elements which means total costs can rise. To conclude this section on EDI carriers, table 2.4, taken from the work of Gudmundson and Schieveen (2001), compares the different EDI carriers previously discussed.

	Direct Link	VAN	Workstation EDI	Internet EDI	Other Platforms non-EDI (Internet)
Data Security	Low	High	Low	Low	High
Transmission Speed Guarantee	High	High	Low	Low	High
Capacity to Integrate Data	Yes	Yes	No	Yes	Yes
Service Areas	Local	Local/Global	Local	Global	Local/Global
Number of Trading Partners	Very Limited	Unlimited	Unlimited	Unlimited	Limited
Ease of Implementation and maintenance	Low	High	Very High	High	High
Costs	Low	High	Low	Very Low	Low
Expertise Level Needed	High	Low	Low	Low	Low
Audit Traceability	High	High	Low	Low	High
Message Volume	High	High	Low	Low	High
Implementation & Support Services	Low	Depends on VAN	Low	Depends on Provider	Depends on Provider

Table 2.4 - Comparison of EDI Carriers (Gudmundson and Schieveen, 2001)

The origins of table 2.4 stem from the work of Esichaikul and Chaichotiranant (1999). The author's work provides a useful insight into a number of different EDI carriers, some of which do not appear exclusively in table 2.4.

2.3.3.3.3 The Impact Of Internet Technologies on EDI

The Internet has impacted EDI in a number of ways. Not surprisingly, today most businesses use the Internet mostly for e-mail. From an EDI perspective the Internet offers some impressive possibilities. Barber (1997) reported that some preliminary studies have indicated that EDI transmissions, through the Internet, rather than an EDI VAN, could be as much as 80% cheaper, whilst Adams (1997) stated that Internet EDI transactions cost from one-half to one-tenth the price of VAN-based transactions.

However, as mentioned earlier security issues would have to be accounted for when not choosing to incorporate a VAN. It is evident that the Internet is having an impact by the actions of many of the traditional EDI and VAN providers. Companies such as Harbinger Corp. of Atlanta, General Electric of Rockville, MD., Sterling Commerce of Dublin, Ohio, Premenos Corp. of Concord, Calif., IBM, EDS and GE Global eXchange Services have all rushed to the market with Internet-based EDI Products (Adams, 1997, Ericson, 2002).

As mentioned earlier, with regards to the Internet, there are two principal methods of conducting EDI. The first method uses the Internet as a platform for exchange of transactions only. E-mail and FTP services are common here and the data within the EDI transactions can be integrated into the internal information systems. The second method encompasses the World Wide Web to create a trading community of shippers, logistics companies and carriers, all linked electronically. Via technologies such as EDI translators and web browsers, data can be transformed into EDI transactions. General Electric Information Services is now offering a service called GETradeWEB (Adams, 1997). Users can use their web browsers to translate forms into EDI Formats.

The advantages to this approach have been well documented by Barber (1997). First of all, browser technology and ISP rates are relatively inexpensive. Combined with this a website can be continually updated with the most up-to-date layout or requirements. Websites require relatively little maintenance on the part of the person or organisation accessing the site. Finally, it is possible to add other pieces of constructive information such as contact names, procedures and policies that you cannot do with EDI. The Websites functionality can be enhanced at a later stage by enabling database access for pre-editing of data and incorporating Java applets, which would allow plug-ins to be downloaded for those accessing the site. An example of a company that allows its customers to download their free software is Federal Express. FedEx uses the Internet to offer additional customer services such as onscreen preparation of air-shipment documents, storage of address books, ordering, tracking and management of shipping history information (Gudmundsson and Schieveen, 2001).

In summary, the Web can provide smaller organisations with an easy, inexpensive method to enter data. With the Web and E-commerce the need to wait for EDI standards to stop evolving is no longer necessary. A study undertaken by Deloitte & Touche Consulting Group and the Electronic Commerce Process Improvement Group, revealed statistics that indicate the Internet could be of greatest value to those who do not presently have a clear business case for traditional EDI (Koloszky, 1998). Thus table 2.5, proposed by Barber (1997), acts as guide for when to incorporate traditional EDI or Web-based Electronic Commerce.

Traditional EDI	Web-based Electronic Commerce
Large volume of transactions	Low or intermittent volume of transactions
Business systems allowing integration	No systems or difficult integration
Existing technical resources	Limited or no technical resources
Dealing with many trading partners	Dealing with few trading partners
Open trading partner community	Relatively closed trading partner community
Broad set of business transactions	Limited set of business transactions

Table 2.5 - Incorporation of Traditional EDI or Web-based EDI? (Barber, 1997)

2.3.3.3.4 The Pros and Cons of EDI

Many companies have adopted EDI, often with results inconsistent with the expectations of the company (Walton & Gupta, 1999). Discussing the benefits first, Stone (1994) asserted that the advantages of speed and accuracy are difficult to quantify, but in terms of the elimination of the plethora of paperwork, combined with the reduced levels of re-keyed data, EDI definitely removes the human error. Although cost benefits are difficult to quantify in terms of EDI, RJB Nabisco estimated that processing costs for a paper-based purchase order is almost $70, whereas the same transaction through EDI costs less than $1 (Millman, 1998).

Ivcovou *et al* (1995) placed the advantages that EDI technology has to offer in two distinct categories. In their paper, the authors stated that direct benefits encompass mostly the operational savings related to the internal efficiency of the organisation, whereas, the indirect benefits received refer to the impact of EDI on the business processes and relationships. With this in mind, Walton & Marucheck (1997) declared the benefits of EDI to be reductions in delivery lead-times and inventory levels, lower error rates, and less clerical effort to complete purchase orders (Escichaikul & Chaichotiranant, 1999; Lim & Palvia, 2001). The latter clearly falls under the umbrella of direct benefits.

On the other hand (indirect benefits) Hoogeweegen *et al* (1998) drew attention to the premise that the large-scale use of EDI leads to improvements in the communication infrastructure between organisations. Furthermore, the authors consider it to be widely recognised that EDI enables organisations to redesign their processes significantly because of its three main capabilities: high speed, reliability, and ease of data capture. On a similar theme, Walton & Gupta (1999) believed that many of the benefits from the technology that accrue to an adopting firm come about through changes made to assimilate the technology into the organisation.

Rassameethes and Kurokawa (2000) looked at the effects of EDI within industry. The authors believed that EDI can benefit many departments within an organisation. It enhances purchasing effectiveness through decreases in vendor selection costs and easier monitoring of suppliers' delivery and quality performance. Manufacturing is improved through more effective just-in-time inventory management, order processing and engineering design benefit from more efficient data usage. Providing an example, the authors described how in the US automotive industry, with its just-in-time environment, EDI is a powerful supply chain technology allowing automakers and many of their first-tier suppliers to quickly communicate their requirements to component and material vendors and to receive back precise delivery schedules.

Drawing from the above the benefits of EDI appear to be widely documented. However, according to Walton & Gupta (1999), EDI has been implemented with mixed results when compared to company expectations. Millman (1998) identified EDI's high cost of acquisition as the major complaint within industry. The author reported that EDI costs come from three different sources. (1) The cost of EDI-enabling software, (2) annual software maintenance contracts and (3) telecommunication charges. It is reported that software purchase and implementation costs can exceed $10,000. In larger corporations, software vendor support agreements and telecommunications charges can triple and quadruple that expense each year. Other costs include the need for appropriate hardware to support the system, initial and ongoing training of EDI operators and the actual shipping of goods often requires the implementation of costly EDI-compliant barcode printing and scanning equipment. The author reported that in large companies, the cost of EDI is offset by the increase in efficiency. But for smaller companies the cost can be prohibitive.

Contact Internet Solutions (2002) described the problems associated with standards and how the incremental cost of translating native formats to standard EDI formats has kept many small and medium sized companies away from electronic commerce. They believed that large companies have been derailed by their inability to bring smaller trading partners on board with EDI. Large organisations can only seem to automate 60% to 80% of all transactions, leaving 20% to 40% of the traditionally more complex transactions to be manually dealt with. In the paper by Ericson (2002), Rabin highlighted the problems associated with VANs and their deployment costs (refer to 2.3.3.3.2). The author also referred to the prohibitive cost of subscribing to a VAN for no other purpose than to transmit EDI documents. Adams (1997) also mentioned the huge challenge of reengineering business applications and building EDI interfaces. Hart & Saunders (1997) reported that the transition from paper to EDI often requires more than a year in time and considerable infrastructural changes to a wide range of business procedures, practices and strategies. Finally, Barber (1997) mentioned the complexity created by incorporating EDI software (translators, mappers) and the inflated communication costs all combine to make EDI very expensive.

In summary therefore, the advantages of a company adopting EDI are reduced inventories, improved customer relationships, reduced production time of finished product and of course an improvement in information quality. Although these benefits are impressive, the true value of EDI lies in its ability to allow the total re-engineering of business processes and information flows (Hodgson, 1995).

However, as the previous discussion suggests, a number of problems exist with EDI, which have left many pondering its real worth. Even though standard message formats have emerged, few trading partners are alike, and therefore it is seldom the case that transaction sets are identical (Barber, 1997). Moreover, EDI can be very expensive to implement, and so both small and medium-sized companies are often discouraged by the high cost of installing EDI, as Lee & Whang (2000) expressed.

Therefore, the arguments above lead many to the opinion that EDI is far from effective. Those who have successfully introduced EDI are sure to have experienced a number of benefits. Conversely, those who have not been able to afford EDI or those who have simply just avoided it for their own reasons may well feel relieved that they missed out. With the emergence of new technologies, EDI is not disappearing but evolving, and thus, becoming increasingly available. However, the extent to which companies will choose to incorporate EDI will depend on the range of viable alternatives in the marketplace.

2.3.3.4 The Internet

The Internet has been hailed as the dawn of a new era of global communication (Microsoft Corporation, 1996). The first documented recordings of the social interactions that could be enabled by networking were reported by J.C.R. Licklider in 1962 when he discussed his "Galactic Network" concept. Based originally in MIT, Licklider moved over to the Defense Advanced Research Projects Agency (DARPA) in late 1962 to head the work to develop his concepts on networking. Leonard Kleinrock of MIT and later UCLA developed the theory of packet switching, which was to form the basis of Internet connections, (Howe, 2002).

In the early years, e-mail, file transfers, and listservs were the major Internet applications. Since then, the introduction of user-friendly browsers, World Wide Web (WWW) applications, have been increasing in an exponential fashion and have become the driving force behind the expansion of the Internet user base (Lu & Yeung, 1998). The Internet is now a critical tool for cross company communications. As Cronin (1995) stated, '*with its expanding user base, the Internet has been recognised as a technology which can make a significant contribution to components of a company's value chain, for it can improve a company's relationships with vendors and suppliers, internal operations, and customer relations*'.

Having discussed EDI and VANs and Internet EDI, discussion here concern how the Internet is used to transfer other types of documents namely e-mail and XML.

2.3.3.4.1 The Internet Communication Channel

The Internet's ability to facilitate the exchange of EDI messages has already been covered in section 2.3.3.3.3. However, the Internet's influence on EDI has only emerged in recent years. As the introduction states, the first real 'killer application' of the Internet was e-mail (IBS Inc & Focus Software Int. Inc, 1995). To send e-mail, a company or individual are required to have access to the Internet and a mail server. The standard protocol used for sending Internet e-mail is called Simple Mail Transfer Protocol (SMTP). It works in conjunction with Post Office Protocol (POP) servers. Originally the first e-mails consisted of simple text. It was impossible to send attachments such as formatted documents. With the advent of MIME, (Multipurpose Internet Mail Extension) and other types of encoding schemes, such as UUencode, it has become possible to send formatted documents, photos, sound and video files.

Without discussing the capabilities of individual systems, Mohamed (2003) stated that with new web technologies, Internet-based systems can deliver functionality and information to users through a standard web browser, thereby eliminating requirements for traditional EDI or client-based software. In terms of electronic commerce the advantages of using the web can be classified into three channels, based on the functions performed (Kiang *et al*, 2000):

(1) As a communication channel: information exchange between sellers and buyers:

- Accessing, organising and communicating information
- Improving interactivity and perceptual experience
- To gather information about customers

(2) As a transaction channel for: sales activities.

- Streamlining transaction processing, thereby reducing task complexity, paperwork and transaction costs
- To customise promotion and sales to individual customers and improve flexibility
- To improve visibility and reach a much bigger customer base
- To improve revenues by exploiting cross-selling opportunities

(3) As a distribution channel: physical exchange of products/services

- To eliminate huge inventories, storage costs, utilities, and space rental.
- To shorten supply chain and reduce commission and operating costs.

One of the key developments within the area of Internet communication is eXtensible Mark-up Language (XML). A constructive description of XML is provided by Walsh (1998). XML is a mark-up language for documents containing structured information. Structured information contains both content (words, pictures, etc.) and some indication of what role that content plays. Almost all documents have some structure. A mark-up language is a mechanism to identify structures in a document. The XML specification defines a standard way to add mark-up to documents.

According to Wrightson (1999) there are technical reasons and business reasons why XML is having such an impact. Discussing the technical reasons first, the author reported that XML is much more suitable than HTML as extracting HTML from documents is difficult since the tags are designed to express presentation. Standard Generalised Mark-up Language (SGML) from which XML is a subset is too complex for the kind of information transfer currently used by HTML. In terms of the business reason expressed by the author, XML is a platform independent and vendor independent standard and it is not linked to any one programming language or interface. The cost of entry to XML is low and the toolset for XML development is growing rapidly with many of the tools freely available on the web. The author acknowledged that XML is young, however, listed the domains of web commerce, publishing databases, inventory access and repositories as just some of the areas in which XML is having an effect.

In terms of supply chains XML is having a profound effect. Ferrar (2000) believed XML offers a great opportunity to promote Internet communications of data, which is essential for supply chains. Whittle (2001) stated how XML can reduce communication costs, thus allowing smaller companies into the communications arena. Nurmilaakso *et al* (2002) presented a prototype of an XML-based system implemented in a 'real' supply network. The authors concluded that the prototype provided a sound basis for XML-based supply chain integration. Evidence from the study suggests significant cost savings (in comparison to EDI), and increased flexibility, as other companies in the supply chain do not require an integration system. In summary the authors' stance is that XML-based integration systems provide a significant alternative to EDI.

Therefore, the rapid growth of Internet communication has been unparalleled in the history of technology (Boyle & Alwitt, 1999). Osmonbekov *et al* (2002) quoted statistics from 'eMarketer.com', which state that over 90 percent of medium/large firms have Internet connections, and, by the year 2003, nearly $3 trillion or fully 25 percent of business purchasing will involve e-commerce.

Clearly the Internet has had a profound effect on the way companies do business. As new Internet-based technologies emerge its influence on society is only likely to increase. The emergence of XML has warranted discussion and the way in which the Internet and XML are changing the structure of supply networks has also been examined.

2.3.4 Planning Systems

2.3.4.1 Introduction

The historical evolution of these systems has already been discussed in section 2.3.2. Here the author seeks to guide the reader through the core functionality of these different systems and identify the trends that are currently directing the large software companies. An analysis of 12 software applications currently on the market supports the discussions in this section. The 12 companies include a range of ERP, SCM and Internet Service Providers (ISPs) in order to gain a clear picture of the range and functionality of products currently on the market. The final part of this section attempts to identify the issues and problems associated with legacy systems.

2.3.4.2 MRP II & ERP Applications

According to Hong Kong Productivity Council (HKPC, 2000), ERP/MRP II is a closed loop planning and control system that covers the three key cycles in a manufacturing business. These are: - Revenue Generation, Production and Procurement Cycles. Figure 2.23 illustrates how these three business areas interact.

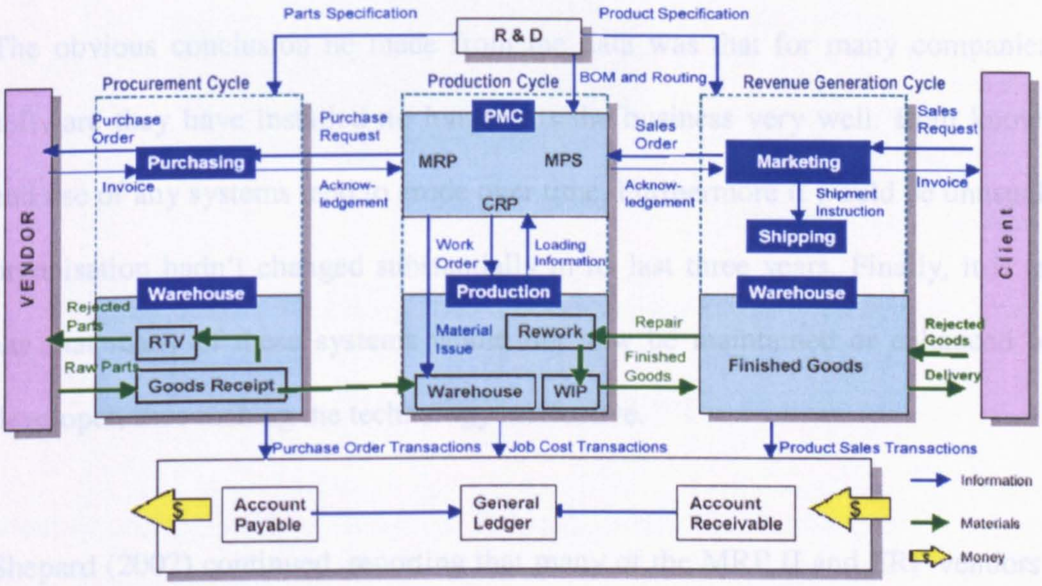


Figure 2.23 - MRP II/ERP Architecture Breakdown (HKPC, 2000)

Luebbers (2001) of Gartner Research stated '*today's ERP applications automate business processes across four main functional areas: Manufacturing, Financial Information Systems (FIS), Human Resources, and Distribution & Logistics/Supply Chain Management*'. However, in a survey undertaken by Shepard (2002) and AMR Research, it was found that half of all the companies interviewed had purchased their ERP systems more than five years ago and nearly 70% were purchased prior to the introduction of client/server ERP systems in 1993 (refer to figure 2.24). Therefore, figure 2.23 provides a realistic illustration of a typical MRP II/ERP system.

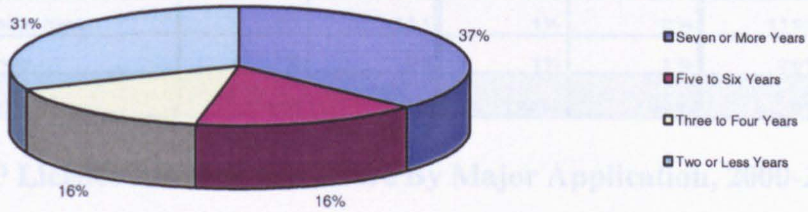


Figure 2.24 - Age of Installed Systems (Shepard, 2002)

Shepard (2002) made a number of key assumptions based on the information above. The obvious conclusion he made from the data was that for many companies, the software they have installed no longer fits the business very well. Both knowledge and use of any systems tend to erode over time. Furthermore it would be unusual if an organisation hadn't changed substantially in its last three years. Finally, it is true to say that many of these systems would not now be maintained or enhanced by the developer, thus making the technology ineffective.

Shepard (2002) continued, reporting that many of the MRP II and ERP vendors have suffered major disruptions from mergers, acquisitions, and management changes in recent years. This has come about as software companies have recognised the need to evolve to encompass new concepts and strategies such as SCM and CRM. As Kraus and Shepard (2002) account, ERP vendors are beginning to get substantial returns from this investment in newer application categories. These application extensions represent 19% of total ERP vendor license revenue in 2001. The authors continue, stating that the products are certainly improving, and in some cases the ERP vendors can offer SCM and CRM functionality that rivals the top-ranked specialist vendors. Table 2.6 and figure 2.25 demonstrate the areas of growth within ERP products.

Application	Revenue, 2000 ($M)	Revenue, 2001 ($M)	Revenue Share, 2000	Revenue Share, 2001	Growth Rate, 2000-2001
Core ERP	5906	5770	86%	81%	-2%
Procurement	129	178	2%	3%	38%
Supply Chain Management	306	349	4%	5%	14%
Customer Management	440	596	6%	8%	36%
Product Lifecycle Management	51	111	1%	2%	119%
B2B Exchange Platforms	75	94	1%	1%	26%
Total	6906	7098	100%	100%	3%

Table 2.6 - ERP Licence Revenue and Share By Major Application, 2000-2001 (Kraus & Shepard, 2002)

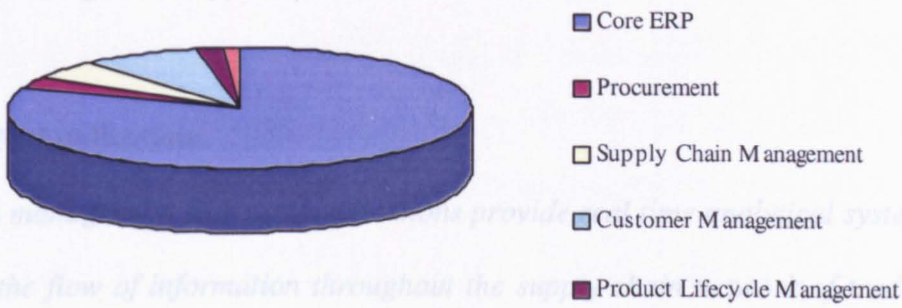


Figure 2.25 - ERP License Revenue Share By Major Application, 2001 (Kraus & Shepard, 2002)

Moving on, the work of Kraus & Shepard (2002) also focused upon the area of enterprise resource planning technology environments. The authors' work identified that even though client/server is still the dominant platform in terms of revenue share (57%), Web-based applications are right behind it with 38%. Web-based applications are rising as new license purchases are more collaborative in nature and focused on self-service capabilities. However, the authors note that while most vendors have begun to move existing client/server architectures to Web-based architectures, the deployment of Web-based applications is still sparse, and most vendors have had to develop a more evolutionary migration strategy rather than adopt a re-implementation strategy.

In summary, ERP vendors are clearly undergoing a period of transition as they are trying to keep pace with the developments in both technology and strategy. Products are becoming increasingly modular and the influence of the web is having a pronounced effect. Combined with this, traditional ERP vendors now have to compete against specific SCM vendors that have emerged in recent years. As Shepard (2002) identified, supply chain functionality is an evident weakness within many of the present ERP systems. The following section explores the literature surrounding Supply Chain Management Applications.

2.3.4.3 SCM Applications

'Supply chain management software applications provide real time analytical systems that manage the flow of information throughout the supply chain network of trading partners and customers in both direction.' (Sahey & Gupta, 2003)

It has become difficult to classify SCM software with any degree of uniformity due the diversity of the systems that have emerged within the confines of SCM. A report by AMR Research (Grackin *et al*, 2002) split SCM into two distinct areas; supply chain execution and supply chain planning, as table 2.7 illustrates.

SUPPLY CHAIN MANAGEMENT SOFTWARE	
Supply Chain Execution	**Supply Chain Planning**
Order Management	APS Distribution Planning
Inventory Management	APS Manufacturing Planning
Transportation Management	APS Production Scheduling
Warehouse Management	APS Supply Planning
Supply Chain Event Management/Visibility	APS Demand Planning and Forecasting
	APS Supply Chain Network Design

Table 2.7 - SCM Software Breakdown (Grackin *et al*, 2002)

However, Green (2001) made reference to there being three distinct groups: supply chain planning and execution software, warehouse management systems, and transportation management systems.

The difficulty in classifying SCM systems can be largely associated with the growing trend by software companies to modularise their product suites. Reddy (2002), stated that software vendors are choosing to develop modular applications rather than tightly integrated technologies that provide a wide range of functionality for two principal reasons, namely to reduce implementation risk and also to increase the customer base by offering lower-priced modules.

Allen (1998) identified a number of other important trends that are shaping the SCM application landscape. First, leading ERP vendors were all reacting to the increased popularity of SCM software by revamping previous versions or newly developing their own. There has also been a trend for vendors of SCM and ERP software to consolidate their product suites as McVey & Cundiff (2002) demonstrate in table 2.8.

The second recognisable development relates to the fact that most SCM products are now being designed with the Internet in mind, and typically they are providing facilities to complete transactions over the Web rather than the more expensive EDI route. The advantages of doing the latter have been well documented by authors such as Sheridan (1996) and Cross (2000). The trends above will become increasingly evident in the subsequent analysis of twelve SCM related products (section 2.3.4.4).

Enterprise Vendor	Type	SCM Vendor	Date	Acqu. Size or Percent Stake
Aspen Technology, Inc.	Acquisition	Chesapeake Decision Sciences	5/98	$135 M
Baan Co. N.V.	Acquisition	Berclain Group CAPS Logistics	5/96 9/98	$70 M $68 M
J. D. Edwards & Co.	Acquisition	Numetrix	6/99	$80 M
PeopleSoft, Inc.	Acquisition	Red Pepper Software Distinction Software	10/96 12/98	$60 M $10 M
SCT Corp.	Acquisition	Fygir Logistic Information Systems	9/98	$35 M
JBA Holdings plc (GEAC)	Embedded License	Symix Systems	7/99	--
Mapics Solutions, Inc.	Embedded License	Symix Systems	7/98	--
Oracle Corporation	Embedded License	i2 Technologies	11/97	--
SAP AG	Investment	OKEF-tech ILOG Catalyst International	6/98 7/98 9/99	51% 5% 10%
Oracle Corporation	JMA	Industri-Matematik	1/97 (and "informal" earlier)	--
i2 Technologies	Interface	EXE Technologies	4/99	--

Table 2.8 - Markets Converge (McVey & Cundiff, 2002)

Acquisition: One company taking over controlling interest in another company
Investment: Equity investment by one partner in another in exchange for product technology
Embedded License: Code or Application-level integration of product in exchange for license fee
JMA: Joint marketing agreement
Interface: Standard interface development through shared technology

2.3.4.4 SCM Software Application Analysis

Here four leading SCM Software vendors, supply chain products from four leading ERP vendors and four supply chain products developed and maintained by Internet service providers (ISPs) are examined. The information used to generate the following comparison was compiled through independent research companies, journals and the websites of the companies involved in the study. Table 2.9 lists the companies selected for the comparison. Appendix A contains the final analysis of the 12 software applications.

	Company Name	Product Name
SCM Software	i2 Technologies	i2-Six
	Manugistics	Manuguistics SCM Solutions
	IBS	IBS Solutions
	Manhattan Associates	Manhattan Associates
ERP Software	SAP	MySap SCM
	Oracle	Oracle SCM
	PeopleSoft (Acquired J.D. Edwards)	Peoplesoft SCM
	SSA (Acquired Baan)	SSA SCM
ISP Software	WeSupply	On Demand
	Vertical Net	VerticalNet
	Elcom Inc	Elcom/Pecos (depending on product)
	Supply Works	Supply Works MAX/SOURCE

Table 2.9 - Selected Companies

2.3.4.4.1 SCM Software Companies

- i2 Technologies

In a report by AMR Research (Grackin *et al*, 2002) on supply chain management applications, i2 technologies were identified as the sector leader, with 27% market share of Supply Chain Planning (SCP) total revenue in 2001. However, its market share was down from 32% in 2000 with further losses expected. The beneficiaries are reported to be the large ERP players such as SAP and PeopleSoft. The same report revealed 5 different application segments on offer from i2, namely, procurement, SCM, customer management, product lifecycle management and B2B platforms. Significantly there is no enterprise management application segment on offer. In 2001, i2's SCM component received sales totalling $828 million, which was $362 million dollars more than its nearest rival (SAP).

In terms of Supply Chain Execution (SCE), the marketplace is considerably more fragmented and the i2 product does not have the same domination as with its SCP suite. It is hoped that a number of strategic partnerships with EXE Technologies, Vastera, and Qiva will help them emerge as a key player in this particular field.

- Manugistics

Manugistics developed and marketed the very first supply chain management software in 1980, (Allen, 1998). AMR Research ranked Manugistics in third place within their analysis of the revenue and growth of SCM vendors. SAP is the only company of a non-SCM background to have achieved superior results. In terms of the 5 different application segments mentioned above, Manugistics focus intensely upon SCM as the report indicates. In 2001, the Manugistics SCM component received sales of $319 million, which placed it firmly between the SAP and IBS supply chain products. The Manugistics SCP product was positioned third place in terms of revenue, and future growth looked good. Manugistics was reported to have always had a strong presence in SCE with its dominant TMS application and was situated in sixth place in the corresponding SCE table.

- IBS

Situated fourth for revenue generated by their SCM product, IBS did not appear to be particularly strong within the SCP market, not appearing in the top 10. However, according to AMR, Sweden-based IBS continued to lead the SCE market. The companies held 9% of the market in 2001. An important point to note is that figures would suggest that it won't be too long before SAP take over the lead in this particular market.

- Manhattan Associates

The Manhattan Associates product completes the line up for 'pure' SCM products. Similar to IBS, its product did not perform so well in SCP but made up for it with strong results and excellent growth potential in the execution market. Its 5th place for revenue generation and the company's 3% hold of the market support the belief that the future could be promising.

- SAP

SAP is considered to be the market leader in ERP software around the globe. SAP was situated in second position within the SCM market, holding an 8% share of the total business. Its SCM revenue was derived not only from its Advanced Planning & Optimising (APO) software but a variety of traditional ERP offerings that fall beneath the canopy of SCM. SAP's growth rate forecast exceeded that of any competitor by a considerable margin. From a SCE perspective, SAP's R/2 days, have brought about capabilities in WMS and Transportation Management System (TMS) applications. Although these capabilities are not advanced enough to compete with best of breed, SAP's large installed base and integration services continue to provide revenue. SAP was situated second for both SCP and SCE respectively.

- Oracle

Oracle Corporation was formed in 1977 by three systems analysts that wanted to provide the first commercial relational database product. The revenue generated from the different application segments provided interesting reading. Oracle came in second place based on sales of its enterprise management application and scored highly in terms of sales in the majority of the remaining application segments. However, the Oracle SCM product received low revenues in comparison to others in the study, coming at number 36 for SCM revenue. On the positive side, Oracle have made a number of key strategic alliances, that have improved its product considerably. Forecasted growth for its SCM product was amongst the highest of the top 100 companies.

- PeopleSoft

Since the report by AMR Research, PeopleSoft have taken major steps to improve their product, the most significant being the acquisition of J.D. Edwards Corporation. This made sense as the SCM component of the J.D. Edwards product had strong growth forecast and was positioned high in the revenue table. Through this acquisition, PeopleSoft have now taken onboard all of the customers loyal to J.D. Edwards. It also gives them a vital foothold in a highly competitive market.

- SSA

A second instrumental acquisition involved SSA purchasing Baan and more recently EXE Technologies. The latter acquisition is highly significant as EXE Technologies are able to provide SSA with advanced supply chain execution software to add to their ERP roots. EXE's SCM product was positioned in seventh and its predicted growth rate was promising for perspective buyers. This product is sure to grow in stature once the two companies have managed to combine their particular strengths.

- WeSupply

The first of the Internet service providers, WeSupply, looked to enhance supply chain operations by enabling real-time sharing of demand and fulfillment information between a company and its network of suppliers. It provides a customisable interface that provides visibility across a supply chain. They do not provide MRP/ERP functionality, but they do provide connection tools to integrate their product to a selected business system.

- VerticalNet

Verticalnet's supply management solutions help clients to set up supply strategy, select suppliers, execute ongoing procurement, and manage supplier performance. According to the AMR Research, VerticalNet were placed in 90th position according to revenue. The company's expected growth rate was high with the procurement element of its product gaining the highest revenue, thus far. VerticalNet provided both hosted and installed options.

- Elcom Inc

Elcom Inc. provides rapidly deployable, remotely hosted eProcurement and eMarketplace solutions. Elcom, inc., the eProcurement and eMarketplace solutions subsidiary of Elcom International, Inc., offers its clients remotely-hosted (ISP) eProcurement and eMarketplace systems and services with a single point of responsibility. Whilst it does not appear in the top 100 SCM products, Elcom Inc. has a number of large clients and is part of a larger corporation.

- SupplyWorks Inc

SupplyWorks, Inc. offers end-to-end strategic sourcing and purchasing solutions that help discrete manufacturers improve their supply management and lower their direct material costs. Global Logistics & Supply Chain Strategies magazine (GL&SCS, 2003) named SupplyWorks in its top "100 Supply Chain Partners" list in the August 2003 issue. Once again, the company does not appear in the top 100 AMR list but it does have a number of recognised clients.

2.3.4.4.2 SCM Software Discussion

From the analysis undertaken (refer to Appendix A for tables) no single product can be singled out as demonstrating best of breed attributes under all the criteria analysed. Each product and their associated configuration clearly have their own unique advantages. SAP has led the ERP industry in terms of revenue for many years, however, analysis reveals that 57% of SAP customers that took part in a survey by Nucleus Research did not believe they had received positive ROI from their deployments. Oracle on the other hand received significant plaudits and with their recent bid for PeopleSoft their customer base could escalate notably.

It s fair to say that the BAAN product, now under the ownership of SSA has been through an unsteady few years with its initial sale to Invensys and then re-sale to SSA. SSA was clearly looking to the future with the acquisitions of both EXE Technologies and BAAN. However, its ability to integrate the technologies acquired will determine its immediate success.

The PeopleSoft product benefited hugely from the acquisition of the SCM software vendor J.D. Edwards and a research study performed by Forrester found that PeopleSoft scored highest overall in Forrester's Application Ownership Satisfaction Index. This is noteworthy as PeopleSoft outscored companies such as SAP, Oracle and Siebel.

In terms of SCM software, i2 technologies was ranked the highest in terms of revenue by AMR Research. However, similar to SAP, i2 customers were less than satisfied with the product they received. 55% of the customers interviewed did not believe they had received positive ROI from their deployments after 2.2 years. It is not unfair to speculate that an element of complacency may have crept into the two highest ranked ERP/SCM vendors.

Manugistics and Manhattan Associates achieved 80% and 67% respectively in terms of customers receiving positive ROI from their products. 64% of Manugistics customers reported a reduction in inventory costs and 71% reported shortening their order-to-fulfilment cycle time. In regard to the IBS product there was limited independent analyses available as to its success and failure. Late in 2003, however, the company received the Supply Chain Council European Award for its IBS Business Intelligence software.

The final group of products to be discussed come under the umbrella of Application Service Providers. All the ISP companies studied in the analysis revealed successful implementations of their product suites. However, independent analyses were difficult to obtain in this particular sector. A relevant point to mention however concerns the movement from hosting unique product suites to hosting developed applications such as SAP. Whilst all of the products studied in this analysis offered only their own products it was increasingly apparent during the study that many ISPs have digressed from designing and offering unique products to hosting well known applications such as those discussed earlier. A possible explanation for this could be the growing capabilities of both SCM and ERP products are limiting the marketspace available.

In conclusion, each of the vendors offerings have both positive and negative aspects. It is for a prospective company to decide which product fit their needs most.

2.3.5 Legacy Integration

'Legacy means computing assets spawned in pre-web architectures' (Hurwitz Group, 2000).

A topic of importance in most traditional manufacturing companies is how to integrate vast corporate 'legacy' systems with modern day e-business strategies and architectures. Throughout this research there has been constant concern with legacy integration. CIO Insight (2002) reported that 45% of all systems are legacy systems, 33% of IT spending goes to operating and maintaining legacy systems, and 37% keep old systems because they are still more cost effective than the alternatives. The following dialogue looks to document what the literature articulates concerning the methods that have emerged to enable legacy integration.

According to Chiang (2001), companies adopt one of two methods when modernising their centralised legacy systems: convert or facelift. The convert method involves converting their current legacy systems from older computing environments to modern computing languages, platforms and architectures. This involves a rigorous assessment of existing systems, followed by a transformation into a completely new system. The second approach is to facelift the existing system by means of middleware. The author believed that while some functionality could be added using this approach it is generally only a stopgap solution as the inherent deficiencies of the system remain. The 'convert' method of legacy transformation is generally considered to be the best for modernising a corporate legacy system. However, it is not always the most appropriate as systems need to remain operational and companies cannot afford to have their businesses interrupted during a complex conversion process.

Therefore, the second 'facelift' approach is considered as the more appropriate and cost-effective way of modernising the legacy systems through the use of middleware.

The work undertaken by Ulrich (2001) in the field of e-business integration provides a detailed analysis of middleware and its component parts. Middleware allows applications running on one computer or platform to communicate with applications and data residing on others. Middleware can be synchronous or asynchronous, point-to-point or many to many, direct or queued. The author describes how middleware has evolved into three major categories: communication, data management, and platform. Remote procedure calls (RPCs) were performed by earliest middleware. RPC technology is both synchronous and tightly coupled to an application. Even though it emerged many years ago it is still embedded in the most up-to-date middleware on the market. Along with RPCs, communication middleware comprises a second element known as message-orientated middleware (MOM). MOM uses asynchronous communications and is not coupled to an application.

The second middleware platform mentioned by Ulrich (2001) is known as data management middleware. This particular category of middleware permits applications to access data not 'natively defined within that application'. This middleware has advantages as it allows applications to access data structures outside of their immediate environment.

Platform middleware can be described as a combination of transaction-orientated middleware, object request brokers (ORBs) and a host of other services all packaged together. Transaction-orientated middleware sends a bounded transaction to carry out an activity involving a database or message queue. A more advanced version of transaction-oriented middleware is the application server. Application servers are web-enabled systems that provide facilities to share and process application logic, connect front-end to back-end operational environments (legacy systems, ERP systems, databases). Ulrich (2001) identified application servers as a critical step for middleware technology as they support the development of web-enabled environments. Selected application servers also support specific connectors to major ERP products. Thus, the author believed application servers are to become increasingly important in the e-business integration environment.

Other important issues mentioned in the literature concern the different approaches to legacy data integration: invasive and non-invasive. Also, another relevant issue concerns ERP integration and the standards that have emerged to facilitate data access. An example of one such standard is the Common Object Request Broker Architecture (CORBA), which eliminates the need for a specialised interface to be created for each ERP vendor.

This discussion concerning legacy integration provides a brief overview of a complex topic. It is fair to say that there are numerous avenues available for legacy system integration. Within this research, legacy integration has been a topic of concern through each of the case studies. Whilst it has not been possible to integrate every system/prototype with a legacy system, the methods of how this can be achieved have been discussed.

2.3.6 Part Two: Summary

This section of the literature review has discussed the communication systems in the context of supply chains. A brief account of the historical evolution of supply chain systems was followed by an examination of communication techniques, with EDI and XML being the media most prominently featured.

The systems present in supply chains (SCM systems, ERP systems, internet-based systems) were then analysed. The focus here turned to the individual capabilities of the different systems on the market. The analysis of 12 software applications currently in operation provided an interesting comparison of the capabilities of the different software suites. The discussion also recognised a number of key trends that have emerged in recent years as many of the larger institutions have consolidated their products. Legacy integration and its associated issues concluded this section.

2.4 Chapter Summary

This chapter was divided into two primary sections, covering each of the topics on which this research was based. The first covered the core concepts of supply chains and supply chain management (SCM). This was accompanied by a review of the literature on modern day high-volume SCM. The final part of this section looks closely at the supply chain structures that have emerged as policies to counteract the challenges such as demand amplification. Part two, discussed the systems associated with supply chains. Following a historical review, both communication media (EDI, web, fax, telephone) and also specific planning systems (MRP, ERP MRPII, SCM) are examined. The final part of this chapter considers legacy integration and the problems associated with this complex topic.

3. RESEARCH METHODOLOGY

3.1 Introduction

The aim of this chapter is to describe the research approach that was used to achieve the research objectives set out in Chapter 1. In order to accomplish this aim, figure 3.1 reveals the overall approach to this research.

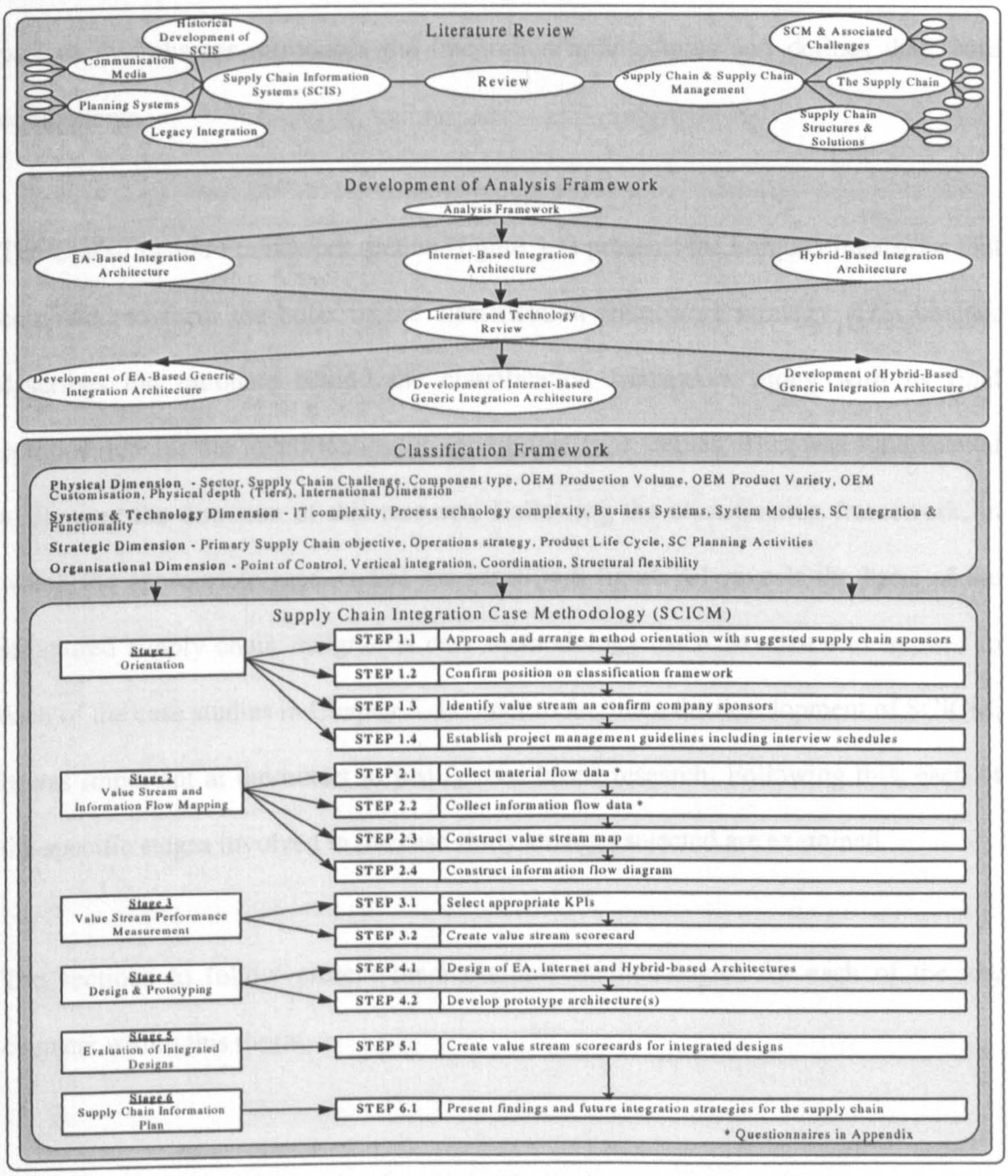


Figure 3.1 – Overall Research Approach

As figure 3.1 illustrates, the research methodology is broken down into three sub-components, each with its own distinctive methodology: the Literature Review, Analysis Framework and Classification Framework. The Literature Review section (figure 3.1) reveals the topics that were selected for discussion. This chapter discusses the techniques that were used to locate and review the appropriate literature. The Analysis Framework section (figure 3.1) exhibits the three generic integration architectures, which form the basis of each of the case studies in Chapter 5. The latter part of this chapter introduces the integration architectures and defines their core components.

The Classification Framework section (figure 3.1) presents the unique dimensions that combined to form the basis of the classification framework strategy. This chapter describes the rationale behind the classification framework along with its final composition for the identification of appropriate case studies. This was fundamental to shaping the direction of this research. Following the classification framework, in which the appropriate case studies are identified, figure 3.1 reveals the basis of the structured supply chain integration case methodology (SCICM) that was applied to each of the case studies in Chapter 5. In order to facilitate the development of SCICM, it was important at the outset to justify case-based research. Following this, each of the specific stages involved in the case study strategy selected are examined.

The sections to follow present the individual methodologies for each of the key chapters within this thesis.

3.2 Literature Review Methodology

3.2.1 Introduction

The aim of a literature review is to describe and critically appraise studies written by accredited scholars and researchers on topics identified as central to the particular research theme. Thus, the early stages of the literature review involved the identification of all the subjects that would need to be considered. Figure 3.2 demonstrates how the initial topics were dissected to provide a skeletal plan of the literature review.

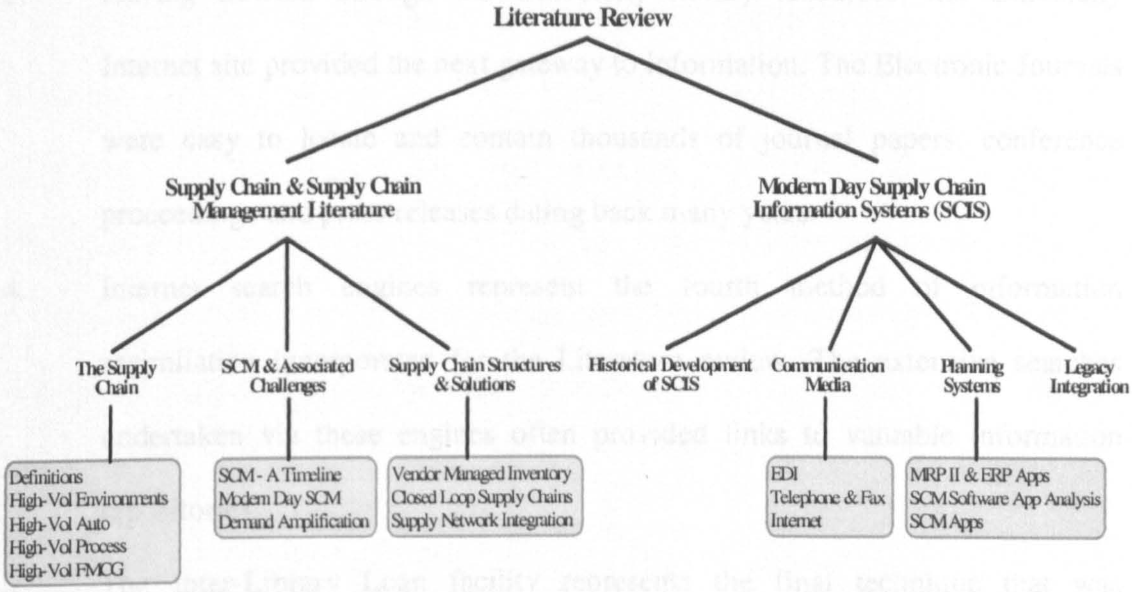


Figure 3.2 – Literature Review Roadmap

3.2.2 Search Process

Following the initial brainstorming sessions in which the core research areas were identified the next stage involved an exhaustive search of the literature for the relevant subject matter. Within certain fields there are individuals and/or groups that are recognised experts. This became the first point of call for each of the selected subjects. Following this, specific strands of the literature would be explored further depending on the pre-defined direction of the literature analysis. Often this involved citing and referencing individuals from a range of different sources. The search process involved the following stages:

1. Identification of experts in the specific field. Academics directly and indirectly involved with FUSION (Kehoe and Lyons, 2000) provided guidance here. Extensive reading around the subject matter accompanied this.
2. Following this a search of University library resources was undertaken.
3. Having trawled through the University library resources, the University Internet site provided the next gateway to information. The Electronic Journals were easy to locate and contain thousands of journal papers, conference proceedings and press releases dating back many years.
4. Internet search engines represent the fourth method of information assimilation incorporated for the Literature review. The extensive searches undertaken via these engines often provided links to valuable information repositories.
5. The Inter-Library Loan facility represents the final technique that was incorporated in this research. The Inter-Library Loan service provides access to material from other libraries, which is not held by the University Library. It covers all manner of printed materials, including books, theses, journals and conference papers.

3.2.3 Review Process

Obtaining and analysing the material represented the first stage of the literature review. Writing the literature review was the next logical step. A consistent approach was followed throughout the course of the literature analysis. Depending on the specific section or sub-section the review has either been ordered chronologically or grouped into specific areas or clusters. When similar information/references have been clustered together it is generally the case that the chronological ordering system would re-emerge.

This section of the overall research methodology has attempted to demonstrate how the author selected and reviewed the literature for this thesis. The Introduction illustrates how the larger topics were dissected into smaller more manageable segments. Once the final subjects had been decided upon, it became necessary to first of all locate all of the relevant literature and then review it systematically. This section reveals the steps that were undertaken to achieve the final literature review for this research.

3.3 Classification Framework

'The ability to develop a well-defined theoretical or empirical classification is a basic step in conducting any form of scientific or systematic inquiry into the phenomena under investigation' (McCarthy, 1995).

3.3.1 Introduction

This section describes the development of a classification/taxonomy for the companies to be investigated within each of the case studies. It is therefore central to this research methodology chapter. According to Rich (1992), organisational classification provides the basis for strong research by breaking the continuous world of organisations into discrete and collective categories well suited for detailed analysis. The Framework was developed with the assistance of an extensive body of literature on classification frameworks and systems. In particular, the framework presented by Carbonara *et al* (2002) provided an ideal structure to expand upon.

The majority of frameworks and classifications are unique depending upon the particular aims they are looking to achieve. The key to a successful classification is being able to select the most appropriate characteristics on which the classification is to be based. As Bailey (1994) stated, '*a classification is no better than the dimensions or variables on which it is based*'. Therefore additional variables were added to the framework highlighted by the authors, so that the objectives of this research outlined in Chapter 1 could be achieved. The following sections define classifications and the literature relating to classifications and frameworks in the context of organisational structure. Following this the specific framework designed for this research is considered.

3.3.2 Classifications

According to Bailey (1994), classifications can be distinguished by the following characteristics. They can be identified as either taxonomies or typologies depending on their precise aims. Typologies are more often than not conceptual, multidimensional and qualitative whilst taxonomies generally involve empirical, quantitative analysis. Furthermore, typologies can be labeled as monothetic due to the identical nature of the variables or dimensions being measured. Polythetic cases are associated with taxonomies due to their empirical attributes. Here there are no identical cases with respect to the variables, but rather they are grouped by their overall similarity. Finally, classifications are called synchronic (or phenetic), if they refer to characteristics at a certain point in time. Conversely, classifications are called diachronic (or phyletic) if they involve measuring change or measures of evolutionary resemblance. Figure 3.3 demonstrates this dissection of classifications.

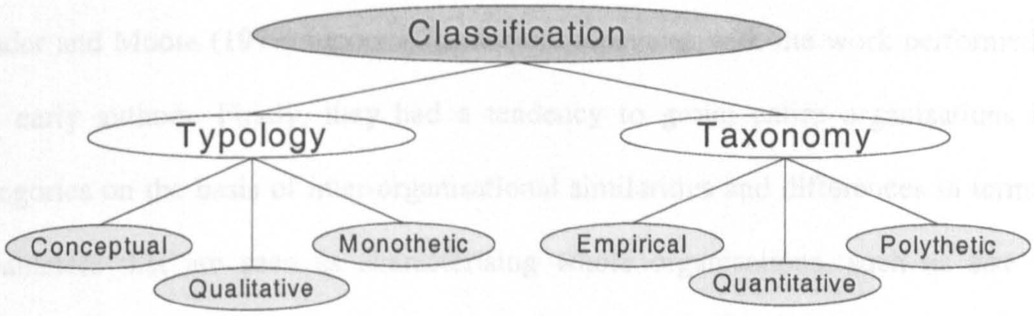


Figure 3.3 - Classification Dissection

Applying the narrative above to this particular research permitted a clearer picture to emerge as to the nature of this classification. First of all it is important to note that one of the most significant attributes of any taxonomy relates to its empirical nature. Furthermore, this work can be described as quantitative rather than qualitative due to 'actual' values being noted where appropriate. Finally, a key aspect of this research is that each of the case studies to be undertaken should differ in a number of the analysed attributes. Thus the research can be regarded as being polythetic.

3.3.3 Literature Review

The study of organisational structure has been a topic of interest for many years. The literature concerning early attempts to form typologies or taxonomies of organisations revealed a number of recurring themes. As noted by Pugh *et al* (1968, 1969a, 1969b), McKelvey (1975), Pinder and Moore (1979) and more recently Rich (1992), many of the early authors' classifications were heuristic and based on prior theory. Their typologies consisted of maybe one or two attribute dimensions, with little attention being paid to underlying theory for the development of a comprehensive set of classificatory variables. Consequently, their schemes have provided us with little more than simplistic overviews of the organisations concerned.

Pinder and Moore (1979) reported further discrepancies with the work performed by the early authors. Firstly, they had a tendency to group entire organisations into categories on the basis of inter-organisational similarities and differences in terms of parameters that are seen as characterising whole organisations, such as size and technology. The authors also report that the schemes focused on parameters that vary across organisations at given points in time, but that have been assumed to be constant over time. The final point the authors focus upon involves estimates of central tendency, such as means or modes, that have been widely adopted to characterise the organisational units to be sub grouped.

Having discovered flaws in prior work many academics sought to provide a more disciplined and structured methodology for classifying organisations. Pugh *et al* (1968, 1969a, 1969b), developed a taxonomy of organisational structure using three established dimensions, developed in earlier related work. The three orthogonal dimensions, structuring of activities, concentration of authority, and line control of workflow, were incorporated to identify clustering within 52 organisations studied. Mckelvey (1975) set out some guidelines for using multivariate analyses to aid in the development of taxonomies of organisations. With the exception of two issues Pinder and Moore (1979) on the whole agreed with the suggestions put forward by Mckelvey (1975). The authors provided a useful review of the organisational taxonomies that have been suggested thus far, and recommended a new strategy for subgrouping which employed (1) multiple parameters, (2) measures of dispersion, and (3) measures of change. Carper and Snizek (1980) published a thorough review of past theoretical and empirical efforts thus enabling future research issues to be identified.

Moving away from the earlier writings it was important to focus upon more recent research in this area. In chronological order, Ulrich and McKelvey (1990) reported upon a general organisational classification for both the United States and Japanese electronics industries. Rich (1992) discussed contemporary organisational classifications in the context of empirical, theoretical and evolutionary perspectives. The author provided a framework by which to both review the field and address questions essential to the development of complete typologies. In terms of classifying specific entities, Silvestro *el al* (1992) looked to classify service processes by redefining service classifications, as defined in the literature, in order to rank their sample of 11 service organisations. From this the authors proposed there to be three types of service process: professional, service shop and mass. Fransoo & Rutten (1993) presented a typology of process industries, which recognises two extreme production systems on a continuum.

McCarthy (1995) examined manufacturing classification in terms of its usefulness by reviewing existing classifications to identify essential attributes. From this the author listed preliminary guidelines for the classification of manufacturing systems. Fiedler *et al* (1996) developed an empirical taxonomy that has implications for matching information technology (IT) and organisational structures. Cluster analysis was utilised to empirically drive the IT structural taxonomy, which derived the four IT structure types identified in the paper. In total, 313 firms were involved in the study and the authors believe the derived taxonomy to be exhaustive, mutually exclusive, stable and consistent.

Melcher *et al* (2002) introduced a classification for production systems in manufacturing and processing industries. They considered that their approach has better potential for discriminating among production systems than past classifications as it includes both organisational and technological variables. For the purposes of this research this paper combined with the work of Carbonara *et al* (2002) provided a useful platform from which to expand upon. The work of Carbonara *et al* (2002) is discussed in greater detail in the following section.

The vast amount of research undertaken in the areas of classification systems/ taxonomies has provided a wealth of information to assist in the development of new classifications. For obvious reasons, not all of the work carried out could be reviewed for the purposes of this research; however, the above has hopefully supplied a useful insight into the taxonomy development. The framework applied to this research along with its customisation is now discussed.

3.3.4 Classification Framework

Selecting the most appropriate variables for the framework would help determine the success of this research. For this reason alone, considerable time and effort was taken in developing this framework. Carbonara *et al* (2002) provided the basic structure and variables for the classification. The authors put forward a list of variables that are grouped into the dimensions: physical, technological, strategic, and organisational. The 'Physical' dimension has been adapted to consider factors such the sector the companies are positioned within and key supply chain challenges. Other variables include component type, OEM production volume and variety along with OEM customisation.

The second 'Systems and Technology' dimension proposed by the authors has been modified extensively due to its strategic importance to this research. First of all, the process technology complexity and information technology (IT) complexity is assessed for each of the companies considered. Following this, the individual business systems in operation at each of the companies were identified and recorded. Breaking this variable down to the system modules within each of the business systems was important to allow the core functionality of the business systems in place to be distinguished. The final part of this dimension was perhaps the most important element. The selected variables here focused upon the amount of supply chain integration in place at the point in time when the case studies were undertaken. This section enabled areas for improvement to be identified.

The third 'Strategic' dimension within the framework encompassed all of those variables concerned with the strategic positioning of the firm. Within this category the company's primary business objectives and operations strategy were analysed. The length of the product life cycle and whether the supply chain planning activities were centralised or decentralised made up the final variables in this dimension.

The final part of the classification, the 'Organisational' dimension, included variables such as level of vertical integration, which represents the extent to which the SC firms own the whole production process; co-ordination, in terms of level of formalisation (ranging from high – i.e. contractual agreement – to low– i.e. informal arrangement) and mechanisms adopted to manage the inter-firm relationships (such as market price, transfer prices, incentives mechanisms); and finally structural flexibility, which is the rapidity/ability to responsively reconfigure the SC based on customer needs.

Tables 3.1 to 3.4 illustrate the final classification that was incorporated in the research. As discussed, there are four dimensions to the table. Each dimension has been completed accordingly to enable the reader to understand clearly the case study selection criteria.

Classification Framework		CASE 1		CASE 2			CASE 3			CASE 4		CASE 5				
Physical Dimension	**Value**	A Manufacturer (Coating)	B Supply Chain Solutions Provider (SCSP)	A Food Manufacturer (FM)	B Logistics Service Provider (LSP)	C Retailer	A Distributor (Office Products)	B Manufacturer (Office Products)	B1 Manufacturer (Office Products)	A Manufaturer (Automotive Transmissions)	B Remanufacturer (Automotive Transmissions)	A Manufacturer (Automotive)	B Sequenced Supplier (Seat Module)	C Manufacturer (Seat Track)	C1 Assembler (Rear Centre Headrest)	D Supplier (Cloth)
Sector	Yes No															
Automotive OE (discrete)	● ○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●
Automotive Service Parts (discrete)	● ○	○	○	○	○	○	○	○	○	●	●	○	○	○	○	○
Office Supplies (Semi-continuous)	● ○	○	○	○	○	○	●	●	●	○	○	○	○	○	○	○
Food/FMCG (continuous)	● ○	○	○	●	●	●	○	○	○	○	○	○	○	○	○	○
Process (Continuous)	● ○	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Supply Chain Challenge																
Comms Ignorance/ Systems Proliferation 'UPSTREAM'	● ○	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Systems Proliferation/ Legacy Integration 'UPSTREAM' & 'DOWNSTREAM'	● ○	○	○	●	●	●	○	○	○	○	○	○	○	○	○	○
Power Delgation/ Legacy Integration/VMI 'DOWNSTREAM'	● ○	○	○	○	○	○	●	●	●	○	○	○	○	○	○	○
Remanufacturing/ Supplier Monopoly/ Comms Ignorance 'REVERSE'	● ○	○	○	○	○	○	○	○	○	●	●	○	○	○	○	○
Cross Supply Chain Visibility/ Legacy Integration 'UPSTREAM'	● ○	○	○	○	○	○	○	○	○	○	○	●	●	●	●	●
Component type OE Parts/Materials	● ○	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Service Parts	● ○	○	○	○	○	○	○	○	○	●	●	○	○	○	○	○
OEM Production Volume (units unless stated)	Daily	102564 sqm	N/A	4000kg per line item	N/A	N/A	N/A	640 packs per line litem	N/A	2000	100	430	N/A	N/A	N/A	N/A
	Case Study	102564	N/A	4000kg	N/A	N/A	N/A	640	N/A	2000	95	430	N.A	N/A	N/A	N/A
OEM Product Variety	Full Range	100	N/A	550	N/A	N/A	N/A	3000	1000	8	300	9	N/A	N/A	N/A	N/A
OEM Customisation	WR0/BTO	WRO	N/A	WRO	N/A	N/A	N/A	WRO	WRO	BTO	BTO	BTO	N/A	N/A	N/A	N/A
Physical depth (Tiers) (Upstream of OEM)		2	N/A	2	N/A	N/A	N/A	2	2	2	3	6	N/A	N/A	N/A	N/A
International Dimension	● ○	●	○	●	○	●	○	●	●	●	●	●	●	●	●	●

TABLE 3.1 - Classification Framework – Physical Dimension

Classification Framework

Systems & Technology Dimension	Value	CASE 1: A Manufacturer (Coating)	CASE 1: B Supply Chain Solutions Provider (SCSP)	CASE 2: A Food Manufacturer (FM)	CASE 2: B Logistics Service Provider (LSP)	CASE 2: C Retailer	CASE 3: A Distributor (Office Products)	CASE 3: B Manufacturer (Office Products)	CASE 3: B1 Manufacturer (Office Products)	CASE 4: A Manufaturer (Automotive Transmissions)	CASE 4: B Remanufacturer (Automotive Transmissions)	CASE 5: A Manufacturer (Automotive)	CASE 5: B Sequenced Supplier (Seat Module)	CASE 5: C Manufacturer (Seat Track)	CASE 5: C1 Assembler (Rear Centre Headrest)	CASE 5: D Supplier (Cloth)
IT Complexity	Scale (1-10)	5	3	7	5	6	6	5	5	6	4	7	5	4	4	4
Process technology complexity	Scale (1-10)	6	N/A	5	N/A	N/A	N/A	4	4	6	6	7	5	6	4	3
Business Systems	Yes No															
Joint ERP-SCM System	● ○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
ERP	● ○	●	○	●	●	●	●	●	●	○	●	○	●	●	●	●
MRPII	● ○	○	○	○	○	○	○	○	○	●	○	●	○	○	○	○
Bespoke	● ○	○	○	●	○	●	○	○	○	●	○	●	○	○	○	○
System Modules																
Financial	● ○	●	○	●	●	●	●	●	●	●	●	●	●	●	●	●
Human Resource	● ○	○	○	○	●	●	○	○	○	○	○	○	○	○	○	○
Manufacturing Management	● ○	●	○	●	○	○	○	●	●	●	●	●	●	●	●	●
Inventory Management	● ○	●	○	●	●	●	●	●	●	●	●	●	●	●	●	●
Purchasing Management	● ○	●	○	●	○	●	●	●	●	●	●	●	●	●	●	●
Product Technology	● ○	○	○	●	○	○	○	●	●	●	●	●	●	●	●	○
SC Integration & Functionality																
Upstream SCM Software	● ○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Supply Chain Execution	● ○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Supply Chain Planning	● ○	○	○	○	●	○	○	○	○	○	○	○	●	○	○	○
General Modules	● ○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Upstream EDI	● ○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Internet Architecture	● ○	○	○	○	○	●	○	●	●	○	●	○	○	○	○	○
ISP Collaboration	● ○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

TABLE 3.2 - Classification Framework – Systems & Technology Dimension

Classification Framework		CASE 1		CASE 2			CASE 3			CASE 4		CASE 5				
Strategic Dimension	Value	A Manufacturer (Coating)	B Supply Chain Solutions Provider (SCSP)	A Food Manufacturer (FM)	B Logistics Service Provider (LSP)	C Retailer	A Distributor (Office Products)	B Manufacturer (Office Products)	B1 Manufacturer (Office Products)	A Manufaturer (Automotive Transmissions)	B Remanufacturer (Automotive Transmissions)	A Manufacturer (Automotive)	B Sequenced Supplier (Seat Module)	C Manufacturer (Seat Track)	C1 Assembler (Rear Centre Headrest)	D Supplier (Cloth)
Primary Supply Chain objective	Cost reduction (CR), Flexibility (F), Quality (Q), Variety (V), Efficiency (E)	E & CR	E & CR	CR & E	CR	CR & Q	CR & E	CR & V	CR & V	CR & F	CR & E	V & F	V & F	CR & F	V & F	V & CR
Operations strategy	MTR or MTO	MTR	N/A	MTR	N/A	N/A	N/A	MTR	MTR	MTO	MTO	MTO	MTO	MTO	MTO	MTO
Product Life Cycle	Changes to product (Months)	6	N/A	6	N/A	N/A	N/A	6	6	24	24	24	6	6	6	6
	Complete Lifecycle (Years)	5	N/A	6 months	N/A	N/A	N/A	5	5	7	7	10 to 15	10 to 15	10 to 15	10 to 15	10 to 15
SC Planning Activities:																
Procurement (buying)	Centralised (C), Decentralised (D)	D	N/A	C	N/A	C	C	C	C	C	C	C	C	C	C	C
Demand planning		C	N/A	C	N/A	C	C	C	C	C	C	C	C	C	C	C
Inventory management		D	D	D	D	D	D	D	D	D	C	D	D	D	D	D
Production planning		D	N/A	D	N/A	N/A	N/A	D	D	C	C	C	C	C	C	C
Distribution planning		D	C	D	C	N/A	D	D	D	D	C	D	D	D	D	D
Transportation planning		D	C	D	C	C	D	D	D	D	C	D	D	D	D	D

TABLE 3.3 - Classification Framework – Strategic Dimension

Classification Framework

Organisational Dimension		Value	CASE 1		CASE 2			CASE 3			CASE 4		CASE 5				
			A Manufacturer (Coating)	B Supply Chain Solutions Provider (SCSP)	A Food Manufacturer (FM)	B Logistics Service Provider (LSP)	C Retailer	A Distributor (Office Products)	B Manufacturer (Office Products)	B1 Manufacturer (Office Products)	A Manufaturer (Automotive Transmissions)	B Remanufacturer (Automotive Transmissions)	A Manufacturer (Automotive)	B Sequenced Supplier (Seat Module)	C Manufacturer (Seat Track)	C1 Assembler (Rear Centre Headrest)	D Supplier (Cloth)
Point of Control		Parent Company (P), OEM, Retailer (R)	P	P	R	OEM	P	P	P	P	P	R	P	OEM	OEM	OEM	OEM
Vertical integration		Scale (1-10)	2	4	5	6	N/A	2	6	6	7	3	7	6	3	3	3
Coordination:	Formalisation	Contractual agreement (CA), Standard Procedures (SP), Informal Arrangements (IA)	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA	CA
	Mechanisms	Transfer Price (TP), Incentive Mechanisms (IM), Quantity Discount (QD), Market Price (MP)	QD	N/A	QD	N/A	TP	MP	TP	TP	TP	TP	TP	TP	TP	TP	TP
Structural flexibility		Scale (1-10)	5	N/A	5	N/A	N/A	N/A	7	7	4	6	3	6	7	7	7

TABLE 3.4 - Classification Framework – Organisational Dimension

3.4 Analysis Framework Methodology

3.4.1 Introduction

The Analysis Framework section of this thesis is the most important in terms of defining the direction of the research. It was envisaged that a selection of generic architectures would have to be devised in order that they could act as templates for each of the case studies to be undertaken. Therefore, three alternative generic architectures were defined. Two of the generic architectures were based upon contemporary industry trends (ERP and Internet-based), whilst the other, a 'hybrid' architecture, was very much dependent on the information systems infrastructure in each case study. The following section expands the methodology shaping the Analysis Framework along with considering the selection of the three particular architectures.

3.4.2 Approach

The most important element of the methodology behind the Analysis Framework Chapter was the identification and definition of the three generic architectures. There are a plethora of different systems in modern day manufacturing companies. To name a few, there are bespoke forecasting and scheduling systems, MRP, MRP II and ERP Systems, transportation and logistics systems, and more recently SCM and CRM systems have emerged. However, the literature combined with the applied case study work provided the insight necessary to profile the three application areas from which the generic architectures were designed. The following sections define each of the three areas in greater detail.

1. Enterprise Application (EA)-based Systems
2. Internet-based Systems
3. Hybrid-based Systems

3.4.2.1 Enterprise Application (EA)-Based Systems

The notion of an EA-based system configuration that can seamlessly connect supply, planning, manufacturing and distribution across a series of companies in a supply network is the first of the generic architectures to be considered. As mentioned earlier, most manufacturing companies have some form of planning system in operation. Furthermore, it is increasingly apparent that many software vendors have been re-structuring their applications in recent years to enable collaboration with trading partners. With this in mind, the aim of this section is to develop a generic EA architecture, which can act as a template for each of the case studies in Chapter 5.

3.4.2.2 Internet-Based Systems

Internet-based systems are the second area where significant changes have been witnessed in recent years. Internet applications have emerged in both the literature and from commercial vendors to enable supply network participants to communicate more efficiently and effectively. Whilst it is acknowledged that EA systems will play an important role internally, it is the aim of this section to consider the Internet applications that will assist the internal systems and provide the necessary technology infrastructure to permit enhanced supply network operations. The outcome of this analysis is a generic Internet-based architecture, which acts a template for each of the case studies in Chapter 5.

3.4.2.3 Hybrid-Based Systems

This is the last of the three strategies to be discussed as it is expected that the first two strategies will both contribute towards the outcome of this section. The boundaries for this strategy are broad due to the exceptionally different conditions that are likely to be experienced throughout each of the case studies. This strategy will possess little in the way of uniformity as the tools and technologies are likely to differ with each case study. The product of this section is a generic, hybrid-based systems architecture, that has incorporated tools and technologies that are readily available within the companies concerned. Therefore, the architecture will encompass a range of variables that might be used within each case study.

Having considered each of the three generic strategies, it is now appropriate to consider the work supporting each of the strategies. Referring back to the Literature Review (Chapter 2), it was decided that the systems specific literature for each of the architectures considered within the Analysis Framework should be present as part of this chapter. Hence, each of the three generic architectures is accompanied by a review of the literature pertaining to the specific field. Figure 3.4 depicts the structure of the Analysis Framework Chapter.

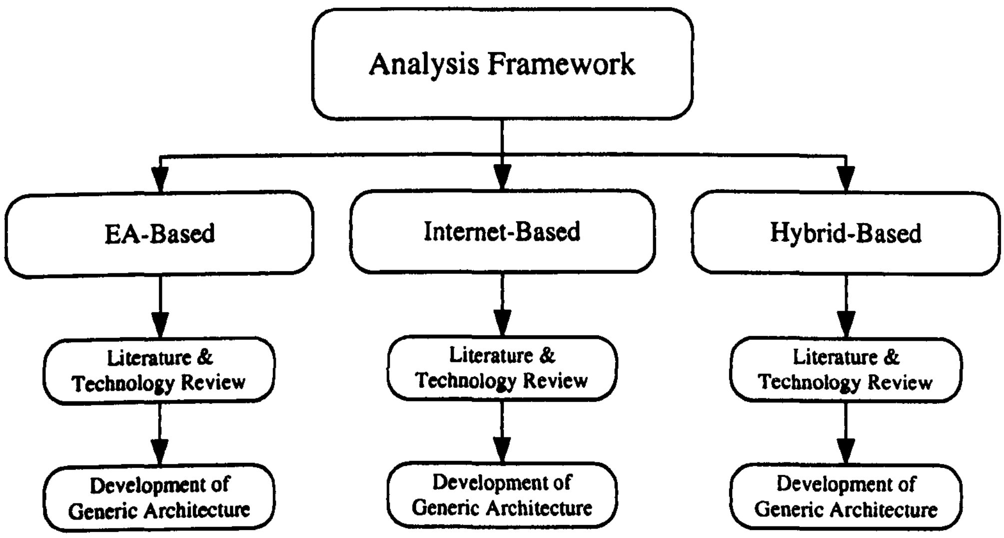


Figure 3.4 – Analysis Framework Structure

The methodology for this section is not based upon any prior work and has been developed to fit this specific research. The structure of this chapter is defined, along with three alternative generic architectures. It is important that this section is well structured as it provides the foundations for the case study chapter in this thesis. The following section considers the structure of the case study chapter.

3.5 Case Study Methodology

3.5.1 Introduction

Case research is the strategy that has been selected for the applied work within this thesis. Case research is the method that uses case studies as its basis (Voss *et al*, 2002). In total this research consists of five case studies all of which have followed the same methodology. The Analysis Framework Chapter identified each of the case study characteristics based upon pre-determined variables. This section defines case study research along with contemplating its positive and negative characteristics. Following this, the selected case study methodology and each of its sub components are considered.

3.5.2 Case Study Research

In terms of defining case study research, most of the literature cites the work of Yin (1994) who defined it as *'an empirical inquiry that:*

- *investigates a contemporary phenomenon within its real-life context; when*
- *the boundaries between phenomenon and context are not clearly evident; and in which*
- *multiple sources of evidence are used'.*

Meredith (1998) on the other hand combined the definitions of a selection of authors (Benbasat *et al*, 1987; Bonoma, 1985; Eisenhardt, 1989 and Yin, 1994) and defined it as follows: '*A case study typically uses multiple methods and tools for data collection from a number of entities by a direct observer(s) in a single, natural setting that considers temporal and contextual aspects of the contemporary phenomenon under study, but without experimental controls or manipulations*'.

Both definitions, clearly define case-study-based research. However, more importantly it is necessary to justify the reasons behind choosing to incorporate a case study strategy within this research.

Eisenhardt (1989) stated that case studies are, '*Particularly well suited to new research areas or research areas for which existing theory seems inadequate. This type of work is highly complementary to incremental theory building from normal science research. The former is useful in early stages of research on a topic or when a fresh perspective is needed, whilst the latter is useful in later stages of knowledge*'.

Rowley (2002) however, considered Eisenhardt (1989) to be somewhat narrow in his conception of the application of case study research. It was the author's contention that it is the specific research question that is most significant in determining the most appropriate approach. This view is put forward by Yin (1994) who stated that each particular type of research had particular advantages and disadvantages, depending on three conditions: (a) the type of research question, (b) the control an investigator has over actual behavioural events, and (c) the focus on contemporary as opposed to historical phenomena. Furthermore, the author stated that case study research is the preferred strategy when 'how' and 'why' questions are being posed. Yin (1994) summarised the different kinds of research questions and methods in table 3.5. Since Yin's (1994) influential work, other authors (Weerd-Nederhof, 2001; Rowley 2002) have referred to or adapted table 3.5 in order to demonstrate how to select the most appropriate research strategy.

Strategy	Form of Research Question	Requires Control over Behavioural Events?	Focuses on Contemporary Events?
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many, how much	No	Yes
Archival Analysis	Who, what, where, how many, how much	No	Yes/No
History	How, why	No	No
Case Study	How, Why	No	Yes

Table 3.5 – Selecting a Research Strategy (Yin, 1994)

In terms of the advantages of case study-based research, the work of Benbasat *et al* (1987) identified three major strengths. (1) The phenomenon can be studied in its natural setting and meaningful, relevant theory generated from the understanding gained through observing actual practice; (2) the case method allows the much more meaningful question of *why*, rather than just *what a*nd *how*, to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon; and (3) the case method lends itself to early, exploratory investigations where the variables are still unknown and the phenomenon not at all understood. Amaratunga and Baldry (2001) stated that that a very important advantage of case material lies in the richness of its detailed understanding of reality. Furthermore, Rowley (2002) suggested that case studies are widely used because they may offer insights that might not be achieved with other approaches.

Thus, with this mind, it is now perhaps appropriate to consider the case study strategy in the context of this research. As discussed in Chapter 1, this research considers evaluating a selection of integration strategies within modern day supply networks. Had case studies not been undertaken then a simulation of modern day supply networks could have been an alternative. Supply networks are characterised by an infinite number of variables and dynamics all interacting to provide a unique environment. Whilst simulation is a proven research technique, it is also effectively an experimental process and so it would not have provided as inclusive an environment as real industry-based case studies would. A second alternative would have been to incorporate surveys for this research. Surveys represent one of the most common types of quantitative, social science research. However, disadvantages such as the standardisation of questions, inflexibility of the survey throughout data collection along with issues relating to the quantity and quality of the information collected meant that it was incorporated for this research. Therefore, the most appropriate means in which the aims and objectives of this research could effectively be met was to apply the three architectures under case study conditions.

A multiple case strategy was selected, as multiple cases can both augment external validity and help guard against observer bias (Voss *et al*, 2002). The classification framework introduced in this chapter provides the basis for this research. Miles and Huberman (1984) discussed the relevance of conceptual frameworks as a guide or roadmap for the research to be undertaken. The following section investigates the individual components of the selected case study strategy.

3.5.3 Supply Chain Integration Case Methodology (SCICM)

As discussed in the previous sections, a multiple case study strategy has been selected to support this research. The structure of this methodology is illustrated in figure 3.5 below.

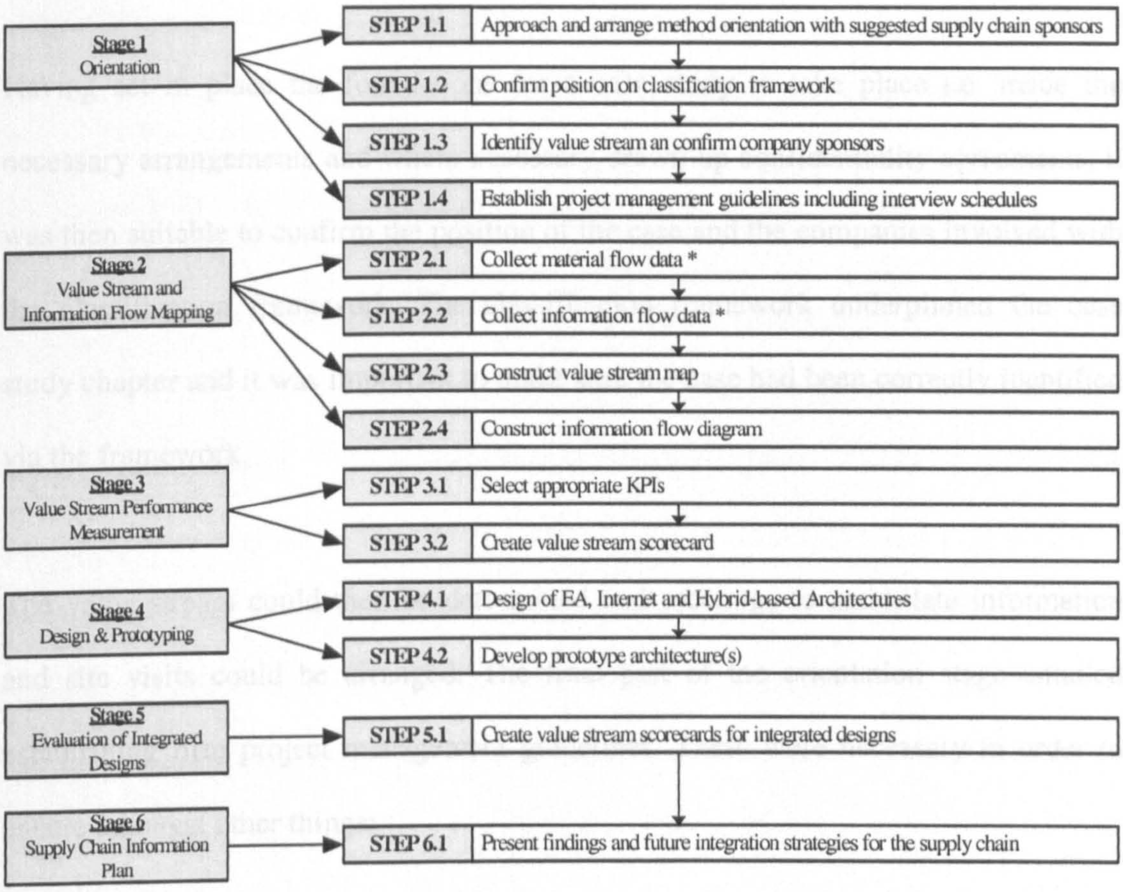


Figure 3.5 – Supply Chain Integration Case Methodology (SCICM)

In total there are six stages to the SCICM. The sub sections to follow define the purpose and objective of each of the stages.

3.5.3.1 Stage 1 - Orientation

The primary stages of each case involved a number of meetings with the lead companies. This stage was important in not only identifying the specific business case but also in isolating the other companies that would best fit with the aims of this research and the objectives of the lead company. Following on from this, it was generally expected that the lead company would initiate a request to the appropriate supply chain partners to provide any help and assistance necessary to complete the case study.

Having set in place the foundations for a case study to take place i.e. made the necessary arrangements and where necessary drawn up confidentiality agreements, it was then suitable to confirm the position of the case and the companies involved with the classification framework. The classification framework underpinned the case study chapter and it was important to make sure the case had been correctly identified via the framework.

The value stream could then be determined and meetings to assimilate information and site visits could be arranged. The final part of the orientation stage entailed establishing firm project management guidelines. These were necessary in order to ensure amongst other things:

- Resource commitment from senior management.
- That the requirements of this research along with the company's objectives were being adequately satisfied.
- That all parties knew what deliverables to expect and when to expect them. These were necessary to define at the outset to prevent the companies associated to a case continuously adding to the requirements.

Stage 1 of this methodology sets out the core criteria to enable to case to move forward.

3.5.3.2 Stage 2 - Value Stream and Information Flow Mapping

Mapping can be described as a systematic approach to analysing, organising, and presenting information in such a way that it provides sufficient evidence that a solution needs to be developed to improve the situation. There are two principal outputs to Stage 2 of this methodology:

- A Value Stream Map (VSM)
- An Information Flow Diagram (IFD)

Value Stream Mapping (VSM) was used to depict all actions (both value added and non-value added) currently required to bring a product from raw material into the arms of the customer. VSM is a method of visually mapping a product's production path (materials and information) from 'door to door'. VSM can serve as a starting point to help management, engineers, production associates, schedulers, suppliers, and customers recognise waste and identify its causes. The process includes physically mapping your 'current state' (MAMTC, 2004)

The IFD was undertaken in conjunction with VSM. It was essential to provide a detailed analysis of the current system architecture and how the systems interact with those of their supply chain partners in order to determine the problematic areas or the areas in which improvements could be made. Furthermore, the basis of this thesis revolves around the generation of three architectures for each case study and so it was critical that a detailed system map was constructed in each case. Also the IFD was developed in order to show the information flow between supply chain partners.

In order to carry out this stage of the SCICM, the following activities were undertaken.

- *Questionnaires* – designed in a structured manner in order to extract as much valuable information as possible and to avoid duplication of questions.

- *General discussions / question and answer sessions* – thus allowing information to be obtained without the necessity for questionnaires.

- *Meeting with key information systems personnel* – thus becoming better equipped to develop a fully integrated solution.

- *Assimilation of historical data* – that can be applied to the scorecard for performance evaluation purposes.

- *Paper-based modelling* – undertaken on an ongoing basis to ensure the final IFD and VSM were as accurate as possible.

All of the stages mentioned above combine to provide all of the necessary data for Stage 3.

3.5.3.3 Stage 3 - Value Stream Performance Measurement

The logical progression from mapping is to evaluate the performance of current systems and working practices. Assessing the performance of both information systems along with internal working practices is necessary in order to identify where problems are arising and what are the consequences to supply partners and/or customers. This initial performance evaluation involved applying a wide variety of measures in order to identify:

1. Supply chain inefficiencies.
2. Internal procedures or processes that are inefficient.
3. Current technology inadequacies.
4. Information flow and potential information traffic jams.
5. Areas for potential improvement.

By evaluating the performance at an early stage, a benchmark could be established as a basis for improvement, which assisted when evaluating the performance in Stage 5.

It was expected that the measures applied would not remain constant as each case was likely to provide a different scenario. For this reason it was decided that a selection of measures should be defined and incorporated where applicable. The following subsections define the tools and techniques incorporated to assess performance.

3.5.3.3.1 Scorecard

A scorecard (figure3.6) was devised by the FUSION (Kehoe and Lyons, 2000) research group to measure supply chain performance from four different perspectives. The fundamental design of this scorecard was adopted from the concept of the balanced scorecard (Kaplan and Norton, 1992) and system thinking (Holmberg, 2000). There are 11 metrics in this scorecard and they are divided into four groups: (1) demand synchronisation measures, (2) responsiveness measures, (3) reliability measures and (4) cost measures, as displayed in figure 3.6. The performance of the individual entities are affected by both the supply chain and each other. The following dialogue examines each of the elements of the scorecard individually.

Composite Supply Chain Scorecard

	Current		Current
SUPPLY CHAIN BEHAVIOUR MEASURES		**RELIABILITY MEASURES**	
Synchronisation index - overall (%)		**Stockout incidents - Overall**	
First tier		First tier RM days stockout	
Second tier		Second tier RM days stockout	
Third tier		**Backorders - Overall**	
Bullwhip measure (OEM - Tier 3)		First tier RM Total backorders	
RESPONSIVENESS MEASURES		Second tier RM Total backorders	
****Forecast accuracy (%)**		**COST MEASURES**	
First tier		**Transport**	
Supply chain cycle times - overall (days)		First tier	
First tier		Second tier	
Second tier		Third tier	
Third tier		**Inventory**	
Pipeline Inventory - overall (days of stock)		Interest on capital cost	
First tier RM		Storage	
Second tier FG		Obsolescence and depreciation	
Second tier RM		Opportunity cost	
Third tier FG		**Yearly Inventory saving**	x
Value adding\Non value adding (%)		**Average yearly cost/benefit**	x
		Implementation cost	x
		Return on Investment	x
		Payback period (years)	x

Figure 3.6 – FUSION Supply Chain Scorecard (Coleman & Coronado, 2002)

(1) Supply Chain Behaviour Measures

Synchronisation Index

The initial condition set for synchronisation says that a 100% synchronisation index will be present in a supply chain if both 2nd and 3rd tier suppliers make exactly to actual demand, but off-set by appropriate supply chain lead times. The following formula shows the synchronisation index for a second tier supplier.

$$Sync = 100 - \left(\frac{\left(\frac{\sum_{i=1}^{p} |a_i - b_{i-1}|}{p} \right)}{\mu} \right) * 100$$

Synchronisation for a second tier supplier, where:

a = requested quantities (daily demand)

b = supplier delivery (daily)

p = days for the period examined

μ = mean demand for the period examined

The measure calculates the mean absolute deviation (MAD) over the period examined, between the appropriate offset OEM demand and the actual demand. Synchronisation for a third tier supplier is shown in the next formula.

$$Sync = 100 - \left(\frac{\left(\frac{\sum_{i=1}^{p} |a_i - b_{i-2}|}{p} \right)}{\mu} \right) * 100$$

Synchronisation for a third tier supplier, where:

a = requested quantities (daily demand)

b = supplier delivery (daily)

p = days for the period examined

μ = mean demand for the period examined

The maximum synchronisation index is 100, however it is possible to register negative values. The synchronisation index is directly dependent on the sum of absolute errors. A synchronisation index is negative if the total sum of absolute errors divided by the number of days comprising the period of study is bigger than the mean demand for the period examined ($MAD_{offset} > \mu$).

A synchronisation index is close to 100 if the total sum of absolute errors divided by the number of days comprising the period of study is significantly smaller than the mean demand for the period examined ($MAD_{offset} < \mu$). Figure 3.7 depicts the observations made above.

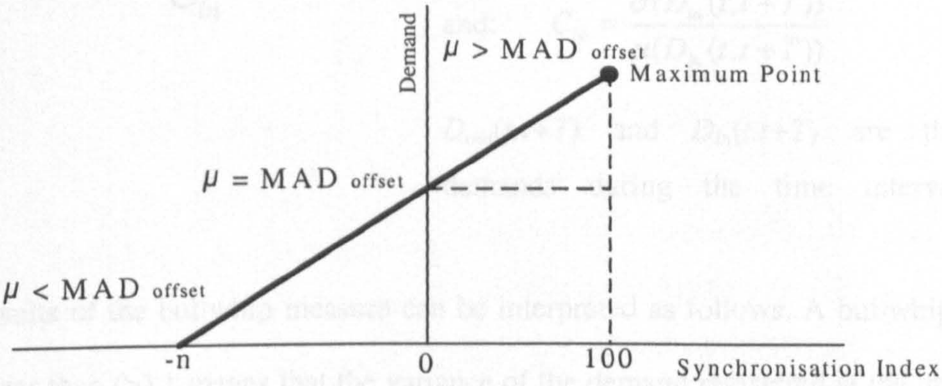


Figure 3.7 – Synchronisation Index

Bullwhip Measure

Bullwhip refers to the increasing variability of demand further upstream in the supply chain. Bullwhip measures the amplification between tiers by comparing the variability of the demand signal from the downstream participant (actual demand) with the variability upstream. Variability is measured by the standard deviation of demand relative to mean demand. Weekly variability: as measured by the standard deviation of weekly demand relative to average weekly demand. Two different formulas were incorporated throughout the case study work. The first one

$$Bullwhip-measure=\frac{\frac{\sigma}{\mu}upstream}{\frac{\sigma}{\mu}downstream}$$

σ = Standard deviation of demand pattern

μ = Mean of demand pattern

upstream = demand shown at 1st, 2nd or 3rd tier supplier

downstream = demand at point of fit of component

The second formula was defined by Fransoo and Wouters (2000).

$$\omega=\frac{C_{out}}{C_{in}}$$

ω = Bullwhip effect

where: $C_{out}=\frac{\sigma(D_{out}(t,t+T))}{\mu(D_{out}(t,t+T))}$

and: $C_{in}=\frac{\sigma(D_{in}(t,t+T))}{\mu(D_{in}(t,t+T))}$

$D_{out}(t,t+T)$ and $D_{in}(t,t+T)$ are the demands during the time interval

The results of the bullwhip measure can be interpreted as follows. A bullwhip index of greater than (>) 1 means that the variance of the demand registered at the upstream tier is higher than that registered at the point of origin. A bullwhip index of less than

(<) 1 means that the variance of the demand registered at the upstream tier is lower than that registered at the point of origin. A bullwhip index equal to 1 means a perfect supply chain. C_{out} and C_{in} are exactly the same. Figure 3.8 depicts the behaviour observed in the bullwhip effect.

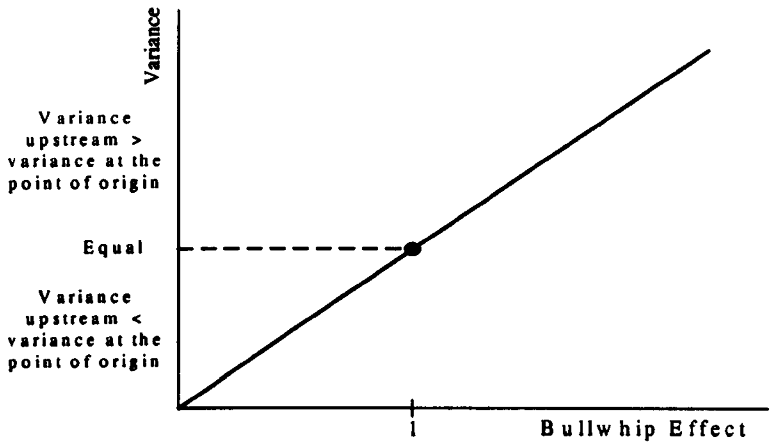


Figure 3.8 – Bullwhip Effect

(2) Responsiveness Measures

Forecast accuracy (only between OEM and the first tier supplier)

Forecast accuracy is the Mean Absolute Deviation (MAD) between forecasted numbers and actual requirements. It compares the output of the MRP system sent to the second tier supplier and the final call-off on each day. The following formula shows the formula used for forecast accuracy.

$$Forecast\_acc = 100 - \left(\frac{\left(\frac{\sum_{i=1}^{p} |a_i - b_i|}{p} \right)}{\mu} \right) * 100$$

Forecast accuracy for a first tier supplier, where:

a = daily final call-off (daily demand)

b = supplier delivery (daily)

p = days for the period examined

μ = mean demand for the period examined

A forecast index is negative if the total sum of absolute errors divided by the number of days comprising the period of study is bigger than the mean demand for the period examined ($MAD_{forecast} > \mu$). A forecast index is close to 100 if the total sum of absolute errors divided by the number of days comprising the period of study is significantly smaller than the mean demand for the period examined ($MAD_{forecast} < \mu$).

Supply chain cycle times

This measure represents a combination of process, transport and waiting times. The 'overall supply chain cycle time' is the sum of cycle time of first, second and third-tier supply chain.

Pipeline inventory

This is calculated by the average on-hand stock, divided by average usage. There are two types of pipeline inventory: raw material (RM) and finished goods (FG). The 'overall pipeline inventory' is the sum of RM and FG from every tier of supply chain.

Value adding ratio

This is expressed as the difference between supply chain cycle time and pipeline inventory, divided by pipeline inventory and multiplied by 100.

(3) Reliability Measures

Stockout Incident

The stockout incident measure gives the number of days on which a stockout occurred and the backorders measure shows the number of orders affected by the stockout. The 'overall stockout level' is the sum of stockout incidents from every tier of supply chain.

Backorders

Backorders totals the number of parts required on a stockout day. Again, the 'overall backorders level' is the sum of backorder incidents from every tier of supply chain.

(4) Cost Measures

Transportation Costs

The transportation costs for the Supply Chains under analysis have generally been calculated using publicly available data from the Road Haulage Association.

Total Inventory Costs

The total inventory costs were calculated as the sum of the following costs. 'Interest on capital cost' was calculated as the total inventory value multiplied by the suggested annual interest rate and divided by 12. The 'Storage cost' was calculated as the total inventory value multiplied by an annual storage cost rate. The 'Obsolescence and depreciation cost' for a Supply Chain made the assumption that there would be one obsolescence incident per year (inventories are scrapped once per year). Finally, the 'Opportunity cost', defined as the cost of passing up the next best choice when making a decision, was calculated as total inventory value multiplied by an opportunity cost factor of 0.1 divided by 12.

3.5.3.3.2 Other Measures

Other measures were incorporated throughout the case study chapter, which are more difficult to quantify. The following will define the 'other measures' that were used throughout this research.

Financial

The cost of running operations prior to and following any innovations spurned from this research. Measures such as employee time saved and reduced use of premium freight shipping were incorporated here.

Social

- Has any improvement in the working practise or flow of information led to improvements in customer/supplier relationships?
- A reduction in the amount of time spent on phone calls.

This information was acquired via the application of a questionnaire.

System

For any application developed as part of this research two main measures were applied:

- How easy was the application to develop and integrate compared to systems already in place?
- In the scenario of creating an innovative application for a particular part of the business, if the application were scaled up would it remain practical or would it become too complex or too costly?

3.5.3.4 Stage 4 -Design & Prototyping

This section of SCICM involves the development of the three architectures as defined in Chapter 4. Three generic templates representing the three integration architectures have been designed to guide this section. The initial mapping provides a view of the systems landscape for the different integration strategies to be applied.

Having adapted the three generic integration architectures to fit the specific scenario, the focus of this stage changed to the development of a prototype application based upon one or more of the designed architectures. Ideally it was hoped that the companies involved in the case studies would agree to implement these prototype systems so that their true benefit could be assessed. However, in the case that a company wanted the prototype to remain informal in nature, a series of simulations were designed to bypass this obstacle (glass pipeline experiments, 3.5.3.4.1).

In order to develop fully functional industry specific applications that would be used on a day-to-day basis it was important to utilise the right strategy. With this in mind it was decided that a 'Rapid Application Development' (RAD) technique should be adapted to act as a roadmap. However, it is important to note that due to the strict rigid nature of the RAD concept that is to be incorporated, elements are ignored. Justification of this is based on the fact that the RAD technique in question was designed with large development teams in mind, and not really individuals developing research-based applications (section 3.5.3.4.2).

3.5.3.4.1 Glass Pipeline Experiments

The glass pipeline experiments (FUSION, 2002) represent a series of simulations to monitor the impact of a prototype application. This is achieved via the channelling of manipulated information to the appropriate supply chain participants. The simulations were designed to observe how cross supply chain information systems affect:

- the dynamic behaviour of the supply chain (in terms of its synchronisation and its propensity to amplify demand changes through the 'bullwhip effect');

- logistics associated business benefits - responsiveness, forecast accuracy, supply chain cycle times, transport costs, pipeline inventory costs and stock out days.

Figure 3.9 depicts the structure of the information sharing prototypes designated as glass pipeline experiments (GP). Three glass pipeline algorithms were designed for this work: GP1, GP2 and GP3 (Coleman *et al*, 2002).

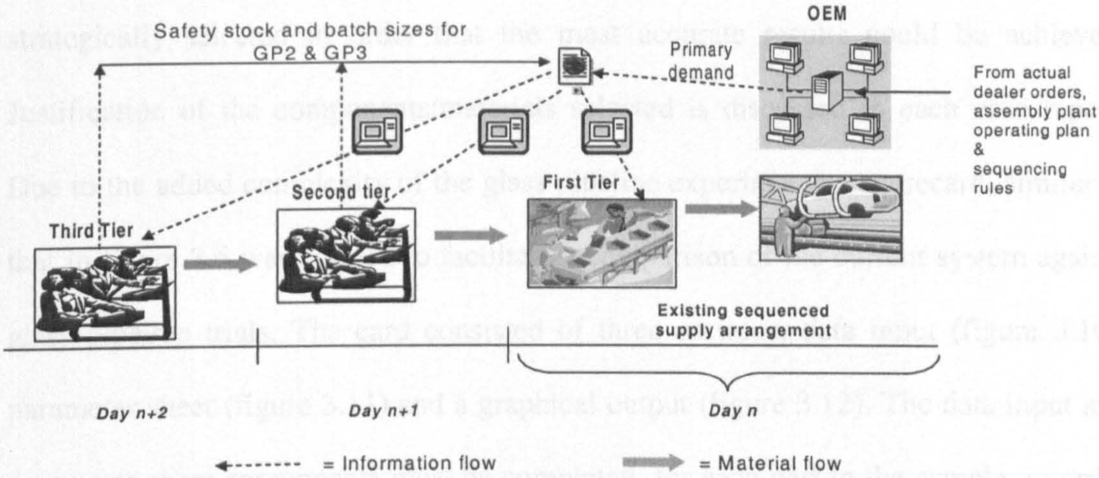


Figure 3.9 - Information Sharing Principle of Glass Pipeline Experiments

A more comprehensive understanding of the GP experiments is obtained when positioning them within the context of the automotive industry. In the GP1 trials, the demand specified on the OEM production files was offset by one day, and passed on to second and third tier suppliers. In practice, this meant that the second tier supplier was asked to deliver the production schedule requirements one full day before vehicle assembly operation's build day. This reflected a one day supply chain cycle time for the seat manufacturer sequenced manufacturing and delivery.

The GP2 uses the same offset as GP1 to arrive at the raw demand for each tier on a given day. The GP2 algorithm compares available stock with a predefined safety stock target level and adds or subtracts from the raw demand to return available stock to the desired level. The quantity used by the algorithm is rounded to the nearest predetermined delivery batch size. GP3 runs using the same approach as in the GP 2 model but without the weekly reference to raw material stock available at the first tier supplier.

Where the GP experiments were applied (cases 2 and 5), components/materials were strategically selected in order that the most accurate results could be achieved. Justification of the components/materials selected is discussed in each case report. Due to the added complexity of the glass pipeline experiments a scorecard, similar to that in figure 3.6 was applied to facilitate a comparison of the current system against glass pipeline trials. The card consisted of three sections, data input (figure 3.10), parameter sheet (figure 3.11) and a graphical output (figure 3.12). The data input and parameter sheet components must be completed, for each part in the sample, in order to generate the graphical output.

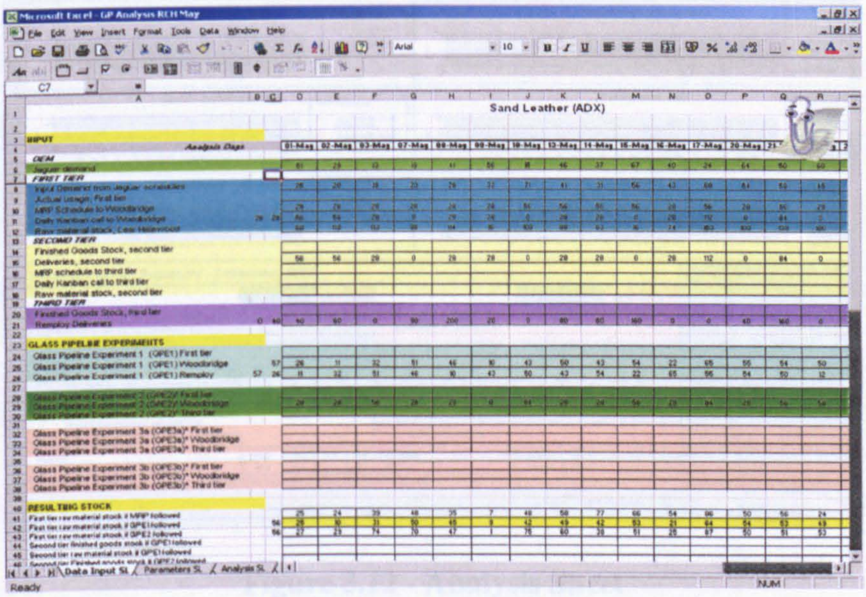


Figure 3.10 - Data Input Sheet

The parameters sheet (figure 3.11) is used to initialise values such as safety stock targets; batch sizes and starting stock for all three tiers, but these values can be altered to simulate an optimal operation.

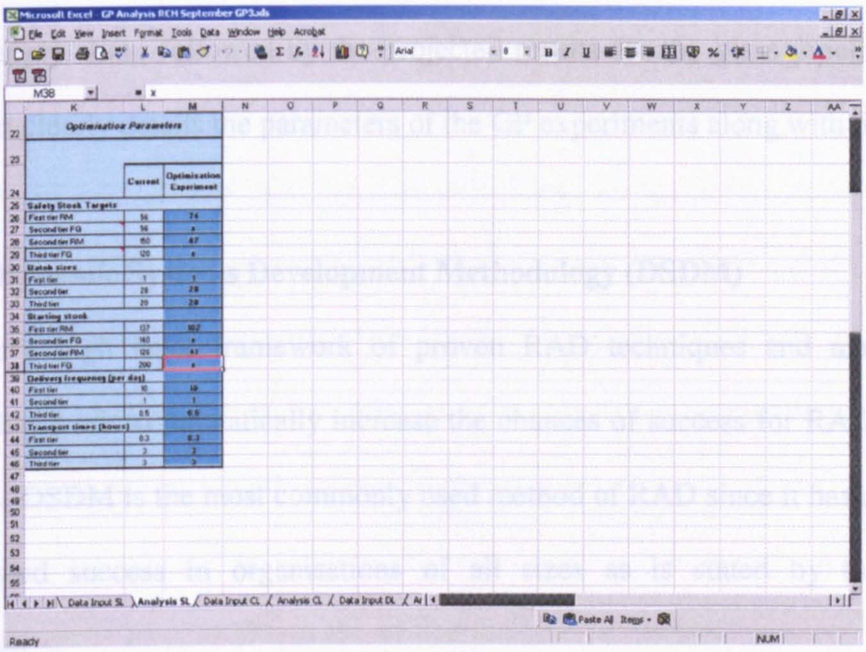


Figure 3.11 - Parameters Sheet

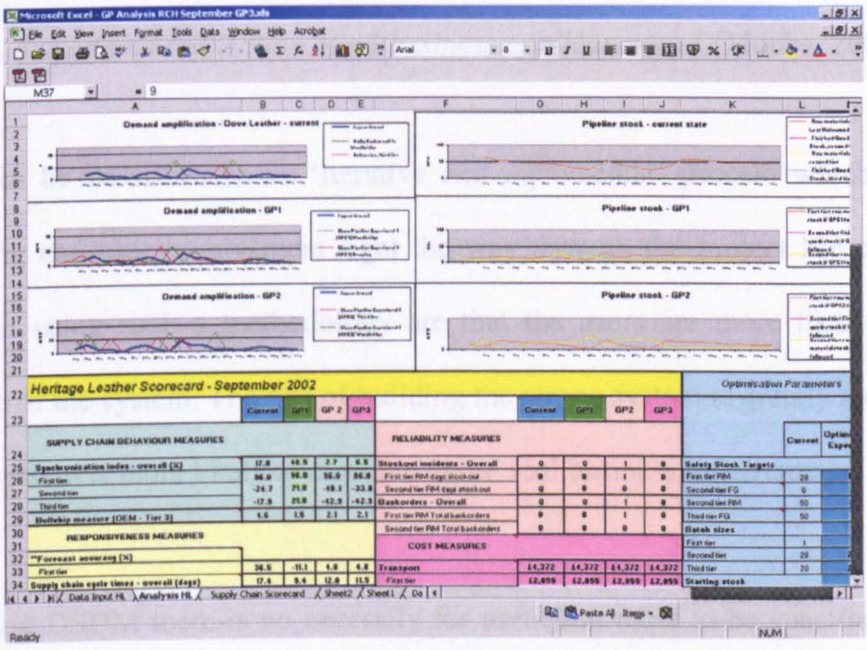


Figure 3.12 - Analysis Sheet

The analysis sheet pictured in figure 3.12 was the main component of the scorecard. It graphically represents data from the data input sheet and provides two sets of graphs. One set shows demand application in the current supply chain and the projected results of the glass pipelines. The second set show the pipeline stock again for the current supply chain followed by the projected results for the glass pipelines. Each case report clearly details the parameters of the GP experiments along with the results.

3.5.3.4.2 Dynamic Systems Development Methodology (DSDM)

DSDM is a high level framework of proven RAD techniques and management controls that work to dramatically increase the chances of success for RAD projects. In the UK, DSDM is the most commonly used method of RAD since it has repeatedly demonstrated success in organisations of all sizes as is stated by the DSDM Consortium.

' *DSDM is becoming the approach of choice for all e-developments, assisting in the definition, design and realisation of all business applications...*' (Mobbs, 2001)

DSDM can be described as an 'Iterative and Incremental' process which involves prototyping and user involvement right the way through the project life cycle. The benefits of using such a methodology are that the users are more likely to claim ownership of the system. The risk of building the wrong system is greatly reduced and the final system is more likely to meet the users' real business requirements.

When using DSDM there is no necessity for particular tools to be specified prior to the start of any particular case study. This is extremely useful as each case study will be sure to provide different challenges. Therefore, the tools required for each case study will be carefully selected during the early stages of any particular project. The explanation above provides sufficient evidence to support the adoption of specific elements of RAD DSDM strategy for this research.

3.5.3.5 Stage 5 - Evaluation of Integrated Designs

Stage 5 is almost identical to Stage 3 with the exception that it is undertaken subsequent to any changes to systems or procedural configurations. Effectively this section incorporated the scorecard along with the other measures to assess the impact, if any, of the changes that have been made. For obvious reasons, results were collected over a period of time following any changes or implementations and results displayed in appropriate formats (graphs, tables, charts).

3.5.3.6 Stage 6 - Supply Chain Information Plan

The findings highlighted in each of the case studies are considered in this section. From discussions here it was hoped that enough information would emerge to effectively respond to the questions and hypotheses in the final chapter of this thesis.

3.6 Chapter Summary

The aim of this chapter was to introduce the research approach that has shaped the course of this research. Hence the strategy behind the Literature Review, Analysis Framework Chapter, Classification Framework and the SCICM have all been included.

The two most significant sections of this chapter were the development of the classification framework and the SCICM. The Classification Framework was required in order to identify the most appropriate case studies to fit with the initial research objectives defined in Chapter 1. Each component of the SCICM has been examined so that the structure of the case studies in Chapter 5 is fully understood.

4. ANALYSIS FRAMEWORK

4.1 Introduction

As discussed in Chapter 1, the research undertaken within this thesis involved investigating and evaluating alternative supply network system integration architectures. It is the aim of this chapter to define the three generic system 'integration architectures' that the author can consider and apply to each of the five case studies in Chapter 5. The 'integration architectures' were formulated through an extensive review of the literature. Prior to each of the integration architectures being applied to a particular case study, the author extensively mapped the systems at each company in order that the three strategies could integrate accordingly. The mapping not only covered how the internal systems communicated but also how suppliers and customers interacted with the companies.

The first architecture of the three examined in this section has been labelled the 'Enterprise Application (EA)-based' supply network integration architecture. Probably the most complex of the strategies to be reviewed, the principal objective of this approach was to investigate and apply advanced EA architectures to each of the case studies in Chapter 5. EA architectures vary hugely depending on the scenario in which they are deployed. Therefore, the aim of this section is to envisage and consider a selection of generic EA integration architectures/strategies that can act as a template for each of the case studies.

The second architecture entails using the Internet in order to facilitate improved information communication within the supply networks considered in Chapter 5. As with the 'EA-based' architectures, 'Internet-enabled' supply network integration architectures will vary considerably depending on a number of different dynamics. The Internet's status as a viable communication medium has been strengthened by the substantial selection of Internet tools and technologies that have emerged in recent years. The technology and literature review in this section demonstrates how both academics and software vendors have developed Internet-based applications that seek to improve supply network communications. From this, two generic 'Internet-based' supply network integration architectures were designed.

The third and final architecture has been termed the 'Hybrid' systems-based supply network integration architecture. The aim of this approach was to enhance the information communications of the particular company, via methods and resources that the company already has in place. It is the last of the three strategies to be discussed as it was expected that the first two strategies would both contribute towards the outcome of this section. The boundaries for this strategy are broad due to the exceptionally different conditions that were likely to be experienced throughout each of the case studies. The initial system mapping allowed the author to ascertain the specific area in which strategy could fit.

In summary, this chapter aims to provide three generic integration architectures, which form the basis of each of the case studies in the following chapter. Following the initial mapping of the systems at the respective companies, the three strategies/architectures were tailored accordingly to fit into each case study scenario. Each of the three integration strategies is now explored in greater detail.

4.2 Enterprise Application (EA)-Based Supply Network Strategies and Architectures

4.2.1 Introduction

The aim of this section is to envision the idea of an EA-based system configuration that is able to seamlessly connect supply, planning, manufacturing and distribution across a series of companies in a supply network. Traditionally EA systems have been aimed at tightly integrating processes within an enterprise. However, increasingly it is being realised that many business processes actually transcend the company boundaries from which they originated. Dabbiere's (1999) research on the 'virtual organisation' concept is central to the theme of this section. The truly integrated supply chain where trading companies not only optimise their internal processes but also their interactions with one another is the basis for the next revolution in supply chain software development. The following section investigates the literature and technologies that have emerged, in order that a selection of generic architectures can be proposed.

4.2.2 Literature and Technology Review

4.2.2.1 Introduction

There is an obvious divide that can be made between the literature that has arisen in academic circles and the work that has stemmed from commercial sources. There is an overlap of course, with many academics referencing commercial products within their work. In order to differentiate between each group's work, the literature to be considered in the first section includes all of the research originating from academic sources regardless of whether commercial products have been discussed. The second, commercial literature section concentrates on the aspirations and key developmental work undertaken by modern day EA vendors.

With the considerable growth of Enterprise Application (EA) system investment (otherwise referred to as ERP) and the growing importance of Supply Chain Management (SCM) in an increasingly competitive global economy, researchers and practitioners are having to seriously think about the design and implementation of EA systems within supply networks. However, many of the EA systems developed to date can be classed as standardised information systems that have limited flexibility in considering the variety of organisational environments across a supply network (AMCIS, 2004). Supporting this theme, Anderson (1999) reported that traditionally many of the technology initiatives for companies based in a supply chain have been focussed around implementations of ERP systems, with the driver in these cases often being the replacement of legacy technology. Importantly the author goes on to state that these enormously complex implementations have often centred on a single ERP vendor and have had a limited impact on supply chain performance. Furthermore, Lipson & Gautheir (2002) discussed how in the past 10 years companies have implemented Enterprise solutions without developing the governance model and focus required to deliver the key business capabilities to support their business strategy. The following section considers the wealth of research that has surfaced from both academic and commercial sources in the area of EA development.

4.2.2.2 Academic Literature

There exists a considerable mass of academic literature covering the technological advancements that have taken place in recent years to enable EA-based supply network integration. Discussing the main themes chronologically, Sauter & Parunak (1999) introduced the concept of a computer-based agent system to assist and succeed human-based interactions (refer to part 1 of the literature review). From their work, the authors maintained that agent-based systems provide a promising alternative to the monolithic ERP software currently used. The Agent Network for Task Scheduling (ANTS) project supported a novel approach to supply chain integration as it decomposed each firm itself into a miniature supply chain made up of a series of producers and consumers. Consequently, the interfaces within a firm were the same as those between one firm and another, and integration of ANTS-based firms into larger supply chains was immediate and transparent.

Lau and Lee (2000) discussed an architectural framework for formulating a data interchange system, a supply chain information system (SCIS) that was aimed at providing accurate and relevant information to enhance the performance of a supply chain network. The proposed SCIS (figure 4.1) focused on the modules necessary for the building up of such an information flow system. The SCIS incorporated object technology in order to enable efficient data exchange among business objects located in distributed platforms over geographically isolated regions.

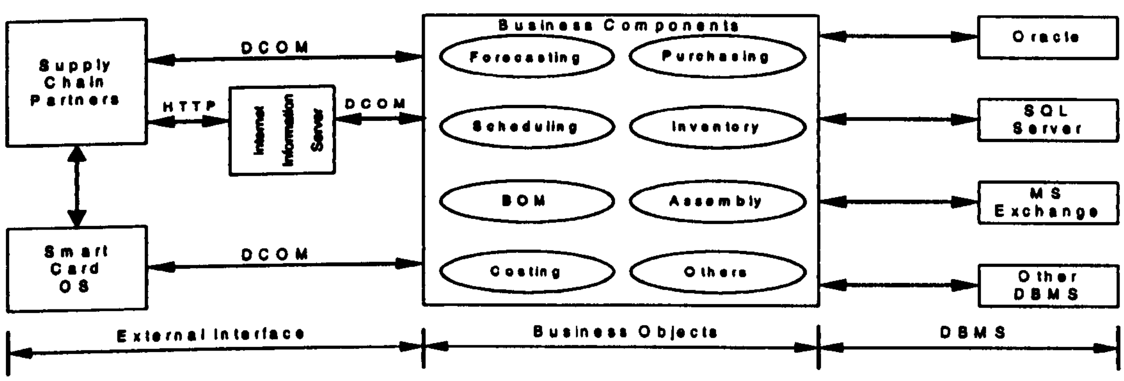


Figure 4.1 – Infrastructure of Proposed SCIS (Lau and Lee, 2000)

Is also important to note that the Internet plays an important role within this system as figure 4.1 illustrates.

Klueber and Alt (2000) proposed an architecture for eBusiness that extends ERP-centric architectures to address the new challenges of Business Networking. The authors achieved this by adding new structural components like eServices application components focusing on inter-organisational tasks like eC, SCM and CRM applications as well as EAI tools on the middleware layer and indicated how they interact with the ERP systems in place. In the same year Gupta (2000) recognised two future developments in ERP. The first concerned the growing influence of web-based procurement applications whilst the second identified a trend towards the outsourcing of ERP applications.

Rashid *et al* (2002) considered the Internet to be the key component to enable the extended enterprise. The authors reported that an environment whereby systems and resources can be accessed from anywhere anytime has helped ERP vendors extend their legacy ERP systems to integrate with newer external business modules such as SCM, CRM, sales force automation (SFA), advanced planning and scheduling (APS), business intelligence (BI), and e-business capabilities.

Pant *et al* (2003) supported this with case studies involving companies with recently installed e-supply chain systems. One case study described an OEM and several of its supply chain partners. Both the OEM and its supply chain partners were in the process of integrating internal systems using the SAP R/3 product. For demand planning and forecasting the OEM used i2's Rhythm software and the CRM component was custom written. The case study described how a powerful web server allowed connectivity to all major databases and supported the three major multiple object component architectures: CORBA, Enterprise JavaBeans and Microsoft's Component Object Model. The web server talked to the SCP system (Rhythm) and the ERP software (SAP R/3) via custom written interfaces. However, the authors reported that the system was very complex as it required real time integration of data from systems that were themselves complex. Furthermore, the coding required considerable effort. From their work the authors identified internal and external challenges that arise when organisations attempt to implement e-supply chain systems.

The more recent work of Davenport & Brooks (2004) provides a few examples of companies that have sought to integrate their supply chains. They describe how Reebok has been concentrating on both internal and external supply chain capabilities. In order to cut inventories, Reebok implemented two SAP enterprise systems in the marketing and retailing parts of the business, and linked them through electronic commerce and EDI connections. This permitted Reebok to integrate everything from new product development to analysing profits in individual stores. Furthermore, through the use of Internet EDI the company also integrated its manufacturing partners' customers around the globe. Future plans involve tying its systems directly to theirs. Eventually, Reebok also expects to have direct linkages with the retailers it does not own through its enterprise system.

Boeing is the other company that Davenport & Brooks (2004) analysed. The company relied on hundreds of internal and external suppliers for the five million to six million components needed to build a large twin-aisle airplane. Using Baan enterprise systems in combination with forecasting software from i2 Technologies, Boeing is reported to be finally beginning to master the complexity of getting the right parts to arrive at the correct time. Communications connections among internal parties are direct, from database to database and the connection to external suppliers is almost as seamless through EDI links to the enterprise system. At the same time, Boeing is giving customers access to enterprise information through its part analysis and requirements tracking (PART) page, a secure Internet site that its customers can use to order spares. The site is especially popular with the 600 or so airlines that have never adopted EDI for parts ordering from Boeing.

The focus of this literature and technology review shall now consider the subject matter that has been discussed within commercial circles.

4.2.2.3 Commercial Literature

The commercial arena has been drastically shaped by the Internet and related technologies in recent years. Enterprise Applications are no exception to this generalisation. This section examines the progress that has been made in a commercial sense to enable supply network integration.

Kulkami (2002) stated that there are three stages in the implementation of an automated electronic supply chain:

- Adoption or updating of ERP or MRP software within an organisation.
- Collaborative planning and scheduling with critical suppliers and customers, allowing them effective sharing of information like forecasts, and orders freely through the supply chain.
- Electronic linking of customer and supplier data using Internet technologies, resulting in a truly virtual corporation that allows contact to (and for) any customer or supplier anytime and anywhere.

There are clear similarities between the concept of the 'virtual organisation' (Dabbiere, 1999; Kulkami, 2002) and the line of research taken by Camstar Systems (2001), whom considered the 'virtual factory' and its enabling structural and technical requirements (refer to table 4.1).

Clearly Kulkami (2002) and Camstar Systems (2001) recognised the importance of a sound internal infrastructure, which can then be integrated with collaborative applications to enable information sharing. Furthermore, both groups discussed the Internet as the enabling technology.

Infrastructure	Technology framework to support data and information interchange and collaboration.
Plant applications	Typical of today's Manufacturing Execution Systems (MES) including production scheduling and tracking, supervisory control and data acquisition, and quality management
Collaborative Applications	Designed to provide for information sharing and joint analysis, and update between distributed sites, corporate offices and suppliers.
Application Integration	Allow disparate applications to communicate: ERP, Product Lifecycle Management (PLM), MES and SCM.
Manufacturing Information Viewing and Analytics	A web based, secure platform for customers and suppliers to view live plant operations data, perform detailed business analytics, and to send and receive critical alarms and notifications

Table 4.1 – 'Virtual Factory' - Key Structural and Technical Requirements (Camstar Systems, 2001)

In terms of integrating Enterprise Applications there has been a plethora of work in this area. Kara (1999) stated that in order to integrate their products, the major ERP vendors publish application programming interfaces (APIs) that let external applications communicate with their ERP systems. However, as the author reported, these APIs are often not sufficient for distributed processing across different applications.

Kulkami (2002) supported the work of Davenport & Brooks (2004) reporting that a number of major e-business innovators like SAP, i2 and Ariba have come up with entire suites of solutions designed to optimise each phase of the supply chain to transform the way companies do business in the new economy. In order to do this SAP provides a rich set of integration technologies to seamlessly integrate their products with software installations residing elsewhere, SAP or otherwise. Table 4.2 illustrates the different integration tools that SAP currently offers.

In terms of other advances that have been made within the commercial arena. NuTech Solutions Inc. provided an example of agent-based technologies in operation (NuTech Solutions, 2004). NuTech developed an agent-based simulation tool to model a portion of the Procter & Gamble retail supply network so that the impact of certain policies in use by members could be investigated. Through iterative simulations, the agents within the simulation tool began to learn optimal behaviour. The supply network was then capable of self-organisation and goods, relevant information and services were able to flow smoothly. As a result P&G saves $300 million annually on an investment of less than 1% of that amount.

Integration Tools	Description
SAP Java Connector (Jco)	A middleware component that enables the development of SAP-compatible components and applications in Java. It supports communication with the SAP server in both directions: inbound calls (Java calls ABAP) and outbound calls (ABAP calls Java). The SAP JCo can be implemented with Desktop applications and with Web server applications and it is used as an integrated component in the SAP Business Connector (SAP BC) and the SAP Web Application Server.
SAP .NET Connector	A programming environment inside of Visual Studio .NET that enables communication between the Microsoft .NET platform and SAP Systems. It supports SAP Remote Function Calls (RFC) and Web services, and allows users to write various applications. It is possible to use all Common Language Runtime (CLR) programming languages such as Visual Basic .NET, C#, or Managed C++.
SAP RFC Library	Provides an interface to a SAP System. It is the most commonly used and installed component of existing SAP Software. The interface provides the opportunity to call any RFC Function in a SAP System from an external application. Moreover, the RFC Library offers the possibility to write an RFC Server Program, which is accessible from any SAP System or external application. Most SAP Connectors use the RFC Library as a communication platform to SAP Systems.
SAP Business Connector (SAP BC)	A middleware product based on webMethod's B2B Integration Server. It allows integration with mySAP business Suite/R3 via open and non-proprietary technology. This middleware component uses the Internet as a communication platform and XML/HTML as data format, thus enabling the integration of different IT architectures. For software vendors who integrate their software with SAP solutions using BAPIs/RFMs/IDocs, the SAP BC can be used in place of the SAP connectors (Java connector, .NET connector), to invoke BAPIs/RFMs or exchange IDocs with the SAP system.
SAP SOAP Processor	Situated within the SAP Web AS 6.20 it contains amongst other things a Web Service Browser for searching and generating WSDL 1.1 compatible function module descriptions and a SOAP Server for RFMs that support synchronous calls that conform to SOAP 1.1, of the RFC-enabled function modules. Therefore, when integrating with SAP Web AS 6.20 based mySAP Business Suite components (e.g. SAP R/3 Enterprise), third party software vendors can use the industry standard WSDL/SOAP-based approach to invoke the RFC-enabled function modules in the SAP system. Furthermore, as BAPIs are special RFMs that are linked as methods of the business objects, BAPIs can also be invoked through the SAP SOAP processor.
Flat file-based data transfer	In some instances SAP applications can also use flat files to import and export data. In general, SAP encourages third party vendors to use BAPIs, released RFMs and IDocs whenever possible and the Flat file-based approach should only be considered when these other means are not available.

Table 4.2 – SAP Integration Technologies (SAP, 2004)

In the press it was announced on April 30, 2003, Sierra Atlantic Inc., the Application Networks Company, and WorldChain Inc., the '*pioneer in supply chain synchronisation solutions*' announced that they were to extend their partnership to jointly deliver solutions for synchronised transactions and business processes across supply networks (Sierra Atlantic, 2003). On March 15, 2004, it was reported that IBM and Global Exchange Services Inc. '*are each leveraging data synchronisation technologies gained through recent acquisitions to aid manufacturers in automating supply chains*' (Ferguson, 2004).

SAP has focussed a considerable amount of time and effort upon what it terms 'Adaptive Supply Chain Networks' (SAP, 2002a). The principle of these adaptive networks is that they should seamlessly connect supply, planning, manufacturing, and distribution operations to critical enterprise applications and provide near real-time visibility across the supply network, thereby enabling rapid decision making and optimal execution. According to SAP it is the technologies such as radio frequency identification (RFID), agent technology and web services that have emerged in recent years that have facilitated the emergence of these 'Adaptive Supply Chain Networks'.

4.2.2.4 Conclusion

The work undertaken in supply chain integration and synchronisation clearly demonstrates the future of supply chains. However, a large proportion of EA system integration research concerns the consolidation of disparate Enterprise Systems within one corporation, as the work of Prior and Zrimsek (2003) and Lipson & Gautheir (2002) maintains. Therefore, the following section aims to provide a range of generic EA-based architectures that encompass complete supply networks.

4.2.3 Development of Generic Enterprise Application (EA)-Based Architectures

4.2.3.1 Introduction

The work of Lipson and Gautheir (2002) has been adapted to form the basis of the generic EA architectures discussed in this section. In their work the authors considered harmonising ERP architectures within one distributed corporation. In order to do this, the authors describe the premise of 'Independent Operation', 'Integrated Operation' and 'Single Instance'. Whilst the authors' work concerned a single organisation, the harmonising of enterprise applications is the central theme to this section, thus the terms 'Independent Operation', 'Integrated Operation' and 'Single Instance' have been adapted for the generic architectures in this section.

The first of the architectures, 'Independent Operation' demonstrates how traditional EA systems are configured within a supply network. In this configuration there is little or no cross-company communications infrastructure. It is relevant to point out that with the exception of OEMs and certain first-tier suppliers, this is how a large proportion of supply chains operate. The telephone, fax machine and increasingly e-mail are the only real methods of communication.

The second EA-based architecture comprises an enhanced level of integration, hence the name 'Integrated Operation'. At present, this is the target of both modern day software vendors and supply chain companies. Whilst some integration is taking place, it is proving somewhat more difficult to integrate enterprise systems across a range of companies within a supply chain.

The third and final architecture envisaged by the author comprises a single EA system across a complete supply network scenario. All of the functions currently undertaken by a large number of disparate EA systems would be merged into one comprehensive system encompassing the entire supply network. This particular architecture is conceptual in nature and it is debateable as to whether it could ever be achieved. However, its inclusion is justified as a point for which to aspire in each of the case studies in Chapter 5. Figure 4.2 depicts the traditional 'independent', EA-based supply network along the notion of an 'Integrated' and 'Single Instance', EA-based supply network.

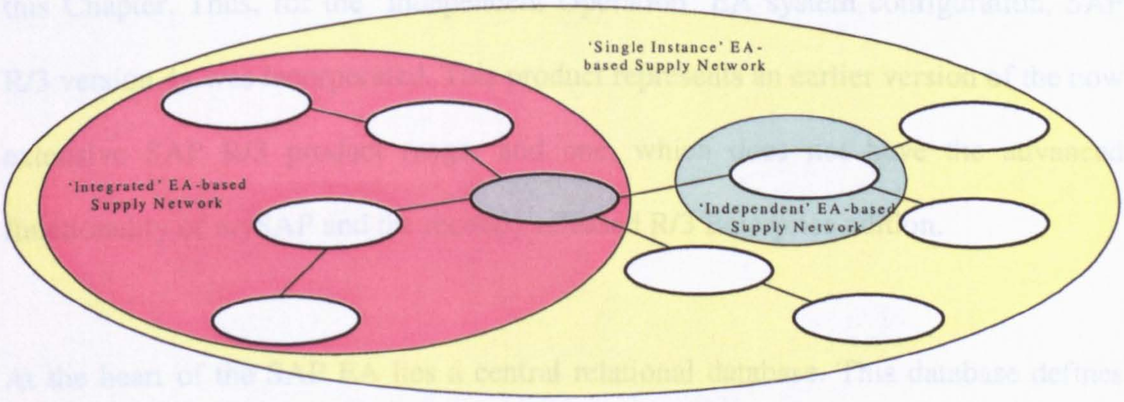


Figure 4.2 – Independent, Integrated and Single Instance EA-based Supply Networks

4.2.3.2 Independent Operation

The first of three generic, EA-based architectures to be discussed has been labelled 'Independent Operation'. Within this particular configuration, there are multiple EA systems distributed within a supply network. Figure 4.3 provides a simplistic example of the overall EA configuration. There is functional independence between each of the entities and materials resource planning is undertaken with limited information. As mentioned in the introduction, aside from certain OEM and first tier suppliers, it is widely accepted that most supply networks function in this manner.

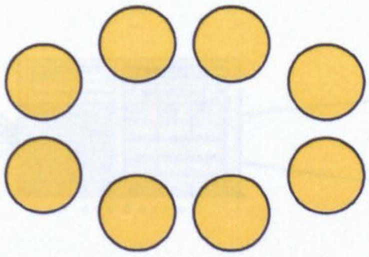


Figure 4.3 – Independent Operation Configuration

The core modules of most EA systems are essentially the same, therefore, it was decided that with SAP representing the most comprehensive solution on the market, its core modules would act as the basis EA for each of the supply chain participants in this Chapter. Thus, for the 'Independent Operation' EA system configuration, SAP R/3 version 4x was incorporated. This product represents an earlier version of the now extensive SAP R/3 product range, and one, which does not have the advanced functionality of mySAP and the recently released R/3 Enterprise edition.

At the heart of the SAP EA lies a central relational database. This database defines and links thousands of tables of information, providing a smooth flow of information across the whole of the operating environment. EA applications are generally based upon a client/server hardware platform. Therefore, the core modules reside on a central host server, which acts as a central point for managing the clients that link to the host server. Figure 4.4 provides an example of a SAP client/server installation in which the host server houses the core SAP software, the overall system profiles and the global settings. In this particular diagram the database is maintained within the host server. However, in a more complex configuration a separate database server may be assigned.

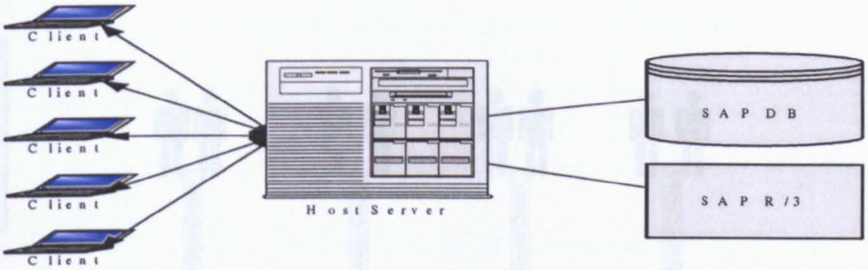


Figure 4.4 – Client/Server Architecture

SAP provides a wide variety of transactions to simplify working with a large number of database tables. SAP groups these transactions into an architectural hierarchy known as business modules (Prince, 1998). All of the business modules reside upon the single relational database platform. Figure 4.5 depicts the modules present in the SAP R/3 system.

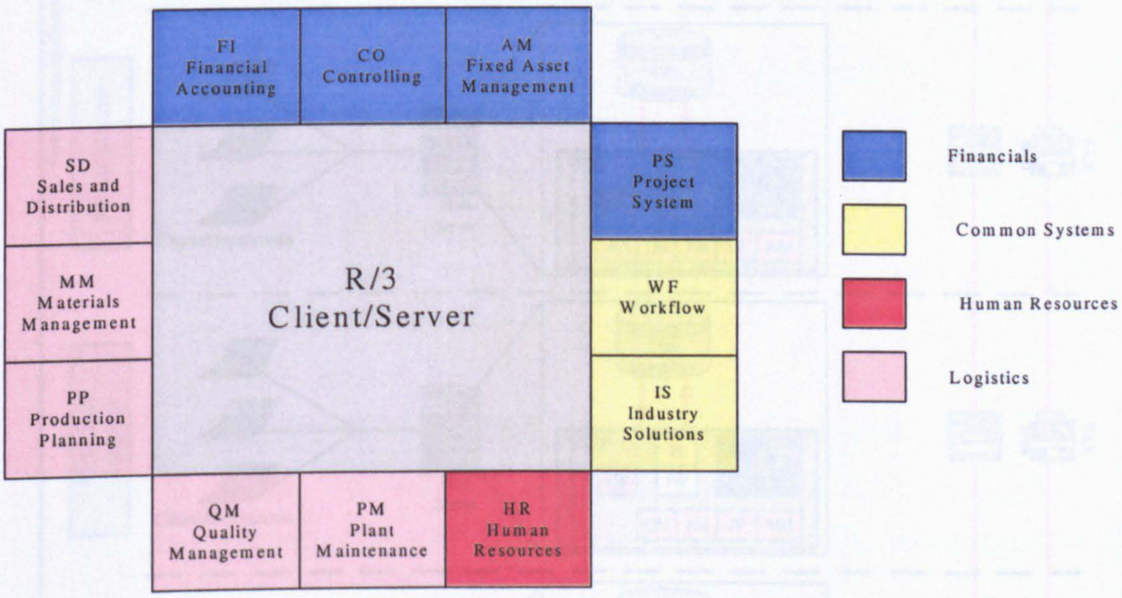


Figure 4.5 – SAP R/3 Business Modules (Hayden, 2000)

Having discussed the fundamentals of the SAP R/3 system, it is now appropriate to see how the EA system would exist when configured in a typical supply network.

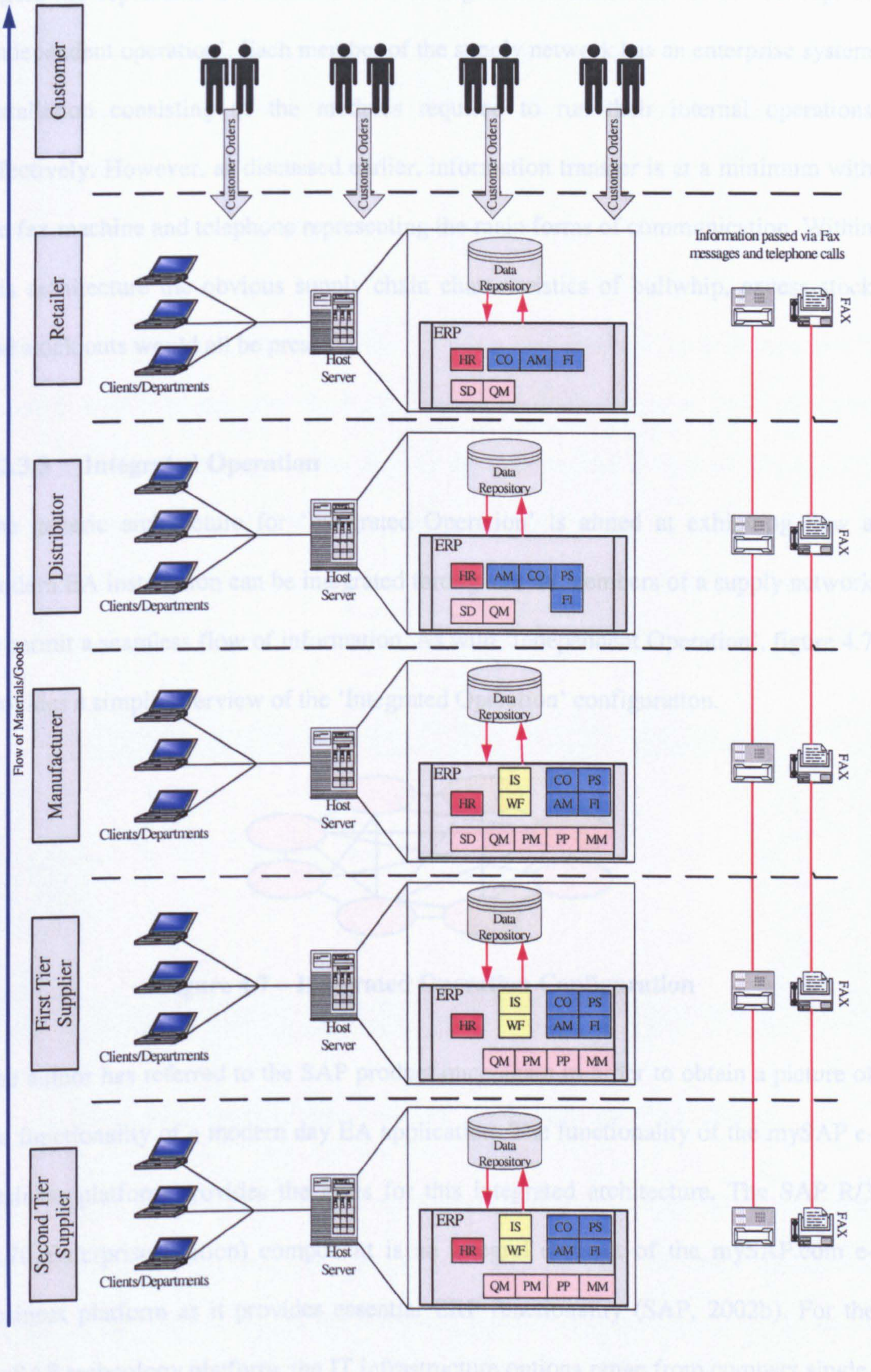


Figure 4.6 –'Independent Operation' EA-Based Architecture

Figure 4.6 represents the author's view of a generic architecture for the concept of 'independent operation'. Each member of the supply network has an enterprise system installation consisting of the modules required to run their internal operations effectively. However, as discussed earlier, information transfer is at a minimum with the fax machine and telephone representing the main forms of communication. Within this architecture the obvious supply chain characteristics of bullwhip, excess stock and stock outs would all be present.

4.2.3.3 Integrated Operation

The generic architecture for 'Integrated Operation' is aimed at exhibiting how a modern EA installation can be integrated throughout all members of a supply network to permit a seamless flow of information. As with 'Independent Operation', figure 4.7 provides a simple overview of the 'Integrated Operation' configuration.

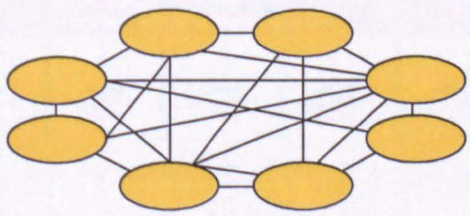


Figure 4.7 – Integrated Operation Configuration

The author has referred to the SAP product once again in order to obtain a picture of the functionality of a modern day EA application. The functionality of the mySAP e-business platform provides the basis for this integrated architecture. The SAP R/3 (4.70 Enterprise Edition) component is an integral element of the mySAP.com e-business platform as it provides essential ERP functionality (SAP, 2002b). For the mySAP technology platform, the IT infrastructure options range from compact single-host and single database installations to highly scalable and secure configurations.

The optimal technical infrastructure for a given business requirement is determined by several factors, such as landscape type, core business processes, transaction volume, security, and availability. With high volume supply chains representing the core focus of this research, the EA-based architecture to follow is designed to take into consideration high volumes of information.

mySAP is SAP's term for its Internet offering and strategy. mySAP acts as an interface to all SAP products which allows users to access the necessary applications via the SAP Workplace application on their desktop. mySAP integrates with existing R/3 functions, however, R/3 is not required to be installed for mySAP to operate. If R/3 is installed, then mySAP.com would sit on top of the R/3 applications. Figure 4.8 illustrates all of the components of mySAP.com and SAP R/3 Enterprise.

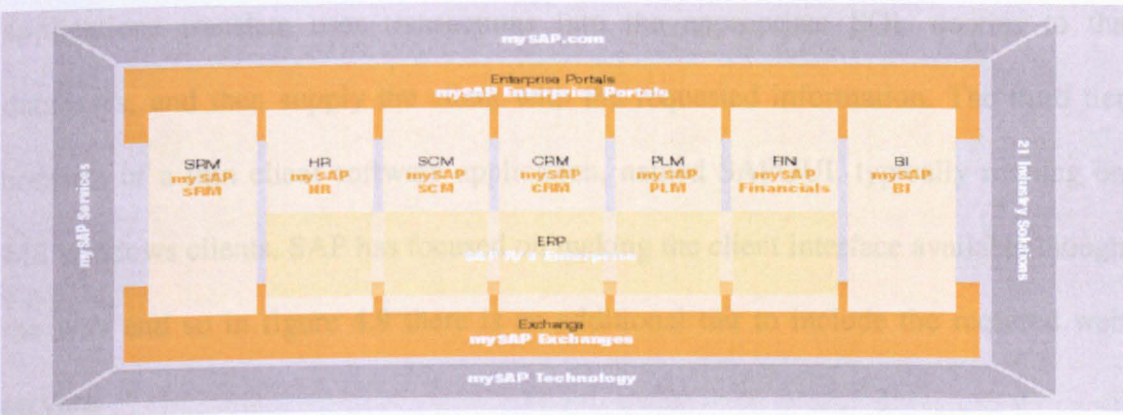


Figure 4.8 – mySAP.com and SAP R/3 Enterprise (SAP, 2002b)

The SAP solution exists as a three-tier client/server architecture. In this environment, the presentation/client, the application, and the database can each reside on separate computers and servers for greater scalability, improved operations, and support for multiple platforms. Figure 4.9 illustrates a typical three-tier architecture for mySAP and R/3.

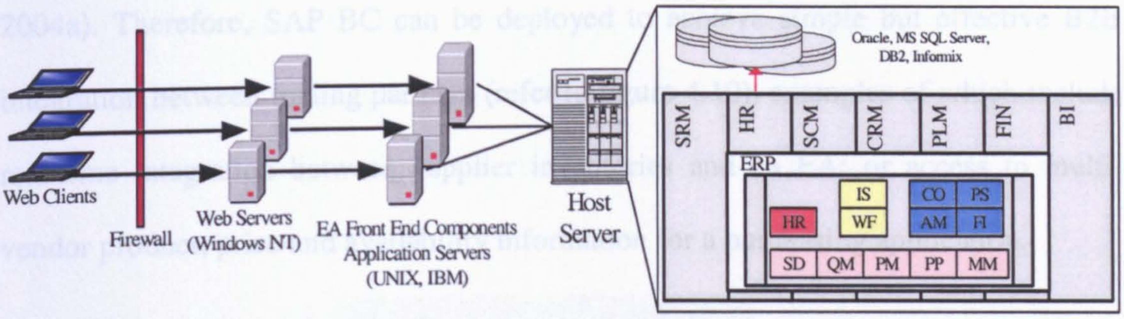


Figure 4.9 – 3-tier SAP Architecture

The SAP/Cisco white paper (2004) discussed each tier individually. The first tier consists of a database management system, which stores the data upon which SAP applications operate. The databases that are deployed are, in general independent of the SAP solution. Database products from Oracle, Microsoft, Infomix and IBM are regularly integrated with SAP. The second tier is the heart of the SAP system, consisting of application logic, for the processing of client transactions. The applications translate user transactions into the appropriate SQL queries to the databases, and then supply the client with the requested information. The third tier consists of a thin client software application, named SAPGUI, typically running on MS windows clients. SAP has focused on making the client interface available though the web and so in figure 4.9 there is an additional tier to include the required web servers.

In order to develop a generic 'Integrated Operation' EA-based architecture, it is not really appropriate to select an individual integration tool. However, further examination of one such tool enables a clearer picture to emerge as to how integration could take place. The SAP Business Connector (BC) integrates RFC server and the client and provides an XML layer over R/3 functionality so that other applications do not need any understanding of R/3 internal data structures or protocols (TopXML, 2004a). Therefore, SAP BC can be deployed to achieve simple but effective B2B integration between trading partners (refer to figure 4.10), examples of which include real-time integration between supplier inventories and an EA; or access to multi-vendor product, price and availability information for a purchasing application.

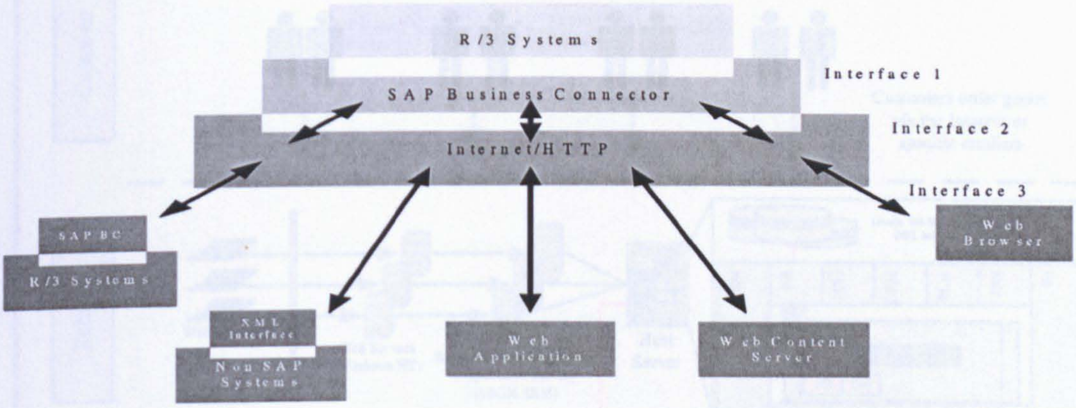


Figure 4.10 – SAP Business Connector (TopXML, 2004b)

SAP BC incorporates a fully-fledged RFC server and client which allows for real-time inbound and outbound communication to and from the R/3 system. It supports both synchronous RFC and asynchronous tRFC protocol. SAP BC can connect two R/3 systems over the Internet with no concerns over the particular version of R/3 (SAPGENIE, 2004). The SAP BC is one of many integration tools that permits integration.

Figure 4.11 illustrates how the author envisions the configuration of an 'Integrated Operation' EA-based architecture. For simplicity, all participants in the supply network have a EA system tailored for their specific requirements. The companies are connected via an integration tool such as the SAP BC, which enables the seamless flow of data between enterprise applications. Orders are received via the Internet or specific retailer and the information is fed into the EA. This information then propagates through each of the participants in the supply network. The main advantage of this approach is that the Internet clearly bridges the gap between the different businesses, systems and users, thus removing or reducing a number of the problems that were experienced in the 'Independent Operation'-based scenario.

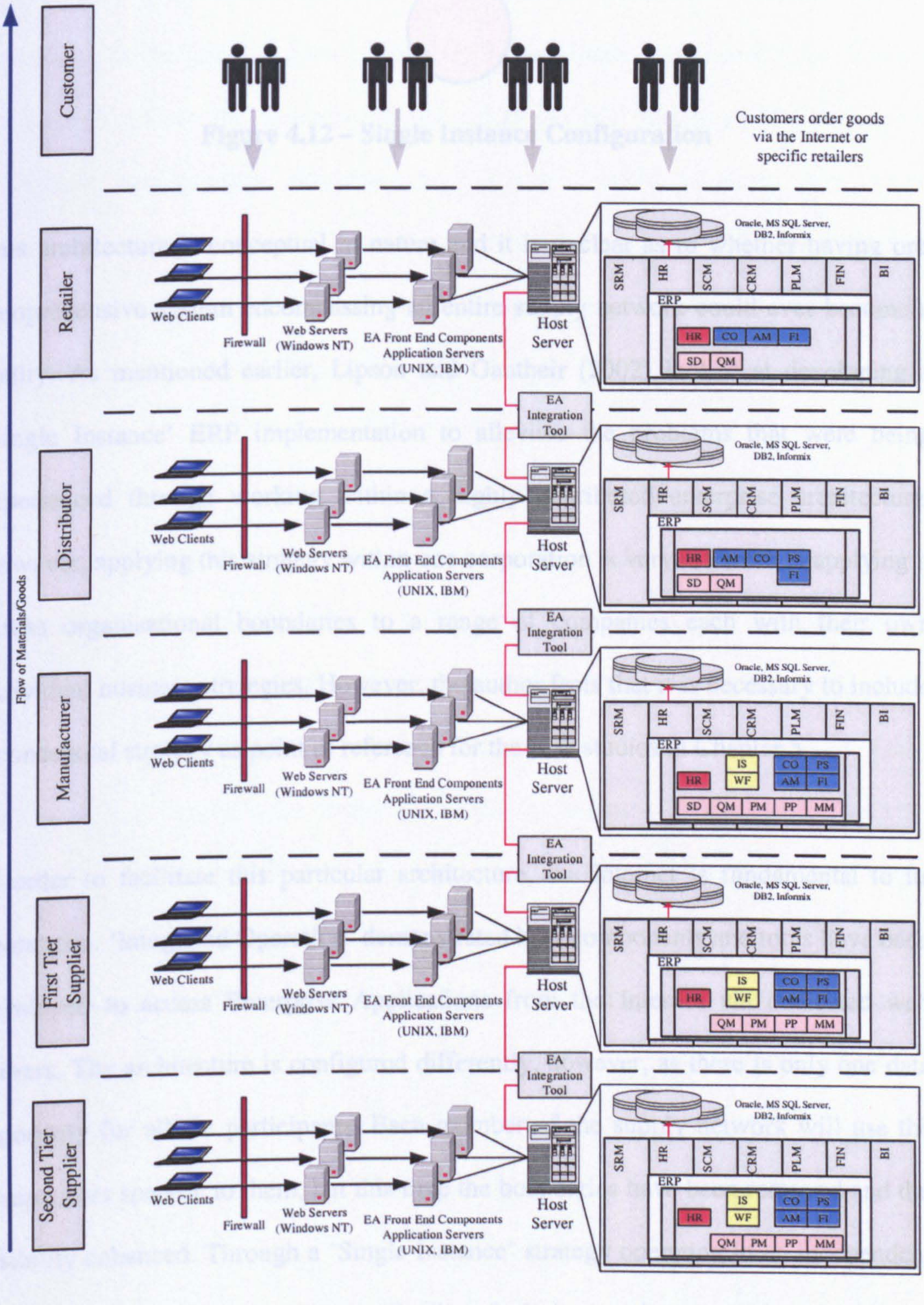


Figure 4.11 – 'Integrated Operation' EA-Based Architecture

4.2.3.4 Single Instance

For the 'Single Instance' EA-based architecture it is proposed that a single EA system would encompass a complete supply network scenario (figure 4.12).

Figure 4.12 – Single Instance Configuration

This architecture is conceptual in nature and it is unclear as to whether having one comprehensive system encompassing an entire supply network could ever become a reality. As mentioned earlier, Lipson and Gautheir (2002) looked at developing a 'Single Instance' ERP implementation to alleviate the problems that were being experienced through working within a highly distributed enterprise architecture. However, applying this strategy within one corporation is very different to applying it across organisational boundaries to a range of companies each with their own individual business strategies. However, the author feels that it is necessary to include a conceptual strategy as point of reference for the case studies in Chapter 5.

In order to facilitate this particular architecture, the Internet is fundamental to its operations. 'Integrated Operation' demonstrated how components and tools have been developed to access Enterprise Applications from the Internet via dedicated web servers. The architecture is configured differently, however, as there is only one data repository for all the participants. Each member of the supply network will use the components specific to them, but this time the boundaries have been removed and the visibility enhanced. Through a 'Single Instance' strategy operating in an independent environment where ownership is distributed, it is anticipated that many of the problems associated with modern day supply networks can be removed. Figure 4.13 illustrates the 'Single Instance' architecture.

Figure 4.13 demonstrates how the organisational boundaries become virtually redundant for the 'Single Instance' EA architecture. Users (based within the different companies) access the Enterprise Application as they would in the 'Integrated Operation' configuration. However, all of the data would be stored in a central repository located elsewhere. Ultimately, this would allow each of the participants in the supply network to optimise their planning and forecasting due to the removal of the disruptive organisational boundaries.

There are of course a number of issues that would have to be confronted in regard to this particular architecture. The confidentiality of certain data within the system (financial, i.e. costs etc) would have to be considered and it would be important for the participants to define a clear set of business rules at the outset. More significantly however is that supply networks can be infinite in width. Figure 4.13 has only taken into account a single value stream of a supply network. If the system were to encompass each branch of suppliers that would emerge from a participant in the supply network in figure 4.13 then the system would grow infinitely. It is for this reason that the 'Single Instance' EA architecture is currently conceptual in nature.

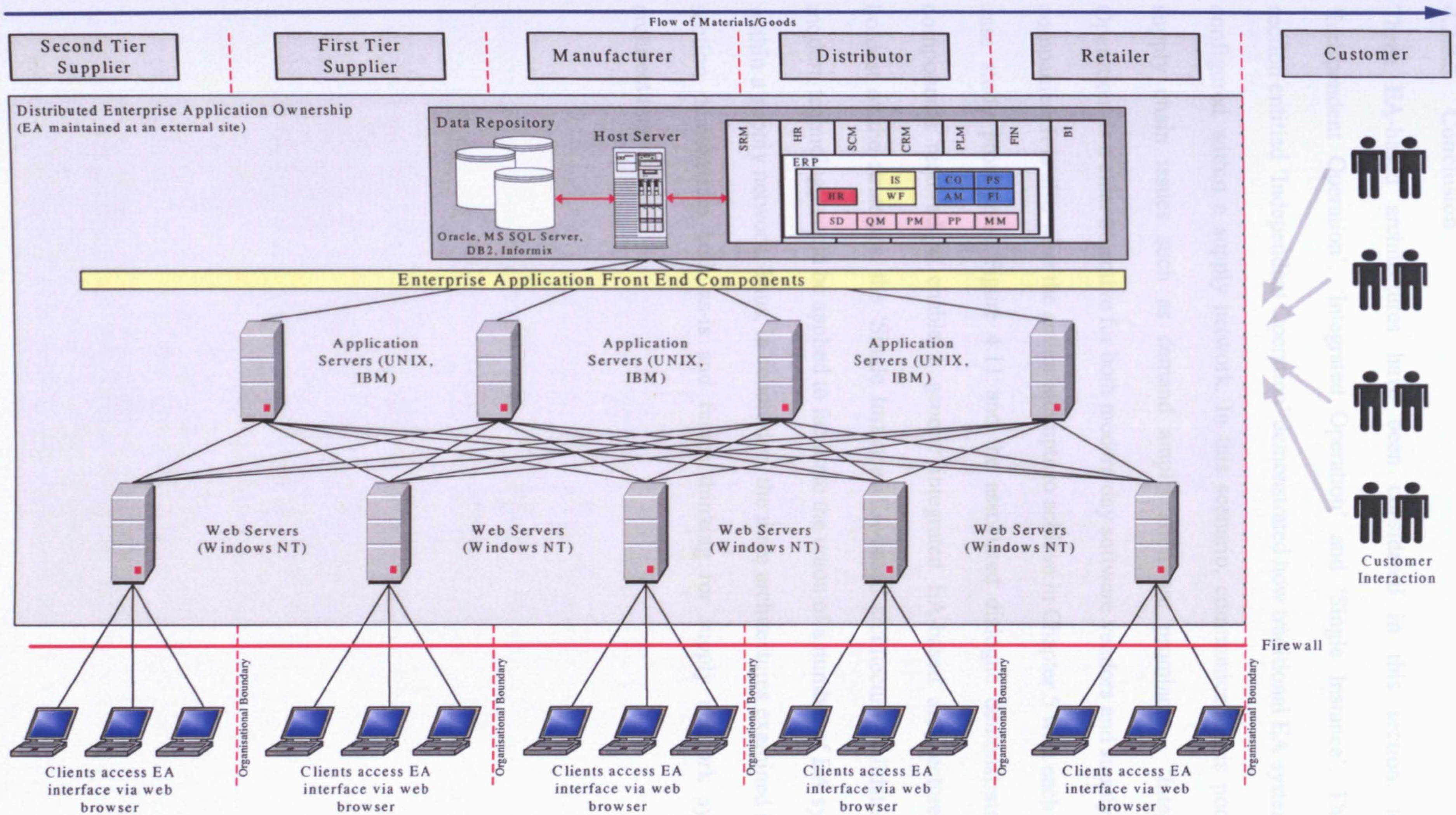


Figure 4.13 – 'Single Instance' EA-Based Architecture

4.2.3.5 Conclusion

Three EA-based architectures have been considered in this section, termed 'Independent Operation', 'Integrated Operation' and 'Single Instance'. The sub section entitled 'Independent Operation' demonstrated how traditional EA systems are configured within a supply network. In this scenario, communication is poor and supply chain issues such as demand amplification are prominent. 'Integrated Operation' is a clear objective for both modern day software vendors and supply chain companies. It is also what the author attempts to achieve in Chapter 5 with each of the case study prototypes. Figure 4.11 and the associated dialogue demonstrated the components required to enable a generic integrated EA-based architecture. The boldest of the strategies, the 'Single Instance' EA-based architecture validates how modern technology could be applied to facilitate the union of a number of EA systems within a supply network. Thus, in conclusion, the three architectures examined in this section demonstrate both as-is and future thinking for supply network systems architectures.

4.3 Internet-Based Supply Network Strategies and Architectures

4.3.1 Introduction

This section involves the examination of a range of Internet-based systems in order that a generic architecture can be applied as a template for the case studies considered in Chapter 5. In the previous section Enterprise Application (EA) integration was the principal theme. Thus, distinguishing this analysis from that of the previous, discussions here focus upon the Internet applications that have emerged in the literature and from commercial vendors to enable supply network participants to communicate more efficiently and effectively. Whilst it is acknowledged that EA systems play an important role internally, it is the Internet applications (bespoke/commercial) that provide the necessary technology infrastructure to permit enhanced supply network operations in this section.

The technology and literature review to follow consists of two key sections. The first part discusses the applications that have been considered in the literature to enable cross company planning and communication whilst the second part focuses on the products and technologies that have been developed by commercial vendors. Having gained a sound understanding of the key tools and technologies, it is then possible to envisage a generic, Internet-based Supply Network integration architecture.

4.3.2 Literature and Technology Review

4.3.2.1 Introduction

The evolution of Information and Communication Technology has fostered the development of powerful tools that are expected to improve supply chain performance dramatically, through higher levels of process efficiency and integration (Cagliano *et* *al*, 2003). Therefore, it is the aim of the literature and technology review to examine the Internet-based systems and technologies that have been developed to enhance supply network communications.

4.3.2.2 Academic Literature

Yucesan & Wassenhove (2002) examined the impact of Internet technologies on supply chain management. More specifically, part of the authors work covered the emergence of 'hubs' that have the capacity to engage multiple suppliers. Furthermore, by engaging multiple suppliers, the authors stated that 'hubs' are an example of how the Internet is ideally suited for eliminating the inefficiencies of the current channel by reducing transaction costs and integrating lower-tier suppliers. Referring back to the work of Anderson (1999), it is the author's contention that one of the key developments within the products that have emerged to combat supply chain inefficiencies is associated with the rapid evolution of the Internet and its ability to provide an open technical architecture to support B2B collaboration efforts. Lancioni *et al* (2003) and Rahman (2003) listed the operational areas of purchasing/procurement, inventory management, transportation, order processing, customer service, production scheduling and relations with vendors as being the core focus of Internet applications within SCM. Focusing on each operational area demonstrates how the Internet has influenced each one.

The research of both parties illustrates that within purchasing/procurement the Internet is utilised for a variety applications including communication with vendors, checking vendor price quotes and making purchases from vendor catalogues. The work of Lancioni *et al* (2003) revealed that in nearly every area of purchasing, the percentage of firms utilising the Internet nearly doubled between 1999 and 2001. The most noticeable growth within the area of Internet procurement was 'early warning damage' notification systems from vendors along with status of vendor warranty programmes for buyers, both of which are critically important within supply networks.

Inventory management is one of the most discussed areas of SCM. It is also widely regarded as the area in which the most cost benefits can be achieved should improvements be implemented. David Sommer, Vice President, Electronic Commerce, CompTIA stated that, '*successful companies have recognised the importance of better inventory management*'. Furthermore, he states that '*it is a major source of competitive advantage for a company to know what it has in inventory and where*' (Business Wire, 2004). Lancioni *et al* (2003) reported that Internet usage has grown considerably from 1999 to 2001 in several inventory areas such as JIT delivery programmes and the communication of stock-outs to customers. However, the largest increase within this operational area reported by the authors was in the development of EDI programmes with vendors. Here the Internet is either replacing existing EDI systems or augmenting those systems already in place. Existing EDI programs can be transformed into IEDI applications or replaced with less expensive Internet systems as Chapter 2 asserts. Rahman (2003) stated that the overall benefit of the Internet to firms in managing their inventory in their supply chains is to keep inventory levels low, reduce overall holding costs, and still provide high levels of customer service.

Transportation is the third operational area considered by both parties. Modern Materials Handling (MMH, 2000) stated that a company implementing its first

Transportation Management System (TMS) can expect to save from 10% to 40% on its transportation costs. Given that Rahman (2003) reported that transportation is typically the second highest cost component in a supply network it is understandable that transportation applications are proving increasingly popular. Lancioni *et al* (2003) reported that the Internet has reduced the number of lost shipments and therefore reduced shipper claims.

Order Processing is reported by both authors' work to be the second most popular use of the Internet in supply chains. Furthermore, both Lancioni *et al* (2003) and Rahman (2003) affirm that within this operational area, the key applications where the Internet was having the most significant impact were that of 'order placement and status' and the monitoring of 'vendor order efforts'. Using the Internet for the aforementioned functions has dramatically reduced the cost of order processing through the reduction in paperwork traditionally associated with order processing (Rahman, 2003). Internet applications that track returned goods are another area that has become more prominent in recent years. Returned goods and the associated areas of remanufacturing and reverse logistics represent an integral component of modern day manufacturing supply networks (refer to Chapter 2).

The penultimate Internet application area involves customer service and the Internet. Customers are increasingly able to contact the service centres of companies 24 hours a day via the Internet. The Internet application for the receipt of customer complaints, technical service, emergency notification and managing outsourcing service are all areas in which usage has escalated.

Finally Lancioni *et al* (2003) and Rahman (2003) considered vendor relations and the Internet. Chapter 2 has already illustrated that the Internet is proven as an important communication link between supply network participants. There was a significant rise in the usage of vendor relation applications between 1999 and 2001 (Lancioni *et al*, 2003). The authors relate this increase to the development of online catalogues, Internet exchanges and the ability of firms to integrate their production plans with the procurement support needed from vendors. The Internet has enabled implementation of JIT and VMI policies between trading partners, thus permitting a more seamless flow of information.

The operational areas discussed in this section reveal the fundamental areas in which Internet-based applications are being developed. This literature and technology review next focuses upon the actual applications that have been developed in these areas. Discussing examples from the literature first, Olafsson *et al* (2001) have made use of the Internet to develop a management and archival system for recyclable products. Figure 4.14 illustrates the database management system architecture deigned by the authors.

Kokkinaki *et al* (2002) have discussed electronic markets for re-usable products, and also how web based systems can be integrated with business processes in closed loop supply chains (CLSC's) (Kokkinaki *et al*, 2001). The Reverse Logistics for end of life PC's system (RL4PC) that the authors envisaged is a three-tier architecture based upon the Model-View-Controller (MVC) design pattern. The model (repository) is implemented as an RDBMS. The view (client tier) is situated on a web browser and the controller (application tier) incorporates Java Servlets and Java Server Pages.

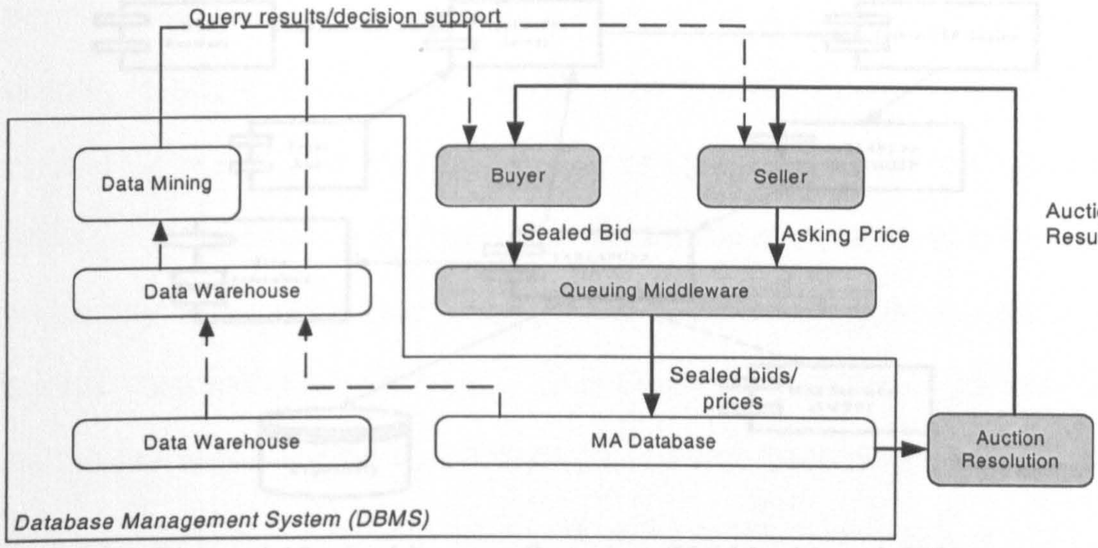


Figure 4.14 – Sealed bid double auction and the DBMS (Olafsson *et al*, 2001)

The foremost vocation of RL4PC is to allow e-commerce and www technologies to permit the remote monitoring and benchmarking of end-of-life PCs. Figure 4.15, taken from the work of Kokkinaki *et al* (2001) reveals an overview of the architecture for this Internet application. Both these examples support the findings of Lancioni *et al* (2003) and Rahman (2003) in relation to the operational area of order processing.

The third example in the literature originates from the work of Nurmilaakso *et al* (2001) who examined the extent to which XML-based integration systems can support supply chain integration between companies. In this paper, the authors implemented a prototype of the integration system called the Communication Application (CA). The prototype was studied with a real case, where the main contractor was a switchgear production company called ABB Control. The CA was integrated to other systems using standard techniques such as HTTP, ODBC and SMTP. Figure 4.16 illustrates the engine processor architecture of the CA.

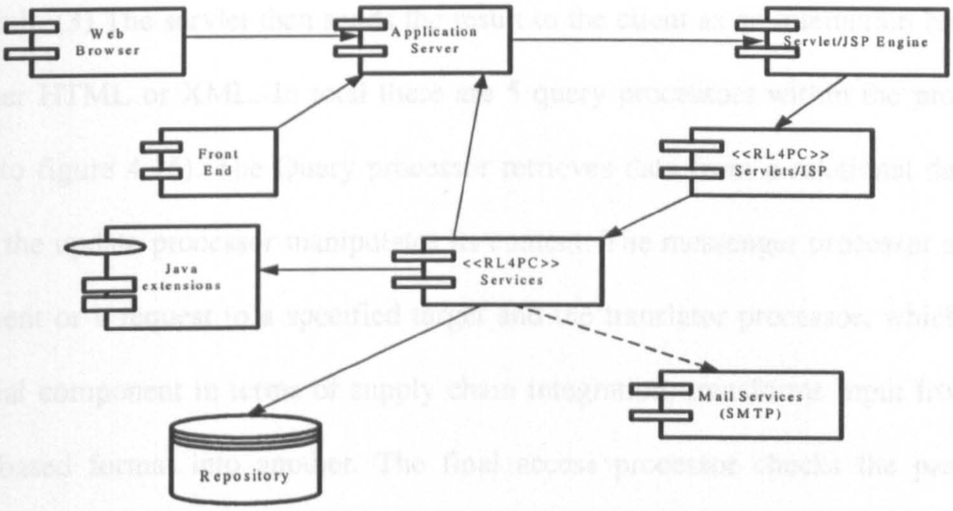


Figure 4.15 - Architecture Overview (Kokkinaki *et al*, 2001)

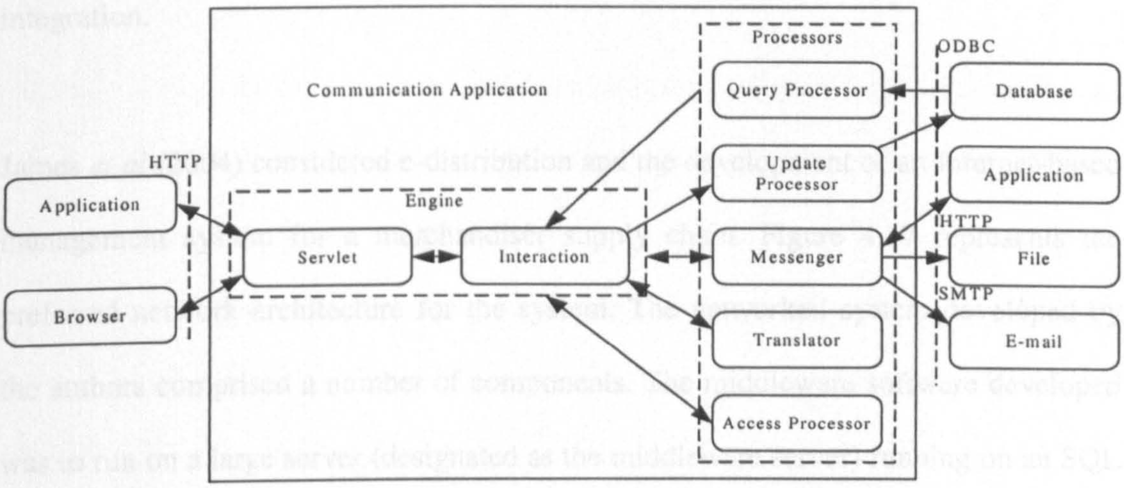


Figure 4.16 – Architecture Prototype (Nurmilaakso *et al*, 2001)

Briefly discussing the functionality, the engine of the CA processes the interaction requests. The processing logic involved 3 stages, (1) the engine processes the interaction requests from the client (HTML or XML). A Servlet then passes the call to an interaction. (2) The interaction executes the requested interactions with the given parameter values and configured interaction definitions as inputs. It interprets the XML-based configuration language and calls the processors according to configured definitions. When all operations of the interaction are executed the interaction returns the result. (3) The servlet then sends the result to the client as an interaction response in either HTML or XML. In total there are 5 query processors within the prototype (refer to figure 4.15). The Query processor retrieves data from a relational database whilst the update processor manipulates its content. The messenger processor saves a document or a request to a specified target and the translator processor, which is an essential component in terms of supply chain integration, transforms input from one XML-based format into another. The final access processor checks the password given by a user. Having implemented and tested the system, Nurmilaakso *et al* (2001) concluded that the prototype provides a sound basis for XML-based supply chain integration.

James *et al* (2004) considered e-distribution and the development of an Internet-based management system for a merchandiser supply chain. Figure 4.17 represents the preferred network architecture for the system. The networked system developed by the authors comprised a number of components. The middleware software developed was to run on a large server (designated as the middleware server) running on an SQL database engine. Connections to this server were made via socket-to-socket connections (from the pocket PC to the middleware server).

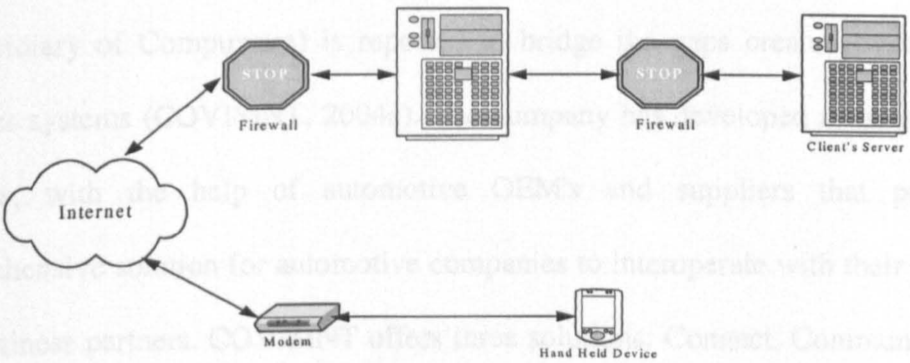


Figure 4.17 – Network Architecture (James *et al*, 2004)

A series of FTP transfers are then made of data from the pocket PC that is followed by a set of transformations and updates of the SQL server database. A build of tables ready for the Pocket PC is then performed and another set of FTP transfers is made reflecting any changes at the host since the last synchronisation. In order to interface to the production arm of the client's organisation the middleware consolidates the orders it has received throughout the day and builds a set of EDI transmissions to be sent to the client's ERP system. It is the authors' contention that the solution discussed, developed significant cost savings and additional functionality.

4.3.2.3 Commercial Literature

Moving away from the academic literature, the spotlight now turns to the Internet-based products that have been developed and implemented by commercial vendors. Presently there are a significant number of vendors that provide e-procurement services and applications to improve supply chain management issues. Probably one of the most widely publicised commercial web-based systems is COVISINT (Collaboration-Vision-Integration).

COVISINT provides services that enable the communication and sharing of information between business partners in large complex supply networks. COVISINT (a subsidiary of Compuware) is reported to bridge the gaps created by dissimilar business systems (COVISINT, 2004a). The company has developed a focused set of services, with the help of automotive OEM's and suppliers that provide a comprehensive solution for automotive companies to interoperate with their suppliers and business partners. COVISINT offers three solutions: Connect, Communicate and Collaborate. COVISINT Connect is a data messaging service that provides a single connection for a company's computers to exchange data with the computers of its partners (COVISINT, 2004b). The Connect application incorporates XML as an alternative to traditional EDI transmission methods. The Covisint Communicate Portal Solutions enables industry participants to access OEM applications, supplier applications and Covisint applications via one common infrastructure. Covisint Communicate also serves as the framework for OEM-to-Supplier and Supplier-to-Supplier communications (COVISINT, 2004c). Covisint Collaborate provides an environment for the automotive industry to implement web services to enable application interoperability using XML (COVISINT, 2004d). The COVISINT solution is reported to have had much success with companies such as DaimlerChrysler, Ford and Lear to name a few.

Moving on, WeSupply provides a solution that fits into the criteria of an Internet-based supply chain solution. The WeSupply solution framework comprises of four integrated layers labelled (1) Intelligent Process Agents (IPAs), (2) Collaborative Repository, (3) Dynamic Event Management and (4) Rapid Integration Service. The four integrated layers can be broken down into smaller components in order to demonstrate the core functionality. The Intelligent Process Agents consist of four fundamental modules known as supply, inventory, delivery and bill. WeSupply report that their IPA's are able to sense and respond to changes in the extended supply chain and are made up of three core elements (Business Rules, Workbenches & Managers), which enable, support and manage specific collaborative supply chain processes. Example IPAs include forecast, order schedule, supply demand alignment and VMI. The second integrated layer, the collaborative repository enables all participants to gain value from being able to look at the same whole picture, not simply a series of isolated views. Increased Supplier visibility is recognised as being the solution to the much publicised bullwhip phenomenon. The dynamic event management layer provides workflow, alerting and process milestone management for all supply chain participants and the rapid integration service offers an immediate means of rapidly integrating delivery mechanisms, applications, message formats and mobile devices across a corporation, trading partner network and customers (WeSupply, 2004).

Elcom's PECOS product is the third solution of bearing. Elcom's product consists of a number of components (refer to chapter 2). Briefly reviewing its functionality, the PECOS Internet Procurement Manager e-enables the process of procurement whilst the Internet Commerce Manager is the eDistribution component of PECOS. Other solutions offered from PECOS include the Internet Marketplace Manager, the Dynamic Trading System and the eCommerce system. Figure 4.18 illustrates the PECOS Internet Procurement Manager as envisaged by the Aberdeen Group.

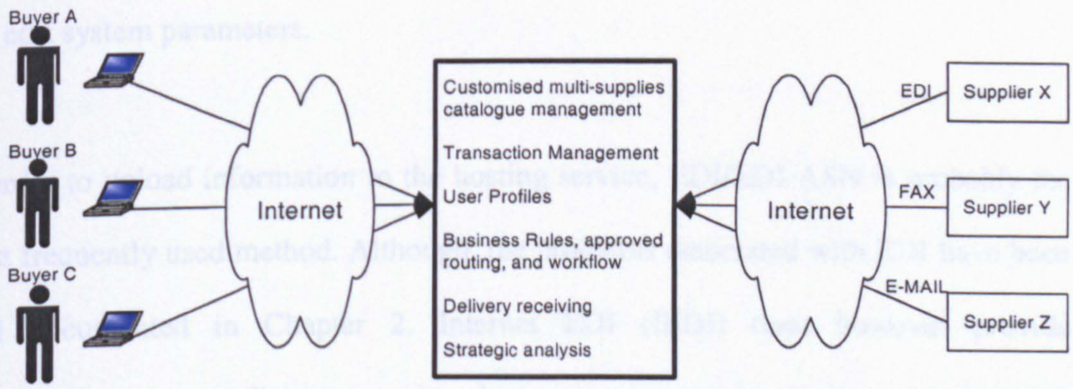


Figure 4.18 - Internet Procurement Manager (Aberdeen Group, 1999)

SupplyWorks represents another Internet-based supply chain solution situated within this increasingly competitive market. The SupplyWorks solution consists of two parts, SOURCE and MAX. SupplyWorks SOURCE provides manufacturers with the visibility and tools they need to understand, analyse, and manage component and materials costs across multiple plants and procurement centres. SupplyWorks MAX helps discrete manufacturers optimise the flow of parts and materials and manage their relationships with key suppliers by combining procurement execution, planning, and management in one integrated application.

Having discussed the functionality of each of the commercial products, it is now relevant to consider the range of connection techniques that they have to offer. There are various connection techniques offered by the vendors and the selected choice on the whole depends on the technical infrastructure in place at the company. Appropriately, the Internet represents the modus operandi that is offered by each of the vendors. Requirements for this method typically involve a browser, which acts as an interface between the company and the information held at the vendor's hosting service. From their browser, users can view data that has been uploaded to the system and edit system parameters.

In order to upload information to the hosting service, EDI/EDI ASN is probably the most frequently used method. Although, the problems associated with EDI have been well documented in Chapter 2. Internet EDI (IEDI) does however provide opportunities for smaller companies that were previously cautious of the high implementation and running costs associated with EDI. The important factor here however, is that the vendor's hosting service is configured to accommodate those wishing to upload via EDI.

Other connection tools include 'Comma Separated Variable' (CSV) file format/XML, which is available for those companies with less sophisticated information systems who seek to integrate vendor information into their own systems. Barcode readers are also becoming increasingly common and if necessary bespoke connection tools can be developed to integrate with any data format or information system.

4.3.2.4 Conclusion

This literature and technology review has covered the research in both academic and commercial circles. Both sections are supported with examples of real world applications. The commercial products are also reported upon in Chapter 2. The following section seeks to build upon the information assimilated within this literature and technology review and provide a generic Internet-based architecture.

4.3.3 Development of Generic Internet-Based Architectures

4.3.3.1 Introduction

Following the analysis undertaken in the literature review, it is apparent that there are various methods to facilitate Internet-based communication. The literature has demonstrated how the incorporation of commercial software vendors is not a necessary requirement for cross company communication. However, as there are two obvious paths that can be taken in terms of Internet-based architectures, it is appropriate that two generic architectures be considered in this section. The first draws from the methods that have emerged in the literature to enable interactions between trading partners. In general the architectures in this section tend to be of type 'one-to-one', that is to say that a single interface is designed and implemented between two trading partners.

The second generic architecture is based upon the solutions provided by commercial vendors. The design of the commercially developed products is such that either a 'one-to-one' or a 'one-to-many' application architecture can be configured. The development of two generic Internet architectures provides a solid platform for the applied case study work in Chapter 5.

4.3.3.2 Internet-based Generic Architecture Version 1

This generic architecture is based around methods that have been discussed in the literature combined with the author's perception of the particular tools that will be incorporated. A number of assumptions have been made in the following architecture. First of all it is to be assumed that each of the participants within the supply network will be running some type of planning system. Having made this assumption it is also conjectured that the systems in place will be linked to a data repository. These two assumptions enable the author to discuss the other requirements for an Internet-based architecture.

In order for this architecture to remain generic, the specifics of the individual tools are not discussed. Terms such as 'Data Source Connection Method' (figure 4.19) represent a range of possibilities and are determined by the particular information systems in operation. Furthermore, in order for companies to exchange information or interact with one another, applications are required. Applications are very much tailored to specific scenarios, and therefore are not discussed until Chapter 5. Thus, figure 4.19 demonstrates the generic Internet architecture based upon the literature. Examples in the literature are largely focussed around single interfaces between trading partners (one-to-one or point-to-point). Thus figure 4.19 illustrates the components required to facilitate this point-to-point communication infrastructure. Each participant has a data repository, an application server and a web server. Depending on the particular situation, an application would be designed and implemented on the application server. From this the web server can send information directly to a trading partner's information systems or it could simply facilitate the dissemination of specific data. Chapter 5 demonstrates in more detail the inner workings of the components required for this generic Internet Architecture.

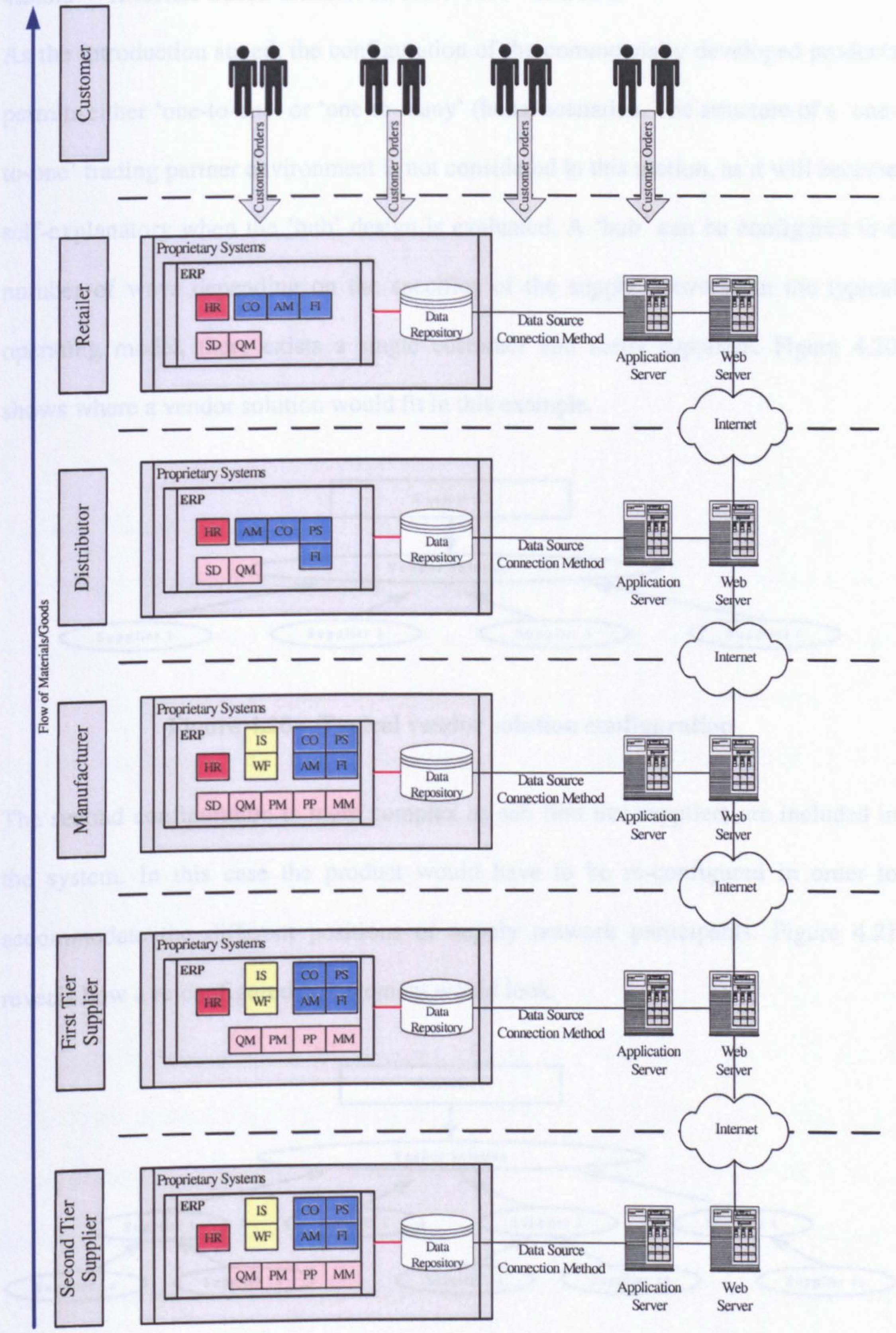


Figure 4.19 – Internet-Based Generic Architecture Version 1

4.3.3.3 Internet-based Generic Architecture Version 2

As the introduction stated, the configuration of the commercially developed products permits either 'one-to-one' or 'one-to-many' (hubs) scenarios. The structure of a 'one-to-one' trading partner environment is not considered in this section, as it will become self-explanatory when the 'hub' design is evaluated. A 'hub' can be configured in a number of ways depending on the specifics of the supply network. In the typical operating model, there exists a single customer and many suppliers. Figure 4.20 shows where a vendor solution would fit in this example.

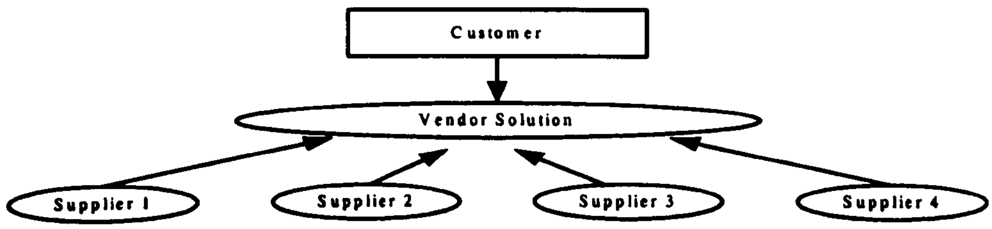


Figure 4.20 – Typical vendor solution configuration

The second configuration is more complex as sub first tier suppliers are included in the system. In this case the product would have to be re-configured in order to accommodate the different positions of supply network participants. Figure 4.21 reveals how a re-configured arrangement would look.

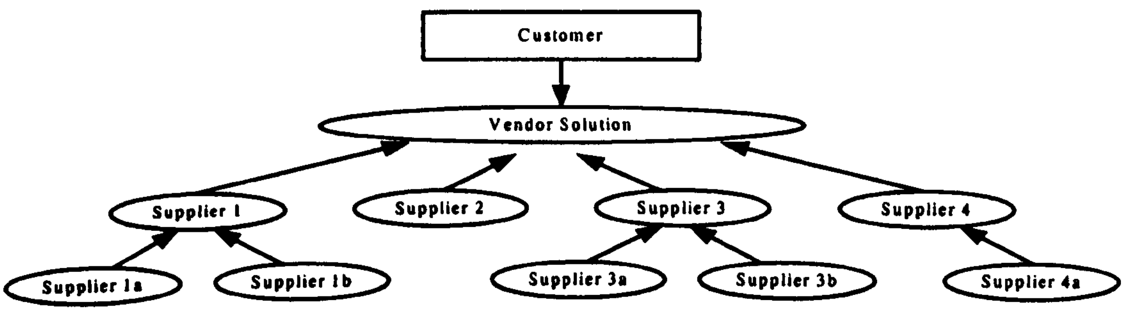


Figure 4.21 – Reconfigured vendor solution

The vendor in general acts as a hub where companies are given access permissions dependent on their specific role. Taking all of this into account, a generic architecture based upon the inclusion of a vendor is illustrated in figure 4.22. Here, each of the participants has their own planning system operating independently. However, the vendor application is designed to extract specific information from each company, which it then stores in a data repository. Participants can then access the information relevant to them. This information can also be manipulated by the vendor application depending on the supply situation between each participant (VMI, Kanban).

4.3.3.4 Conclusion

The Internet-based generic architectures considered in this section can be divided into two streams. The first has been developed with the literature on Internet-based information systems in mind. As stated above, the Internet architectures in the literature are generally of type 'one-to-one'. The second generic architecture has been shaped by a selection of commercial vendor products that have emerged in conjunction with the Internet revolution. These vendor products provide a vast array of functionality and can be configured to interface and connect to a considerable number of trading partners. Both architectures have their advantages. The architectures developed in the literature clearly demonstrate how with minimum investment, problematic supply chain issues can be resolved. On the other side of the coin, commercial vendors can now take full responsibility for connecting trading partners with a valuable information stream. Their pledge to improve cross company communications provides reassurance to companies with poor trading partner relations. However, both solutions serve a purpose and it is the specific supply scenario that decides which generic architecture would best fit.

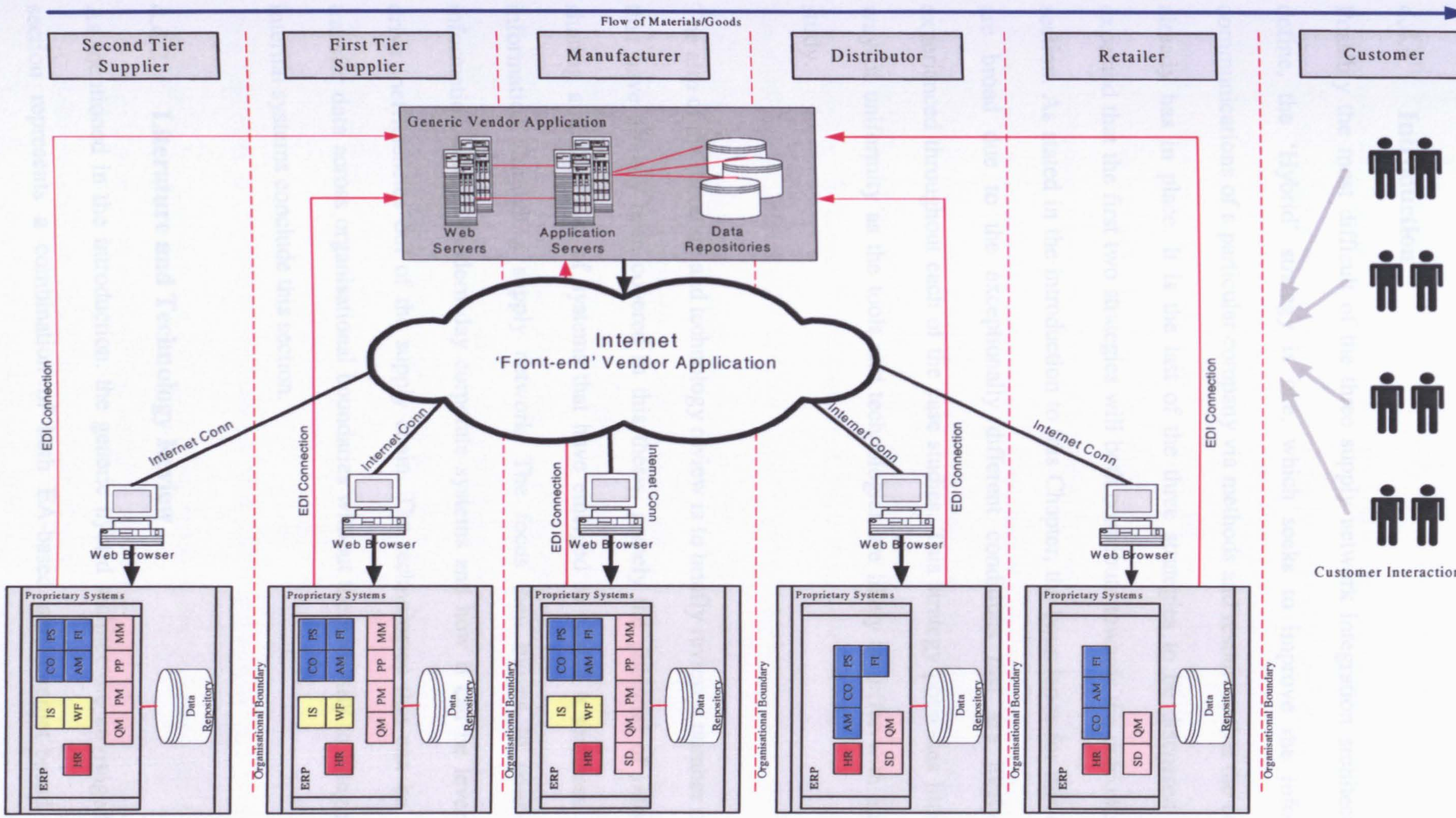


Figure 4.22 – Internet-Based Generic Architecture 2

4.4 Generic Hybrid-Based Strategies and Architectures

4.4.1 Introduction

Possibly the most difficult of the three supply network integration architectures to define, the 'Hybrid' strategy is one, which seeks to improve the information communications of a particular company via methods and resources that the company already has in place. It is the last of the three strategies to be discussed as it is expected that the first two strategies will both contribute towards the outcome of this section. As stated in the introduction to this Chapter, the boundaries for this strategy are broad due to the exceptionally different conditions that are likely to be experienced throughout each of the case studies. This strategy possesses little in the way of uniformity as the tools and technologies are likely to differ with each case study.

The aim of the literature and technology review is to briefly review a number of issues that have already been covered in this thesis, namely the potential of information sharing and examples of systems that have emerged to enable a seamless flow of information through a supply network. The focus then moves to consider the information held in modern day corporate systems and how it can be leveraged to drive inefficiencies out of the supply chain. The technologies that can be used to transfer data across organisational boundaries without the necessity to integrate with internal systems conclude this section.

4.4.2 Literature and Technology Review

As mentioned in the introduction, the generic hybrid architecture envisaged in this section represents a combination of both EA-based and Internet-based generic architectures. For this reason much of the literature and technology has already been considered in previous sections and the Literature Review. Therefore, this section briefly reviews a number of previously discussed topics in order that the picture of a generic 'hybrid'-based systems architecture can be painted in the section to follow.

Planning tools from the older MRP systems to the more recent ERP and SCM software suites provide invaluable information to assist companies in their daily routines. Whether the information is financial or production related, these systems deliver vital support on a timely basis. The importance of 'information' and its dissemination have been referred to on numerous occasions throughout the early stages of this thesis. Lee *et al* (1997a, 1997b) along with others (Simchi-Levi *et al* 2000; Yu et al 2001; Lau *et al* 2002) stated that it is actually distorted information in the supply chains that creates demand variation amplification. Lee & Whang (2000) believe 'Information Integration' is the key to the successful running of any supply chain. Lau and Lee (2000) discussed the importance of information in the context of a supply chain information system and Davenport and Brooks (2004) stated that SCM has always been the challenge of information integration. However, Monczka and Morgan (1997) maintain that historically there has been a lack of information systems in organisations that enable cross-location, cross-site, cross-company information transfer planning.

This however, is no longer the case as both the functionality and presence of information systems has evolved rapidly in recent years. In terms of enterprise application systems and associated advances in technology, Sauter & Parunak (1999) along with NuTech Solutions have made advances within the area of agent technology. Davenport & Brooks (2004) have discussed the implementation of leading edge enterprise systems such as SAP, i2 and Baan in Boeing and Reebok in order to enhance their trading partner communications. Kulkami (2002), reported that a number of major e-business innovators like SAP, i2 and Ariba have come up with entire suites of solutions designed to optimise each phase of the supply chain to transform the way companies do business in the new economy.

In terms of purely Internet-based systems there are examples within the literature. Olafsson *et al* (2001) have made use of the Internet to develop a management and archival system for recyclable products. Kokkinaki *et al* (2002) have discussed electronic markets for re-usable products, and also how web-based systems can be integrated with business processes in Closed Loop Supply Chains (CLSC's) (Kokkinaki *et al*, 2001). Nurmilaakso *et al* (2001) examined the extent to which XML-based integration systems can support supply chain integration between companies. In their paper, the authors implemented a prototype of an integration system called the Communication Application (CA). James *et al* (2004) considered e-distribution and the development of an Internet-based management system for a merchandiser supply chain. Moving away from the literature, WeSupply, Elcom and SupplyWorks are examples of the companies that offer hosted supply chain information systems.

Although the developments in the area of information systems have been profound, many companies' systems are configured for internal processes only and they do not consider issues outside of their organisational boundaries. The information their systems generate is valuable but trading partners are kept in the dark and therefore the typical problems associated with insufficient information are encountered. The previous sections have discussed how Internet-based vendor systems can be integrated via methods such as EDI/EDI ASN and CSV file format/XML. However, without having to integrate directly there are techniques bespoke to each specific system that allow data to be mined from the repository (database). The important fact here however, is identifying the information that is valuable to individual suppliers.

Once the data has been identified there are various methods in which it can be transferred to trading partners without the requirement to involve complex systems. Whilst it has been around for many years the telephone is the worlds' most widely used means of communication (Gardner & Shortelle, 1997). It is a low cost communication tool and one, which can be used to communicate any form of information. Along with the telephone, the fax represents another form of communication that does not require significant investment or integration with proprietary systems. CommerceNet (2002) reported that the fax has been the communication method of choice for smaller companies for many years. Pawar & Driva (2000) authenticated this with an industry-based case study that stated that a medium-sized UK company uses the fax as its main connection to suppliers.

A further method in which information can be transferred between trading partners is e-mail. Reported by IBS Inc & Focus Software Int. Inc (1995) to be the first real 'killer application' of the Internet, e-mails can be sent by a company or individual whose only prerequisite is to have access to the Internet and a mail server. Originally the first e-mails consisted of just simple text and it was impossible to send attachments such as formatted documents. With the advent of MIME, (Multipurpose

Internet Mail Extension) and other types of encoding schemes, such as UUencode, it has become possible to send formatted documents, photos, sound and video files. Alternatively companies can use the Internet as a means to display data that has been extracted from their systems. Although this may seem complex in comparison to the other methods discussed, it would only require a minimum amount of web knowledge to implement such a system.

The methods discussed in the latter part of this literature and technology review demonstrate how information can be passed between trading partners with little or no systems integration. Whilst it is apparent that planning systems provide their owners with valuable information, the true value of this data will only be revealed should they choose to share it. Heavy investment is not a prerequisite for information sharing and the review above combined with the case studies in Chapter 5 demonstrate this. The following section illustrates a 'hybrid' generic architecture that can be applied to the case studies in Chapter 5.

4.4.3 Development of A Generic Hybrid Architecture

4.4.3.1 Introduction

The architecture in this section is simple in comparison to the other architectures in this chapter. It utilises tools and technologies that have been considered in the previous two architectures and in the literature and technology review above. Due to the relative complexity of the other architectures in this chapter, a number of diagrams have been required in order to provide the complete generic picture. However, within this section a single generic architecture is considered. The architecture is based around the discussions that have taken place in the literature review.

4.4.3.2 'Hybrid' Generic Architecture

The generic 'hybrid' architecture to follow has a number of characteristics that should be discussed at the point. First of all, the architecture displayed in figure 4.23 represents a selection of communication methods such as fax/mail that have not been considered in the previous architectures. However, combined with this are a range of technologies that have been discussed in the previous two sections (Internet Version 1 and 2, EA Integration Tool). Thus, it is acknowledged that the systems that have been discussed in the previous sections (EA and Internet-based Systems) may well be working in parallel to the communication methods considered here. The data extraction and insertion methods have not been investigated in much detail thus far as it is expected that each case study will bring a different set of conditions. So, figure 4.23 illustrates a range of methods in which data can be transferred between trading partners.

The architecture is designed to demonstrate that each participant has its own planning system designed to run internal operations. These internal systems hold data relating to planning, future materials requirements and current stock levels, which if used appropriately can provide significant benefit for supply partners. This architecture, whilst not the most innovative of the generic templates considered in this chapter, does represent proven methods to facilitate effective communication.

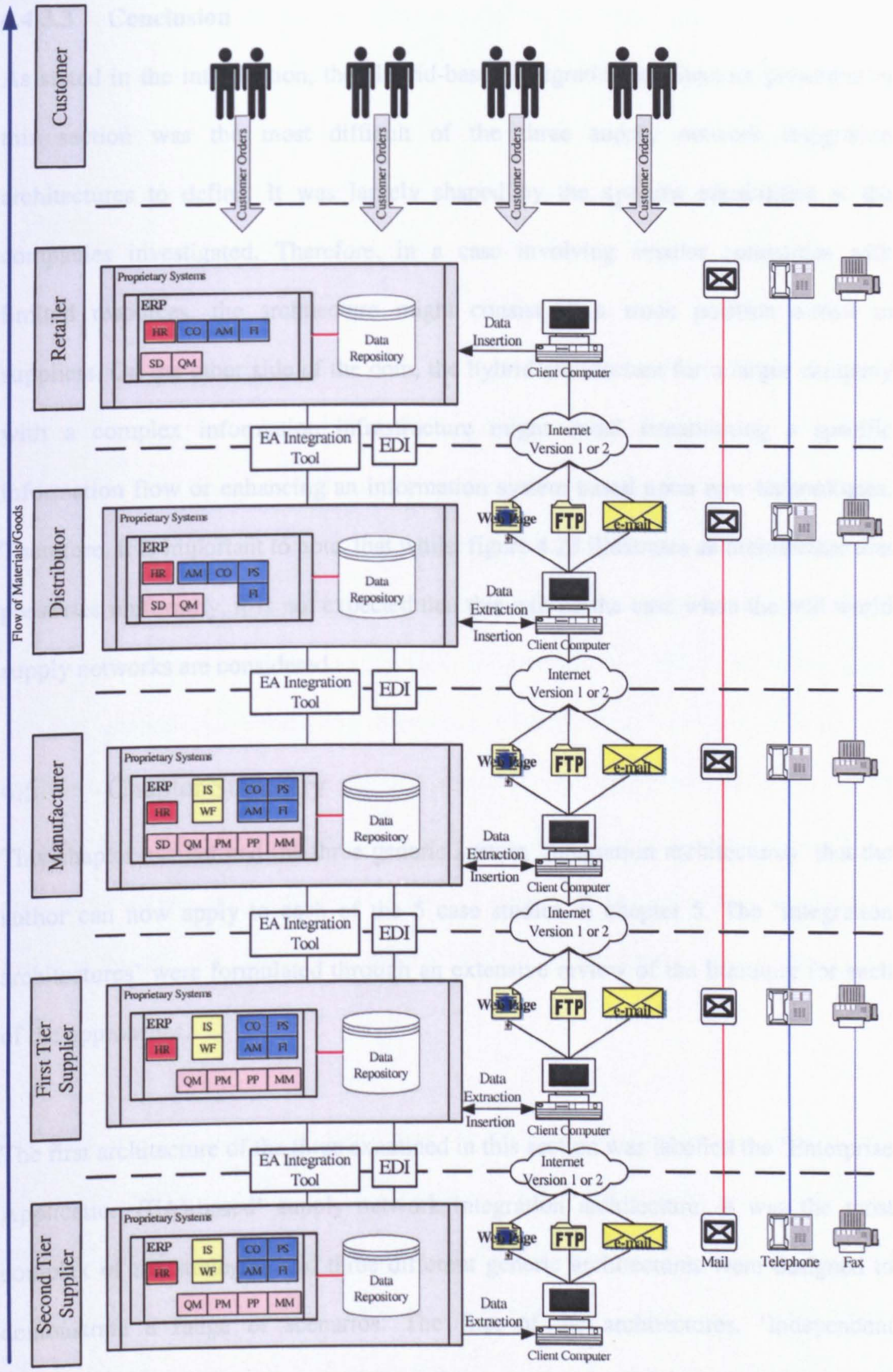


Figure 4.23 – Hybrid-Based Generic Architecture

4.4.3.3 Conclusion

As stated in the introduction, the Hybrid-based integration architecture presented in this section was the most difficult of the three supply network integration architectures to define. It was largely shaped by the systems capabilities at the companies investigated. Therefore, in a case involving smaller companies with limited resources, the architecture might consist of a stock position e-mail to suppliers. On the other side of the coin, the hybrid architecture for a larger company with a complex information infrastructure might entail streamlining a specific information flow or enhancing an information system based upon new technologies. Therefore, it is important to note, that whilst figure 4.23 illustrates an architecture that possesses uniformity, it is not expected that this will be the case when the real world supply networks are considered.

4.5 Chapter Summary

This chapter has defined the three generic system 'integration architectures' that the author can now apply to each of the 5 case studies in chapter 5. The 'integration architectures' were formulated through an extensive review of the literature for each of the approaches.

The first architecture of the three examined in this section was labelled the 'Enterprise Application (EA)-based' supply network integration architecture. It was the most complex of the strategies and three different generic architectures were designed to demonstrate a range of scenarios. The first of the architectures, 'Independent Operation' demonstrates how traditional EA systems are configured within a supply network. The second architecture comprised an enhanced level of integration, hence the name 'Integrated Operation'. This represents the target of both modern day software vendors and supply chain companies. The final architecture envisaged by the author consisted of a single EA system across a complete supply network scenario. It was acknowledged that this particular architecture is conceptual in nature, but it was important to discuss how this would look.

The second architecture entailed using the Internet in order to facilitate improved information communication within the supply networks considered in chapter 5. Discussions here focussed upon the Internet applications that have emerged in the literature and from commercial vendors to enable supply network participants to communicate more efficiently and effectively. From the literature and technology review it became apparent that two generic architectures would have to be designed. The first generic architecture was based around methods that have been discussed in the literature combined with the author's perception of the particular tools that will be incorporated. The second architecture is based upon how a commercial vendor's product would be configured within a supply network. Both solutions serve a purpose and it is the specific supply scenario that decides which generic architecture would best fit.

The third and final integration strategy is the 'Hybrid' systems-based supply network integration architecture. The 'Hybrid' strategy is one, which improves the information communications of a particular company via methods and resources that the company already has in place. As stated in the introduction to this section, the boundaries for this strategy are broad due to the exceptionally different conditions that are likely to be experienced throughout each of the case studies. This strategy possesses little in the way of uniformity and standardisation as the tools and technologies are likely to differ with each case study. The literature and technology review discussed the potential of information sharing and provided a number of examples of systems that have emerged to enable a seamless flow of information through a supply network. The focus then changed to consider the information held in modern day corporate systems and how it can be leveraged to drive inefficiencies out of the supply chain. Finally, the technologies that could be used to transfer data across organisational boundaries without the necessity to integrate with internal systems concluded this section. The literature and technology review facilitated the development of the 'Hybrid' generic architecture. In summary, this chapter has provided three generic integration architectures that can now form the basis of each of the case studies in Chapter 5.

5. CASE STUDIES AND DISCUSSION

5.1 Introduction

The case studies presented herein, examine a selection of companies operating in a range of different supply network environments. Each of the companies studied was selected for its inherent attributes identified within the classification framework (Chapter 3). Justification of case research along with the specific supply chain case methodology (SCICM) that was followed is considered in Chapter 3. As a reminder figure 5.1 illustrates the SCICM.

In total five case studies involving fifteen different companies were undertaken as part of this research. The early stages of each case study involved orientation, value stream and information flow mapping along with value stream performance measurement (stages 1 to 3 in figure 5.1). Following the initial assessment, three architectures were designed using the templates within the Analysis Framework (stage 4, figure 5.1). Certain factors influenced the supply chain information system designs within each case study. First of all, each case study was operating under different conditions both internally and externally. (Externally, refers to the diverse supply network conditions). Also, in several cases, supply chain integration was facilitated through the use of specific information-driven solutions such as VMI and cross supply chain connectivity.

Following the creation of the three designs, Stage 4 also involved the development of a prototype application(s) based upon the designs previously discussed. In general this entailed the implementation of the Internet-based integration architecture. However, where applicable other architectures have also been considered. This was followed by a second performance evaluation, which incorporated a selection of measures defined in the Research Methodology Chapter to assess the impact of the information systems architecture. Finally Stage 6 highlighted the key themes that were identified from the results of each of the case studies.

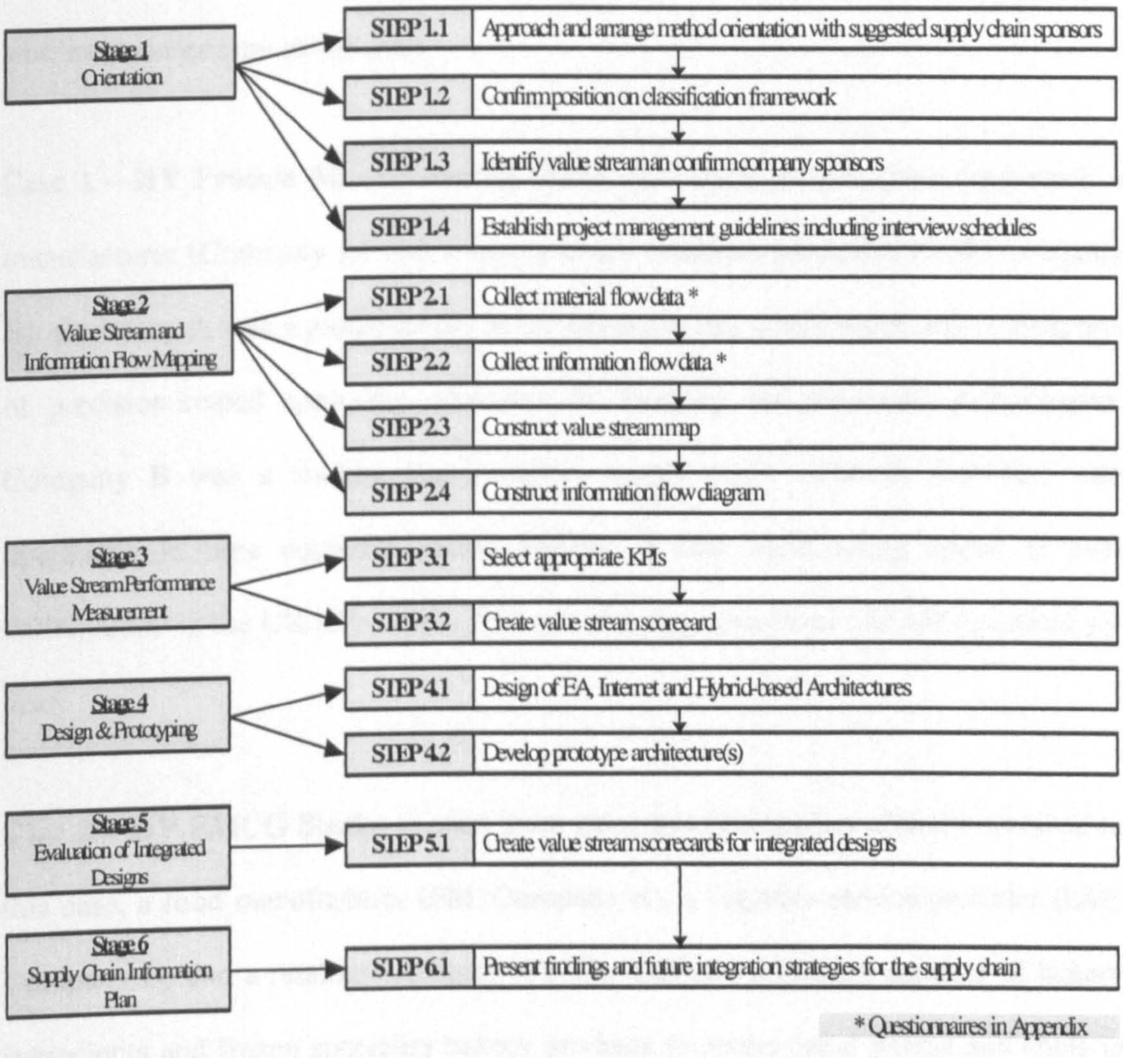


Figure 5.1 – Supply Chain Integration Case Methodology (SCICM)

5.2 Case Studies Identification

As the introduction states, the multiple case studies presented in this chapter represent various manufacturing companies and supply chain sectors. The principal aim of this section is to provide a brief overview of each of the case studies, defining the scope of the study and the key participants. The cases were carried out over a three-year period and they are presented in the order in which they were carried out. The five case studies presented are as follows:

Case 1 – **HV Process Manufacturing Study**; this study involved two companies, a manufacturer (Company A) and a supply chain solutions provider (SCSP, Company B). Company A was a global leader in the development, manufacture and distribution of precision-coated speciality substrates for imaging and electronic technologies. Company B was a leading Pan-European supply chain solutions provider, with operations in nine countries across Europe. It had warehousing space of over 1,000,000m^2 in the UK alone and 1,600 vehicles that cover over 150 million miles per year.

Case 2 – **HV FMCG Study**; in total there were three companies directly involved in this case, a food manufacturer (FM, Company A), a logistics service provider (LSP, Company B) and a retailer (Company C). The FM was a leading supplier of bakery ingredients and frozen speciality bakery products to professional bakers and chefs in the UK. The LSP provided outsourced logistics services in the UK & European markets. The group designed, implemented and operated a range of supply chain management services, which were typically provided on a long-term contractual basis using facilities dedicated to customers. Company C operated within the retail sector of the UK.

Case 3 – **HV Retail Study**; two companies, one of which could be split into two supply network participants formed the basis of this study. Company A (Distributor) was a leading UK supplier of office products. The company had distribution and sales centres across the UK and Ireland, from which they distributed over 7000 products such as desktop stationery, computer consumables, new technology equipment, business machines and furniture. The second company involved in the study could be split into two (Company B and Company B1). Companies B and B1 develop, manufactured and marketed a wide range of products for consumer and industrial markets, including branded office products, self-adhesive materials, peel-and-stick postage stamps, battery labels, reflective highway safety products, automated retail tag and labelling systems, and specialty tapes and chemicals. Companies A and B started to work collaboratively using Vendor Managed Inventory (VMI) in 1995.

Case 4 – **HV Automotive Remanufacturing Study**; This study concerned two companies involved in the manufacture and assembly of automotive transmissions. Company A was a major supplier of automotive transmissions and transmission components. Company B was a customer of Company A and manufactured and assembled both original and re-conditioned transmissions.

Case 5 – **HV Automotive Study**; This case involved a total of five companies and represents the largest case study within this research. Company A, was a major UK-based automotive manufacturer, Company B a first-tier sequenced component supplier, Companies C and C1 were second-tier component suppliers, one of which was affiliated to Company B. Company D was a third-tier material supplier.

5.3 Case Study 1 – High Volume Process Manufacturing Study

5.3.1 Stage 1 - Orientation

This case study was undertaken between two companies based within the northwest of England. Company A (manufacturer) was regarded as a global leader in the development, manufacture and distribution of precision-coated speciality substrates for imaging and electronic technologies. The company offered expertise in the areas of colour laser imaging, dispersion and coating, ceramic coating, optically clear films, fine particle dispersions and high-resolution ink jet receiver coatings to name a few.

Company B was a leading Pan-European supply chain solutions provider (SCSP), with operations in nine countries across Europe. The company worked in partnership with many major blue chip companies, particularly in the FMCG, Chemical and Retail sectors. It also has the UK's largest temperature controlled store network.

The classification framework identified this case to be situated within the Process industries sector with communications ignorance and systems proliferation as being the key supply chain challenges. A three-way systems configuration was in place at the manufacturer whilst the SCSP had no systems infrastructure. Systems integration was non-existent and the supply chain was shallow. Figure 5.2 illustrates the value stream for this case.

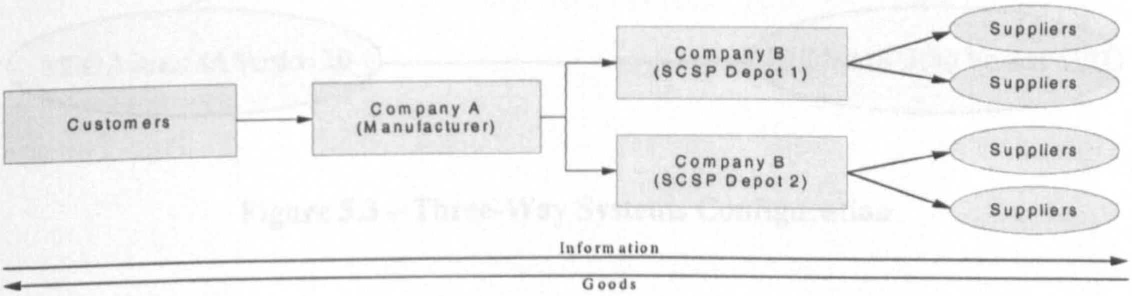


Figure 5.2 – Value Stream

5.3.2 Stage 2 – Value Stream and Information Flow Mapping

The manufacturer had approximately 100 suppliers providing a range of components from raw materials such as chemicals and paper to packaging and consumable items. The suppliers were based throughout Europe and the United States. The manufacturer transmitted requirements information via a fax machine as and when stocks needed to be replenished.

Once an order for supplies had been sent, the supplier would contact the SCSP to arrange delivery of the materials. The SCSP had two storage facilities (Depots 1 and 2) accommodating all the supplies for the manufacturer until they were required for production. Depot 1 e-mailed its stock holding to the manufacturer on a weekly basis. This data was then manually entered into the manufacturer's PRISM MRP system. Depot 2 had no technology infrastructure in place, which meant that when stocks were received, an employee at the SCSP faxed the delivery note to the manufacturer. When goods were required for production they were called off via a fax message.

The manufacturer incorporated a three-way systems configuration with the following version levels:

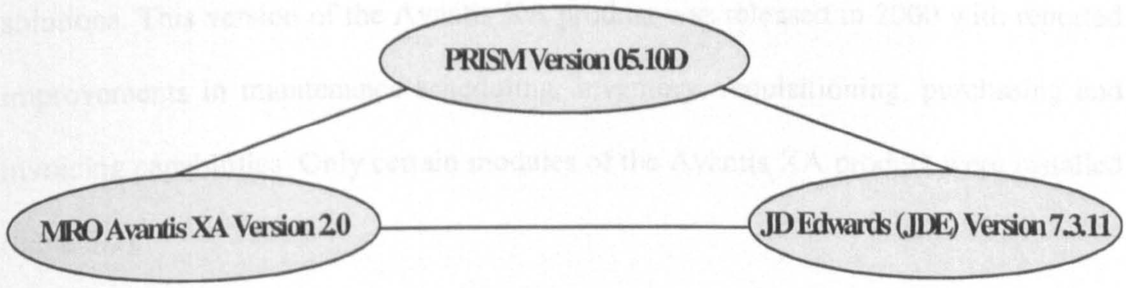


Figure 5.3 – Three-Way Systems Configuration

Discussing each of the systems components in figure 5.3, Invensys PRISM was the enterprise system in operation at the manufacturer. PRISM is a suite of AS/400-based ERP software targeted at process manufacturers. Table 5.1 illustrates the PRISM modules installed at the manufacturer.

Module	Description
Quality Management	All quality data is handled via this module, specifications, tests, results etc
Activity Costing	Installed but not used, all costing is done via Resource Management, JDE or off line
Resource Processor	This is where Production Models are set up. This is the heart of the system along with Resource Management
Financial Support	This is the link between Prism and JDE; it removes the need to enter transaction details twice. Account groups are set up in this module
Resource Management	Along with Resource Processor, the heart of the system. Resources set up here along with locations, warehouses, transactions entered in this module
Customer Order Management	Order entry, shipping and invoicing activities are undertaken in this module
Production Analysis	Installed but not used
Planning	Installed but not used
Quick Scheduler	Installed but not used
Foundation	Used for tailoring set up and system wide functions

Table 5.1 – PRISM Modules at the Manufacturer

The second component of the three-way systems configuration was the MRO Avantis XA 2.0 system. Avantis XA is Wonderware's suite of AS/400 asset management solutions. This version of the Avantis XA product was released in 2000 with reported improvements in maintenance scheduling, inventory, requisitioning, purchasing and invoicing capabilities. Only certain modules of the Avantis XA product were installed (table 5.2).

Module	Description
Accounts Payable	Installed but not used
Invoicing	Used for invoice entry (Accounts payable), invoices passed to JDE for payment
Approvals	Used to approve electronic requisitions
Requisitions	Used to raise requisitions for raw materials, non-stores materials and services
Maintenance Management	A small part of its functionality is used - Works Order Management
Purchasing	Used for purchasing of materials and receipts of PO's. Set up of Vendor master records etc
Project Accounting	Installed but not used
EDI link	Installed but not used
MRO Inventory	Installed but not used
Quotations	Installed but not used

Table 5.2 – Avantis XA 2.0 Modules at the Manufacturer

The final component of the three-way systems integration was the J.D. Edwards Financial module. When the manufacturer installed this particular systems configuration, PRISM did not have the functionality to support any kind of sophisticated financial planning.

The SCSP, and more specifically the particular storage facility (Depot 2) that was selected for analysis in this case had no technology infrastructure in place with the exception of a fax machine and a telephone. Figure 5.4 illustrates the information flow diagram (IFD) for this case.

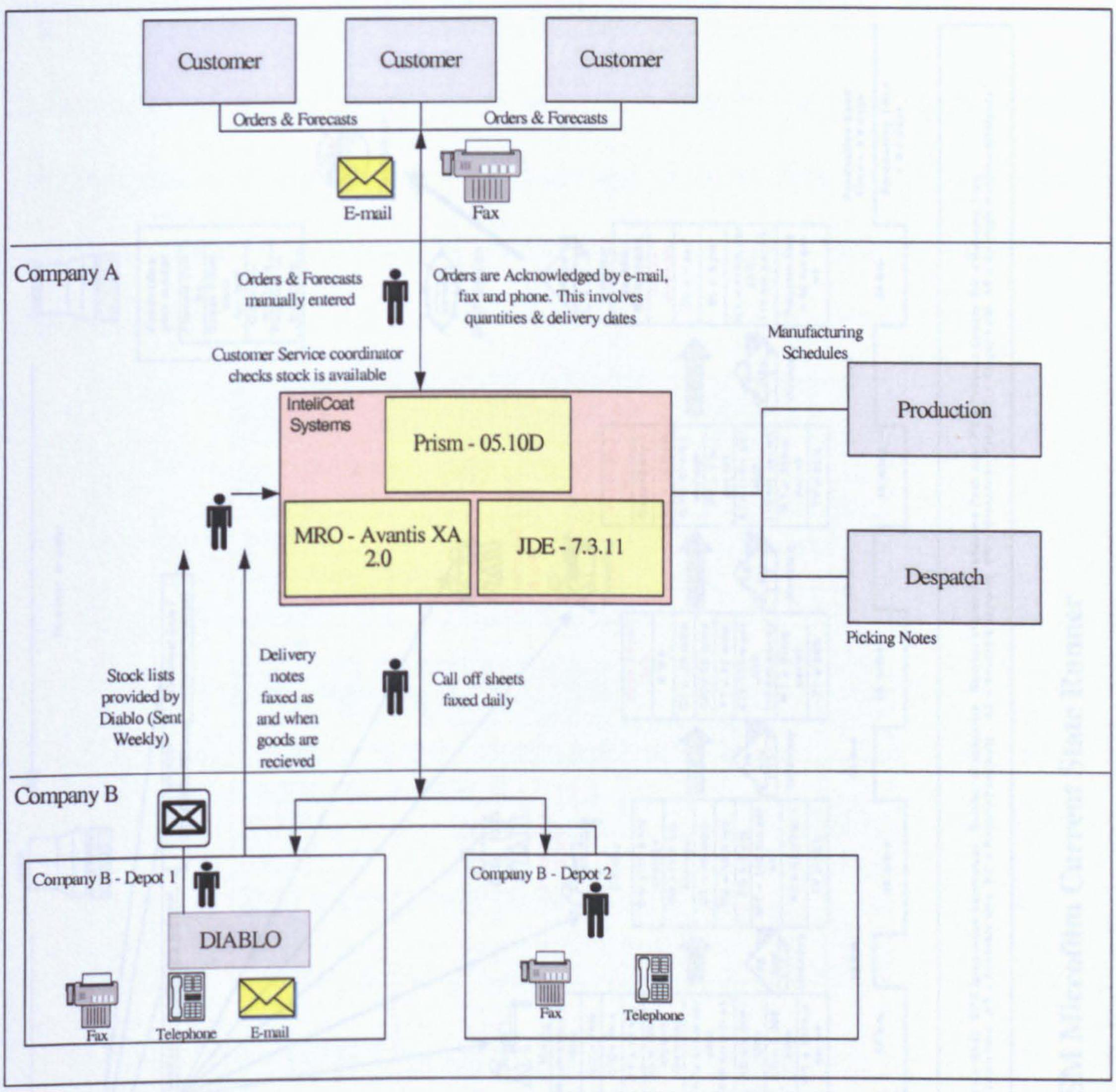


Figure 5.4 - IFD For Case 1

Value stream maps (VSM) were constructed for three different products produced at company A. Figure 5.5 illustrates the VSM for a Microfilm current state runner. Examples of VSMs for two other products can be found in Appendix B part two. In order to obtain the information necessary to complete this section a questionnaire was used. Appendix B part one contains a sample of this questionnaire.

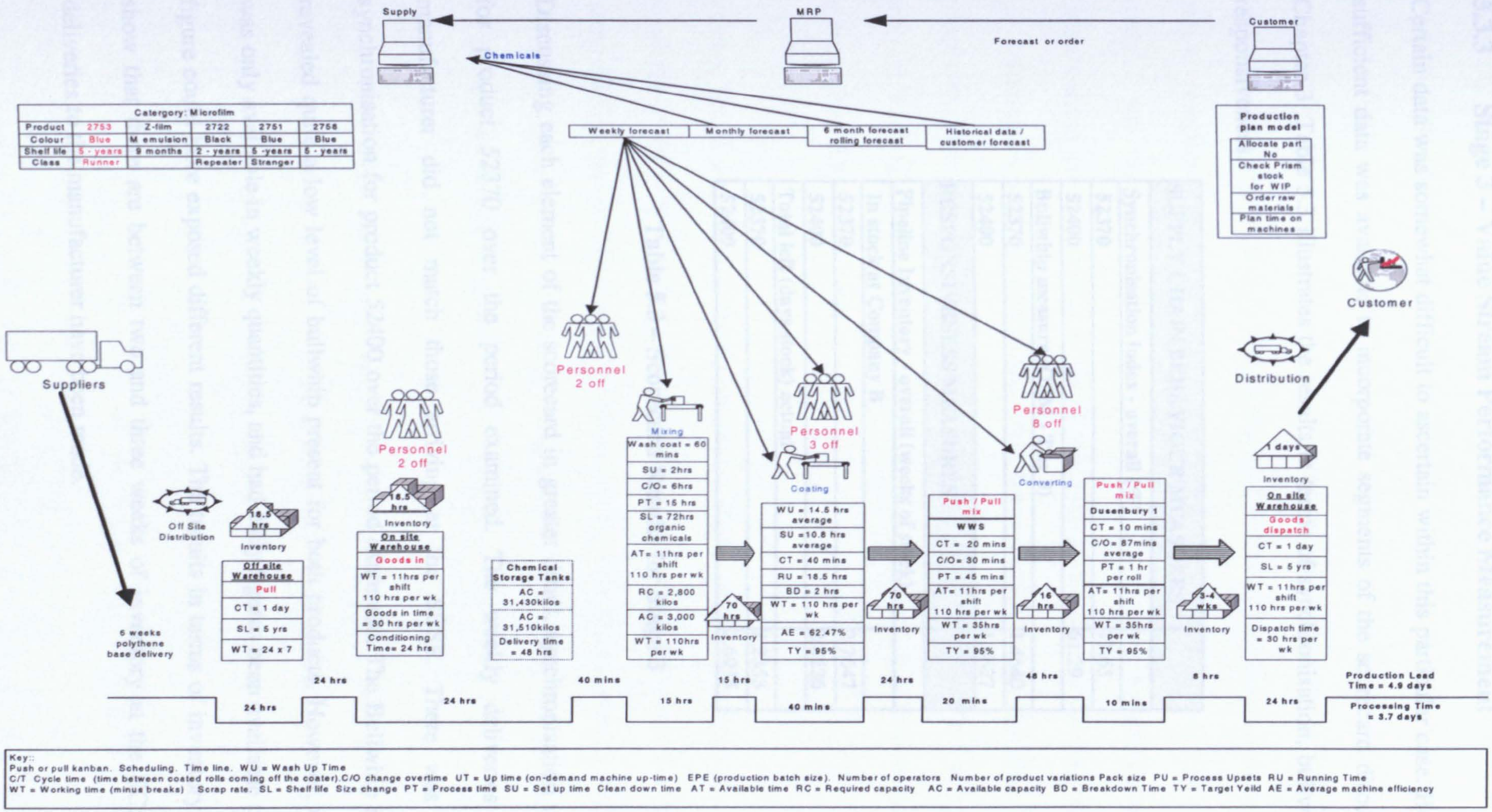


Figure 5.5 – VSM Microfilm Current State Runner

5.3.3 Stage 3 – Value Stream Performance Measurement

Certain data was somewhat difficult to ascertain within this particular case. However, sufficient data was available to incorporate segments of the scorecard discussed in Chapter 3. Table 5.3 illustrates the results in terms of synchronisation, bullwhip and responsiveness.

SUPPLY CHAIN BEHAVIOUR MEASURES	
Synchronisation index - overall (%)	
52370	17.65
52400	61.29
Bullwhip measure (OEM - Tier 3)	
52370	1.4640
52400	1.4627
RESPONSIVENESS MEASURES	
Pipeline Inventory - overall (weeks of stock)	
In stock at Company B	
52370	2.7647
52400	2.8226
Total left (days stock) actual	
52370	2.2353
52400	2.6935

Table 5.3 – Scorecard Results for Stage 3

Discussing each element of the scorecard in greater detail, synchronisation was low for product 52370 over the period examined. The weekly deliveries to the manufacturer did not match those arriving at the SCSP. There was greater synchronisation for product 52400 over the period examined. The Bullwhip measure revealed quite a low level of bullwhip present for both products. However, the data was only available in weekly quantities, and had daily figures been available then this figure could have exposed different results. The results in terms of inventory present show that there are between two and three weeks of inventory at the SCSP after deliveries to the manufacturer have been made.

Focusing on the information systems infrastructure, questionnaires, interviews and the systems map provided ample information to draw a number of conclusions. The obvious flaw in the systems infrastructure related to the lack of integration with both suppliers and customers. Focusing on the supplier relationship, the SCSP (Depot 1) had a stock control system in place along with Internet capabilities. However, there was no integration and consequently information discrepancies occurred on a regular basis. It was reported that stock data sent from Depot 1 was regularly inaccurate. Thus, corrupt data was present in the PRISM system. Depot 2 on the other hand had no information systems capabilities with the exception of a fax machine and telephone. However, the information accuracy was high from Depot 2 due to good internal working practices. Stocks were held in paper format in a structured manner that resulted in very few errors.

Further issues that emerged during the course of this project concerned the internal workings of the PRISM system. The manufacturer's business had changed since 1997 when PRISM was installed, and the system had not been reconfigured to encompass the changing needs of the business. Consequently the employees were not happy with the inflexible nature of the system.

In summary, there was an opportunity for improvements to be made with regards to supplier integration, due to the HUB-like scenario that existed, where the SCSP received all materials and acted as a sole supplier.

5.3.4 Design & Prototyping

Three architectures are presented in this section to facilitate improvement in both the supply chain and also the information systems infrastructure. They are discussed in the order they are considered in Chapter 4. The designs are based upon the identified value stream, however reference is made to the generic designs in Chapter 4.

5.3.4.1 EA-Based Integration Architecture

The introduction of an up-to-date Enterprise Application could significantly alter the way in which the manufacturer communicated with the SCSP. Due to the PRISM system being specifically targeted at the process industries sector, it was decided that it should be incorporated as the basis for the EA-based integration architecture presented in this section. Therefore, the most recent PRISM version, along with other associated components are reviewed in the following sections.

5.3.4.1.1 Invensys PRISM

There are four major components to the most recent version of PRISM: Production, Logistics, Financials and Maintenance (figure 5.6). Highlighting the key components, the production module permits users to scale requirements for a total production plan as well as to check the availability of designated resources. It automatically allocates existing inventory for future production. PRISM planning also highlights any potential equipment capacity overloads. Within the PRISM Logistics module the Customer Order Management components includes order entry and pricing, materials reservations, shipping, invoicing and sales analysis. The Logistics module is tightly integrated with manufacturing, which enables the automatic tracking of complex web interactions between the host company and its customers.

PRODUCTION Inventory Management, Product Structures, Resource Planning, Finite Capacity Scheduling, Production Reporting, Production Analysis, Quality Management, Regulatory Compliance, Quick Scheduler	**LOGISTICS** Customer Order Management, Procurement (ERP & MRO), Warehouse Management System, Radio Frequency, Customer Service, Sales Analysis, Quick Response, EDI
FINANCIAL Activity-Based Costing, Financial Support, General Ledger, Accounts Payable, Accounts Receivable, Budgeting, Financial Reporting, Currency	**MAINTENANCE** Maintenance Management, Approvals, Executive Information System, Project Accounting, Imaging

Figure 5.6 – Invensys PRISM Module Functionality

PRISM also seeks to add value along all areas of the supply chain, as figure 5.7 clearly shows.

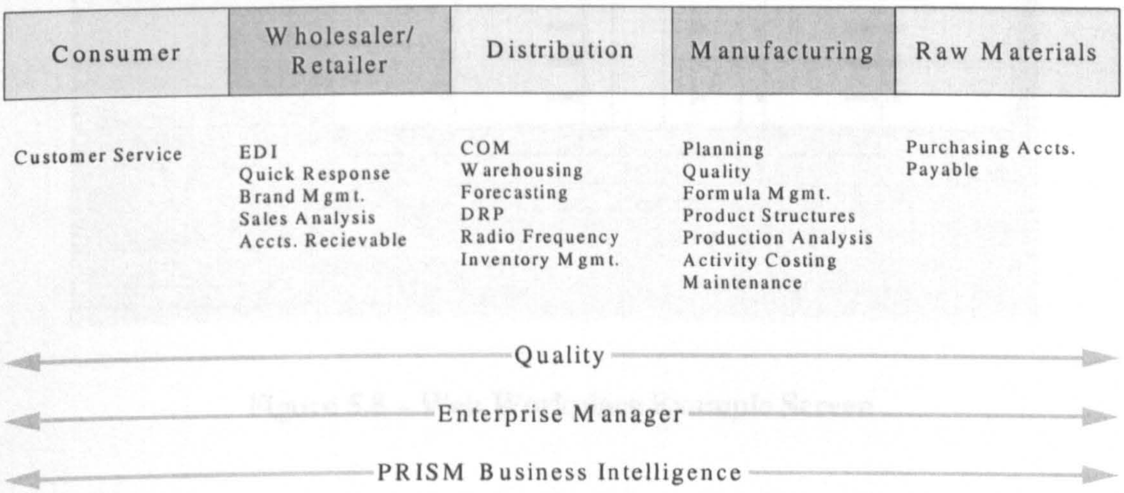


Figure 5.7 – PRISM Supply Chain Functionality

There are a number of key components that Marcam have selected to embrace that facilitate the EA-based architecture in this section. The following sections considers these components.

5.3.4.1.2 *PRISM Web Workplace*

Web Workplace is a new feature to PRISM that enables customers to enter order details through the web. A typical example of the screen the customer would use is displayed in figure 5.8. Within the envisaged ERP architecture, Web Workplace provides the link for customers to communicate demand information in a more efficient way.

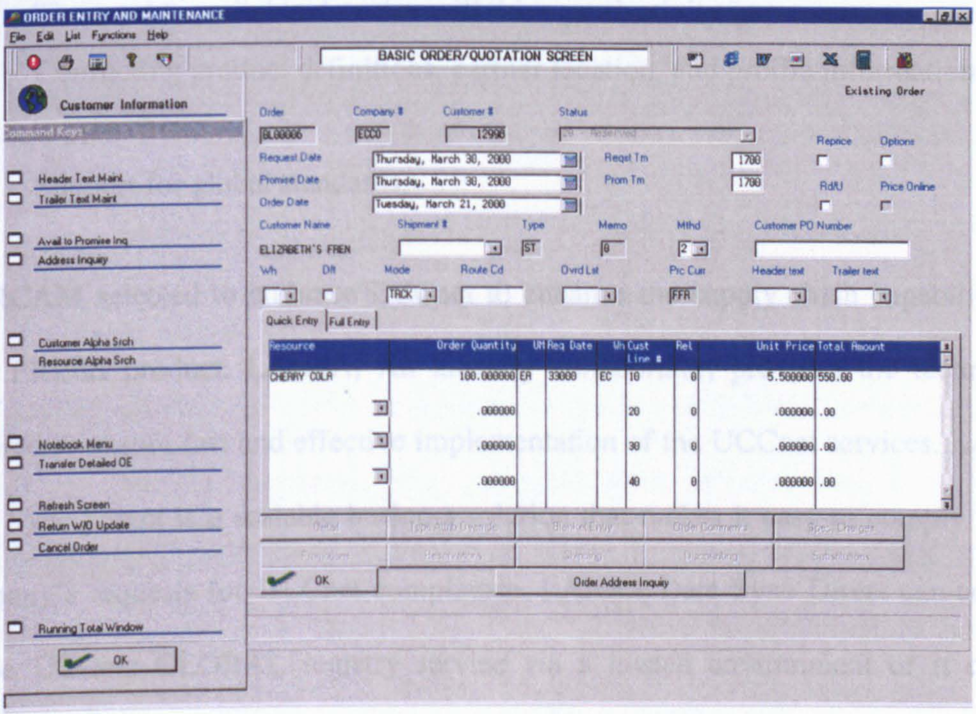


Figure 5.8 – Web Workplace Example Screen

5.3.4.1.3 *UCCnet*

UCCnet was formed in 1999 as a subsidiary of the Uniform Code Council (UCC) and some of the world's leading trade associations. It was established in response to the growing requests from retailers, manufacturers, and suppliers to address information inaccuracy in the global supply chain. There are two principal components to UCCnet. The UCCnet registry is incorporated by companies worldwide as a repository for their product and company data. All the data stored in the registry is validated to ensure compliance to EAN-UCC standards. The second element of the UCCnet concerns the synchronisation services that assist trading partners in exchanging standards-compliant data. The UCCnet services address a number of different issues:

- Accuracy of information that drive efficiencies throughout the supply chain.
- Challenges of getting new products rapidly to market, & lost shelf time.
- The need for reliable data that will drive productivity improvements.
- Conflicting product definitions, partner location, and profile information in the supply chain.
- Support for global standards.

MARCAM selected to embrace UCCnet to enhance the supply chain capabilities of their PRISM product. LANSA, An industry collaborator, provides the technology required to ensure fast and effective implementation of the UCCnet services. LANSA Data Sync Direct is a scalable business solution that makes it easy to comply with a company's requests for UCCnet compliance. LANSA Data Sync Direct can connect to the UCCnet GLOBAL registry service via a hosted environment or it can be implemented as a completely integrated solution. LANSA Data Sync Direct allows suppliers to access and update item information stored in their existing ERP system and securely send it to UCCnet's GLOBALregistry. No additional software or outsourcing services are required. Alternatively the hosted offering is an end-to-end solution designed to get a company connected easily with the functionality they require. Table 5.4 compares the two solutions.

Feature/Benefit	Data Sync Direct	Data Sync Direct - Hosted
Complete End-to-End Fully v2.21 Certified Solution	Yes	Yes
Browser Interface	Yes	Yes
Batch Interface	Optional	Yes
Integration with Enterprise Data	Yes	No
Solution Installed at Suppliers Location	Yes	No
Real-time Access to GLOBALregistry	Yes	Yes
Cost Structure	License Fee	Subscription
Workflow	Yes	No
SKU/GTIN Volume	High	Minimal
Spreadsheet Upload Capability	Optional	Yes
Built-in DTD to Schema Migration	Yes	Yes
Implementation Effort	3-4 Weeks	Hours

Table 5.4 – Data Sync Direct Solution Comparison

5.3.4.1.4 Architecture

The architecture envisaged here incorporated a number of different elements. For the immediate issue of improving the communication infrastructure between the manufacturer and the SCSP at Depot 2 there was no real need to incorporate UCCnet and LANSA Data Sync Direct. However, in order to demonstrate how the manufacturer could communicate effectively with a number of different suppliers, the UCCnet/LANSA functionality features in the architecture in figure 5.9.

Therefore, the customer places its orders via the web workplace application. The orders are fed directly into the PRISM where the usual planning and scheduling activities take place. With the enhanced functionality, SCSP Depot 2 now maintains their warehouse via the WMS application from within PRISM. As mentioned earlier, this can be accessed via the Internet. Therefore, Depot 2 still manages the stocks, but all of the data is held within PRISM.

The second part of the architecture involves the introduction of the UCCnet Global Registry and Synchronisation Services. First of all the 'Data Sync Direct' is installed at the host company (the manufacturer). Following this the relevant data is extracted and transformed into an XML format. The information is then sent, via a firewall over the Internet to the UCCnet data repository. Any subscribed suppliers can then access this information. Figure 5.9 reveals the architecture for this configuration.

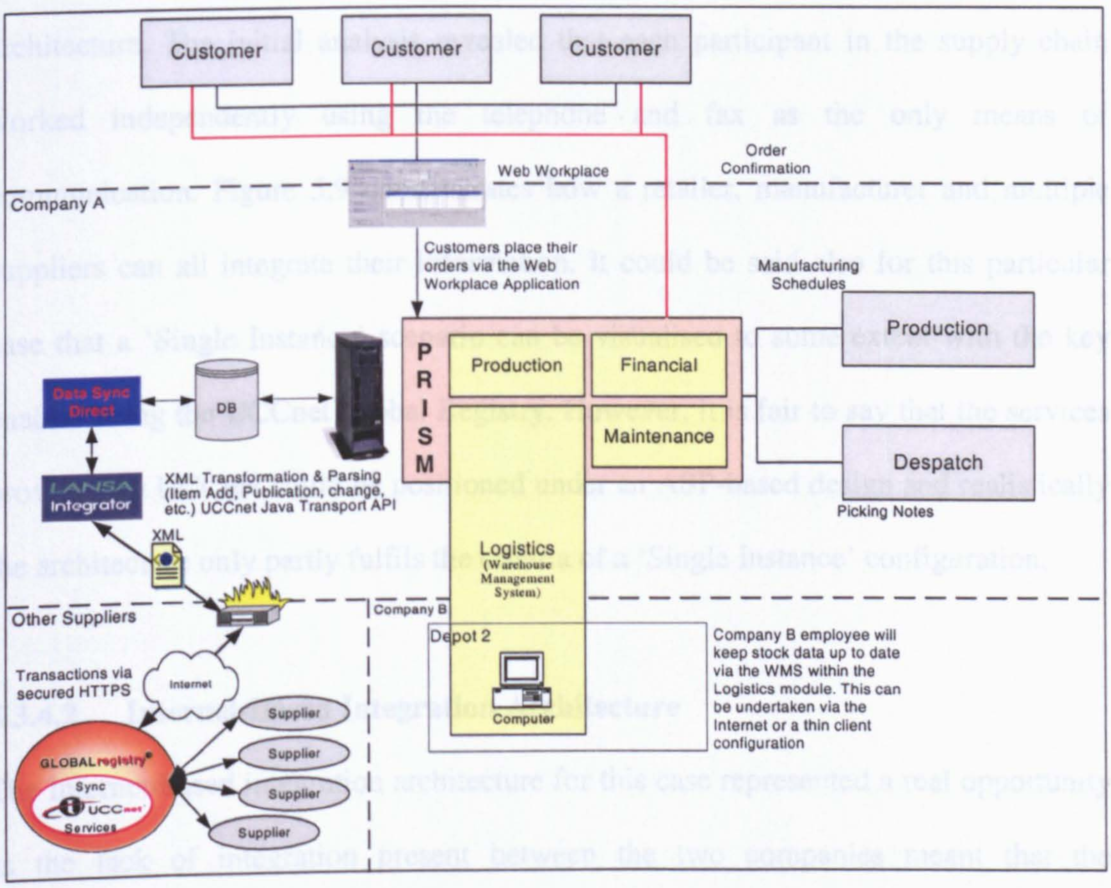


Figure 5.9 – EA-Based Integration Architecture

The proposed architecture (figure 5.9) would alleviate all of the issues that were identified at the beginning of this project. Thus, bullwhip would be reduced and synchronisation increased. Furthermore, pipeline inventory would shrink to a minimum. The incorporation of UCCnet has opened the door for suppliers to have access to previously unattainable information. Focusing on the SCSP at Depot 2, minimal configuration to PRISM would permit improved visibility and control over stock levels. However, a cost benefit analysis would have to be undertaken to assess whether investing in a new system would be worthwhile.

Referring back to the Analysis Framework Chapter, the design in figure 5.9 has clearly evolved from an 'Independent Operation' to an 'Integrated Operation' architecture. The initial analysis revealed that each participant in the supply chain worked independently using the telephone and fax as the only means of communication. Figure 5.9 demonstrates how a retailer, manufacturer and multiple suppliers can all integrate their information. It could be said also for this particular case that a 'Single Instance' scenario can be visualised to some extent with the key enabler being the UCCnet Global Registry. However, it is fair to say that the services provided by UCCnet could be positioned under an ASP-based design and realistically the architecture only partly fulfils the criteria of a 'Single Instance' configuration.

5.3.4.2 Internet-Based Integration Architecture

The Internet-based integration architecture for this case represented a real opportunity as the lack of integration present between the two companies meant that the development of the application could be designed from scratch. Within the Analysis Framework there were two designs for Internet-based integration architectures. As both companies thought a working prototype would demonstrate the true benefits of enhanced integration, version 1 of the Internet integration architectures was selected as the model from which to base developments. The design is based around the implementation of an interface between the manufacturer and Depot 2 that would replicate the sound working practises that were already in place.

The manual information interchange that was currently taking place involved:

- **Daily Call Off** from Manufacturer to SCSP Depot 2
- **Delivery Notes** from SCSP Depot 2 to Manufacturer

From the analysis, an interactive web-based database application was envisaged to fit the specifics of both the generic Internet architecture (version 1, Chapter 4) and the requirements of the scenario in question. Based upon the identified information flows there were two main elements to the system. Firstly, the 'Call-Off' component permitted the manufacturer to submit a web form as and when materials were required. On a separate but related page, this information was displayed on-line, enabling Depot 2 to react to the request. Once Depot 2 had acknowledged the call off it was removed from the 'Call-Off' screen, and the manufacturer knew to expect the requested materials

The second part of the system involved the development of a system to monitor the stock held at Depot 2. It was foreseen that an employee from Depot 2 would maintain and update this part of the application and the manufacturer would use it purely to view stock levels for reconciliation purposes. This particular element of the system permitted the user to query specific materials or view all the materials held at Depot 2. An employee from Depot 2 entered the relevant data as and when stocks arrived, and edited the records when stocks were called-off by the manufacturer.

A strategy incorporating the Apache Web Server and the Tomcat Application Server provided the basis for this design. This strategy was selected as it was successfully implemented by a member of the FUSION research group in an earlier project (Bremang, 2004). Java servlets allowed the application to successfully interact with a database and java server pages provided the required web interface. Figure 5.10 illustrates how the configuration of the Apache Web Server, Tomcat Application Server and MS Access Database would look.

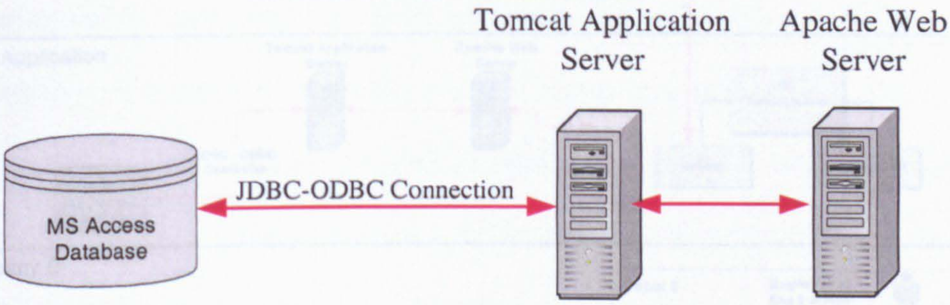


Figure 5. 10 – Database, Application Server and Web Server Configuration

The database stored all of the data relating to stock and call-offs. The Web Server displayed the front end of the application and the Tomcat Application Server housed the application. Screen Shots of the working application can be viewed later in this section.

5.3.4.2.1 Architecture

Figure 5.11 illustrates the proposed architecture for the Internet-based application. Internally the systems at the manufacturer remain the same. An employee fills in a web form to create a 'call off' procedure. The majority of the interactions with the system take place with Depot 2, as it is their responsibility to maintain the stock and respond to call-off requirements.

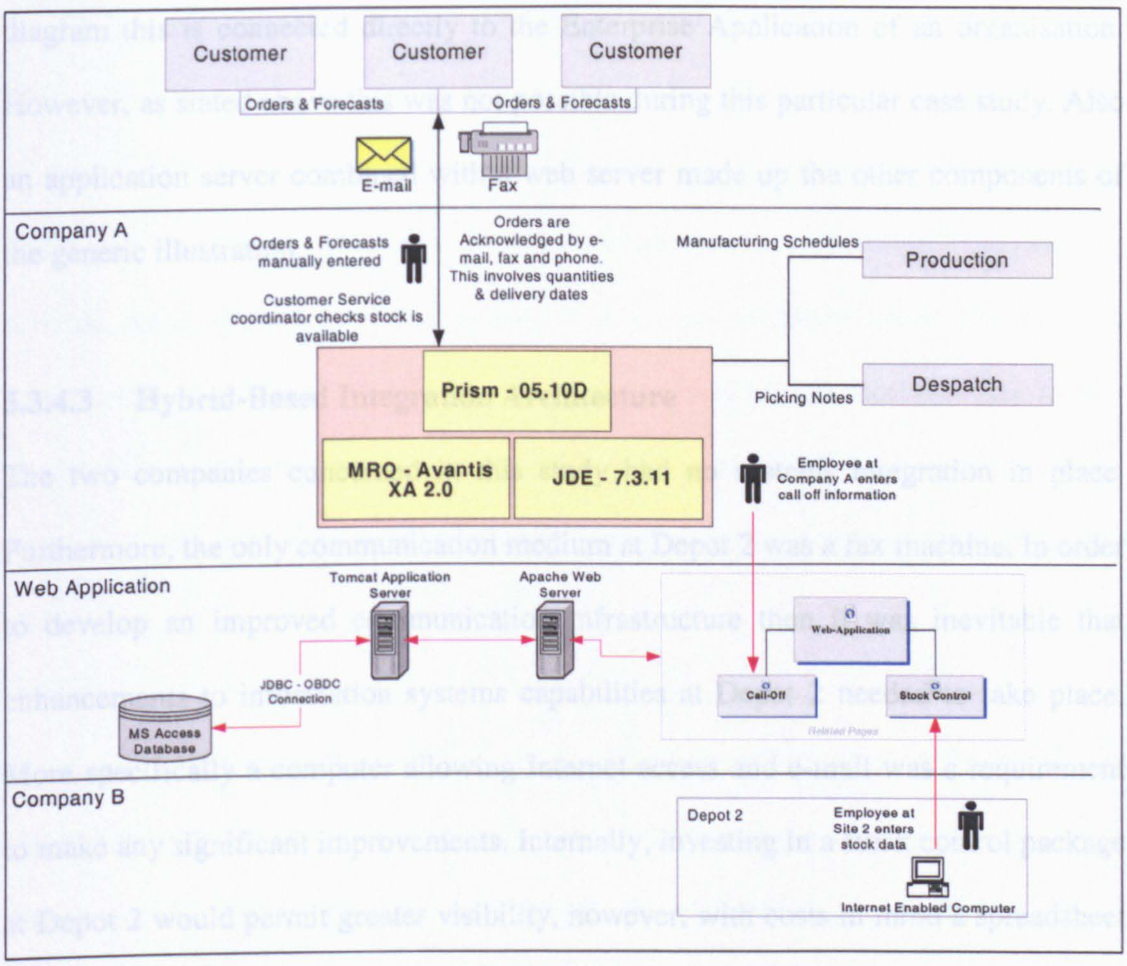


Figure 5.11 – Internet-Based Integration Architecture

The application enabled both parties' visibility of the stock control element of the system. The SCSP (Depot 2) maintains the system and the manufacturer can view its stock records online. In regards to the 'call off' system, the principal aim of this was to remove the current requirement of faxing call off requests each day. The 'call-off' system was not integrated with the internal systems at the manufacturer, however, it is envisaged that this would be the next step to provide complete integration across the supply chain as the generic Internet Integration Architecture aims to achieve.

Referencing Version 1 of the generic Internet architectures (Chapter 4), it is clear that there are a number of similarities with the proposed architecture in figure 5.10. First of all there is a data repository (MS Access) that is storing the data. In the generic diagram this is connected directly to the Enterprise Application of an organisation. However, as stated above this was not possible during this particular case study. Also an application server combined with a web server made up the other components of the generic illustration.

5.3.4.3 Hybrid-Based Integration Architecture

The two companies concerned in this study had no systems integration in place. Furthermore, the only communication medium at Depot 2 was a fax machine. In order to develop an improved communication infrastructure then it was inevitable that enhancements to information systems capabilities at Depot 2 needed to take place. More specifically a computer allowing Internet access and e-mail was a requirement to make any significant improvements. Internally, investing in a stock control package at Depot 2 would permit greater visibility, however, with costs in mind a spreadsheet package such as MS Excel could be incorporated as an effective substitute.

In this particular case, it was determined that the architecture would be very similar to that of the original systems map. An employee at Depot 2 would incorporate MS Excel to keep track of all in coming and out going materials. Then on a daily basis the Excel file would be attached to an e-mail and sent to the relevant party at the manufacturer. Once at the manufacturer, the data could be extracted and inserted into the PRISM data store. This could be done via a conversion application or by manual methods. This procedure permits greater visibility of current stock levels residing at Depot 2. Figure 5.12 demonstrates how this architecture would look.

5.3.4.3.1 Architecture

The architecture designed in this section can be described as somewhat simplistic. However, with no real communications infrastructure in place, it would be difficult and unnecessary to foresee a more complex architecture for this particular section. As well as being widely available, e-mail is a proven communication medium. By incorporating this e-mail based architecture (figure 5.12) it is hoped that information would flow more freely between the trading partners. Furthermore, reducing the amount of re-keyed data should enhance the information accuracy throughout the system.

Relating this to the generic Internet-based integration architecture in Chapter 4 it is clear that with the exception of only two trading partners existing the diagrams possess similar traits. For this case e-mail is the method of communication and as mentioned above data extraction/insertion can be undertaken manually or via a conversion application.

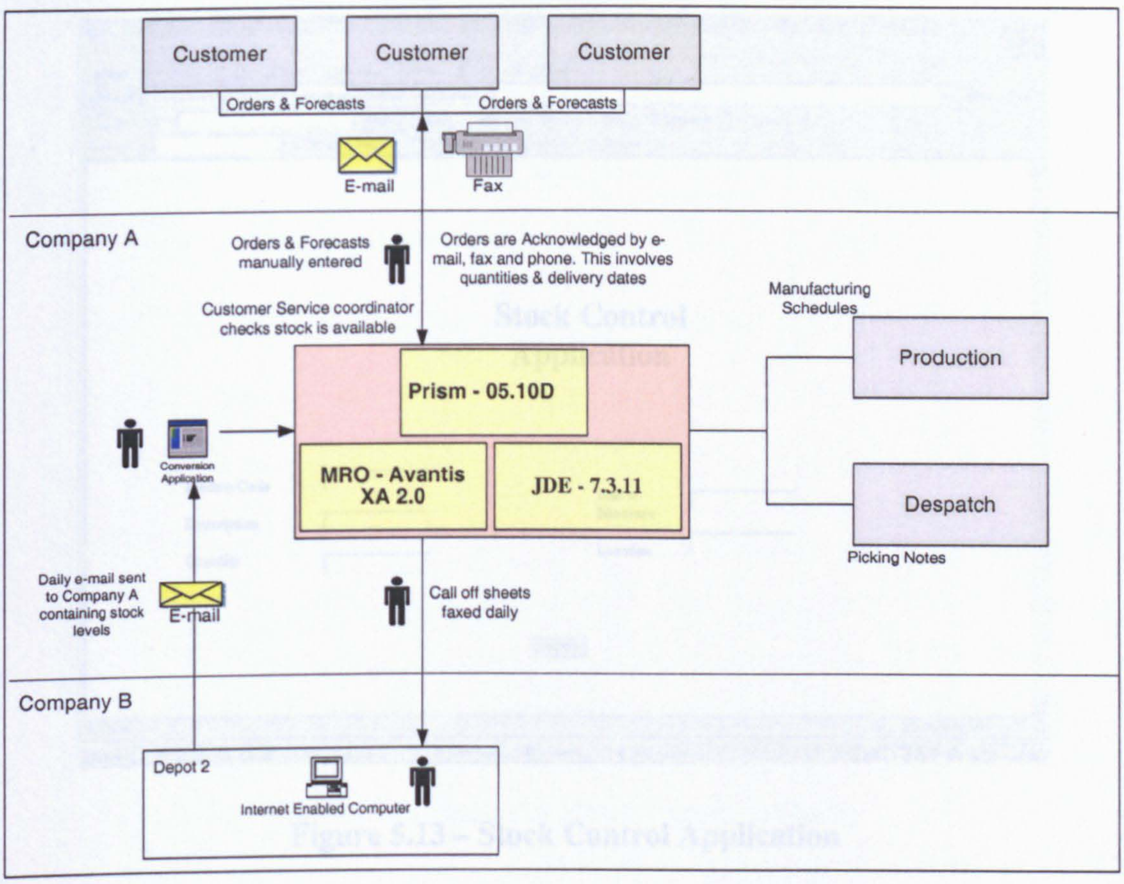


Figure 5.12 – Hybrid-Based Integration Architecture

5.3.4.4 Prototype

In this case the Internet-based integration architecture was prototyped. The decision to prototype the Internet architecture was based on a formal expectation of improved performance. In addition to this there were no plans for future investment in an EA system. The first screenshot (5.13) illustrates the stock control application. Here an employee at Depot 2 entered the data as and when stocks arrived. The screen in figure 5.14 allowed the manufacturer to enter information on this screen as to when it required stock. In figure 5.15 both parties could use this part of the application to search for stocks held at Depot 2.

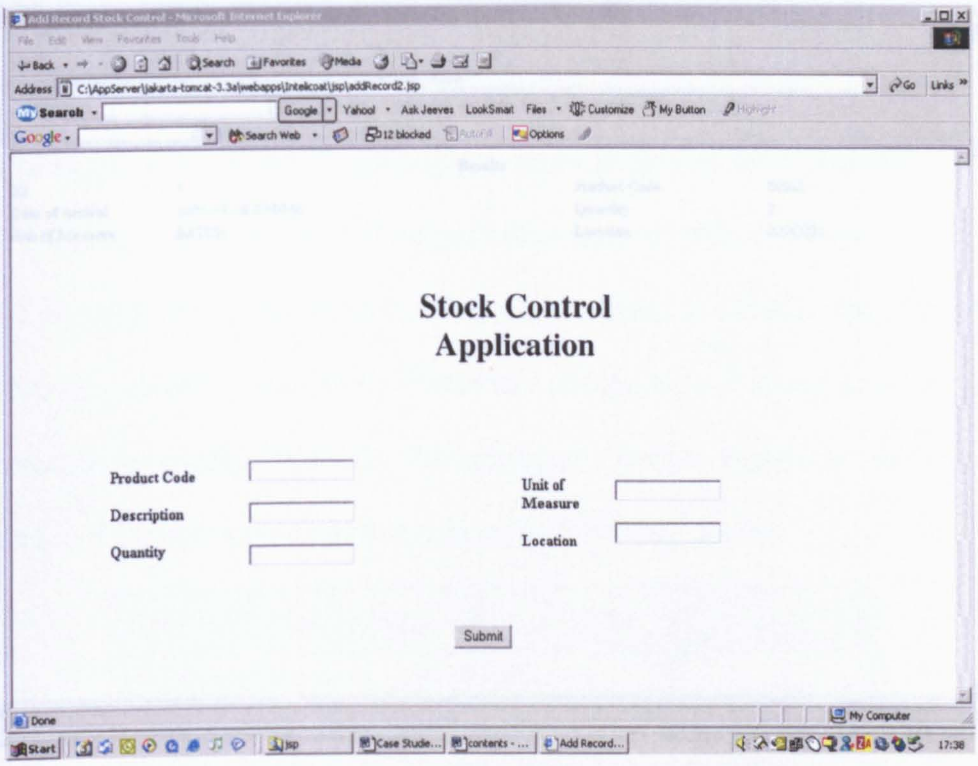


Figure 5.13 – Stock Control Application

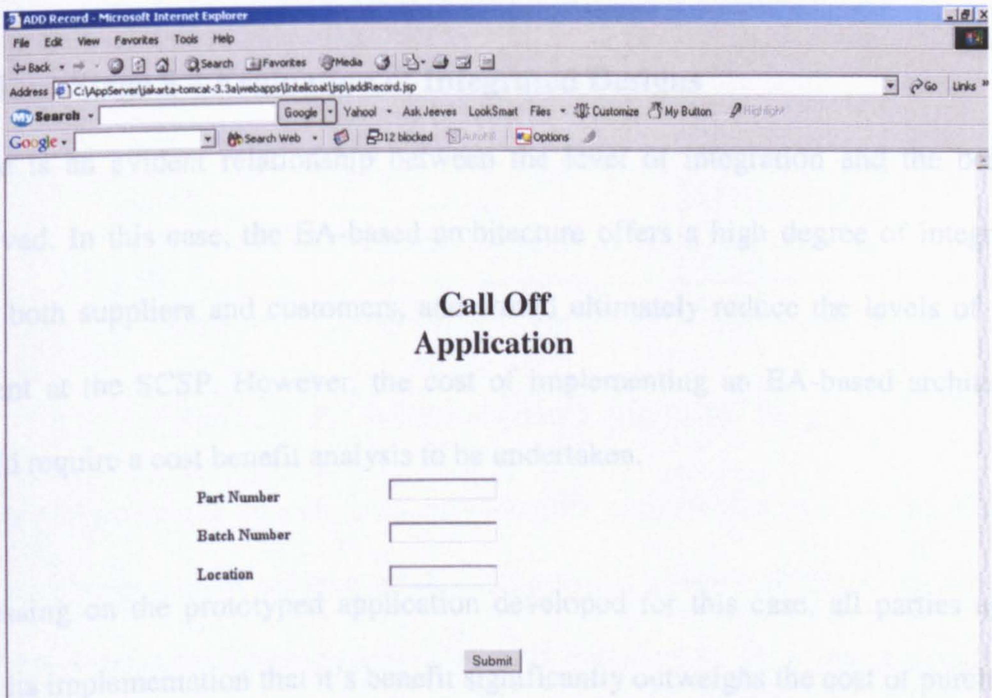
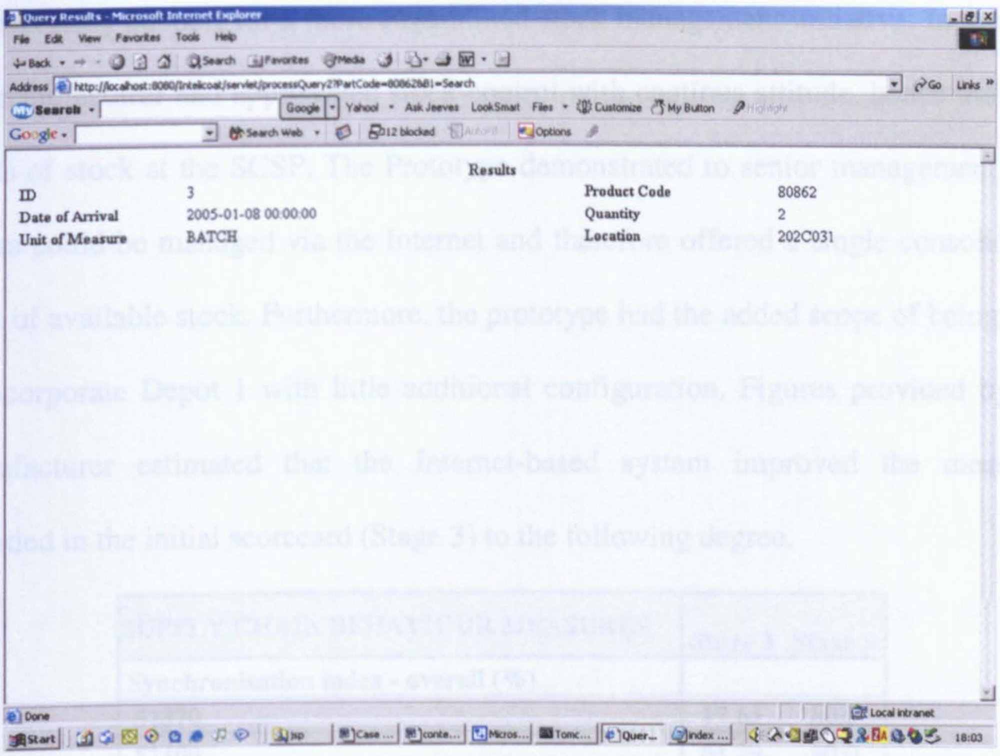


Figure 5.14 – Call Off Application



5.15 – Manufacturer Stock Location Query

5.3.5 Stage 5 – Evaluation of Integrated Designs

There is an evident relationship between the level of integration and the benefits received. In this case, the EA-based architecture offers a high degree of integration with both suppliers and customers, and would ultimately reduce the levels of stock present at the SCSP. However, the cost of implementing an EA-based architecture would require a cost benefit analysis to be undertaken.

Focussing on the prototyped application developed for this case, all parties agreed after its implementation that it's benefit significantly outweighs the cost of purchasing an Internet enabled computer for Depot 2. Stock control was the main focus of this case. As Stage 3 reported, in some cases there was in excess of three weeks stock being held at the SCSP. Coinciding with this, synchronisation was poor as expected. The prototype facilitated a more accurate stock control system and therefore provided the necessary support for a more streamlined stock management initiative. In the past the manufacturer had approached stock control with cautious attitude, hence the high levels of stock at the SCSP. The Prototype demonstrated to senior management how stocks could be managed via the Internet and therefore offered a single consolidated view of available stock. Furthermore, the prototype had the added scope of being able to incorporate Depot 1 with little additional configuration. Figures provided by the manufacturer estimated that the Internet-based system improved the measures recorded in the initial scorecard (Stage 3) to the following degree.

SUPPLY CHAIN BEHAVIOUR MEASURES	**Stage 3**	**Stage 5**
Synchronisation index - overall (%)		
52370	17.65	80.0
52400	61.29	80.0
Bullwhip measure (OEM - Tier 3)		
52370	1.4640	1.2
52400	1.4627	1.2
RESPONSIVENESS MEASURES		
Pipeline Inventory - overall (weeks of stock)		
In stock at Company B		
52370	1.7647	1.0
52400	2.8226	1.0
Total left (days stock) actual		
52370	2.2353	1.6
52400	2.6935	1.6

Table 5.5 – Predicted Scorecard Results for Stage 5

The prototype did not attempt to directly integrate with PRISM as it was decided that this would represent a separate project altogether. However, with the expansion of available integration technologies it was not foreseen to be a major concern. In summary, whilst the figures present within the scorecard are estimated they do demonstrate the effects of the implemented prototype as experienced by senior management.

5.3.6 Stage 6 - Supply Chain Information Plan

This case represents the least complex of all the studies undertaken. However, important conclusions can be drawn from this study. First of all, it is evident that a poor communication infrastructure was causing a number of problems for both parties involved in the case. At the manufacturer, there were problems relating to information discrepancies. Furthermore, the analysis of synchronisation, bullwhip and responsiveness revealed poor results in all areas.

Three alternative architectures have been presented to demonstrate the EA and Internet technologies that are available to support integration between trading partners in this case. The EA-based application demonstrated how the manufacturer could become increasingly integrated with both suppliers and customers if it selected to upgrade its PRISM system. In doing so costs would be driven out of the supply chain. The second, Internet-based architecture permitted an increased level of integration with very little expenditure required. For the immediate future this represented the most logical solution. The prototype, developed on the foundations of this architecture provided evidence to both parties of how communication could be improved to enrich the performance of the supply arrangement. The final hybrid-based architecture illustrated that improved integration can be achieved via the purchase of an Internet-enabled PC.

In terms of selecting the most appropriate supply chain information architecture for this case there is some debate. With the supply chain being shallow, there exists an ideal opportunity to implement a comprehensive EA-based integration architecture. This would facilitate significant benefits to the supply chain as a whole. However, the cost of implementing an EA architecture combined with the fact that the products being produced were low in value indicated that for this case it would not be the best solution. On the other hand, the Internet architecture demonstrated improvements in performance whilst keeping expenditure to a minimum. For this case the Internet-based integration architecture represented the best way forward.

The classification framework identified this case to be situated within the Process industries sector. As the Literature Review (Chapter 2) stated, process industries are characterised by shallow supply chains involving non-discrete products, as is the situation in this case. In relation to integration, the characteristics of process industry supply chains along with this research suggest that ultimately an EA-based integration architecture would generate the most benefit as the lack of depth would permit more integration. However, it is the authors opinion that the particular item being produced/manufactured would also have a significant role in determining the integration strategy.

In conclusion this case illustrated how companies with little or no external communication infrastructure can experience improvements on a variety of different fronts via relatively basic means. In this particular case, time spent administering the supplier relationship was reduced and therefore reallocated to more important tasks, visibility over stock holdings was improved and consequently the improved stock data facilitated enhanced replenishment planning to take place.

5.4 Case Study 2 – High Volume FMCG Study

5.4.1 Stage 1 – Orientation

This case study concerned three companies based within the northwest of England. As section 5.2 stated, this case involved a food manufacturer (FM) (Company A), a logistics service provider (LSP) (Company B) and a retailer (Company C). The FM was a leading supplier of bakery ingredients and frozen speciality bakery products to professional bakers and chefs in the UK. The LSP provided outsourced logistics services in the UK & European markets. Company C was a major international retailer with outlets in both the UK and America.

In relation to the Classification Framework, this case study analysed a sub section of an FMCG supply chain. Systems proliferation and legacy integration represented the main supply chain challenges at the outset. Production volume at the OEM was high as with all the cases in this chapter and the supply chain was shallow in configuration.

The FM supplied the retailer with a number of different products ranging from doughnuts to baps paste. However, the LSP acted as an intermediary by receiving the products from the manufacturer and storing them for distribution to Retail outlets (Company C) as and when required. Figure 5.16 depicts the value stream.

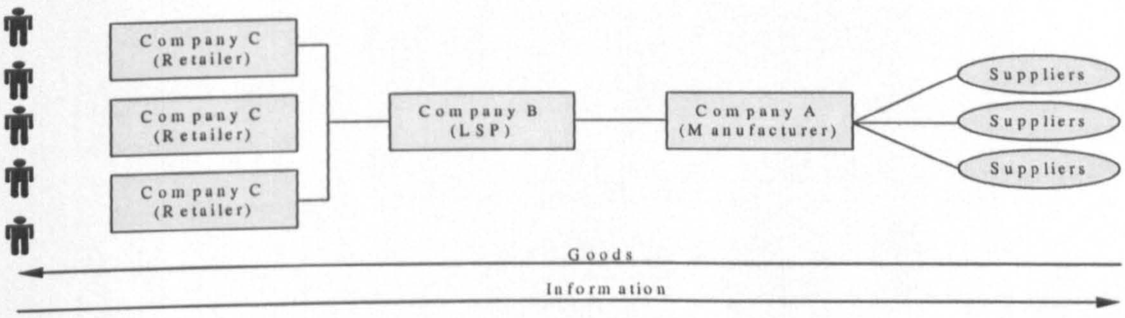


Figure 5.16 – Value Stream

5.4.2 Stage 2 – Value Stream and Information Flow Mapping

Considering the FM (Company A) first, it became apparent from an early stage that the systems architecture in place was extremely complex due to the considerable number of systems in operation. Figure 5.17 illustrates a complete list of all the systems operating at the FM. For practicality, the only systems discussed in this section are those deemed to be strategically important in terms of this particular case. As the LSP was closely affiliated with the manufacturer, their main system is also present within figure 5.17. The systems that are highlighted in red represent those that identified as relevant to this case.

- **MFG PRO (Version 9eB/Progress 9.1C)**

This represents the FM's main transaction processing system, holding information relating to products, customers and suppliers. Many other systems interface to MFG/PRO via batch interfaces or manual input and where bespoke systems have been provided they have been written in Progress. MFG/PRO is purchased in modules that form the basis of the main menu numbered 1 to 36. The FM had over 300 additional bespoke programs relating to MFG/PRO (refer to Appendix 'C' for a list of all the menu items along with a brief description).

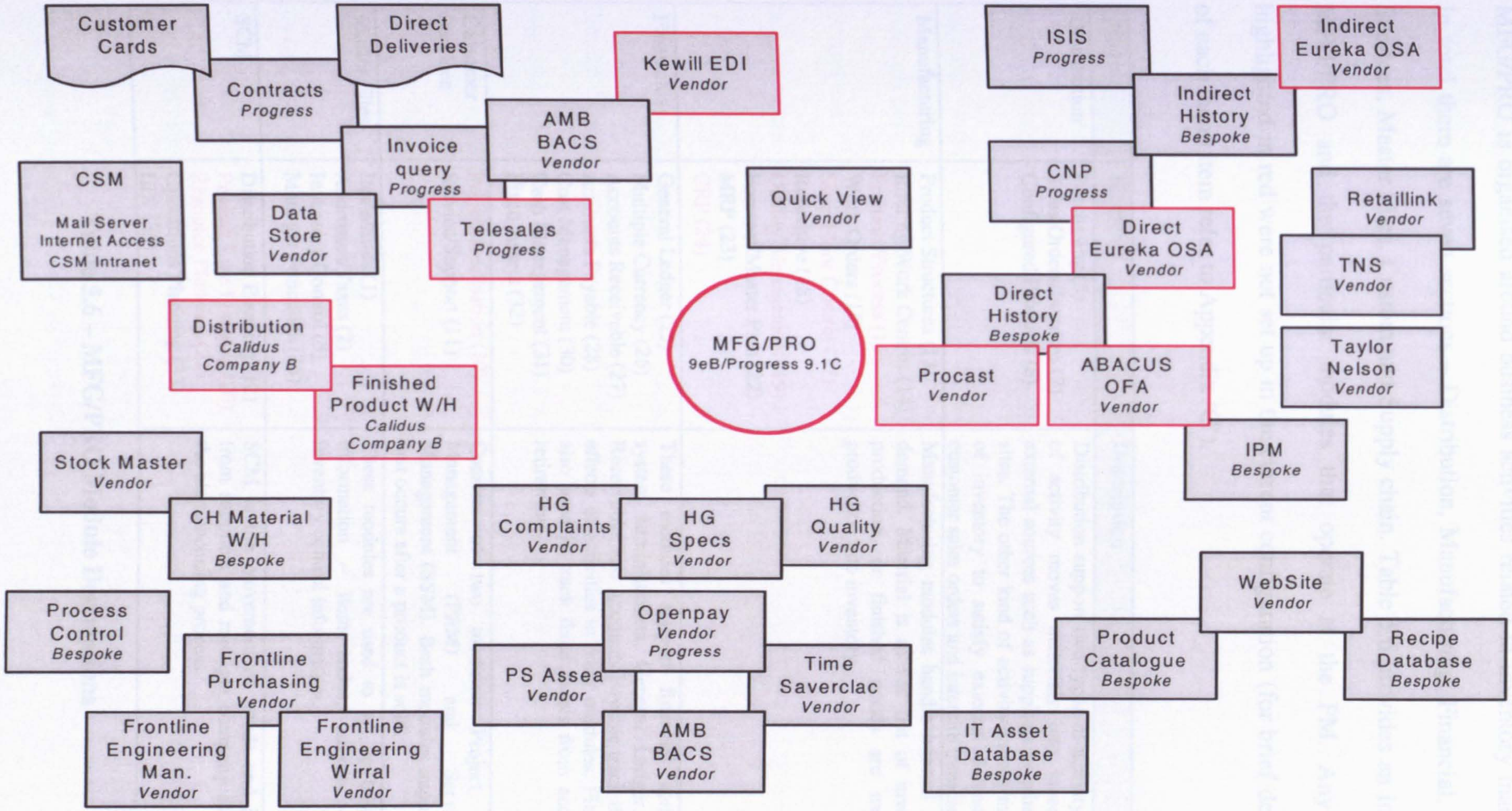


Figure 5.17 – IT Systems at the FM

MFG/PRO is organised around business activities related to inventory management. In total there are seven sections – Distribution, Manufacturing, Financial, Customer Services, Master Files, Custom and Supply chain. Table 5.6 provides an insight into MFG/PRO and the particular modules that operate at the FM. Any modules highlighted in red were not set up in the current configuration (for brief descriptions of each menu item refer to Appendix 'C').

Module	Elements	Description
Distribution	Purchasing (5) Sales Orders/Invoices (7) Configured Products (8)	Distribution support two types of activity. One kind of activity moves materials into inventory from external sources such as suppliers or other company sites. The other kind of activity moves materials out of inventory to satisfy external demand such as customer sales orders and intersite transfers.
Manufacturing	Product Structures (13) Routing/Work Centres (14) Formula/Process (15) Work Orders (16) Shop Floor Control (17) Repetitive (18) Quality Management (19) Forecast/Master Plan (22) MRP (23) CRP (24)	Manufacturing modules handle internal supply and demand. Material is moved out of inventory into production, or finished goods are moved from production into inventory.
Financials	General Ledger (25) Multiple Currency (26) Accounts Receivable (27) Accounts Payable (28) Cost Management (30) Cash Management (31) Fixed Assets (32)	These modules support financial activities and system administration. General Ledger, Accounts Receivable, and Accounts Payable track the financial effects of activities in other modules. Financials are also used to track fixed assets from acquisition to retirement.
Customer Services	Project Realisation (10) Service/Support (11)	Consists of two modules: Project Realisation Management (PRM) and Service/Support Management (SSM). Both modules support activity that occurs after a product is sold.
Master Files	Items/Sites (1) Addresses/Taxes (2) Inventory Control (3) Manager Functions (36)	These modules are used to set up basic business information – item codes, address codes and inventory control information.
SCM	Distribution Planning (12) Product Line Planning (20) Resource Planning (21) Operations Planning (33) EDI (35)	SCM is the movement of goods and information from suppliers and multiple company sites through the manufacturing process.

Table 5.6 – MFG/PRO Module Descriptions

- **Telesales (Progress)**

This system enabled telesales personnel to take or amend orders from customers and is therefore a critical system to the businesses operations. The system relies on MFG/PRO for providing Product, Customer and Pricing information and for updates of Order status and such information is refreshed daily.

Orders are received into the Telesales system either via a sales representative or directly from customers through EDI. New orders are received through the Kewill system. Twice a day, batch processing is invoked that extracts the new orders, together within any amendments, and uplifted into MFG/PRO. Subsequently, two files of new orders, one for Ambient and one for Frozen, are passed to the LSP. Orders are only passed to the LSP if they are within eight calendar days of their delivery date. Appendix D displays the flow diagram for the Telesales system.

- **Eureka (Non-Progress System)**

Eureka (figure 5.19) provides information on a company's customers and products. The FM uses Eureka for Sales Information and has implemented the Eureka Oracle RDBMS database and Oracle's OLAP application Sales Analyser. The organisation has two implementations of EUREKA: one, containing Direct Customer/Product Sales (Company Eureka) information and another containing Indirect Customer/Product Sales information. A further function of Company Eureka is to act as a small data warehouse, from here sales measures are fed to Abacus, Procast and Reps Call Sheets. 'Company Eureka' is fed from four sources and 'Indirect Eureka' is fed from two sources (figure 5.18). The complete flow diagram and narrative for the Eureka system can be found in Appendix 'E' part one.

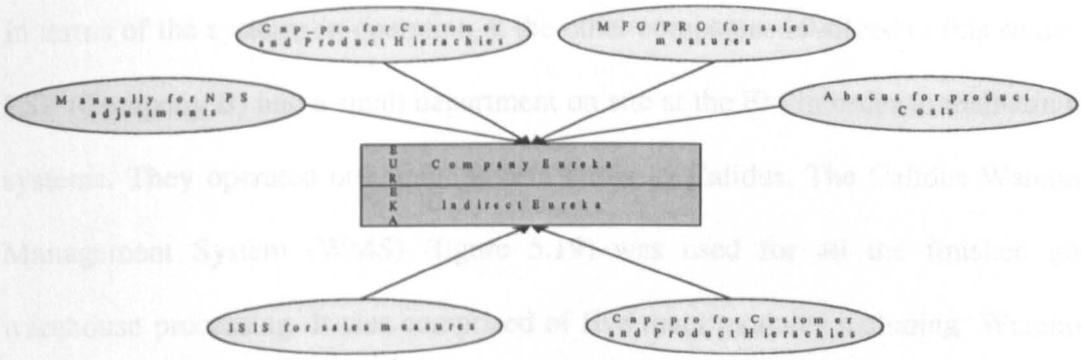


Figure 5.18 – Eureka and Information Sources

- **Abacus (Non-Progress System)**

Abacus (figure 5.19) is the Unilever name for its implementation of the Oracles OLAP application, Oracle Financial Analyser. Its relevance for this particular case was minimal. A flow diagram and narrative can be found in Appendix 'E' part two.

- **Procast/Proplan (Non-Progress System)**

This is a third party Oracle OLAP application written by Cube Software. It is the first step in producing a businesses forecast. Procast is automatically fed with despatch sales information from the Eureka system, which the FM uses to access sales data. Forecasts are built up from history of despatches, and manual input from Sales personnel. Once the forecast has been established, it is automatically fed into MFG/PRO and Abacus. Appendix 'E' part three demonstrates the flow of information and illustrates the interfaces with other systems.

- **Kewill EDI**

Kewill was the system used to process incoming EDI messages. Appendix E part 4 illustrates the complete process that was undertaken when EDI messages were received. At this point it is just relevant to mention that Kewill is the system that processes the messages.

In terms of the systems in operation at the other companies involved in this study, the LSP (Company B) had a small department on site at the FM in order to maintain their systems. They operated one main system know as Calidus. The Calidus Warehouse Management System (WMS) (figure 5.19) was used for all the finished goods warehouse processing. It was comprised of five main modules including: Warehouse Management, Stock Management, Radio Data, Sales Order and Purchase Order Processing. The system carried out all the processing necessary for receiving, despatching and managing warehouse stock. The order files are uplifted into Calidus automatically where they remain until they need to be picked and despatched. The systems analysis at the retailer (Company C) was somewhat limited. However, having established that they communicated their orders via EDI, it can be assumed that they had a large ERP system planning their operations across the UK.

Figure 5.19 illustrates the information flow diagram (IFD) this case. The IFD is a simplified version of complex infrastructure that exists between the FM and its trading partners. For a more comprehensive insight into the information flows that take place then refer to Appendix F.

Following the IFD, the Value Stream Mapping (VSM) tool was used to identify the number of value adding activities involved in the production of certain lines of cakes. In total three VSM diagrams were produced in this case. Figure 5.20 illustrates an example of a VSM diagram for a product manufactured at the FM. Another VSM diagram for product code DAM can be viewed in Appendix G.

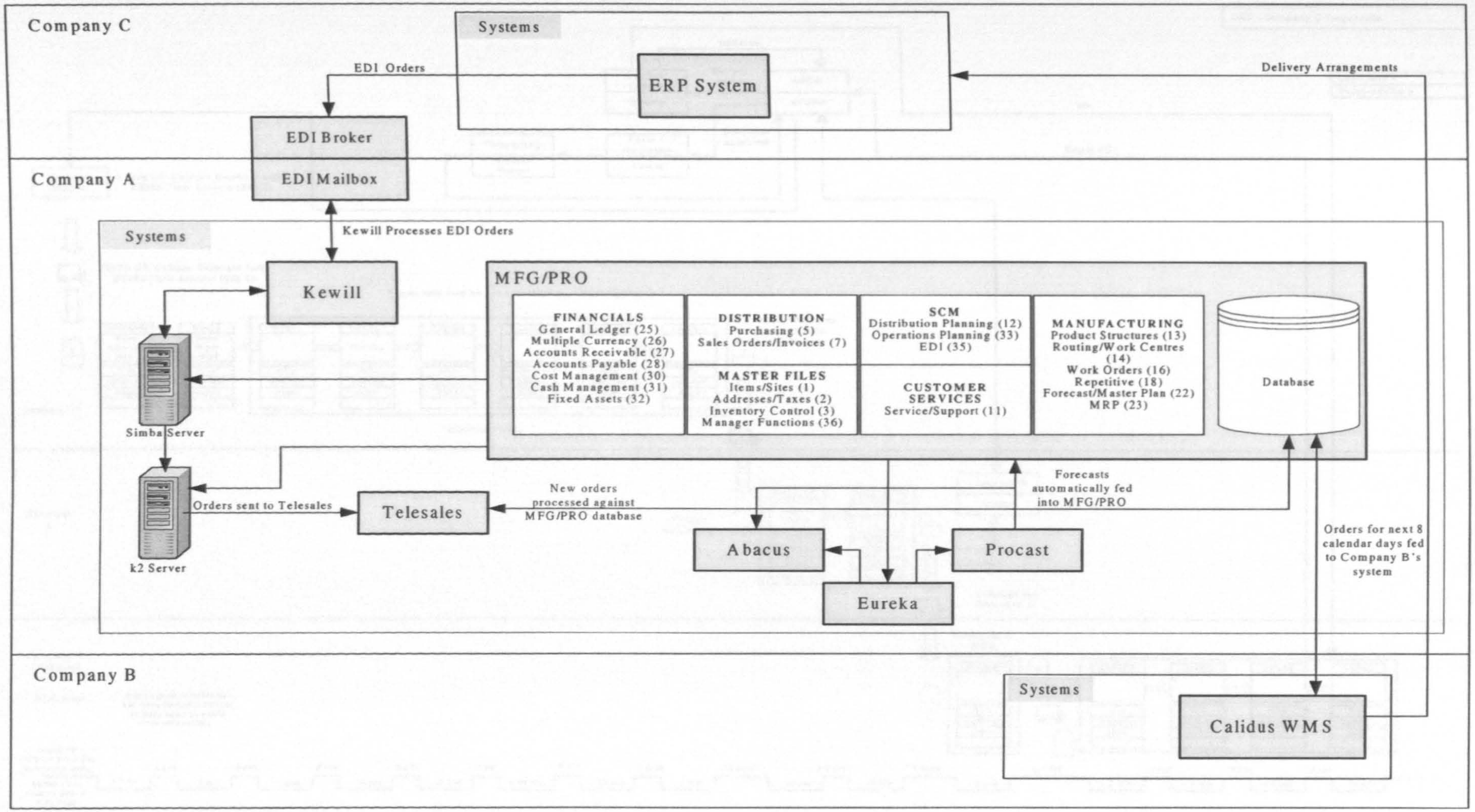


Figure 5.19 – IFD For Case 2

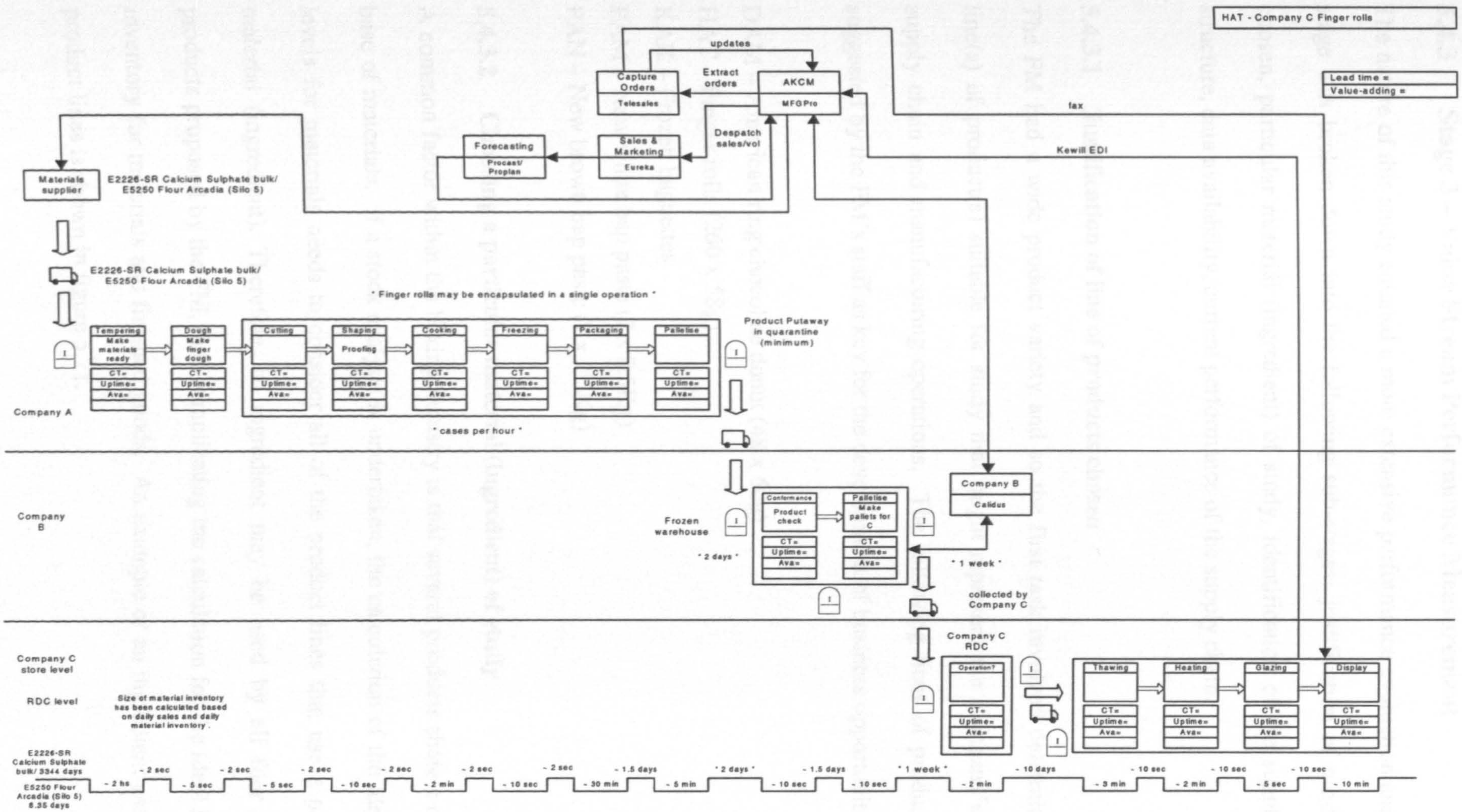


Figure 5.20 – VSM - Product Code - HAT Finger Roll

5.4.3 Stage 3 – Value Stream Performance Measurement

The nature of this study entailed a more extensive performance evaluation and so this stage was broken down into the following sub-stages: justification of product line chosen, particular material (ingredient) of study, identification of the supply chain structure, data availability, current performance of the supply chain.

5.4.3.1 Justification of line of products chosen

The FM had a wide product variety and so the first task involved determining the line(s) of product(s) suitable for study that might represent the company's typical supply chain and manufacturing operations. The following lines of products were suggested by the FM's staff as key for the development of business opportunities:

DAM – American ring chocolate donut (48 x 60g)
HAT – Finger rolls (260 x 58g)
KAK – Frozen baguettes
PAM – New white bap paste (7 x 2.5Kg)
PAN – New brown bap paste (7 x 2.5Kg)

5.4.3.2 Choosing a particular material (ingredient) of study

A common factor within the baking industry is that several products share a common base of materials. If a stock analysis is undertaken, the calculation of the ideal stock levels for materials needs to consider all of the product lines that use a particular material (ingredient). Therefore, an ingredient may be used by all four lines of products proposed by the FM, thus complicating the calculation for the ideal levels of inventory for materials and finished goods. An example of an ingredient used by all product lines is shown in figure 5.21.

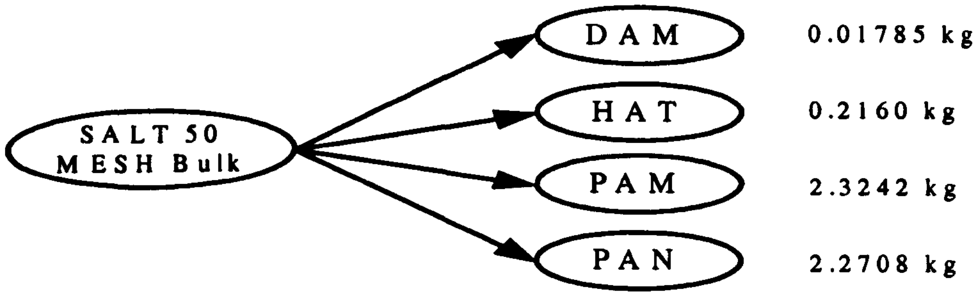


Figure 5.21 –Ingredient Shared by Four Product Lines

In order to overcome this problem, a limited number of materials associated to the four lines of products were traced:

- *HAT - Finger rolls (260 x 58g)*
  - E2226-SR calcium sulphate bulk dihydrate superfine (0.02431 kg per box)
  - E5250 – Flour A (Silo 5) (8.9302 kg per box)
- *DAM - American Chocolate Ring Donut (48 x 60 g)*
  - E8006 – Vermicelli Jumbo Light (0.2566 kg per box)
  - E2127 – Euroblend Brown Oxide (0.036 kg per box)
- *PAN - New brown bap paste (7 x 2.5 Kg)*
  - E3025 – EM3 NA DIACETYL TARTARIC (0.3562 kg per box)
  - E7101 – Maltone malt flour (0.8905 kg per box)
- *PAM - New white bap paste (7 x 2.5 Kg)*
  - S9907 - P/P CORRUGATED LAYER (0.1754 EA per box)

The period of data analysed covers a total of 55 days.

5.4.3.3 Supply Chain Structure

Figure 5.22 represents the supply chain structure identified for the study. Three major components form part of this chain.

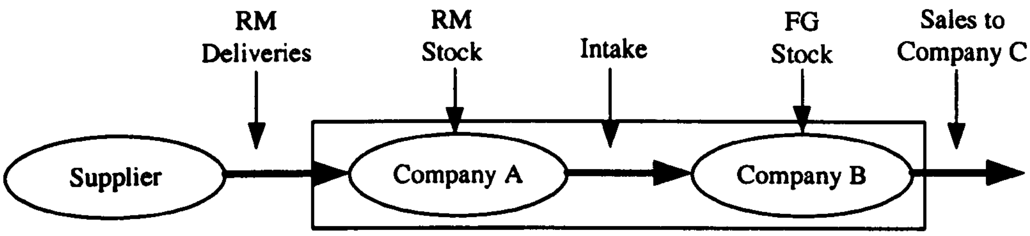


Figure 5.22 - Supply chain Structure Analysed

The data sets available for the analysis of the supply chain depicted in figure 5.21 are:

- **Company B (LSP) – Frozen Warehouse**
  - Intake (overall)
  - Despatch = Overall Company C (Retailer) sales
  - Opening C/S (overall)
  - Daily invoice history (quantities invoiced to retail outlet in kg)

- **Company A (FM) – Planning and stocks**
  - Overall sales
  - Overall sales in kg
  - Required daily usage (kg) – based on daily sales
  - Extracts V101 (Production work orders backflushed on a daily basis)
  - Ingredient inventory
  - WO issues (materials issued to a production work order).
  - Materials receipt (in kg)

- **Suppliers of raw material**
  - Materials despatch = FM materials receipts (in kg)

It is important to note at this point that the data sets were provided by the FM and the LSP. Also no data from the retailer's distribution centres and stores was included in the study. Therefore, the study was limited to the FM's operations.

5.4.3.4 Supply Chain Performance Analysis

The nature of the products and materials used by the FM made it appropriate to select only one product (material) to illustrate the scope of the supply chain performance analysis. The results of the analysis presented in this section refer exclusively to HAT – finger rolls line.

The finger roll (HAT) line had the second highest demand for the period examined (354.6 tonnes). A total of 31 different ingredients were used to manufacture HAT. The ingredient labelled as Flour A (Silo 5) was identified as being suitable for this analysis. Figure 5.23 shows for the period examined, overall sales in kg, overall FG stock in kg, overall intake in kg and raw materials receipts for this ingredient.

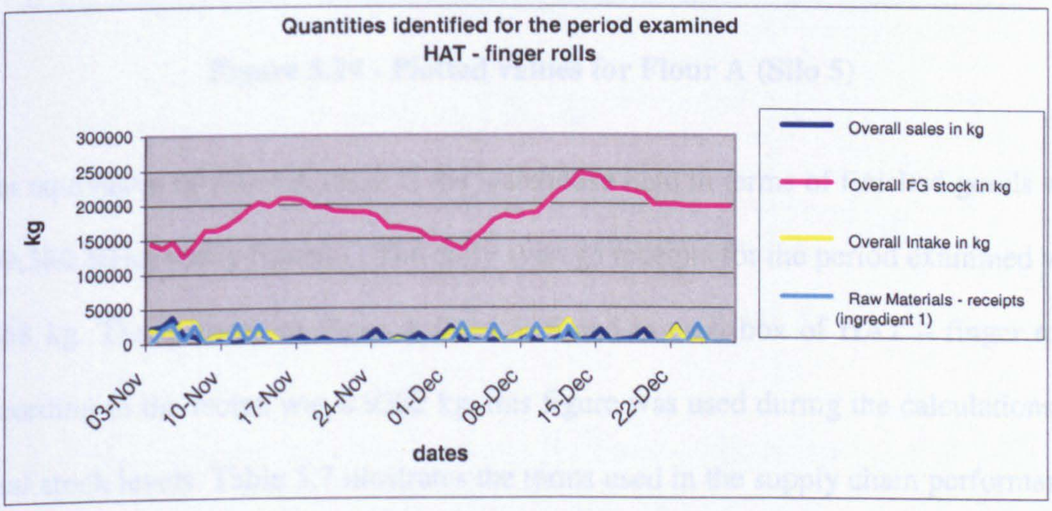


Figure 5.23 - Plotted values for HAT – Finger Rolls

From the plotted values it is possible to identify the following:

- Number of days scheduled for production during the period examined: 21 of a total of 56 days.
- Daily average size of material inventory: 31333.14 kg
- Average size of material inventory hold based on sales: 8.49 days
- Average size of finished good stock hold: 29.62 days

As mentioned earlier the total period covered in this study was 56 days. Figure 5.24 illustrates Flour A (Silo 5) plotted values for:

- The equivalent hold in finished goods stock
- Inventory reported in the Excel files, and
- Receipts reported in the Excel files

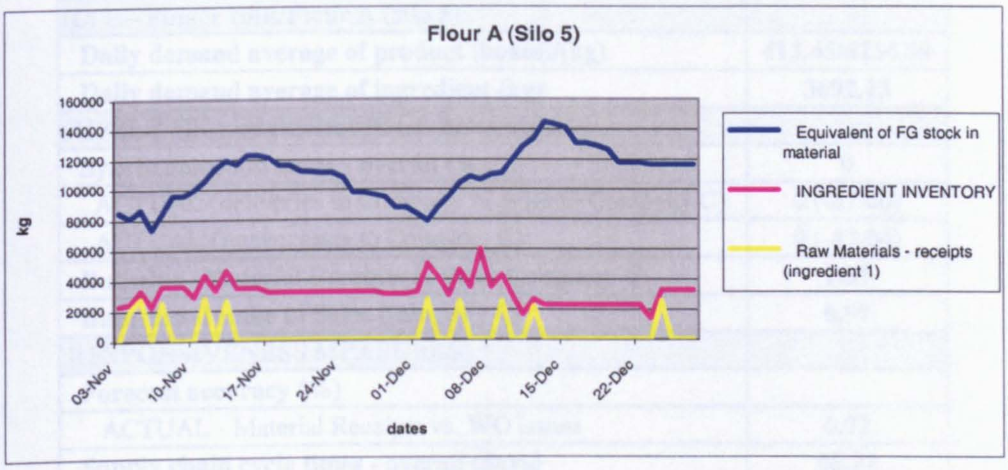


Figure 5.24 - Plotted values for Flour A (Silo 5)

The equivalent of Flour A (Silo 5) the warehouse held in terms of finished goods was 109,380.50 kg (daily figures). The daily average receipts for the period examined was 4568 kg. The quantity of Flour A (Silo 5) found in each box of HAT – finger rolls according to the recipe was 8.9302 kg, this figure was used during the calculations of ideal stock levels. Table 5.7 illustrates the terms used in the supply chain performance analysis.

Term	Definition
Sales	overall sales to Company C as specified in the Excel file (boxes).
FG stock	overall finished good stock (boxes).
Intake	number of boxes moved from Company A to the frozen warehouse operated by Company B.
Required daily usage	calculated from total daily sales and the quantity of material used per box.
Material receipt	raw materials receipt.
WO issues	materials issued to a production work order
Ingredient inventory	material inventory registered in a period of time.
Prod WO backflushed	production work orders backflushed on a daily basis.

Table 5.7 – Supply Chain Performance Analysis Terms

5.4.3.5 Scorecard

The scorecard was the main tool employed in the analysis of the performance of the current supply chain for HAT – finger rolls and Flour A (Silo 5). Table 5.8 shows the results of the scorecard tool for these items.

HAT – Finger rolls/Flour A (silo 5)	
Daily demand average of product (boxes)/(kg)	**413.45/6234.89**
Daily demand average of ingredient (kg)	**3692.23**
SUPPLY CHAIN BEHAVIOUR MEASURES	
Synchronisation index - overall (%)	**0**
ACTUAL (deliveries to Company A, sales to Company C)	0 (-87.00)
ACTUAL (Intake, sales to Company C)	0 (-43.04)
Bullwhip -Material Receipts to Sales Company C-	**1.61**
Bullwhip -Intake to Sales Company C-	**0.97**
RESPONSIVENESS MEASURES	
Forecast accuracy (%)	
ACTUAL - Material Receipts vs. WO issues	**0.72**
Supply chain cycle times - overall (days)	**48.22**
Company A	38.12
Material supplier	10.10
Pipeline Inventory - overall (days of stock)	**48.11**
FINISHED GOODS Company B	29.62
Raw Material Company A	8.49
Supplier Materials	**10.00**

Table 5.8 - Scorecard Results for Stage 3

The scorecard revealed poor results across the board. A bullwhip figure of 1.61 was recorded, supply chain cycle time was 48.22 days and pipeline inventory 48.11 days. Reasons for these results include high levels of FG inventory in hand, use of production workplans based on forecasts and not on real-time customer demand, and the absence of dedicated production lines for the products investigated.

5.4.4 Stage 4 – Design and Prototyping

Stage 3 highlighted the areas in which the architectures in this section seek to improve. Three architectures are presented in this section to facilitate improvement in both the supply chain and also the information systems infrastructure. They are discussed in the order they are considered in Chapter 4. The designs are based upon the identified value stream, however reference is made to the generic designs in Chapter 4.

5.4.4.1 EA-Based Integration Architecture

This case represented a slightly different scenario in terms of the enterprise application architecture. At the time this project was undertaken, the FM had commissioned a consultancy company to carry out a detailed study of their systems. The aim of this study was to assess the functional alignment and suitability of the Navision Kernal system for the FM. Due to this, it was decided that the Navision system infrastructure should represent the basis of the EA-based architecture in this section.

5.4.4.1.1 Navision

Navision comprises of a number of different components (table 5.9). Navision is deployed by certified Business Solutions providers, who install the system and modify it to encompass the exact requirements of the company concerned. The focus of this section is to demonstrate how the Navision system could have been configured to encompass each of the participants in this FMCG supply network. Therefore, the following section concentrates upon the elements of Navision that enable an improved supply network scenario.

FINANCIAL MNGT	DISTRIBUTION	MANUFACTURING	CRM
• General Ledger • Receivables & Payables • Cash Manager • Fixed Assets • Human Resources • Budgeting and Reporting • Consolidation • Project Management • Multiple Dimensions • Multi Currency	• Inventory Management • Warehouse Management • Order Processing • Returns Management • Automated Data Capture Systems (ADCS) • Pricing for Sales & Purchasing • Inventory Costing • Shipment & Delivery	• Production Orders • Bill of Materials • Supply Planning • Demand Forecasting • Capacity Requirements Planning • Manufacturing Costing	• Contact Management • Contact Classification • Campaign Management • Opportunity Management • Task Management • Document Management & Interaction Log • Contact Search • E-Mail Logging for Microsoft Exchange • Outlook Client Integration

SERVICE MANAGEMENT	E-BUSINESS SOLUTIONS	APPLICATION WIDE
• Service Item Management • Service Price Management • Service Order Management • Service Contract Management • Planning and Dispatching • Job Scheduling	• Microsoft Business Solutions–Navision Commerce Portal — For customer, vendor and partner access and self-service through an Internet browser (human-to-application) • Microsoft Business Solutions – Navision Commerce Gateway — For conducting automatic Internet-based commercial transactions (application-to-application)	• DB Platform: - Microsoft Business Solutions–Navision Database Server - Microsoft SQL Server • Multi Language • Microsoft Business Solutions–Navision User Portal — Personalized browser-based remote access to the solution for employees • Connectivity: - C/ODBC, C/FRONT - Microsoft Business Solutions–Navision Application Server • Built in OLAP (SIFT) • Reports

Table 5.9 – Microsoft Navision Modules

5.4.4.1.2 Navision Components for an EA Architecture

From the literature available on the Navision product the main integration techniques involved portal technology. The 'Commerce Portal' leverages the Internet to streamline interactions with vendors and customers. It allows supply chain partners to interact through a personalised Web portal that matched each of their particular needs. The second portal, known as the 'Commerce Gateway' enables business-to-business collaboration by opening the installed Navision system to electronic exchange of trading documents with other systems. The functionality of the system meant it was possible to map data between different formats like XML, EDIFACT, SAP IDOC and flat files, using an XML standard. The FM currently receives EDI orders from the retailer as well as other customers. In an ideal world, all parties in a supply network would have a homogeneous system. However, presently this is more of a vision than a realistic alternative and so the 'Commerce Gateway' could significantly improve the communication infrastructure between the FM and the retailer.

Aside from the functionality enhancements of the Navision system, the new system has a number of benefits in terms of cost. Annual maintenance amounts to £45,000 and upgrades take between 1-2 months in total. New functionality can be added with relative ease and the system runs on a Microsoft platform and therefore can reside on a windows based server, thus reducing costs significantly.

5.4.4.1.3 Architecture

Figure 5.25 illustrates the EA-based integration architecture. The architecture is derived from the analysis above along with the generic templates considered in Chapter 4. Two portals are envisaged in figure 5.25 that would enable the supply network to become more integrated. The 'Commerce Gateway' portal translates all orders into a pre specified format that would enable them to be inserted into the Navision system. In terms of the FM it is likely that many of the disparate systems would be removed due to the enhanced functionality of Navision. Hence, Kewill, Telesales, Abacus, Eureka and Procast have all been removed from figure 5.25. The Calidus WMS retains its position as it is under control of a separate organisation. The final component of the architecture involves the 'Commerce Portal'. The implementation of this portal would create visibility to suppliers that were previously contacted via telephone or fax. The systems requirements for both portals are listed on the left side of figure 5.25.

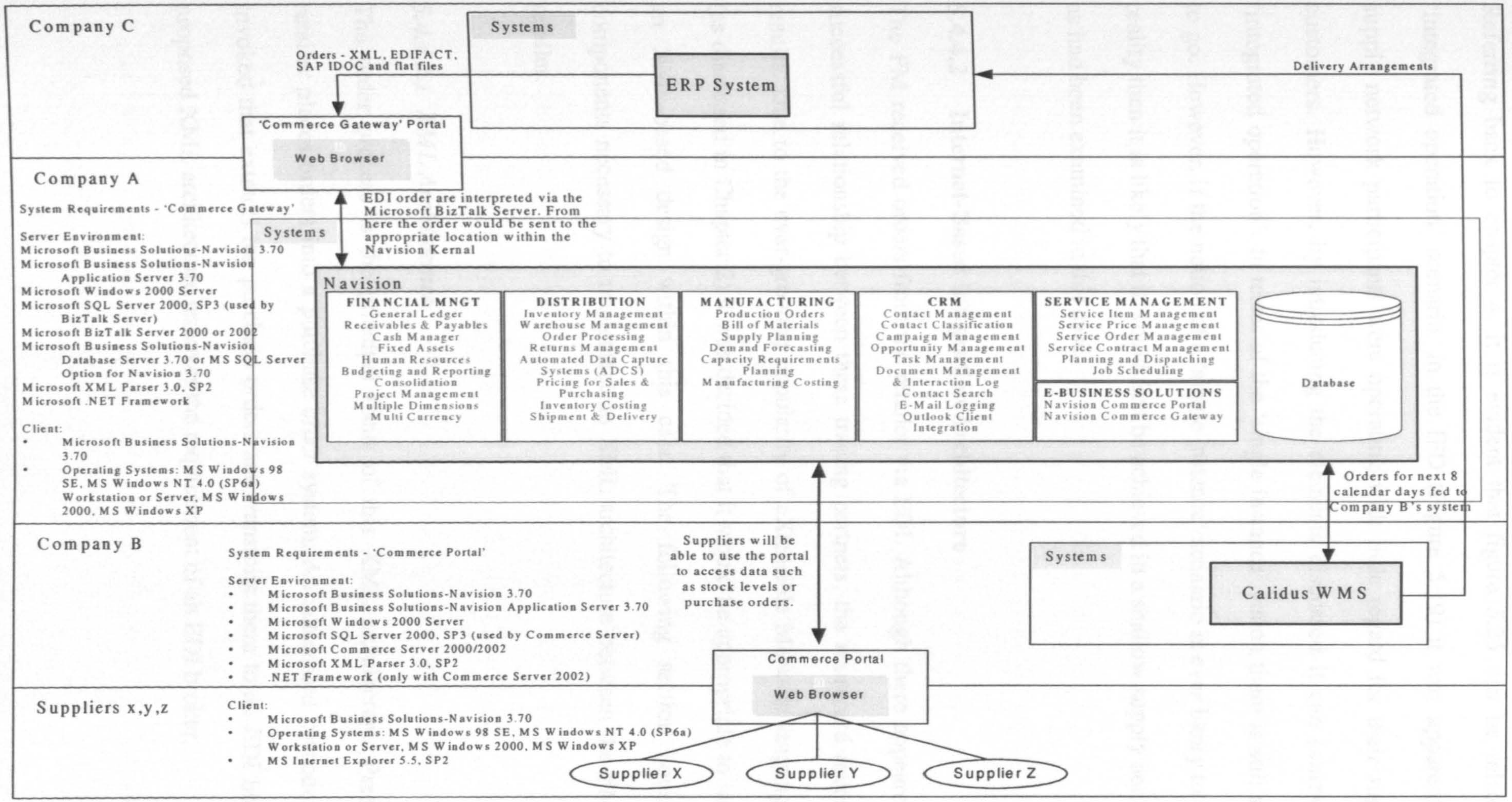


Figure 5.25 - EA-Based Integration Architecture

Referring back to chapter 4, it is evident that figure 5.25 can be related to the 'integrated operation' scenario. In the IFD (Figure 5.19) it was apparent that the supply network participants were operating with little regard for their suppliers or customers. However, by introducing the elements discussed it can achieve a truly 'integrated operation'. In terms of the 'single instance' vision there is still some way to go. However, if the notion of a 'single instance' scenario is ever likely to become a reality then it is likely that it would first be achieved in a shallow supply network such as had been examined in this case.

5.4.4.2 Internet-Based Integration Architecture

The FM received orders from the retailer via EDI. Although there appeared to be a successful relationship between these trading partners, the scorecard revealed poor results. Due to the ever-growing popularity of eXtensible Mark-up language (XML) (as discussed in Chapter 2) it was decided that it would be appropriate to incorporate an XML-based design within this case. The following section considers the components necessary to implement an XML architecture between the FM and the retailer.

5.4.4.2.1 XML Architecture

The order process is the principal focus of this XML architecture. Presently the retailer places orders into a purchase order system. An automated procedure is then invoked that extracts the purchase orders and transmits them to an EDI broker. The proposed XML architecture removes the requirement of an EDI broker.

Discussing each component in turn. A servlet was introduced to extract the data from the purchase order system and then convert the data into a pre-defined XML format. Following this the third operation performed by the servlet situated at the retailer was to send the XML file to the servlet based on a server at the FM. A 'mapfile' and 'actionfile' housed on this servlet then unpacked the XML document and inserted the data into the Telesales system. By packing and sending the data in this way the Kewill system becomes redundant as its core activity was concerned with sending and receiving EDI messages. Telesales functions as before and telesales personnel can amend or remove orders from customers as required. Once the orders are present within MFG/PRO, the other systems all function as usual.

In the current architecture a number of procedures are invoked on a weekly basis to deal with customer invoices. The proposed XML design does not require any of these processes to run, as their principal function was to prepare the invoice files for EDI. Instead, the servlet at the FM extracts the data from the appropriate location within MFG/PRO and converts the data into a suitable invoice-XML file. Once it has been packed and sent, the servlet at the retailer uses the 'mapfile' and 'actionfile' to unpack the data and insert it into the correct location within their systems. Figure 5.26 illustrates the Internet-based architecture for this case. As with the Internet-based integration architecture for case 1, the configuration is very similar. Although they are not visible in figure 5.26, both a web server and application server are present to house the necessary components for the extraction and insertion of data. The Internet acts as the medium to communicate the order data and the other components carry out the processing. Therefore, the architecture can be related to the generic Internet Architecture Version 1 (Chapter 4).

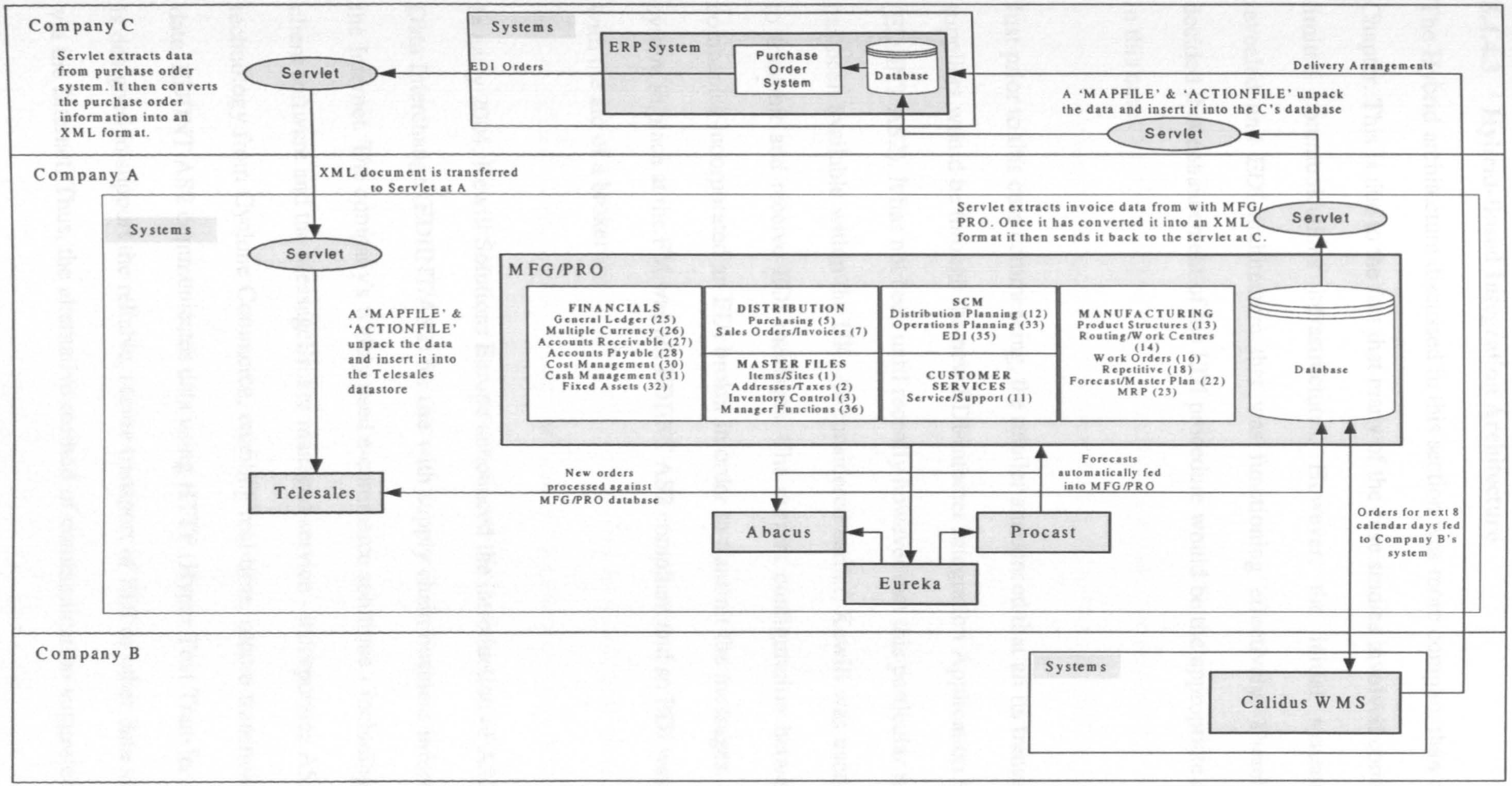


Figure 5.26 – Internet-Based Integration Architecture

5.4.4.3 Hybrid-Based Integration Architecture

The Hybrid architecture discussed in this section was more complex than most in this Chapter. This is due to the fact that many of the case studies involved companies with limited communications infrastructures. However, the initial systems analysis revealed and EDI architecture that was functioning effectively. Therefore it was decided that enhancement of the EDI procedure would be the appropriate step to take in this case.

Just prior to this case commencing, the retailer announced that all its transactions with suppliers would be through the new EDI-Internet Integration Application Statement 2 (EDIINT AS2). It has not been until recently however that this particular functionality has been available within the UK. As considered earlier, Kewill was used by the FM to transmit and receive EDI messages. The current configuration between the two companies incorporated an EDI broker in order to transmit the messages. The Kewill system in place at the FM was not EDIINT AS2 compliant and so EDI was continuing with the aid of a broker.

In early 2004, Kewill Solutions Europe announced the introduction of AS2 Electronic Data Interchange (EDIINT/AS2) for use with supply chain business information over the Internet. The company's widely used e-commerce solutions - including EasyTrade client software and the MessageBroker managed service - incorporates AS2 compliant technology from Cyclone Commerce, enabling real-time, secure transmission of EDI data. EDIINT AS2 communicates data using HTTP (Hyper Text Transfer Protocol). It is designed to support the reliable, secure transport of EDI or other data such as XML via the Internet. Thus, the alternative method of communication suggested within this section looks to incorporate the enhanced functionality of the improved Kewill system.

5.4.4.3.1 EDIINT AS2 Architecture

No longer requiring the services of a VAN is the most obvious advantage of incorporating the enhanced functionality Kewill system. The retailer would place their orders via EDIINT AS2 and they would be directly received by the Kewill system at the FM, utilising the Internet as the communication medium. Regardless of the FM's plans to revise their internal systems, updating the Kewill system would be sure to show a quick return on investment as the added costs of running a VAN are eliminated. The architecture appears to be almost identical to the current configuration with the only alterations appearing between two companies. Figure 5.27 depicts the minor changes to the current systems architecture should Kewill be upgraded.

In terms of the Hybrid-based generic architecture in Chapter 4 it is clear that figure 5.27 bares little resemblance. However, the criteria for the hybrid architecture state that it will utilise tools and technologies that have been considered in the previous two architectures. Hence EDI is applicable here. The hybrid architecture looks to fine tune the Kewill system with the added functionality and in doing to reduce the costs associated with EDI.

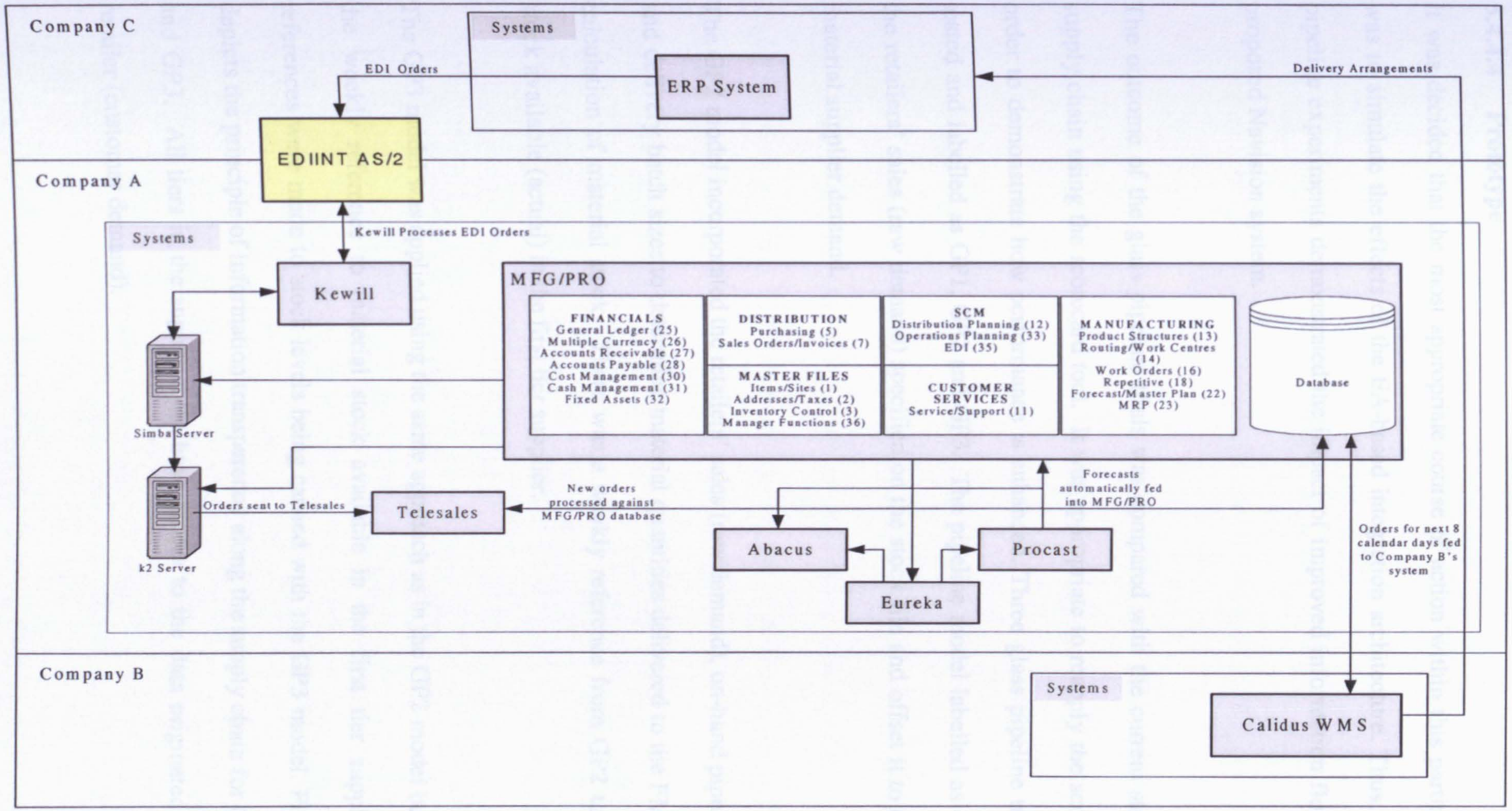


Figure 5.27 – Hybrid-Based Integration Architecture

5.4.4.4 Prototype

It was decided that the most appropriate course of action within this particular case was to simulate the effects of the EA-based integration architecture. Thus, the glass pipeline experiments demonstrated the impact of improved information flow via the proposed Navision system.

The outcome of the glass pipeline trials was compared with the current state of the supply chain using the scorecard tool. It was appropriate to reapply the scorecard in order to demonstrate how performance is enhanced. Three glass pipeline trials were tested and labelled as GP1, GP2 and GP3. The pipeline model labelled as GP1 took the retailers' sales (raw demand) specified on the stock file and offset it to create the material supplier demand.

The GP2 model incorporated the retailers' sales (raw demand), on-hand pipeline stock and delivery batch sizes to determine material quantities delivered to the FM plus the calculation of material stock. There was a weekly reference from GP2 to material stock available (actual) in the first tier supplier.

The GP3 model was applied using the same approach as in the GP2 model but without the weekly reference to material stock available in the first tier supplier. All references were made to stock levels being carried with the GP3 model. Figure 5.28 depicts the principle of information transparency along the supply chain for GP1, GP2 and GP3. All tiers in the supply chain have access to the data originated from the retailer (customer demand).

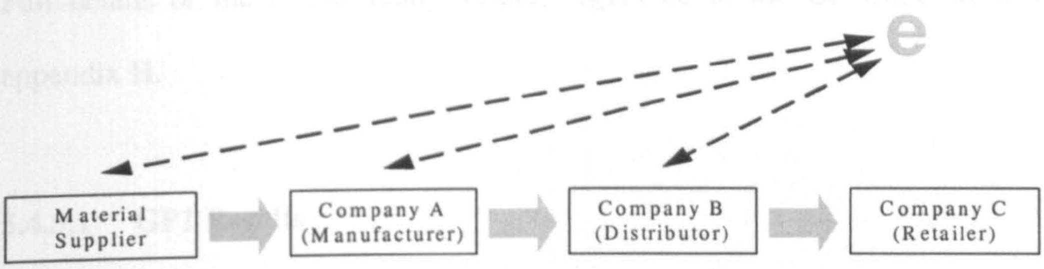


Figure 5.28 - Information Broadcast To All Levels of the Supply Chain

An important point to note is that in the GP trails customer demand, represented by sales to the retailer is the information available to the suppliers of material.

5.4.5 Stage 5 – Evaluation of Integrated Designs

This Stage illustrates the results from the glass pipeline experiments undertaken. The results demonstrate the effects of improved information flow on the supply chain under observation. Table 5.10 reveals the current values of the supply chain and the results of the GP trials.

HAT – Finger rolls/Flour A (silo 5)				
Daily demand average of product (boxes)/(kg)	**413.45/6234.89**			
Daily demand average of ingredient (kg)	**3692.23**			
SUPPLY CHAIN BEHAVIOUR MEASURES		**GP1**	**GP2**	**GP3**
Synchronisation index - overall (%)	**0**	**100.00**	**16.68**	**32.90**
ACTUAL (deliveries to Company A, sales to Company C)	0 (-87.00)	100.00	16.68	32.90
ACTUAL (Intake, sales to Company C)	0 (-43.04)			
Bullwhip -Material Receipts to Sales Company C-	**1.61**	**1.00**	**1.02**	**0.90**
Bullwhip -Intake to Sales Company C-	**0.97**			
RESPONSIVENESS MEASURES		**GP1**	**GP2**	**GP3**
Forecast accuracy (%)				
ACTUAL - Material Receipts vs. WO issues	**0.72**			
Supply chain cycle times - overall (days)	**48.22**	**18.60**	**22.15**	**26.46**
Company A	38.12	8.49	12.05	16.36
Material supplier	10.10	10.10	10.10	10.10
Pipeline Inventory - overall (days of stock)	**48.11**	**18.49**	**22.04**	**26.35**
FINISHED GOODS Company B	29.62	7.00	7.00	7.00
Raw Material Company A	8.49	1.49	5.04	9.35
Supplier Materials	**10.00**	**10.00**	**10.00**	**10.00**

Table 5.10 - Scorecard Results for the Current State and GP trials

Full details of the results (daily values) registered of the GP trials are shown in appendix H.

5.4.5.1 GP1 Results

The information transparency trials were focused on reducing the size of current material inventory. Furthermore, the information transparency trials look into replacing 'WO issues' by information based on current sales, leading to a substantial reduction on material inventory.

Starting material inventory: 14768.93 kg
Average daily material inventory hold: 5494.5 kg
Average size of deliveries: 3585.07 kg
Average size of material inventory hold based on sales: 1.49 days
With no stockout or backorder incidents reported.

The main disadvantage of this approach was that 100% availability of the production line was required to implement this solution. The initial stock of material hold was equivalent to four days of sales. Figure 5.29 shows the values plotted for GP1.

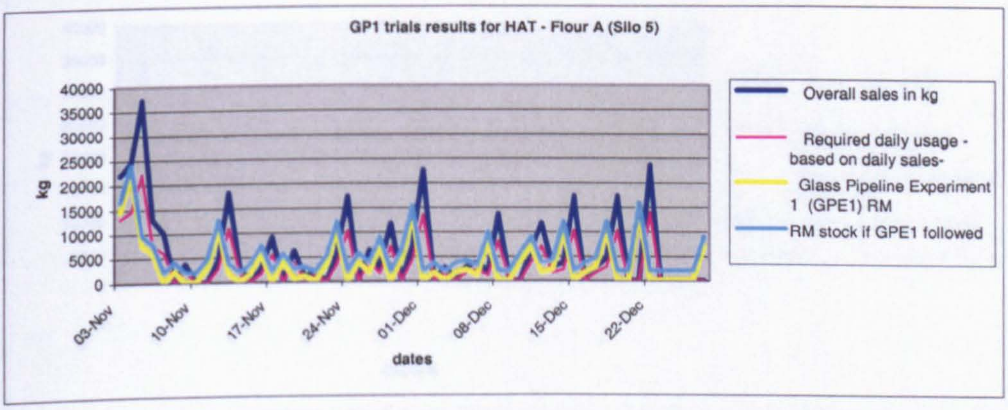


Figure 5.29 - Plotted values for GP1 trials

Figure 5.29 demonstrates perfect synchronisation between deliveries and sales to the retailer. The ideal scenario here would emphasise the fluctuation of material inventory dependent on sales to the retailer (customer demand).

5.4.5.2 GP2 Results

Starting material inventory: 14768.93 kg

Average daily material inventory hold: 18619.0 kg

Average size of deliveries: 3890.91 kg

Average size of material inventory hold based on sales: 5.04 days

Batch size of supplier deliveries used in the calculations: 1000 kg

Desired level of RM stock at Company A used in the calculations: 18461.15 kg

With no stockout or backorder incidents reported.

The initial stock of material hold was equivalent to four days of sales. Figure 5.30 shows the values plotted for GP2. The GP2 trial represents a viable solution for the FM given the batch-based nature of material deliveries. Also, it keeps updating its RM stock levels on a weekly basis.

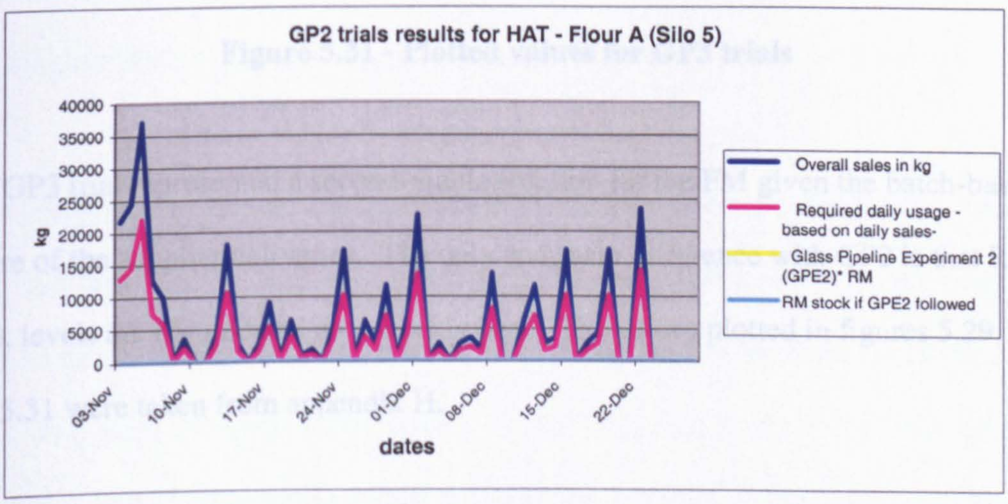


Figure 5.30 - Plotted values for GP2 trials

5.4.5.3 GP3 Results

Starting material inventory: 14768.93 kg

Average daily material inventory hold: 34528.1 kg

Average size of deliveries: 4527.27 kg

Average size of material inventory hold based on sales: 9.35 days

Desired level of RM stock at Company A used in the calculations: 18461.15 kg

With no stockout or backorder incidents reported.

The initial stock of material hold was equivalent to four days of sales. Figure 5.31 shows the values plotted for GP3.

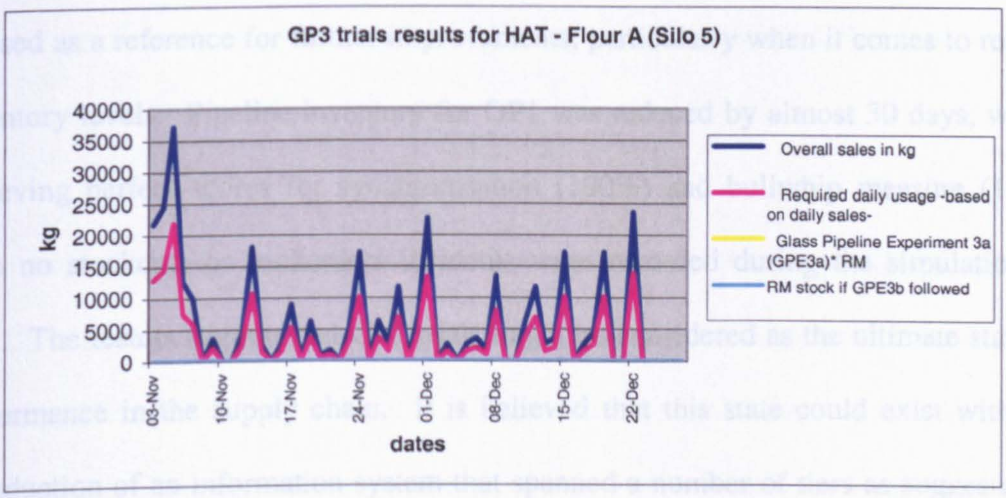


Figure 5.31 - Plotted values for GP3 trials

The GP3 trial represented a second-viable solution for the FM given the batch-based nature of the supplier deliveries. The only and main difference with GP2 is that RM stock levels are not updated on a weekly basis. The values plotted in figures 5.29, 5.30 and 5.31 were taken from appendix H.

5.4.5.4 GP Trials Analysis

The scorecard tool used to assess the performance of the supply chain (Stage 3) was also used to assess the outcome of the GP trials. This section discusses the results ascertained in the previous GP experiments.

The GP1 trial stands out from the other trials undertaken in this case. It is admitted that it would be difficult to implement a solution in the process and food industry where suppliers' deliveries exactly match customer's demand. However, the usefulness of the GP1 trial relates to the fact that the results from the simulations can be used as a reference for further improvements, particularly when it comes to reduce inventory levels. Pipeline inventory for GP1 was reduced by almost 30 days, whilst achieving perfect scores for synchronisation (100%) and bullwhip measure (1.00). Also no stockouts or backorders incidents were recorded during the simulation of GP1. The results suggest that GP1 trials might be considered as the ultimate state of performance in the supply chain. It is believed that this state could exist with the introduction of an information system that spanned a number of tiers as suggested in the 'Single Instance' Integration Architecture (Chapter 4).

The GP2 trial introduced the use of supplier deliveries using a defined batch size and a desired level of material stock (RM). The size of material batch deliveries was fixed to 1000 kg and the desired level of material stock was fixed to 18461.15 kg equal to 5 days of stock. The results of the GP2 trial 2 show the possibility of improving supply chain operations by reducing pipeline inventory to 22 days (a reduction of 26 days). Supply chain cycle time was reduced to 22.15 days. The synchronisation of 17% is a substantial improvement from the 0% synchronisation that characterises the current operations of the supply chain. The bullwhip measure for GP2 recorded an almost perfect 1.02. Also, no stockout and backorder incidents were recorded whilst running the GP2 trials.

The GP3 trial followed the same operation principle as GP2 without the weekly stock updates. The synchronisation index achieved was almost 33%, better than the synchronisation index registered with GP2. However, GP3 registered a bullwhip index of 0.90, slightly inferior to the 1.02 recorded with GP2. Pipeline inventory was reduced to 26.35 days. That figure represents a reduction of almost 22 days from current pipeline inventory. Also no stockout and backorder incidents took place during the simulation of GP3.

Once the results of each of the GP trials have been analysed it is possible to suggest that GP2 represents the most viable solution for the FM. It is possible with GP2 to reduce pipeline inventory to 22 days, compared with the 48 days that characterises current supply chain operations. Although improvements in the synchronisation index for GP2 are not massive, it does represent a substantial improvement from current supply chain operations. If GP2 is put in place Flour A (silo 5) deliveries will be more in accordance with the retailer's daily demand. Therefore in reference to the Stage 4 of this case it is sufficient to state of the EA-based architecture possesses the functionality to facilitate the improved performance considered in this section.

5.4.5.5 Safety Stock Recommendation Analysis

The results presented in the supply chain analysis motivated the use of safety stock calculations as a recommendation to reduce significantly finished goods stock levels held at the FM's frozen warehouse (finished goods storage). The average stock level of HAT was 29.62 days. The purpose of the calculations presented in this section is to illustrate the potential benefits of changing the current FG stock management between the FM and the LSP. Quantities specified over the analysis period were used for this section. Figures for HAT – finger rolls are shown below:

Total sales for the period: 22740 boxes
Average sales per day: 424.36 boxes
Daily stock average: 12248.38 boxes

The minimum sales reported for the period was 60 boxes. The maximum number of sales was 2460 boxes. Table 5.11 shows the results of descriptive statistics applied to the sales figures of the period examined. Given the number of sales per day the average stock hold was equal to 29.62 days. The standard deviation of 568.37, rounded to 568 boxes, was used when setting safety stocks. When defining safety stock levels, the main concern revolves around the probability that events might exceed the mean value of 424.36 boxes per day. Table 5.12 shows the descriptive statistics for the replenishment operations.

Based on the stock, sales and intake figures reported for HAT - finger rolls, it became evident that the current FG inventory policy for the FM needed to be adjusted. A total of 23 intake (replenishment) operations took place during the period examined. Based on the results shown in table 5.12, replenishment experiences ranged from one to twelve days. The mean of the replenishment cycle was equal to 2.13 days. The standard deviation for the replenishment cycle was 2.94.

Mean	424.36364
Standard Error	76.639329
Median	180
Mode	0
Standard Deviation	568.37248
Sample Variance	323047.27
Kurtosis	2.1529238
Skewness	1.6075727
Range	2460
Minimum	0
Maximum	2460
Sum	23340
Count	55
Confidence Level (95.0%)	153.65273688

Table 5.11

Descriptive Statistics of Sales (Demand)

Mean	2.1304348
Standard Error	0.6137565
Median	1
Mode	1
Standard Deviation	2.9434727
Sample Variance	8.6640316
Kurtosis	7.2237873
Skewness	2.8234695
Range	11
Minimum	1
Maximum	12
Sum	49
Count	23
Confidence Level (95.0%)	1.272854417

Table 5.12

Descriptive Statistics of Replenishment Cycles

The mean and standard deviation values obtained for the sales and replenishment cycles are used to determine stock with uncertainty. The next formula has been used:

$$\sigma c = \sqrt{\left(TS_s^2 + D^2 S_t^2\right)}$$

$$\sigma c = \sqrt{\left(2.13(568.37)^2 + (424.36)^2(2.94)^2\right)}$$

σ_c = 1497.99 (round to 1498)

Where

σ_c = standard deviation of combined probabilities
T = ave performance of cycle time
S_t = standard deviation of the performance cycle
D = ave daily sales, and
S_s = standard deviation of daily sales

The formula estimates the convoluted or combined standard deviation of T days with an average demand of *D* per day when the individual standard deviations are St and Ss, respectively (Bowersox *et al*, 2002). The estimated filling rate can be calculated by using the combined standard deviation.

$$SL = 1 - \frac{f(k)\sigma_c}{Q}$$

Where

SL = the stockout magnitude (the product availability level)
$f(k)$ = A function of the normal loss curve which provides the area in a right tail of a normal distribution;
σ_c = standard deviation of combined probabilities
Q = the replenishment order quantity

In this example, HAT – finger rolls was set to 99 percent product availability. The value for Q observed during the stock analysis was 900 boxes. The following formula has been used to calculate the value of $f(k)$.

$$f(k) = (1 - SL) * (Q/\sigma_c)$$
$$f(k) = (1-0.99) * (900/1498)$$
$$f(k) = 0.006$$

The calculated value of $f(k)$ was compared against the values of 'Loss Integral for Standardised Normal Distribution'. The value of k that better fits the condition is 1.4 where:

SS = safety stock in units
k = the k factor that corresponds with f(k)
σ_c = the combined standard deviation

by substituting values it is possible to obtain:

$$SS = 2.1 * 1498 = 3145.8 \text{ boxes}$$

The safety stock required to provide a 99 percent product fill rate when the order quantity is 900 boxes is approximately 3145.8 boxes. The safety stock specified is equal to 7.60 days, which is similar to the quantity used in the GP trials. The same approach presented in this section can be used on the other lines of products manufactured at the FM. Nonetheless, the current levels of stock can be reduced significantly if the procedure explained in this section is implemented.

5.4.6 Stage 6 – Supply Chain Information Plan

Discussing the overall performance first, the supply chain configuration revealed high stock levels of HAT – finger rolls at the LSP. The analysis exposed finished goods daily stock equivalent to almost 30 days (29.62 days) of sales. The application of the scorecard tool made it possible to highlight areas in the supply chain that need further work. The analysis of stock, sales and deliveries for HAT – finger rolls and the other lines of products revealed the unsuitability of the current finished goods inventory policy.

The bullwhip and synchronisation indices confirmed the uncertainty of the relation between sales to the retailer, intakes and material deliveries. With the glass pipeline trials it was possible to record solutions that achieved synchronisation indices that ranged from 18% to 100%. Also, the three glass pipeline trials presented in this work, GP1, GP2 and GP3 achieved almost perfect bullwhip measures (1, 1.02 and 0.90). Certainly the forecast-based policy used by the FM to plan production has not been successful.

The safety stock recommendations section highlighted the need to review the current levels of finished goods stock. In fact, based on the calculations made, the FM and the LSP can guarantee 99 percent product availability (HAT – finger rolls) by keeping a daily stock of 3146 boxes. There is a difference of 22 days of finished goods stock between the current supply chain and the recommended safety stock quantity.

In order obtain an enhanced supply chain performance, three integration architectures have been designed to facilitate improved information integration. The EA architecture considered the use of portal technology to enable a greater level of integration with both customers and suppliers. The Internet architecture focused upon removing the current EDI connection with the retailer and replacing it with a more cost effective XML-based system. Finally the hybrid architecture demonstrated how the current EDI procedure could be reconfigured using the latest technology.

Identifying the most appropriate architecture for this case was relatively straightforward. The company was undertaking a major systems overhaul at the time this project commenced. This presented a number of significant opportunities for not only the FM but also the retailer and its suppliers. The retailer could continue to communicate via EDI but there is also the possibility for the FM to obtain point-of-sale (POS) data with their new system, which would assist with planning and forecasting. On the other side of the supply arrangement, the raw materials suppliers could monitor stock levels and become more proactive in their approach to stock replenishment. The other architectures do offer advantages, but with a shallow supply chain the EA integration architecture represents the most comprehensive solution.

Implementing the EA system was likely to be expensive, however annual maintenance was reported to be less than that for the current MFG/PRO system. Over time the benefits in terms of cost reduction for the whole supply chain would definitely make the investment worthwhile. In terms of the other two systems there would be very little cost associated to their implementation. The benefits would be evident but not to the extent as the EA integration architecture.

The Classification Framework identified the core characteristics for this case and the companies involved. As the Literature Review (Chapter 2) stated, profits are thin and demand visibility poor and retailers are reported to have much of the power within FMCG supply chains. Therefore, it should be the manufacturer's prerogative to achieve the highest degree of integration possible.

In summary, this case represented a study of an FMCG supply chain. Three architectures to facilitate an improved level of integration have been considered. Analysis before and after revealed the extent to which improvements can be achieved. The analysis suggests that an EA-based integration architecture would best fit this scenario.

5.5 Case Study 3 – High Volume Retail Study

5.5.1 Stage 1 – Orientation

Two companies, one of which could be split into two supply network participants formed the basis of this study. Company A (a distributor) was a leading UK supplier of office products. The company has regional distribution centres (RDC) across the UK and Ireland, from which they distribute over 7000 office products.

The second company (a manufacturer) involved in the study can be split into two (Company B and Company B1). Company B and B1 developed, manufactured and marketed a wide range of products for consumer and industrial markets, including branded office products, self-adhesive materials, peel-and-stick postage stamps, battery labels, reflective highway safety products, automated retail tag and labelling systems, and specialty tapes and chemicals. The manufacturer supplied over 300 products to the distributor. The classification framework positions this case within the office supplies sector with the key supply chain challenges being power delegation, legacy integration and VMI. Figure 5.32 depicts the value stream for this case study.

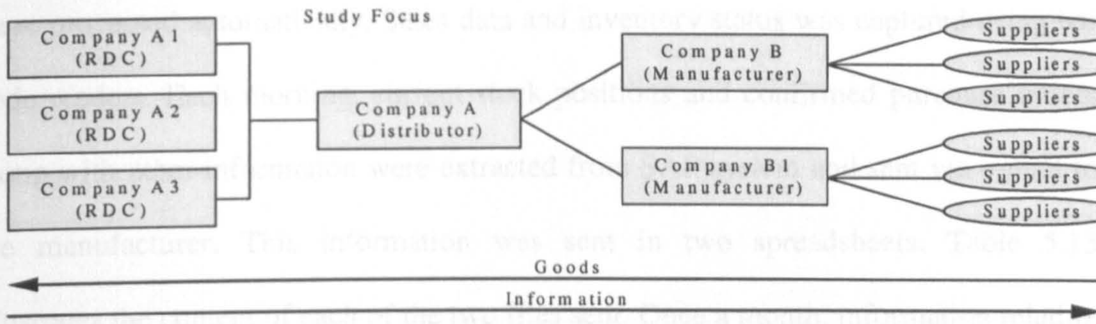


Figure 5.32 – Value Stream

The distributor and the manufacturer started to work collaboratively using Vendor Managed Inventory (VMI) in 1995. The VMI procedure, whilst being successful since 1995, does not encompass a particularly integrated system.

5.5.2 Stage 2 – Value Stream and Information Flow Mapping

The value stream and information flow mapping undertaken in this section was based around the components that were in place to enable VMI between the trading partners. There were three main systems components at the distributor. An older version of SAP was operating, which comprised of a Materials Management (MM) system and a number of financial components. There was no Production Planning component or forecasting module and most MRP was based on consumption based planning (Historical Data). The other system was a bespoke Sales Order Process & Distribution (WMS) system. This controlled the distribution centre in Hampshire. An interface existed between SAP and the WMS in Hampshire as all of the other RDCs utilised the SAP WMS.

The VMI operation with the manufacturer was run via a number of manual tasks and systems. The distributor received customer orders on a daily basis in fax, web or EDI format. Employees manually entered fax/telephone orders, whilst EDI and web orders were processed automatically. Sales data and inventory status was captured using bar code readers. Each morning, current stock positions and confirmed purchase orders along with other information were extracted from SAP system and sent via e-mail to the manufacturer. This information was sent in two spreadsheets. Table 5.13 illustrates the content of each of the two files sent. Once a month, information relating to past consumption is also sent. Figure 5.33 represents a flow diagram for the VMI procedure that takes place at the distributor.

Material File	Receipt File
Product Code	Material
Usage to Date	Open Purchase Orders
Plant Stock (less fixed issues)	Purchase Order Number
Open Sales	Date
Open Purchase Orders	

Table 5.13 – Content of Spreadsheets sent to Company B

The manufacturer (Company B), on receiving the data each morning, undertook a number of steps in order to generate an order recommendation for the distributor. As the data was received, a custom designed Excel macro converted the files into the appropriate flat file format. This information was then processed by the manufacturer's Demand Solutions system. There are two parts to Demand Solutions:

- DSF - Demand Solutions Forecasting, which consisted of 20 formulae all working to process the data.
- DSRP - Demand Solutions Requirements Planning.

The output of these internal processes was a recommendation of what the manufacturer believed it should supply. This data was then sent via a fax message to the distributor. On receiving the fax, it was checked and then manually keyed in by an employee. This was to create purchase order numbers that were subsequently sent to the manufacturer via EDI. An important point to note here is that the manufacturer did not wait for the confirmation of the orders. Instead the manufacturer worked off their own recommendation that were produced.

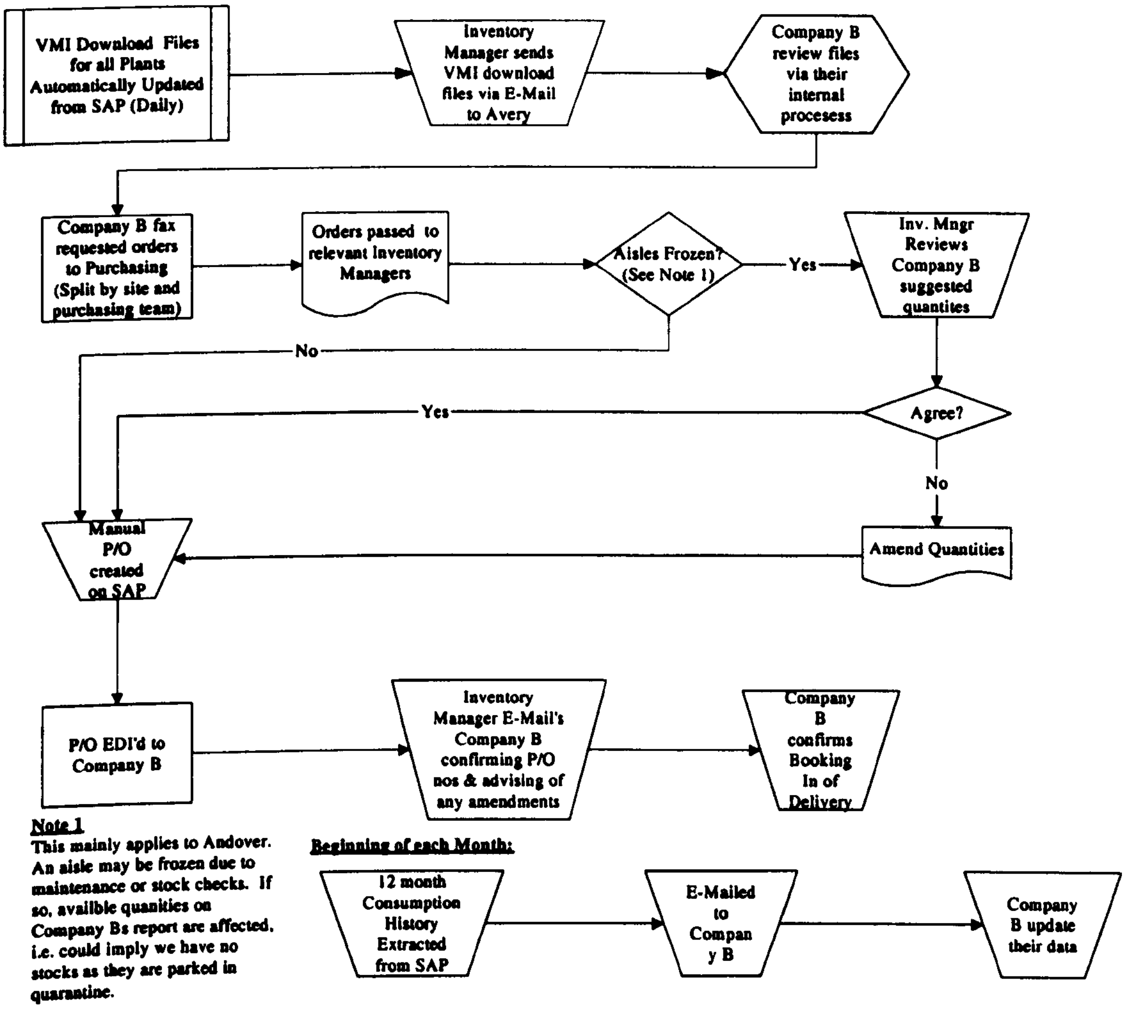


Figure 5.33 - VMI Flow Diagram

The IFD for this case is displayed in figure 5.34. It reveals the systems that are present in both companies along with the flows of information that were taking place to enable VMI. From figure 5.34 a number of problems could be identified. The VMI process whilst being a positive initiative, consisted of a too many manual processes and consequently too much human intervention. This could be associated with the level of integration for the systems and processes involved with VMI.

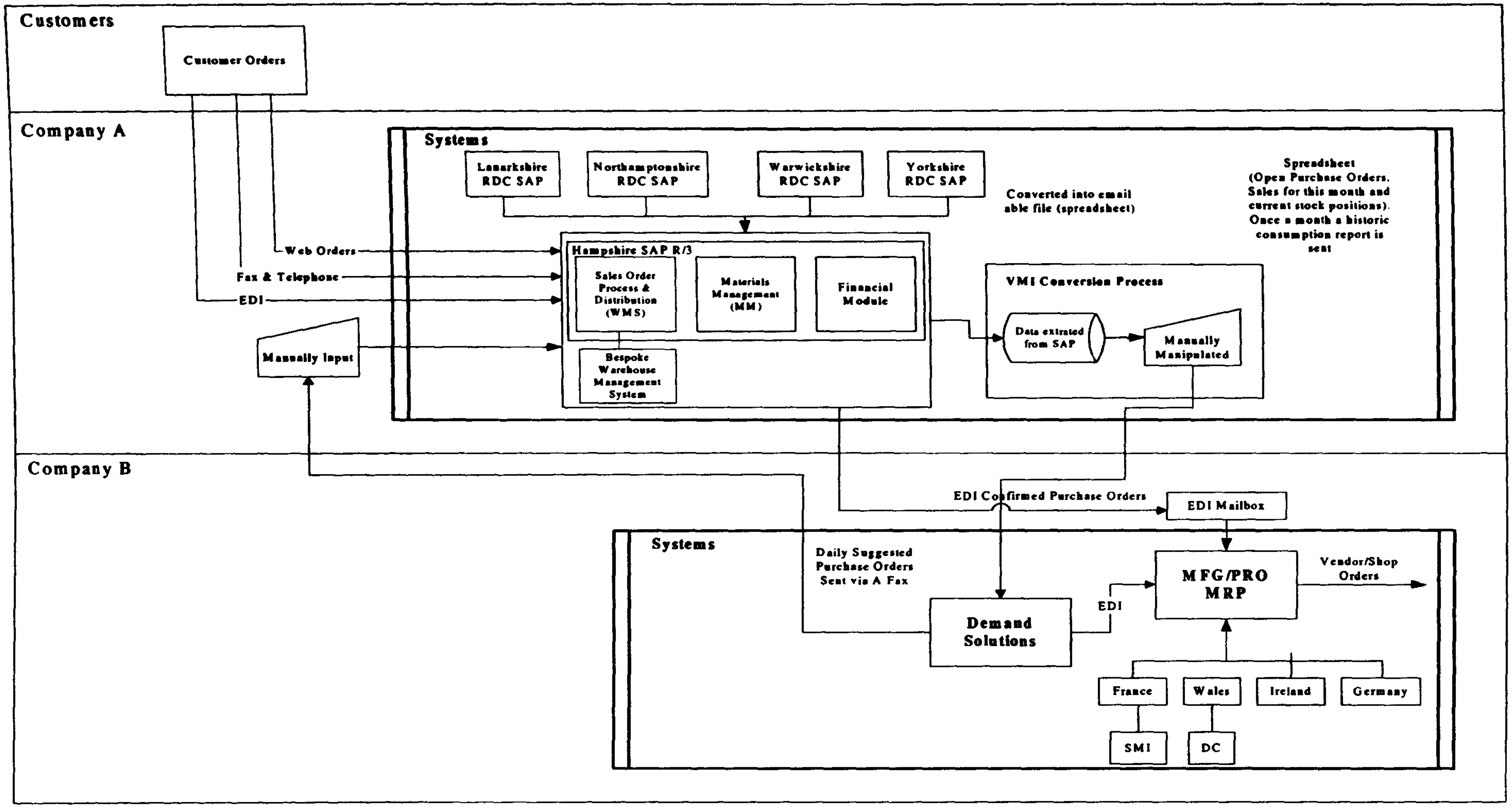


Figure 5.34 – IFD For Case 3

5.5.3 Stage 3 – Value Stream Performance Measurement

The distributor was introduced to the VMI programme operated by the manufacturer in March 1995. A 16-week project plan was drawn up with a target date of the program being operational on 6th Nov 1995 at the distributors' largest site in Hampshire. By May 1997 all products were included in the programme. The achievements to date, as perceived by the manufacturer can be categorised into 3 sectors:

- Cost of Goods Sold
  - On average 3 - & 7% cost of sales saved.
  - No costs to Company A.
  - One particular trading partner gives preferential 3% on tenders through costs saved.
  - Another saved 7% gross at no cost to them.

- Service
  - Service goes up as a greater view of the supply chain means improved feed back of information to scheduling, planning, picking and rework departments.
  - Immediate response to lumpy sales that lead to stock-outs – next day delivery of stock outs.
  - Lead time reduced from 2 weeks to 6 days

- Profits
  - Margins have never been tighter and competition puts pressure on pricing
  - By reducing the cost of doing business, profits and ultimately shareholder value will increase.

In order to analyse the performance of the current VMI procedure with a view to suggesting more integrated approaches to the initiative, data was collected over a period of time. 12 products were selected and closely monitored over the duration of the project. From this analysis of individual items of stock, a number of interesting factors emerged. Figure 5.35 depicts the flow of information and material between the trading partners.

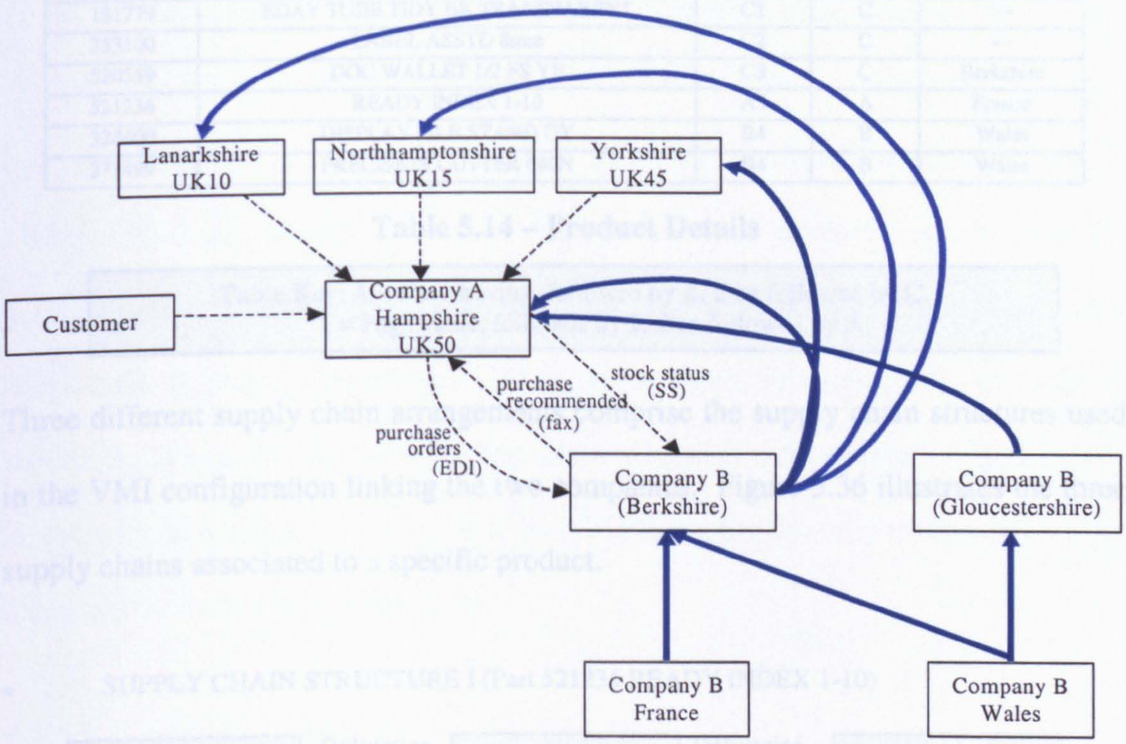


Figure 5.35 - Flow of Information and Material

5.5.3.1 Family of Components Selected for Analysis

The products in table 5.14 were selected for the analysis of sales, stock and deliveries. The products listed were being manufactured in one of the three manufacturing sites (Berkshire, Wales and France). The majority of the shipments to the distributor and its RDCs began at the Berkshire warehouse. Shipments of component 328400 were sent to the distributors Hampshire site directly from the manufacturers' Gloucestershire warehouse.

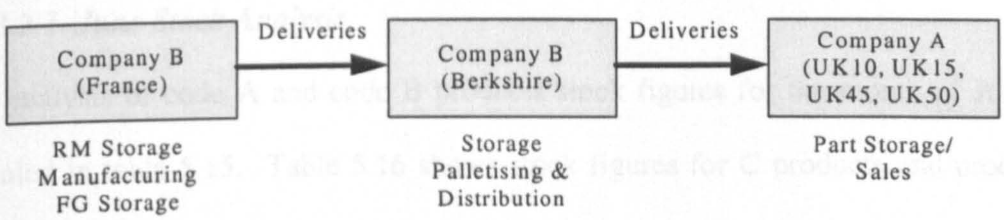
Product	Description	MRP Group	ABC Code	Origin
115992	LASER LABEL 63.5x38.1	A1	A	Berkshire
188619	EDAY SPIRAL PKT FILE M/W FS BL	A2	A	---
526089	SPIRO SORT SPRINGFILE A4 BLUE	A3	A	---
181771	LETTER TRAY BK TRANSPARENT	B1	B	---
524854	DOC WALLET FS ASSORTED	B2	B	Berkshire
182388	PREMIER MODULAR BOOK RACK BK	B3	B	---
181779	EDAY TUBE TIDY BK TRANSPARENT	C1	C	---
353100	LABEL ASSTD 8mm	C2	C	---
520559	DOC WALLET 1/2 FS YE	C3	C	Berkshire
521236	READY INDEX 1-10	A3	A	France
328400	DISPLAY FILE STAND GY	B4	B	Wales
371499	PRECISION CUTTER 640N	B4	B	Wales

Table 5.14 – Product Details

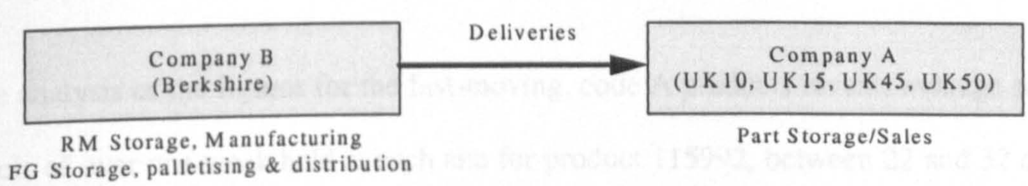
Table Key: A = Fast moving, followed by **B**, then followed by **C**. 1 = High value, followed by **2**, then followed by 3.

Three different supply chain arrangements comprise the supply chain structures used in the VMI configuration linking the two companies. Figure 5.36 illustrates the three supply chains associated to a specific product.

- SUPPLY CHAIN STRUCTURE I (Part 521236 READY INDEX 1-10)



- SUPPLY CHAIN STRUCTURE II (Part 115992 LASER LABEL 63.5x38.1)



- SUPPLY CHAIN STRUCTURE III (Part 328400 DISPLAY FILE STAND GY)

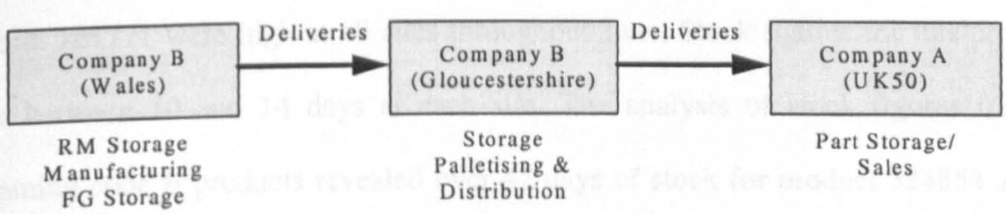


Figure 5.36 - Existing Supply Chain Structures

5.5.3.2 Analysis of Daily Stock Levels, Sales and Days of Stock at each of the Distributors Sites

Data on the 12 different products presented in table 5.14 was collected for the analysis of the performance of the VMI configuration. The results displayed in tables 5.15, 5.16, 5.17 and 5.18 represent the analysis for two months. Based on the data collected, the analysis covers daily stock levels held at each of the distributors' sites (UK10, UK15, UK45 and UK50), daily sales numbers for each product based on monthly sales figures and finally, the size of the stock held in days represented by dividing daily stock figures by daily sales. Also, the analysis for each family of products (codes A, B and C) involved plotting the stock, sales and delivery values of one component in a specific location as a way of illustrating the current management of Company A's stock by Company B.

5.5.3.2.1 June Stock Analysis

The analysis of code A and code B products stock figures for the month of June is revealed in table 5.15. Table 5.16 shows stock figures for C products and products manufactured in Wales and France.

The analysis of the figures for the fast-moving, code A products reveals average stock levels of over one week held at each site for product 115992, between 22 and 32 days for product 188619 and between 18 and 35 days for product 526089. Sales figures for product 181771 were high at all sites throughout June. Stock figures for this product were between 10 and 14 days at each site. The analysis of stock figures for the remaining code B products revealed over 47 days of stock for product 524854 at the

UK15 facility. At the same time UK50 was holding over 14 days of stock. A similar stock pattern was observed for product 182388.

Code A Products (June)						Code B Products (June)					
Part	Site	Daily stock (units)	Daily sales (units)	Daily stock (days of stock)	Sales per month	Part	Site	Daily stock (units)	Daily sales (units)	Daily stock (days of stock)	Sales per month
115992	UK10	119.37	13.86	8.61	291	181771	UK10	524.32	47.95	10.93	1007
	UK15	297.74	24.00	12.41	504		UK15	1140.26	79.76	14.30	1675
	UK45	117.05	8.00	14.63	168		UK45	339.37	32.81	10.34	689
	UK50	341.21	24.90	13.70	523		UK50	1229.74	91.48	13.44	1921
188619	UK10	102.11	3.14	32.49	66	524854	UK10	23.21	0.90	25.65	19
	UK15	199.68	7.67	26.05	161		UK15	35.95	0.76	47.18	16
	UK45	54.32	2.43	22.37	51		UK45	10.05	0.43	23.46	9
	UK50	276.79	10.05	27.55	211		UK50	42.37	2.95	14.35	62
526089	UK10	36.11	2.00	18.05	42	182388	UK10	27.26	2.33	11.68	49
	UK15	28.47	1.14	24.91	24		UK15	55.47	1.90	29.12	40
	UK45	10.11	0.29	35.37	6		UK45	13.42	0.33	40.26	7
	UK50	46.74	1.95	23.94	41		UK50	118.95	5.29	22.50	111

Table 5.15 - Code A and B products Stock Figures For June

Table 5.16 shows the figures of the stock analysis for code C products and for products made in Wales and France. Several inconsistencies in stock management were detected within a single product. For example, UK10's monthly sales of 763 units of product 181779 had on average 13.30 days of stock, while UK50 with monthly sales of 641 units had 24.24 days of stock. Product 353100 had a monthly aggregate figure across the four sites of over 400 days of stock and an aggregate figure of over 150 days of stock for product 520559.

Product 521236, with monthly sales of 8 units (for the month under study) and with more than 350 units of stock available on a daily basis, had over 2.5 years worth of stock at site UK10. Products 328400 and 371499 appear to exhibit a more cautious approach to stock management at the UK50 facility.

Code C products (June)					
Part	Site	Daily stock (units)	Daily sales (units)	Daily stock (days of stock)	Sales per month
181779	UK10	483.11	36.33	13.30	763
	UK15	390.37	19.10	20.44	401
	UK45	133.47	6.86	19.46	144
	UK50	739.89	30.52	24.24	641
353100	UK10	129.53	1.29	100.74	27
	UK15	294.84	5.14	57.33	108
	UK45	118.84	0.57	207.97	12
	UK50	409.37	9.00	45.49	189
520559	UK10	12.53	0.71	17.54	15
	UK15	36.79	3.24	11.36	68
	UK45	11.47	0.24	48.19	5
	UK50	43.58	0.57	76.26	12

Products made in Wales and France (June)					
Part	Site	Daily stock (units)	Daily sales (units)	Daily stock (days of stock)	Sales per month
521236	UK10	355.89	0.38	934.22	8
	UK15	165.32	10.81	15.29	227
	UK45	139.58	0.95	146.56	20
	UK50	231.53	18.10	12.79	380
328400	UK50	9.47	1.52	6.22	32
371499	UK50	9.84	0.95	10.33	20

Table 5.16 - Code C, Wales and France Products stock Figures For June

5.5.3.2.2 July Stock Analysis

The stock patterns for July were similar to those for June. Table 5.17 displays the stock and sales figures for code A and code B products for the month of July.

Code A Products (July)					
Part	Site	Daily stock (units)	Daily sales (units)	Daily stock (days of stock)	Sales per month
115992	UK10	118.83	11.13	10.68	256
	UK15	230.83	23.48	9.83	540
	UK45	104.17	7.52	13.85	173
	UK50	330.26	30.57	10.81	703
188619	UK10	102.83	3.83	26.88	88
	UK15	157.35	8.61	18.28	198
	UK45	33.13	3.22	10.30	74
	UK50	207.43	19.00	10.92	437
526089	UK10	29.26	0.96	30.59	22
	UK15	24.48	1.65	14.82	38
	UK45	7.61	0.74	10.29	17
	UK50	32.61	3.00	10.87	69

Code B Products (July)					
Part	Site	Daily stock (units)	Daily sales (units)	Daily stock (days of stock)	Sales per month
181771	UK10	445.39	58.57	7.61	1347
	UK15	1107.09	74.57	14.85	1715
	UK45	387.61	34.48	11.24	793
	UK50	1132.39	105.39	10.74	2424
524854	UK10	23.09	0.39	59.00	9
	UK15	23.61	1.26	18.72	29
	UK45	6.57	0.22	30.20	5
	UK50	33.13	2.39	13.85	55
182388	UK10	29.48	1.61	18.32	37
	UK15	53.13	2.22	23.96	51
	UK45	7.48	0.30	24.57	7
	UK50	108.61	4.39	24.73	101

Table 5.17 - Code A and B Products Stock Figures For July

The stock levels available for product 115992 during the month of July were similar to those observed in June. The UK15 facility registered on average 9.83 days of stock. For the same item, the UK45 facility registered the highest stock levels (13.85

days). However, reductions in stock caused by sales increases for product 188619 were observed at the UK45 and UK50 sites. Also product 526089 experienced a significant reduction in its stock levels due to an increase of sales at UK45 and UK50. The UK10 unit experienced shrinking sales during the month of July.

For code B products, a similar pattern of stock levels was observed for product 521236 during the months of June and July. The levels available covered between 7 to 14 days of stock. Fewer sales affected the stock levels of product 524854 held at A's sites. Units UK10 and UK45 carried daily stock levels of 59 and 30 days respectively. Product 182388 reported over 20 days of stock at all sites except UK10. Table 5.18 displays the stock analysis for code C products and for products made in Wales and France. At UK45, for each product, the stock levels were high relative to sales (36.04 days for product 181779, 823.63 days for product 353100 and 201 days for product 520559). For product 5212136, more than 50 days of stock was being held at each of the distributors sites.

Code C Products (July)					
Part	Site	Daily stock (units)	Daily sales (units)	Daily stock (days of stock)	Sales per month
181779	UK10	503.65	51.83	9.72	1192
	UK15	276.78	17.96	15.41	413
	UK45	117.52	3.26	36.04	75
	UK50	633.70	29.65	21.37	682
353100	UK10	84.57	2.48	34.12	57
	UK15	193.30	3.83	50.52	88
	UK45	286.48	0.35	823.63	8
	UK50	411.65	14.61	28.18	336
520559	UK10	15.22	0.30	50.00	7
	UK15	40.57	1.83	22.21	42
	UK45	8.74	0.04	201.00	1
	UK50	95.17	2.26	42.10	52

Products made in Wales and France (July)					
Part	Site	Daily stock (units)	Daily sales (units)	Daily stock (days of stock)	Sales per month
521236	UK10	379.78	5.74	66.17	132
	UK15	197.70	2.48	79.77	57
	UK45	118.78	2.04	58.13	47
	UK50	230.17	3.78	60.85	87
328400	UK50	11.09	1.57	7.08	36
371499	UK50	8.57	0.91	9.38	21

Table 5.18 - Code C Products Stock Figures For July

5.5.3.2.3 Plotted Values of Stock Figures for June and July

The figures from the analysis were plotted to provide further illustration of the stock profiles for the as-is VMI configuration. Results for the months of June and July were plotted for one product from each family of products analysed. Stock values for the following products have been plotted (Figure 5.37 – A and B Products):

- Code *A* products: 188619 UK15
- Code *B* products: 524854 UK10
- Code *C* products: 181779 UK45
- Other products made in Wales and France: 521236 UK50

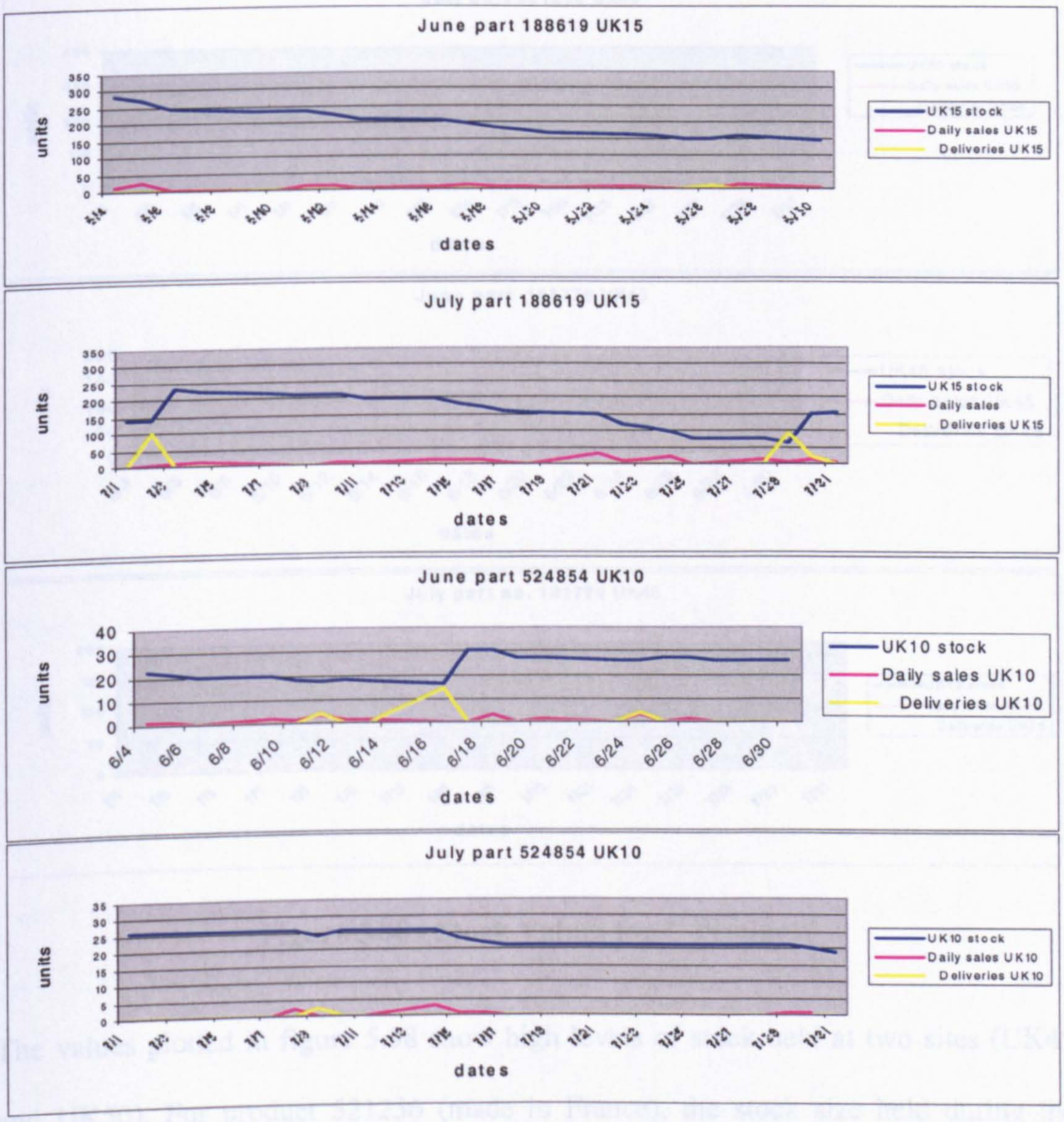


Figure 5.37 - Stock Values for A and B Products

The values plotted for part numbers 188619 UK15 and 524854 UK10 illustrated the significant difference between the number of sales registered for each product, the size of the manufacturers deliveries and the very high levels of stock held at the RDCs. Figure 5.38 reveals the plotted values for code C and products.

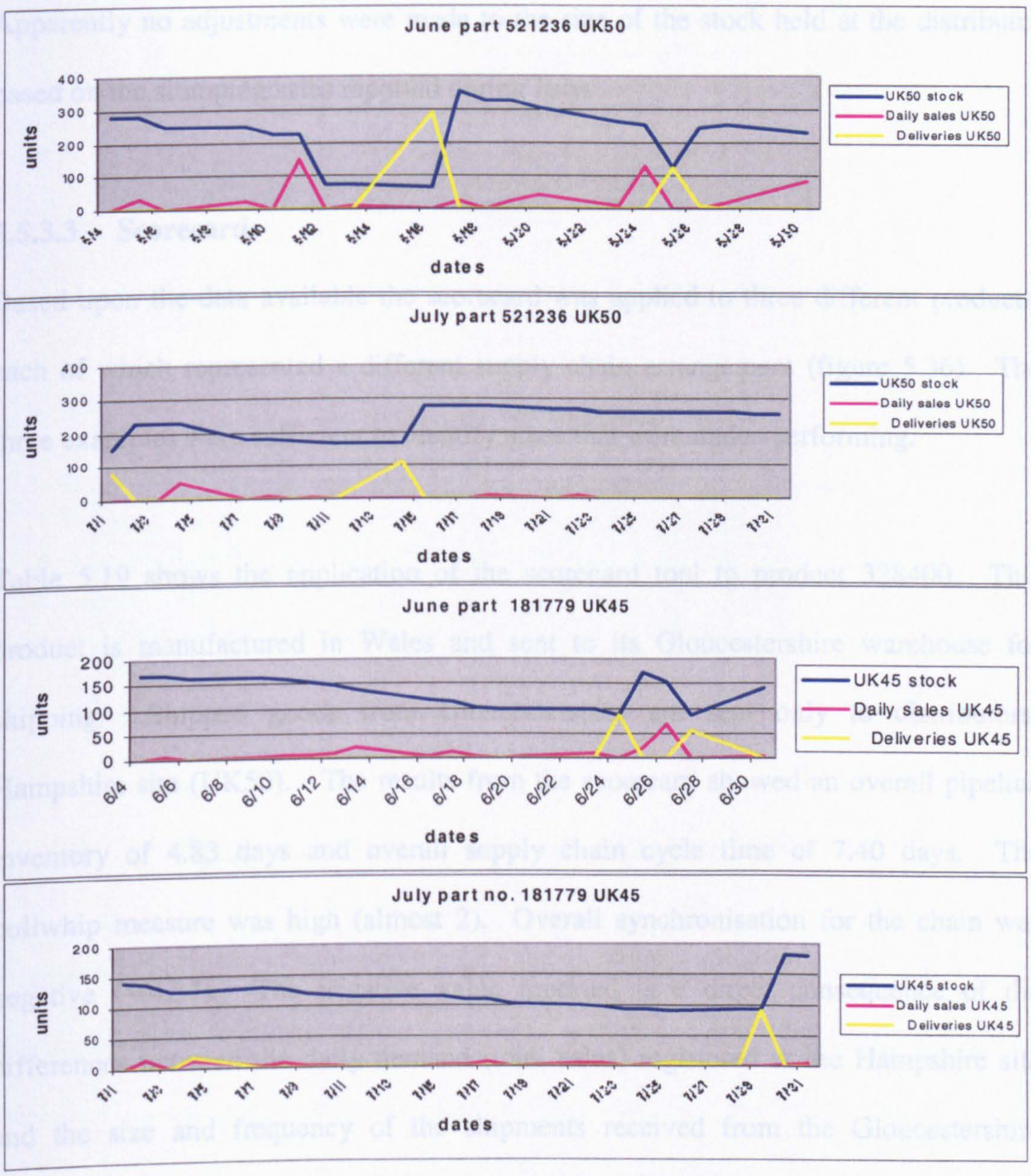


Figure 5.38 - Stock Values for C Products

The values plotted in figure 5.38 show high levels of stock held at two sites (UK45 and UK50). For product 521236 (made in France), the stock size held during the month of June was in the order of 12.79 days. However, with a substantial reduction in sales during the month of July (from 380 units to 87 units sold) stock levels held climbed to 60.85 days. The results of the analysis have revealed the incapacity of the current VMI system to adjust itself to changes experienced in the marketplace. Apparently no adjustments were made to the size of the stock held at the distributor based on the slumping sales reported during July.

5.5.3.3 Scorecard

Based upon the data available the scorecard was applied to three different products, each of which represented a different supply chain arrangement (figure 5.36). The three examples were sufficient to identify areas that were under-performing.

Table 5.19 shows the application of the scorecard tool to product 328400. This product is manufactured in Wales and sent to its Gloucestershire warehouse for shipping. Shipped goods from Gloucestershire are sent only to distributors' Hampshire site (UK50). The results from the scorecard showed an overall pipeline inventory of 4.83 days and overall supply chain cycle time of 7.40 days. The bullwhip measure was high (almost 2). Overall synchronisation for the chain was negative (-44.34). The negative value reported is a direct consequence of the differences between the daily demand (total sales) registered at the Hampshire site and the size and frequency of the shipments received from the Gloucestershire warehouse and from the manufacturing site in Wales. Figure 5.39 provides a graph of the values plotted for product 328400.

SUPPLY CHAIN BEHAVIOUR MEASURES	UK - 50
Synchronisation index - overall (%)	**-44.34**
Company B Berkshire	-71.70
Company B Wales	-16.98
Bullwhip measure (OEM - Tier 3)	**1.98**
RESPONSIVENESS MEASURES	**UK - 50**
Supply chain cycle times - overall (days)	7.40
Company A UK-50	3.40
Company B Gloucestershire	2.57
Company B Plants - Wales	1.43
Pipeline Inventory - overall (days of stock)	4.83
Company A	3.40
Company B Gloucestershire	0.77
Company B Wales - deliveries	0.66

Table 5.19 - Scorecard Results for Part 328400 (Wales)

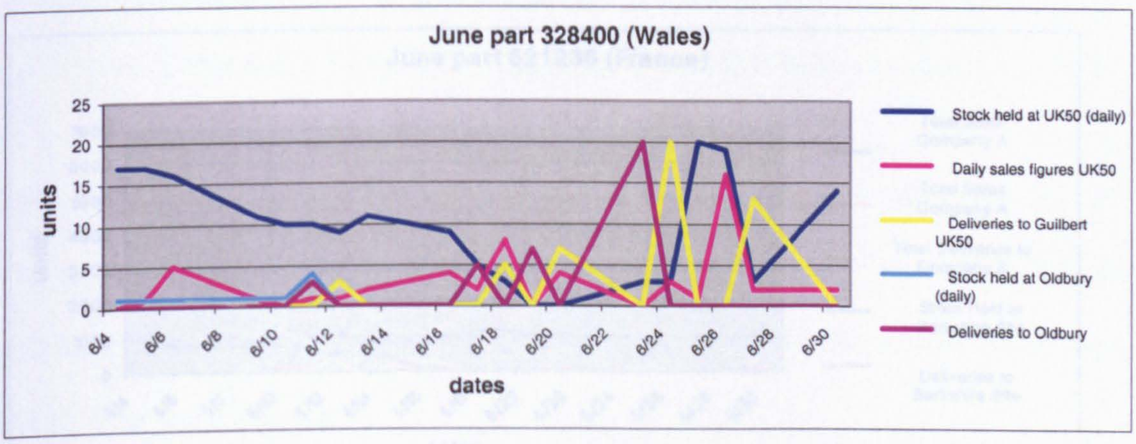


Figure 5.39 - Part 328400 Stock, Sales and Deliveries

Product 521236, manufactured in France, was the next product analysed. Each of the distributors sites appeared to perform differently with regard to this item, with UK10 identified as the most under-performing site based on the interpretation of the scorecard result. Table 5.20 shows the results of applying the scorecard to product 521236. The use of the scorecard for product 521236 required the use of weight coefficients for each of A's site. Figure 5.40 provides a graphical illustration.

SUPPLY CHAIN BEHAVIOUR MEASURES	**UK - 10**	**UK -15**	**UK - 45**	**UK - 50**
Synchronisation index - overall (%)	-7335.48	-180.53	-3.57	-428.65
Company B Berkshire	-14666.67	-45.25	0.00	-62.77
Company B plants	-4.29	-315.81	-7.14	-794.52
Bullwhip measure (OEM - Tier 3)	0.96	1.13	0.52	1.50
RESPONSIVENESS MEASURES	**UK - 10**	**UK -15**	**UK - 45**	**UK - 50**
Supply chain cycle times - overall (days)	**2258.70**	**47.37**	**535.37**	**84.80**
Company A	2254.00	14.21	530.40	7.91
Company B Berkshire	1.55	27.78	1.79	68.08
Company B France	3.16	5.38	3.18	8.81
Pipeline Inventory - overall (days of stock)	**2254.39**	**43.06**	**531.05**	**80.49**
Company A	2254.00	14.21	530.40	7.91
Company B Berkshire	0.36	26.59	0.60	66.89
Company B France	0.03	2.26	0.05	5.68

Table 5.20 - Scorecard results for Part 521236 (France)

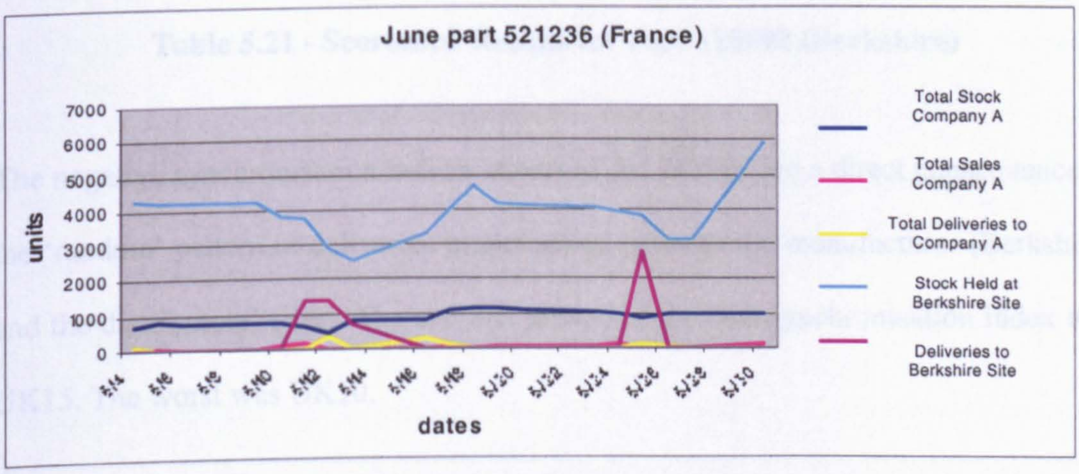


Figure 5.40 - Part 521236 Stock, Sales and Deliveries

The synchronisation indices are negative, a direct consequence of the differences between the actual units sold and the total units shipped to the distributors sites from Berkshire and from France. Supply chain cycle time and pipeline inventory are consistently high. Product 115992, manufactured in Berkshire, revealed a relatively high level of stock for a product with a process time of only few minutes and a lead-time of only one day between Berkshire and the distributors' sites. The site with the lowest overall pipeline inventory was UK10 (11.43 days) and the site with the highest was UK50 (18.79 days). The supply chain for product 115992 represents the simplest supply arrangement between the two companies. Table 5.21 shows the results of the analysis using the scorecard

SUPPLY CHAIN BEHAVIOUR MEASURES	UK - 10	UK -15	UK - 45	UK - 50
Synchronisation index - overall (%)	-157.45	-6.80	-28.22	-41.25
Company B Berkshire	-157.45	-6.80	-28.22	-41.25
Bullwhip measure (OEM - Tier 3)	0.77	0.46	0.46	1.54
RESPONSIVENESS MEASURES	**UK - 10**	**UK -15**	**UK - 45**	**UK - 50**
Supply chain cycle times - overall (days)	12.53	18.42	16.70	19.89
Company A site	8.04	11.31	13.64	12.61
Company B Berkshire	4.49	7.11	3.05	7.28
Pipeline Inventory - overall (days of stock)	11.43	17.33	15.60	18.79
Company A site	8.04	11.31	13.64	12.61
Company B Berkshire	3.39	6.01	1.96	6.18

Table 5.21 - Scorecard Results for Part 115992 (Berkshire)

The negative synchronisation indices observed for 115992 are a direct consequence of the 'random' pattern of deliveries implemented between the manufacturer (Berkshire) and the distributors' sites. The site that presented the best synchronisation index was UK15. The worst was UK10.

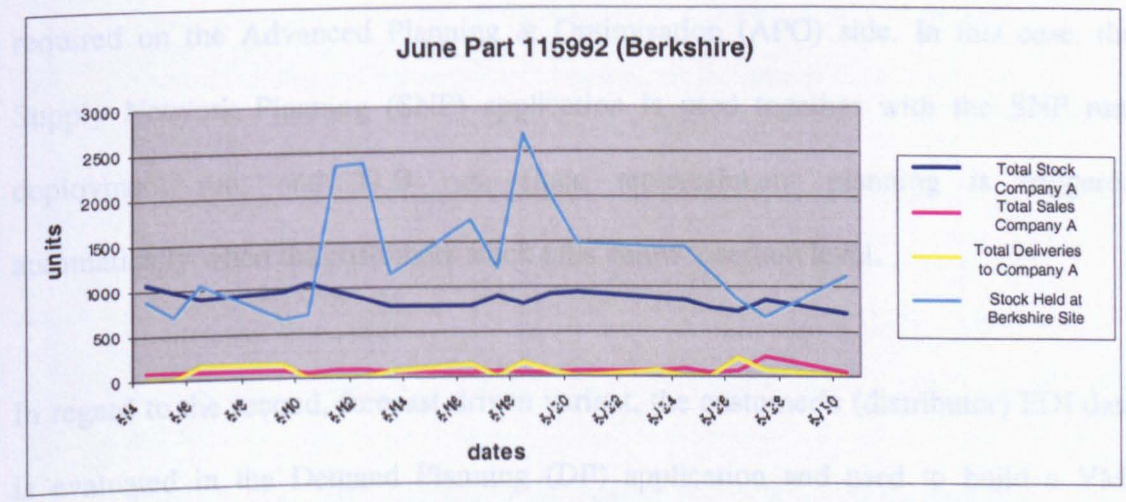


Figure 5.41 - Part 115992 Stock, Sales and Deliveries

5.5.4 Stage 4 – Design and Prototyping

Stage 3 highlighted the areas in which the architectures to follow seek to improve. Three architectures are presented in this section to facilitate improvement in both the supply chain and also the information systems infrastructure. They are discussed in the order they are considered in Chapter 4. The designs are based upon the identified value stream, however reference is made to the generic designs in Chapter 4.

5.5.4.1 EA-Based Integration Architecture

The most comprehensive alternative to enhance the VMI situation would be to install a updated version of the SAP system at both companies. The most recent versions of SAP permit VMI to be carried out in one of two ways – either reorder point planning, which responds to stock reports from the customer, or with extended forecast-driven planning, whereby the customer's requirements are forecast on the basis of sales quantities, customer forecasts, and stock reports.

Focusing on reorder point planning, the Demand Planning (DP) application is not required on the Advanced Planning & Optimisation (APO) side. In this case, the Supply Network Planning (SNP) application is used together with the SNP run, deployment run, and TLB run, since replenishment planning is triggered automatically when the customers stock falls below a certain level.

In regard to the second, forecast-driven variant, the customer's (distributor) EDI data is evaluated in the Demand Planning (DP) application and used to build a VMI forecast, which is then transferred to planning by means of SNP. The data required for VMI planning – warehouse stock, sales history, and demand forecasts – is usually transferred via EDI. As there are two VMI configurations available from SAP, the following sections discuss the two possible techniques to set up systems to run the VMI initiative.

5.5.4.1.1 Vendor APO, R/3 - Customer R/3

Table 5.22 illustrates the technical prerequisites that each party must have installed to enable this VMI configuration to function. Table 5.23 represents the process flow for this particular VMI configuration.

Business Partners Involved	Technical Prerequisites	IMG Activities
Vendor	SAP APO System (as of Release 2.0A) SAP R/3 System (as of Release 4.5B)	APO → Supply Chain Planning → Demand Planning → Basic Settings → Maintain Mapping of External Time Series to Planning Areas
Customer	SAP R/3 System (as of Release 4.5B)	

Table 5.22 – Prerequisites For VMI Initiative

Stage	Process
1	The stock and sales data in the customer's R/3 System is sent to the vendor.
2	From the point of view of the vendor, the customer with his distribution centres is represented by locations. The data for these locations is stored in APO as stocks and historical or forecast consumptions.
3	Demand Planning and Supply Network Planning are then carried out in the vendor's SAP APO System. This generates confirmed transport requests in the TLP run or deployment run.
4	Sales orders are created automatically in the R/3 System on the basis of the confirmed transport requests.
5	The sales order number is transferred to APO as part of an incremental data transfer.
6	An order confirmation is sent to the customer via EDI at the same time as the incremental data transfer between R/3 and APO. The customer's R/3 System automatically creates a purchase order on the basis of the order confirmation.
7	The corresponding order number is transferred to the vendor's R/3 System by means of an IDoc, and entered in the sales order as a reference.
8	Once the sales order has been updated in the vendor's R/3 System, it is processed in the usual manner.

Table 5.23 – VMI Process Flow Vendor APO, R/3 - Customer R/3

5.5.4.1.2 Vendor R/3 - Customer R/3

Table 5.24 lists the R/3 components required to enable the second VMI configuration.

Component	Function
Vendor (in customer system)	Transferring stock and sales data
Sales order (in vendor system)	Receiving stock and sales data via EDI Planning replenishments for customers
Purchasing (in customer system)	Generating purchase orders for an order acknowledgment received by EDI

Table 5.24 – R/3 Components Required

Table 5.25 illustrates the process flow for this VMI configuration.

Stage	Process
1	Transferring stock and sales data via EDI. The customer uses the message category *PROACT* to transfer the current stock as well as the historical sales data or the forecast sales.
2	Receiving stock and sales data via EDI. The sales data for the article is entered in an information structure in the vendor system.
3	Planning replenishments for customers. Using the sales data, vendors can forecast future expected sales of the articles concerned at their customers' sites.
4	Generating purchase orders for an order acknowledgment received by EDI. The order acknowledgment from the vendor is converted in the customer's system to a purchase order.
5	Entering the purchase order number in the sales order. The purchase order number in the customer system is entered as a reference in the associated sales order.

Table 5.25 - VMI Process Flow Vendor R/3 - Customer R/3

The components necessary to enable VMI between the trading partners have been considered. There are two possible architectures available for this EA-based VMI configuration. In the order discussed above, figure 5.42 illustrates how the configuration Vendor APO, R/3 - Customer R/3 would look. In order to deploy this architecture a number of modifications are required to the initial systems map (figure 5.34). Figure 5.43 represents the second of the two architectures.

Figures 5.42 and 5.43 demonstrate the architectures that would enable an EA-based VMI implementation between the distributor and the manufacturer. Significantly, both companies would have to be operating a SAP system, which is currently not the case.

Although Company A was in the process of upgrading their SAP system (the estimated cost of the upgrade to SAP 4.7 is 1.2 million euros) there were no plans to update the MFG/ PRO system at the manufacturer. This represents a major stumbling block in terms of being able to implement an industry proven solution for the VMI initiative.

However, referring back to the generic EA-based architectures in Chapter 4, it is fair to say that figures 5.42 and 5.43 can both be related to the 'integrated operation' architecture. Figure 5.42 represents the most integrated approach whilst figure 5.43 demonstrates a less sophisticated but highly reliable method for VMI integration. It could be said that the companies are integrated already, however, EA-based integration requires that both companies have integrated enterprise systems as illustrated below.

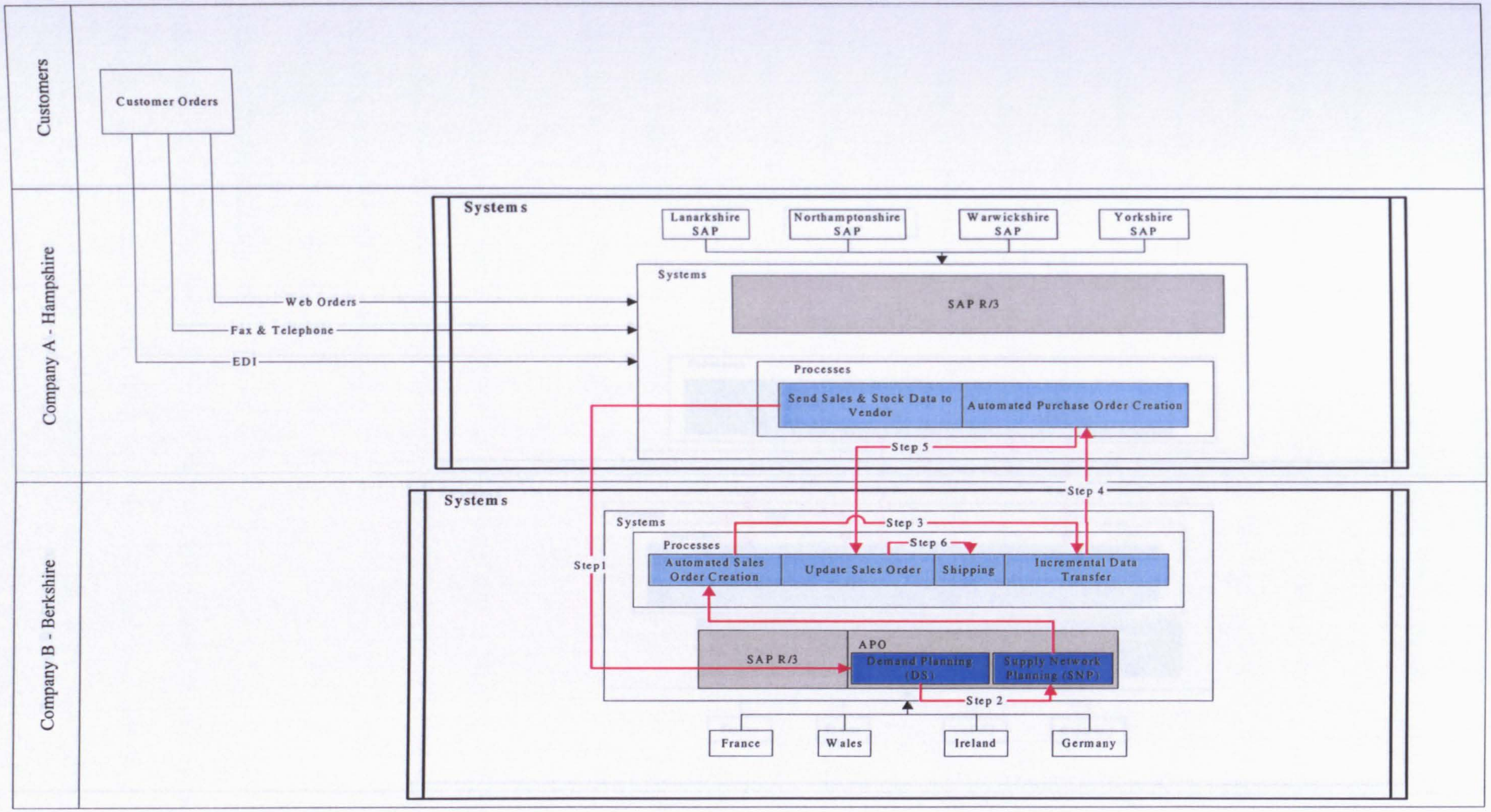


Figure 5.42 – EA-Based Integration Architecture 1 - Vendor APO, R/3 - Customer R/3

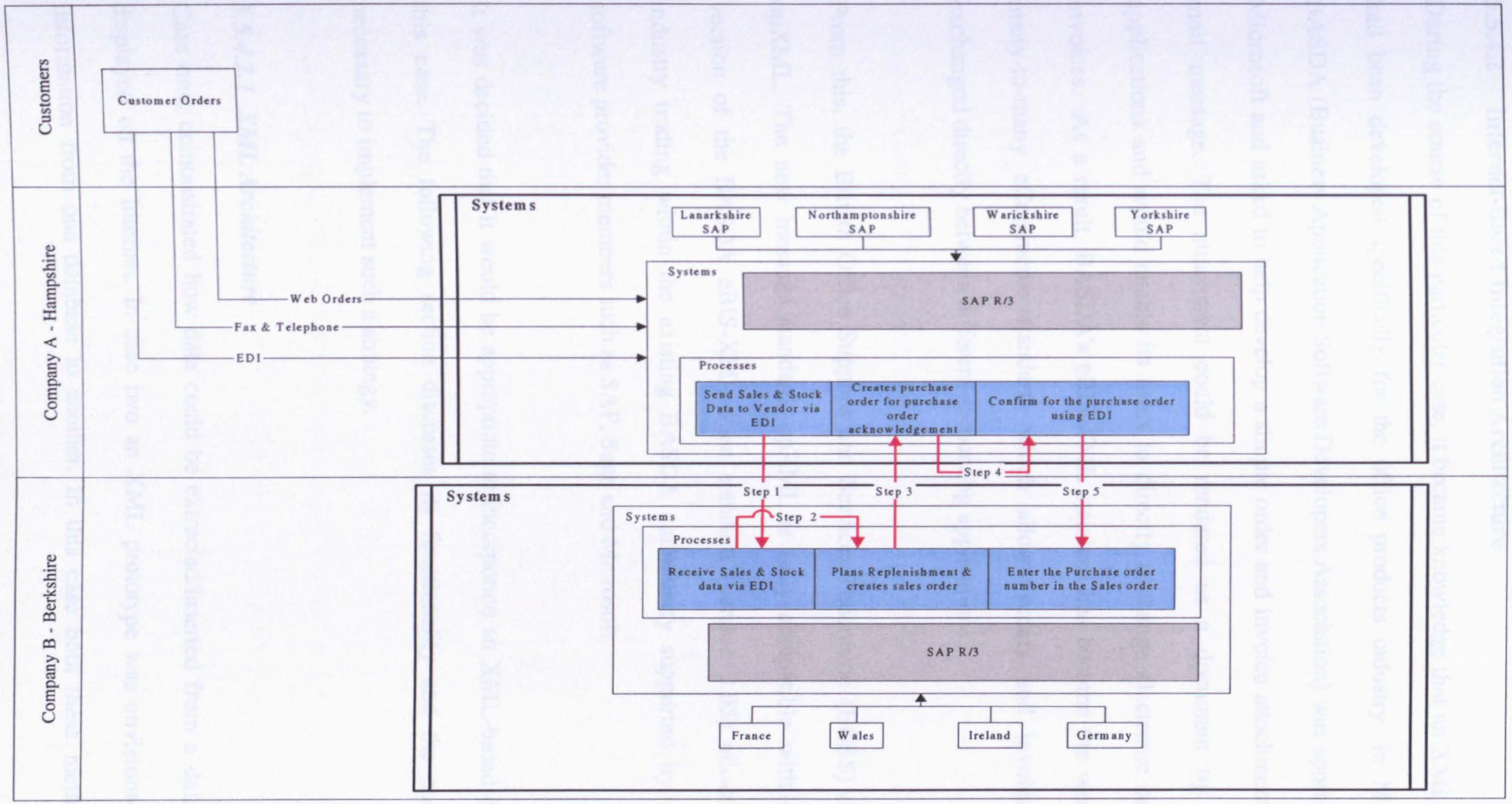


Figure 5.43 – EA-Based Integration Architecture 2 - Vendor R/3 - Customer R/3

5.5.4.2 Internet-Based Integration Architecture

During the course of this particular case, it became knowledge that an XML standard had been developed specifically for the office products industry. In May 1999, BASDA (Business Application Software Developers Association) was approached by Microsoft and asked to help develop a simple order and invoice attachment to an e-mail message. The attachment could be rendered as a document by different applications and would enable its users to directly exchange electronic orders and invoices. As a result, BASDA's eBIS-XML standard has become the world's first many-to-many eCommerce standard, which allows orders and invoices to be exchanged directly between different accounting applications.

From this, the British Office Supplies and Services Federation (BOSS) developed opXML. The new message standard, opXML is fully compatible with the latest version of the BASDA eBIS-XML open standard (version 3.05) allowing cross industry trading within the existing BASDA community supported by over 300 software provider members such as SAP, Sage and Microsoft.

It was decided that it would be appropriate to incorporate an XML-based design for this case. The following section discusses its functionality and the components necessary to implement such a strategy.

5.5.4.2.1 XML Architecture

Case one, demonstrated how data could be extracted/inserted from a database and displayed on the Internet. In case two an XML prototype was envisioned to pass information from one database to another. In this case both these methods were combined to transmit XML documents between the trading partners. Therefore, a strategy incorporating the Apache Web Server and the Tomcat Application Server provided the basis for the design. The principal function of the server applications was to transmit and receive the XML documents as necessary between the companies.

Additional components were required in order to insert and extract XML to and from the database. The first called XMLDBMS, sat in-between the database and programming environment (in this case Access and Java) and transferred data between XML documents and relational databases (Bourret, 2000). The second, known as the Xerces Java Parser – was used by XMLDBMS to handle XML file generation. Figure 5.44 illustrates the basic architecture combined with the additional components.

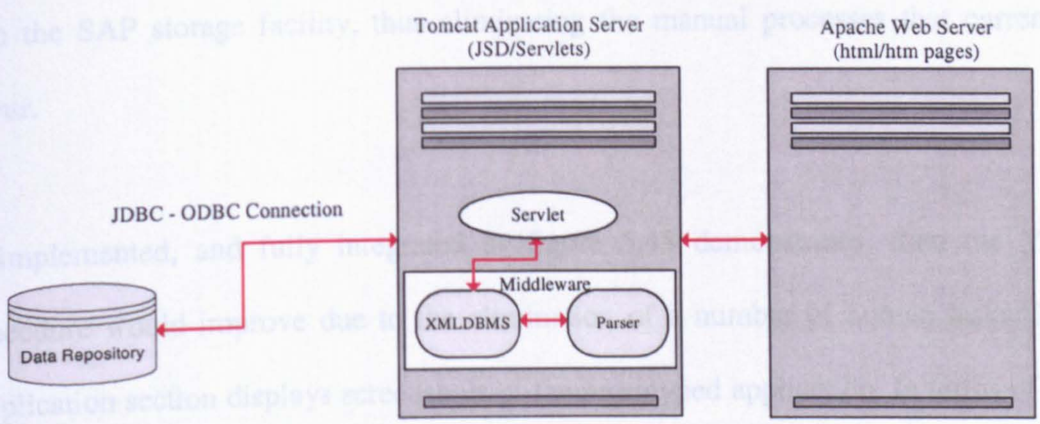


Figure 5.44 – XML Architecture with Additional Components

The Internet-based Integration Architecture displayed in figure 5.45 is based upon the original architecture were certain processes are retained due to their relative importance. XML was incorporated within processes where it was deemed to be beneficial to the current operations.

The servlet situated on the right hand side of figure 5.45 has a number of principal functions. First of all, the relevant VMI information is extracted from SAP. Following this, the data is converted into XML and then transmitted to the Servlet positioned at the manufacturer. A 'mapfile' and 'actionfile' housed on this Servlet unpack the XML document and place the data into the Demand Solutions data store. For obvious reasons the operations that the Demand Solutions system carried out could not be emulated.

On extraction of the data from the Demand Solutions datastore it was transformed via XSLT (Extensible Stylesheet Language Transformations) into the opXML standard discussed earlier. The final stage of the prototype entailed a servlet unpacking the opXML and converting it to standard XML. This information was then placed directly into the SAP storage facility, thus eliminating the manual processes that currently occur.

If implemented, and fully integrated as figure 5.45 demonstrates, then the VMI procedure would improve due to the elimination of a number of human tasks. The Application section displays screenshots of the prototyped application. In terms of the generic architectures in Chapter 4 it is clear to see that figure 5.45 can be associated with the Internet-based integration architecture Version 1. Clearly the Internet is being used as the medium to transmit information and the components required to achieve this are also similar to those displayed in Chapter 4. The extra components that have been introduced in this case are required to transmit XML. In summary, this architecture demonstrates how the Internet can be incorporated to allow integration between trading partners.

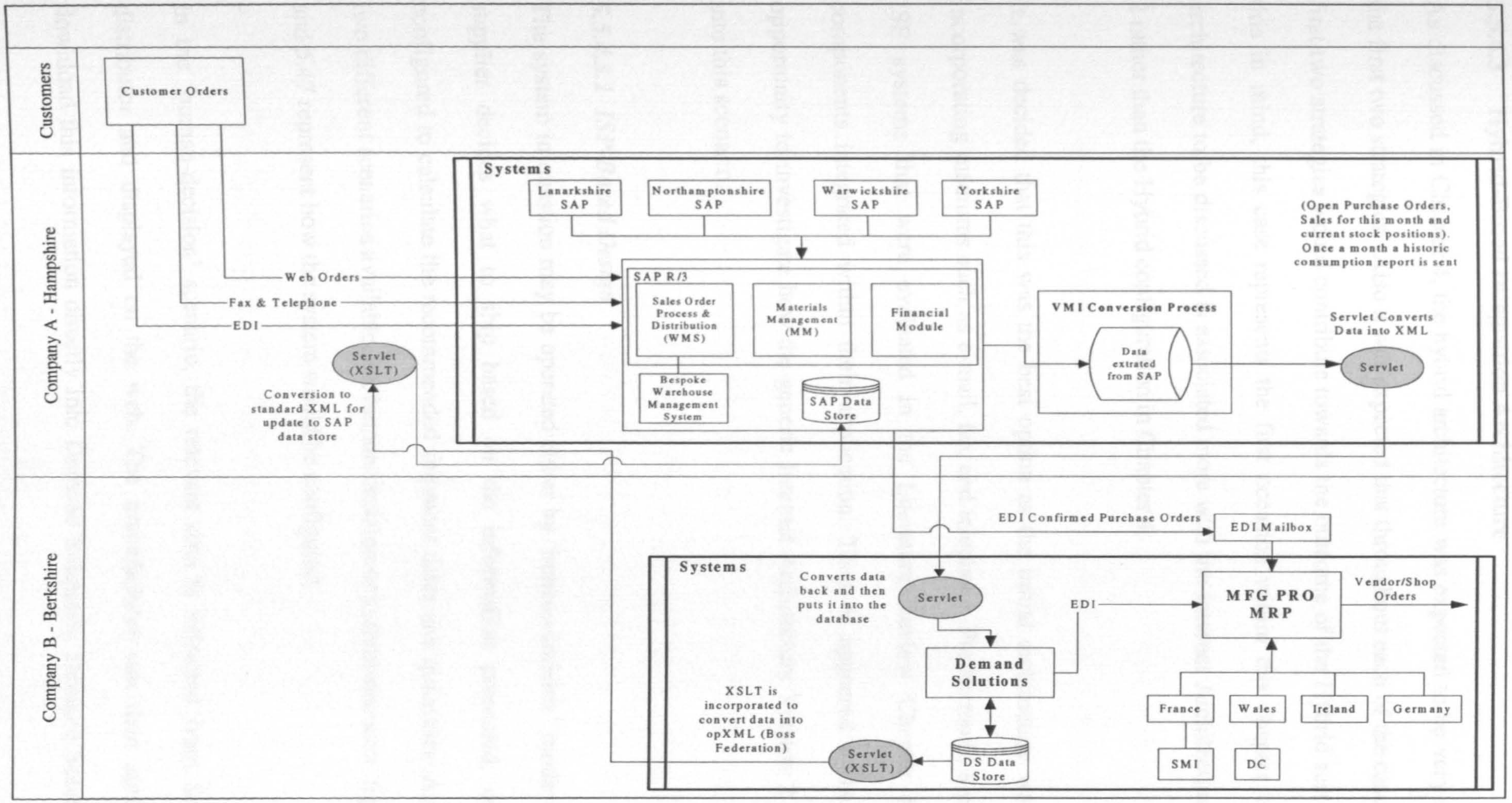


Figure 5.45 – Internet-Based Integration Architecture

5.5.4.3 Hybrid-Based Integration Architecture

As discussed in Chapter 4, the hybrid architecture was expected to be very similar to the first two strategies. Also it was expected that throughout each of the cases that the first two strategies would contribute towards the outcome of the Hybrid section. With this in mind, this case represents the first occasion within this chapter where the architecture to be discussed is associated more with the Internet Architecture Version 2 rather than the Hybrid configuration in Chapter 4.

It was decided that this was the best option as the initial architecture was already incorporating mediums such as e-mail, fax and telephone. Furthermore, a number of ISP systems that were evaluated in the Literature Review Chapter had VMI components integrated within their application. Thus, it appeared to be ideal to opportunity to investigate how the generic Internet Architecture Version 2 would fit into this scenario.

5.5.4.3.1 ISP-Based Design

The system in question may be operated either by 'human-decision' mode where the supplier decides what to ship based on the information presented, or can be configured to calculate the recommended shipment dates and quantities. As there are two different scenarios available, i.e. human-decision or system-decision, figures 5.46 and 5.47 represent how the system would be configured.

In the 'human-decision' scenario, the relevant data is extracted from SAP at the distributor and displayed on the web. The manufacturer can then automatically download this information directly into Demand Solutions. Demand Solutions then carries out its replenishment algorithm and a final recommendation is uploaded to the web. This is loaded back into SAP where purchase order numbers are created. The final process would remain the same, with the order being transferred to the manufacturer via EDI.

The second scenario (figure 5.47) is marginally different as there is less human intervention involved. The web application extracts information directly from SAP. From this data (usage, stock levels, purchase orders) the VMI information is automatically calculated and subsequently displayed on the web. The manufacturer can then directly download this information into MFG/PRO system, which schedules when to manufacture and deliver the order. Having processed the information, two options are available for the next stage. The original method in which the information was printed could be used, however, instead of faxing it to the distributor, it could be manually keyed into the web application. A more integrated method, providing less of a chance for human error would involve a direct upload from MFG/PRO to the web application. The interface between SAP and the web application can then remotely transmit the data.

The Internet-based Generic Architecture Version 2 considered in Chapter 4 can be configured in either a 'one-to-one' or 'one-to-many' (hub) set-up. Clearly this situation represents a 'one-one' trading partner environment. However, it would be possible to develop this application to incorporate other suppliers.

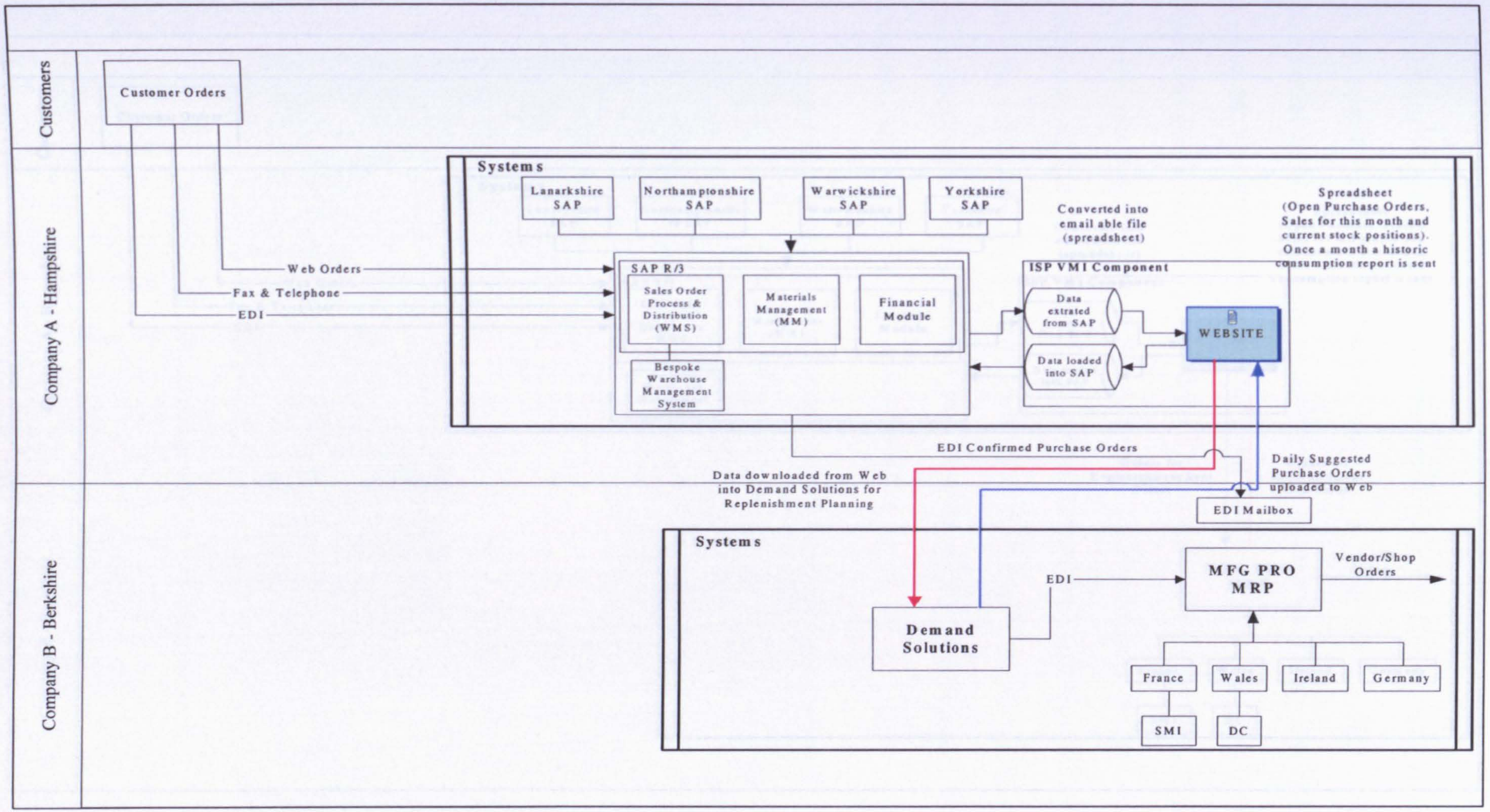


Figure 5.46 – Hybrid-Based Integration Architecture - ISP Solution 'human-decision' Configuration

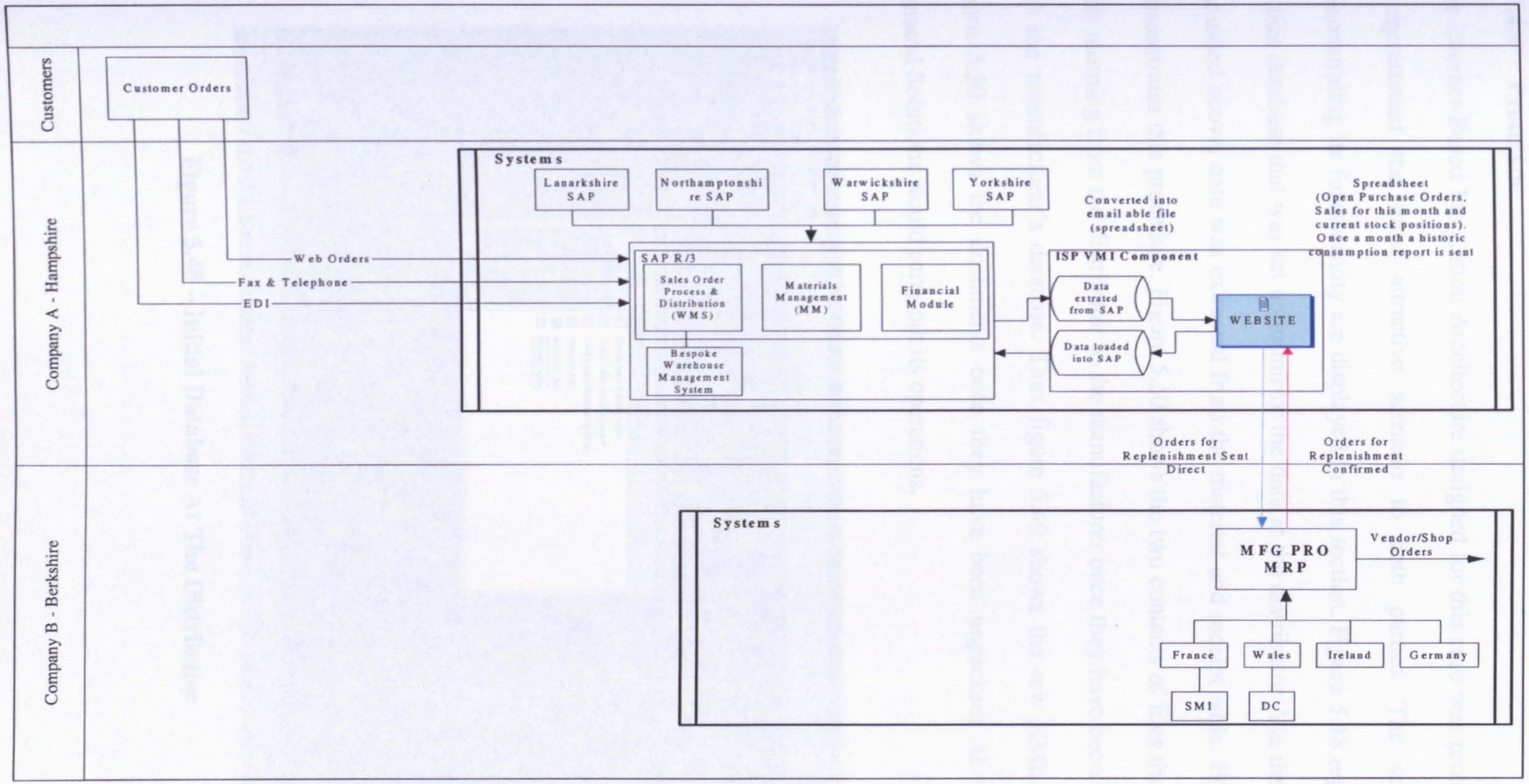


Figure 5.47 – Hybrid-Based Integration Architecture - ISP Solution 'system-decision' Configuration

5.5.4.4 Prototype

The Internet-Based Integration Architecture designed for this case was prototyped as it represented the most attractive scenario to both parties. The screenshots demonstrating its functionality are displayed in this section. Figure 5.48 represents a replica database that was set up to mirror the data at the distributor. Via the methods discussed above, data was extracted from the material and receipt table. Figure 5.49 demonstrates this procedure. Figure 5.50 shows the two contents of files that are sent each morning from the distributor to the manufacturer once they have been unpacked into the manufacturer's database. Thus figure 5.49 shows the raw XML data and figure 5.50 shows the documents once they have been unpacked. At this point Demand Solutions would carry out its operations.

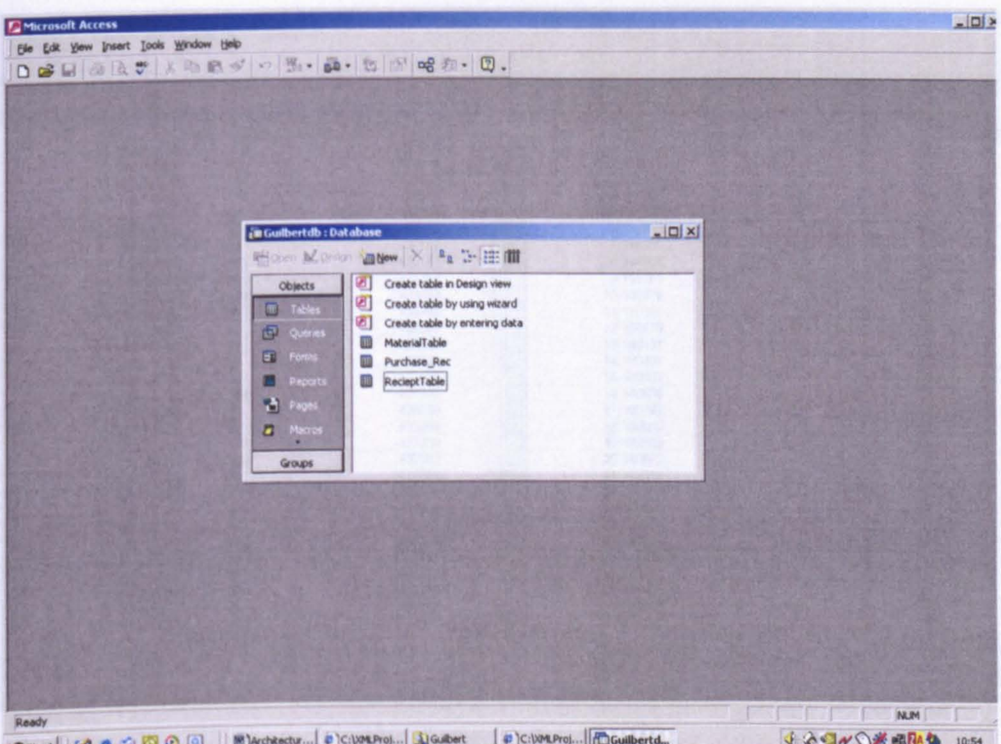


Figure 5.48 – Initial Database At The Distributor

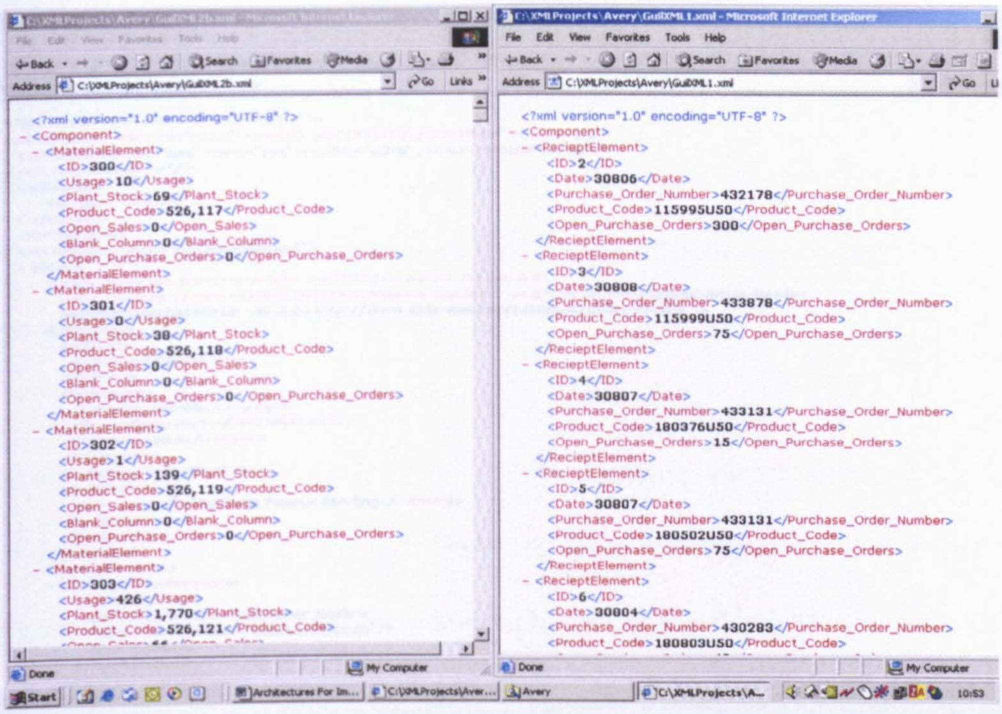


Figure 5.49 – Data extracted from Material Table & Receipt Table

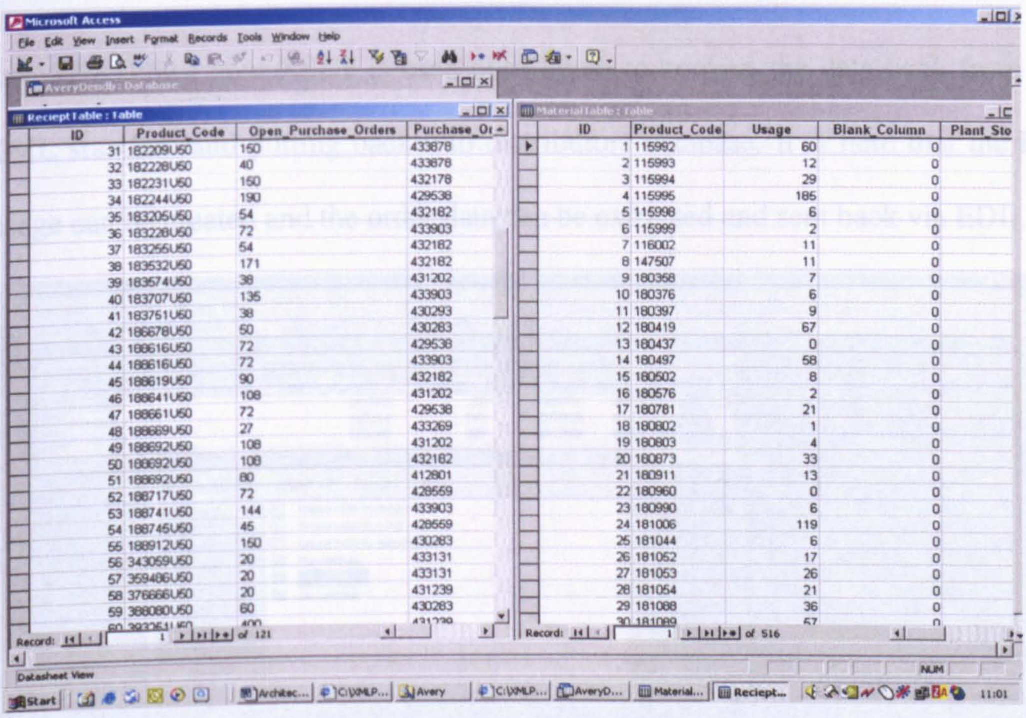


Figure 5.50 – Data inserted into Company B Database

Figure 5.51 shows the data being extracted from the Demand Solution datastore and being converted in the opXML standard via XSLT.

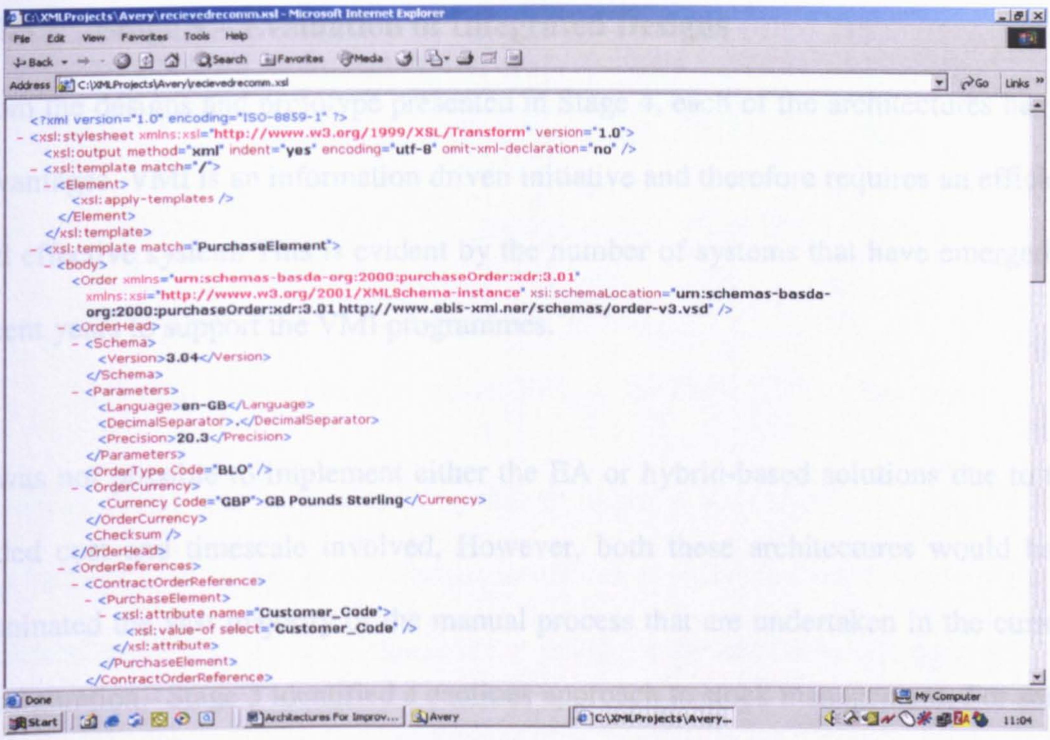


Figure 5.51 – Data extracted & Converted into opXML via XSLT

Figure 5.52 shows how XSLT is used once again to convert the data back from the opXML standard and putting back into distributors database. It is here that the EDI message can be created and the order data can be extracted and sent back via EDI.

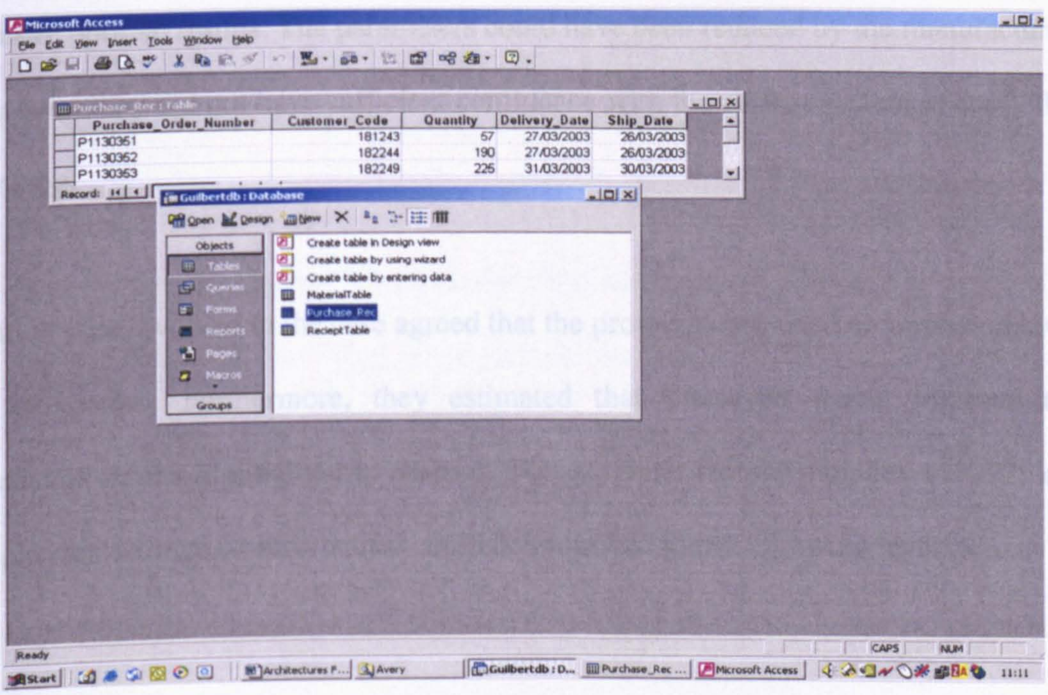


Figure 5.52 – Recommendation converted back from opXML

5.5.5 Stage 5 – Evaluation of Integrated Designs

From the designs and prototype presented in Stage 4, each of the architectures has its advantages. VMI is an information driven initiative and therefore requires an efficient and effective system. This is evident by the number of systems that have emerged in recent years to support the VMI programmes.

It was not possible to implement either the EA or hybrid-based solutions due to the added cost and timescale involved. However, both these architectures would have eliminated the vast majority of the manual process that are undertaken in the current configuration. Stage 3 identified a cautious approach to stock management. For some products, stock coverage at the distributor represents weeks, months and in certain cases years worth of sales. Two main reasons were behind the poor performance of the current VMI configuration. First and foremost the information systems behind the current procedure were disjointed and dated in terms of their functionality (forecast algorithms). Furthermore the parameters of the current system were not being set to achieve optimal results. The parameters could have been reduced by the manufacturer, however, they did not have sufficient confidence with the current system to apply this thinking.

Both parties involved in the case agreed that the prototype provided an improved level of integration. Furthermore, they estimated that prototype would improve the scorecard results highlighted in Stage 3. For example, for part number 115992, key employees estimated performance could be improved to the following levels:

SUPPLY CHAIN BEHAVIOUR MEASURES	UK – 50 Before	UK – 50 After
Synchronisation index - overall (%)	-41.25	40-60
Bullwhip measure (OEM - Tier 3)	1.54	1.3
RESPONSIVENESS MEASURES		
Supply chain cycle times - overall (days)	19.89	10.0
Pipeline Inventory - overall (days of stock)	18.79	9.0

Table 5.26 – Predicted Scorecard Results for Part 115992 (Berkshire)

However, it was decided that the only way to improve VMI significantly in this case was to implement either the EA-based architecture or Hybrid-based architecture. In addition, the failing of the manufacturer to recognise the excess stocks present in the current system supported the business case behind the implementation of a new system.

In summary, both parties agreed the prototype solution represented an improvement in the current situation. However, with the extent of the issues identified with Stage 3 it became apparent that a more sophisticated tool was needed to undertake the demand planning for VMI. Combined with this an increased level of integration was therefore required. Hence the EA or hybrid-based solutions illustrated the best way forward.

5.5.6 Stage 6 - Supply Chain Information Plan

The examination of the VMI arrangement and information and material flow interchange between buyer and supplier revealed that the distributor avoids a potentially labour intensive and expensive purchase ordering system and appears to enjoy a very high level of customer service with the manufacturer. Products are 'pushed' through the system by the manufacturer rather than 'pulled' by the distributor. Benefits of the arrangement include:

- The creation of a close relationship between the staff of both companies.
- Low inventory levels for products manufactured in Berkshire.
- Low procurement/planning overhead expense at the distributor.
- The manufacturer has a streamlined their approach to planning.

In addition, in relinquishing re-supply decisions, the distributor has helped mitigate the uncertainty of demand that otherwise would have been faced at the manufacturer and therefore allowed them to plan their production autonomously and efficiently avoiding schedule peaks and troughs or the maintenance of excess capacity or high levels of stock. However, the analysis revealed a cautious approach to stock management. For some products, stock coverage at the distributor represents weeks, months and in certain cases years worth of sales. The average daily stock for all products represented no less than six days worth of sales. The bullwhip and synchronisation indices confirmed the existing differences between the demand for products (distributors UK sales) and the manufacturers management of their customers stock.

In summary, the current VMI arrangement has yielded a level of operational performance that was better than the previous means of communicating re-supply orders between the trading partners. However, the practice of re-supply could be prosecuted more aggressively and responsively and the existing re-supply indicators and recommended levels of safety stock need to be reviewed and reduced.

Taking the above into account, a selection of architectures were designed to improve the VMI situation. The EA-based architecture discussed a fully integrated SAP VMI solution. The Internet-based architecture enhanced integration by incorporating an

XML standard designed for the office products industry, whilst the hybrid solution discussed the suitability of an ISP VMI solution. The components required to support these architectures are varied. The EA solution requires SAP to be installed at both parties. However, with plans in place for a SAP upgrade at the distributor but not at the manufacturer, this was not ideal. It would be possible for an interface to be developed between SAP and MFG PRO, but as the SAP architecture revealed, the majority of the VMI processes would be undertaken at the manufacturer. For the Internet architecture very little expenditure or development time would be required. The ISP solution required some investment and it is negotiable as to the extent the ISP solution would be integrated.

For this case the most appropriate supply chain information architecture is the hybrid solution. Each of the architectures discussed has its advantages for this particular supply chain scenario. Ideally, the introduction of a fully integrated SAP system at both companies would prove to be the most beneficial. However, this was unlikely to happen and with the manufacturer supplying a range of different companies the probability that everyone would transfer to SAP was unrealistic. Therefore, incorporating a third party ISP into the VMI initiative represents a valid alternative with a number of benefits. The more integrated the ISP VMI solution, the less requirement there is for Demand Solutions. Here both companies could step back from the process and rely on others to ensure its efficiency. However, costs would be incurred and a complete cost benefit analysis would have to be undertaken before following this route. The Internet integration architecture does provide improved integration at minimal costs, however it would not reach the levels of integration of the EA or Hybrid.

If any of the architectures were fully implemented the benefits to the supply chain would be significant. The VMI initiative has proved to be successful to date and this research has identified that it is far from operating at an optimal level. Costs would be further reduced, inventories cut and synchronisation enhanced should a more integrated architecture be introduced.

VMI is an information driven initiative and thus integration is the key. It is fair to say that the faster moving the supply chain the more integration is required to facilitate a competitive VMI operation. Therefore the classification of the supply chain does have a role in determining the configuration of the proposed integration architecture.

In conclusion, the operations analysis revealed that the system is not operating to its maximum potential. Each architecture had its advantages, but in order to make a decision on which particular path to follow, the long-term strategies of both companies would have to be investigated.

5.6 Case Study 4 – High Volume Automotive Remanufacturing Study

5.6.1 Stage 1 – Orientation

This case involved two companies of considerably different size and focus situated in an automotive reverse flow supply chain. The larger of the two (Company A, manufacturer) was a major supplier of automotive transmissions and transmission components. The second, considerably smaller company (Company B, remanufacturer) was a customer of the larger and manufactured and assembled both original and re-conditioned transmissions. The re-conditioned transmissions that Company B manufactured were supplied back to Company A's parent company (Parent Manufacturer) for nationwide distribution. Figure 5.53 represents the value stream for this case.

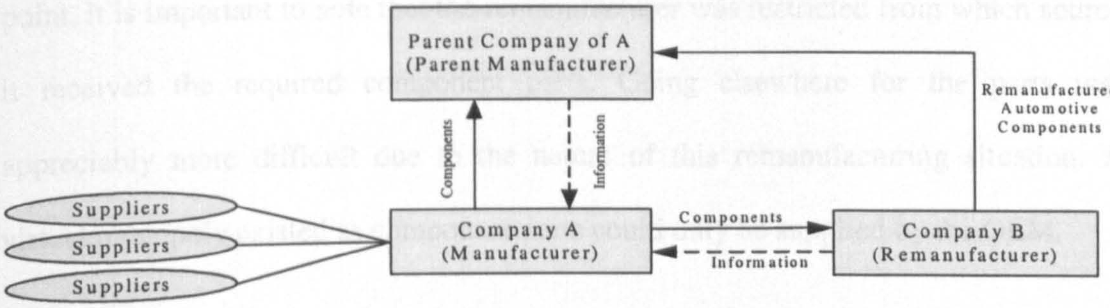


Figure 5.53 – Value Stream

In recent years the information interchange between the manufacturer and remanufacturer took place on the first working day of the month via a fax message. On an *ad hoc* basis when problems arose, a combination of the telephone and fax were used in order for the remanufacturer to obtain emergency stock replenishment. With the exception of a fax message stating 'Part Number' and 'Quantity', no other information was made available for the manufacturer to plan their forecast and build schedule. This situation caused a number of problems as company manufacturer was left to interpret the information and consequently based its forecasts purely on an intuitive assessment of the dynamics of the market.

The inadequacies of the forecasting approach meant that the manufacturer did not know when to supply the parts during any given month. In relation to the fax message it would have been far more beneficial if current stock levels and build forecasts for the following month had been included, as this information could have been transposed to the larger company's MRP system in order to generate accurate schedules. However, a combination of limited investment and restricted functionality of the current MRP system in place at the manufacturer caused significant disruption. The quality and quantity of the information transferred led to regular stockouts in the smaller transmissions producer and consequently customer dissatisfaction. At this point, it is important to note that the remanufacturer was restricted from which source it received the required component parts. Going elsewhere for the parts was appreciably more difficult due to the nature of this remanufacturing situation. A virtual monopoly existed as component parts could only be supplied by the OEM.

The problems that the manufacturer was experiencing could be pinpointed to the quality and quantity of the information being supplied. In summary, the information interchange between the two companies was via fax messages on a once a month basis. Recently, gradual increases in the volume and mix of parts required and the fluctuation of their demand patterns have led both companies to seek a more flexible information system. Thus, the key supply chain challenges were identified as being remanufacturing, a monopolistic supply scenario and communications ignorance.

5.6.2 Stage 2 – Value Stream and Information Flow Mapping

Focussing on Company A (manufacturer) first, the Common Material Management System version 3 (CMMS3) was the principal system at the time of this project. Plans were being put in place at the time to transfer to SAP but this process was expected to last a number of years. The systems infrastructure at the manufacturer was largely determined by their parent company. For obvious reasons the parent company wanted a common system throughout all their subsidiaries. Also the manufacturer's main line of business consisted of supplying transmissions for the vehicles produced by its parent company. The manufacturer had an EDI infrastructure in place that allowed frequent communication with its parent company with regards to build forecasts and schedules.

CMMS3 is a global system controlling material and component supply. It was the mainframe computer system used to support the manufacturer's parent company Assembly and Manufacturing Plants Worldwide. It supported the following operations: shipping, receiving, inventory, scheduling, releasing, bar coding, warehousing, and accounting. This system was also used to support electronic communication between the Parent Company and its suppliers and customers. The CMMS3 system is a relatively old system and one, which is not considered to be advanced when compared to modern day Enterprise Systems such as SAP and i2. Figure 5.54 reveals a detailed analysis of the CMMS3 system. Appendix I illustrates screen dumps from 2 of the more commonly used CMMS3 screens.

The MP&L department whom championed had the following hardware in place: 8 Dell PIII PC's on lease, all with MS Explorer and Internet Access.

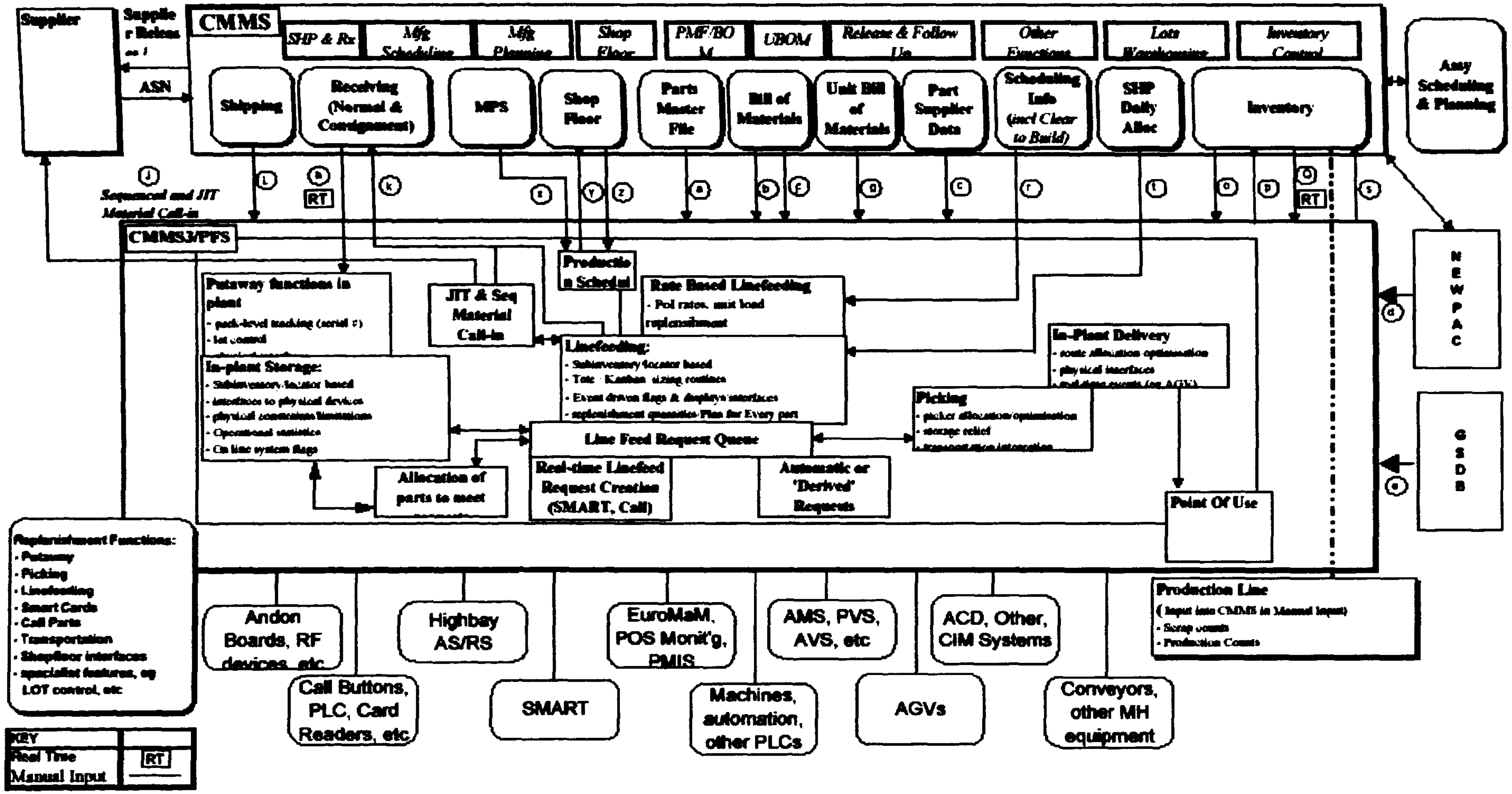


Figure 5.54 - CMMS3 - Modules, Functionality and Interfaces

At the remanufacturer it was not a surprising to see that the systems infrastructure was considerably less complex than that of its supplier. The Excel EFACS ERP system version 7.2 was the system in operation. This system undertook all control of all planning and control operations. A database underpinned the EFACS system. In terms of the hardware and software capabilities there was approximately 30 office standard PIII 750MHZ PC's and 2 Application Servers running the network. The company website was held with external ISP and no infrastructure had been put in place to host their own site. Key software included Macromedia Coldfusion (a rapid application development tool) and a scheduling application to run a number of arbitrary tasks.

Figure 5.55 illustrates the IFD for this case. Internally both systems operated successfully. However, as figure 5.58 clearly shows, there is a poor communication infrastructure in place between the trading partners.

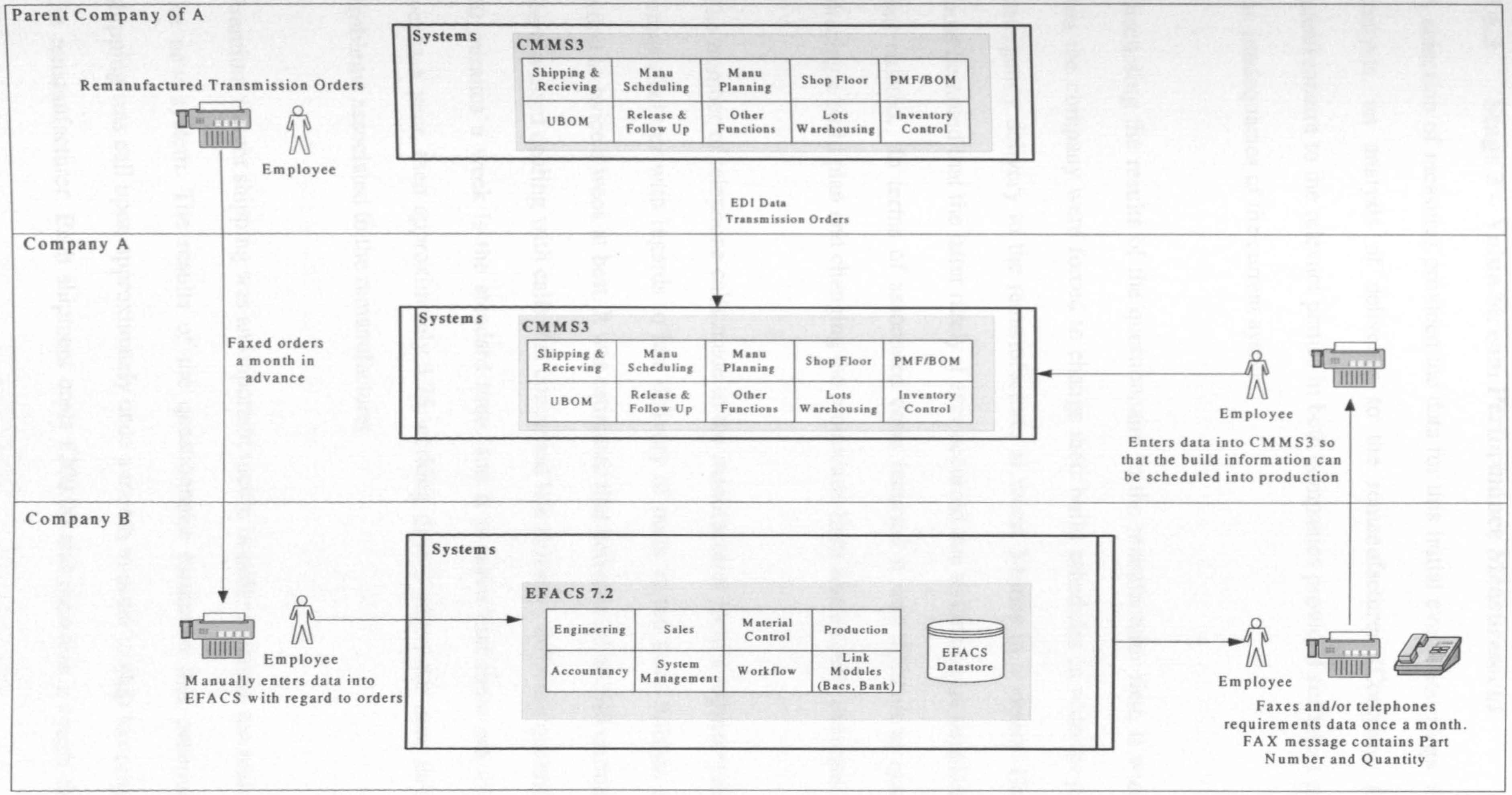


Figure 5.55 – IFD For Case 4

5.6.3 Stage 3 – Value Stream Performance Measurement

A selection of measures provided the data for this initial evaluation stage. A demand analysis, an analysis of deliveries to the remanufacturer (Company B) and a questionnaire to the relevant parties in both companies provided sufficient proof as to the inadequacies of the current system.

Discussing the results of the questionnaire to the manufacturer first, it was revealed that the company were forced to change their build schedules in order to provide an emergency delivery to the remanufacturer at worst 3-times in a month. However, it must be noted that the latter rarely if ever occurred due to the unique supplier scenario that existed. In terms of associated costs incurred it was difficult to quantify but altering a build plan and changing the production lines was a costly exercise.

The number of telephone calls made to the manufacturer from a representative of the remanufacturer with regards to late delivery of parts varied from 5-times a week at worst to twice a week at best. It was estimated that between 20 and 40 minutes a week were wasted dealing with calls that concerned late delivery, differing quantities etc. If 40 minutes a week is the standard time, and it is taken that there are 45 working weeks a year, then approximately 3.75 working days a year were used dealing with problems associated to the remanufacturer.

Premium freight shipping was an important metric in order to gauge the real impact of the new system. The results of the questionnaire estimated that premium freight shipping was call upon approximately once a month in order to ship to components to the remanufacturer. Each shipment costs £200.00 and therefore a rough estimate of over £2000.00 pounds a year can be associated to premium freight shipping. Although this figure is low, it is important to once again refer back to the unique supply scenario and the supply monopoly that existed. In the past they shipped components when it has fitted into their plans and so premium freight was not utilised.

The final section of the questionnaire detailed what representatives from the manufacturer hoped to achieve from the implementation of a new communications system. Most importantly improved relationships between themselves and their customer along with the ability to create stable production schedules were identified as being the most significant aspirations for the new application.

The questionnaire to the remanufacturer revealed a different picture. It was estimated that they were forced to change their build schedule due to the late delivery of components at worst on a daily basis and at best between 2-4 times a week. It was also estimated that between five and ten telephone calls were made to their supplier each week to query the late delivery of components. In total the employee responsible calculated that over 6 hours a week were wasted dealing with late orders. Most importantly however, was that over a six-month period they were forced to cease their production lines on 10 different occasions due to the late delivery of parts. It is difficult to quantify the actual cost of this downtime, however, there is no doubt that they are losses that a small manufacturer can ill afford. In response to what they hoped to achieve from the new application it was unsurprising to see that all the categories had been marked as equally important.

Moving away from the questionnaire, figure 5.56 illustrates the fluctuations in demand of six parts ordered by the remanufacturer over an 11-month period.

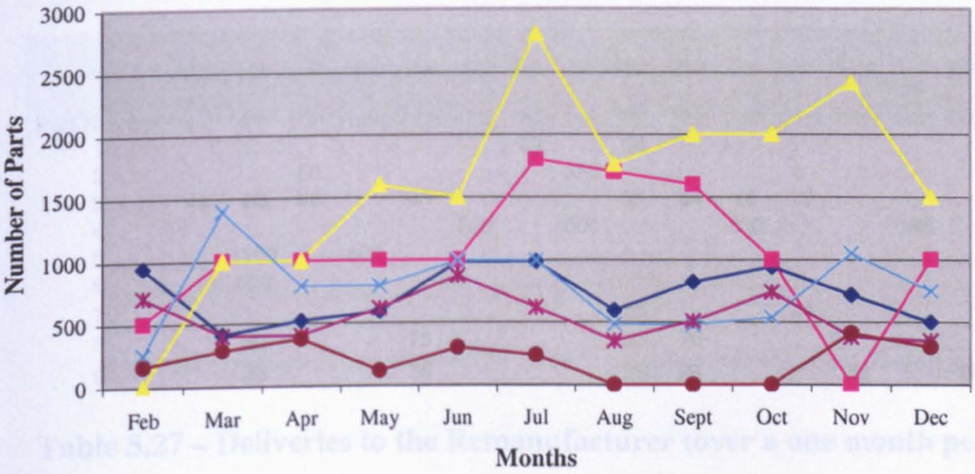


Figure 5.56 – Remanufacturer Demand Fluctuations

From figure 5.56 it is clear to see that the remanufacturer's demand is somewhat erratic over the period examined. However, much of this erratic demand information can be associated to the parent manufacturer as they only provide a forecast of a month in advance for the remanufactured transmissions. The problems that the large automotive transmissions manufacturer was experiencing could be pinpointed to the quality and quantity of the information being supplied. As stated earlier, for a supply chain partner to react accordingly to customer demand fluctuations, a high level of information such as stock levels, forecasted consumption along with actual consumption needs to be made available at the right time (Lee and Whang, 2001). This point is even more relevant for re-manufacturing, as uncertainty in timing and quantity of returns is a reflection of the uncertain nature of the life cycle of a product (Guide, 2000). Although the manufacturer was receiving a monthly demand schedule, staff were not informed at which stage during the month the smaller manufacturer's stock levels would need to be replenished. Thus, they supplied the parts when it suited them to do so, unless a telephone call was made prior to the planned delivery date. Table 5.27 illustrates deliveries to the remanufacturer from the manufacturer for a particular month.

	Mon	Tue	Fri	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Thu	Fri	Mon	Tue	Wed	Fri
Part Number	3rd	4th	7th	10th	11th	12th	13th	14th	17th	18th	20th	21st	24th	25th	26th	28th
1							29		34							
2			50					350								
3	48	23	26		45				31	64	40	79				32
4						200		500			300			186		
5		1100		500												
6		500														
7									66			44				
8		90			78				53	70						
9		36			36				36	24			30		28	90

Table 5.27 – Deliveries to the Remanufacturer (over a one month period)

It was evident that a number of components were being supplied several times over one month. This is due to the fact that the remanufacturer's build schedule did not permit the supplier the ability to see when during a month the parts would be required and what their planned build forecast was. Many of the deliveries above, were for emergency stock replenishment in order to keep the lines in operation. Therefore, this stage has provided sufficient evidence to suggest that there are a number of problems with the current practise.

5.6.4 Stage 4 - Design and Prototyping

Stage 3 highlighted the areas in which the architectures in this section seek to improve. Three architectures are presented in this section to facilitate improvement in both the supply chain and also the information systems infrastructure. They are discussed in the order they are considered in Chapter 4. The designs are based upon the identified value stream, however reference is made to the generic designs in Chapter 4.

5.6.4.1 EA-Based Integration Architecture

As discussed earlier in this case, the parent manufacturer was in the early stages of a SAP implementation. Due to the company wanting to retain a common system throughout all their operations it was also likely that the manufacturer would be upgrading their CMMS3 system in the near future. For this reason it was decided that it would be appropriate to base this EA Integration Architecture on the SAP solution.

5.6.4.1.1 SAP R/3 Enterprise

The communication infrastructure between the manufacturer and the remanufacturer was the main focus of this case. Therefore whilst the SAP upgrade was relevant to mention, it was not likely to have an impact on the relationship between the trading partners. Therefore, as the SAP system has been covered extensively in Chapter 4, it is not discussed in any further detail in this section.

5.6.4.1.2 EFACS E/8

The logical progression for the remanufacturer was to upgrade their internal system. This would enable them to transfer/provide information to their supplier. The EFACS (version 7.2) system was in operation in the remanufacturer at the time of this study. The most recent version of EFACS (E/8 Version 5) has advanced functionality that can be incorporated to enhance supplier and customer relationships. This functionality is now considered in greater detail.

EFACS E/8 Version 5 is business solution built with the latest Internet technology. It has a component structure and it is browser, XML and JAVA based. The range of business functions includes finance, sales, purchasing, stock, manufacturing, field service, contract and project control, customer relationship management (CRM), planning, workflow, document management, e-commerce, and executive information. Figure 5.57 illustrates the core components of the EFACS E/8 system.

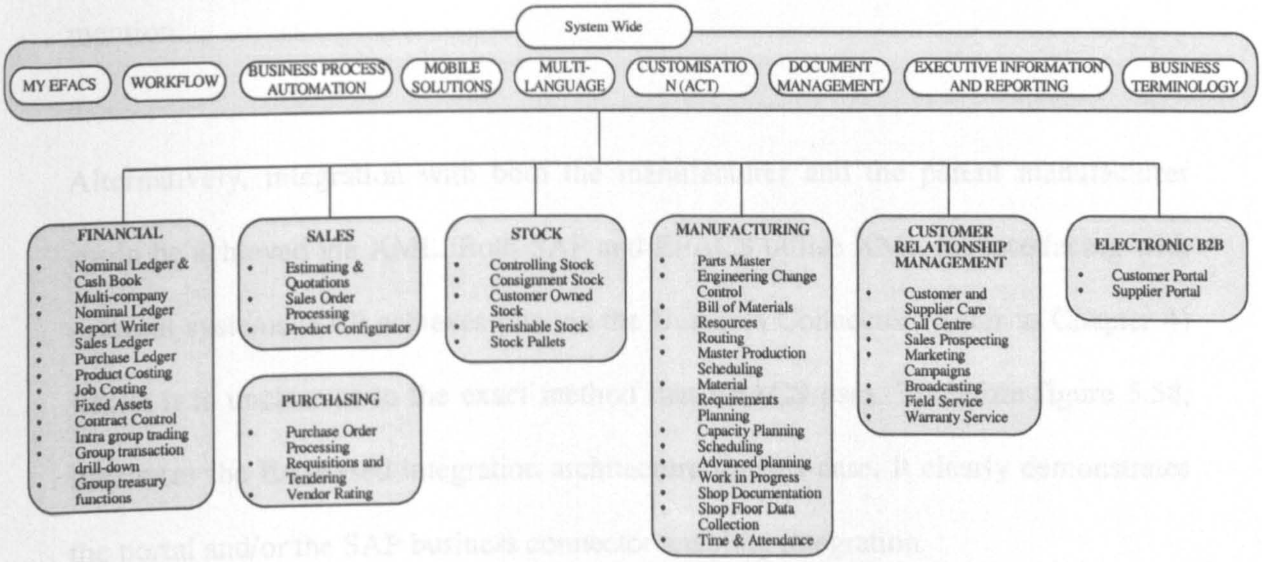


Figure 5.57 – EFACS Components (EXCEL Computer Systems)

From figure 5.57 there are two key components that could be incorporated to facilitate a more integrated architecture: the customer portal and the supplier portal. The supplier portal would permit the remanufacturer to provide secure access into their EFACS system. It is fully customisable and it would allow them to reveal only the information that they choose to release. Typically, the manufacturer would be provided with a username and password and the EFACS system would then present a filtered view of transactions relating to their account. In this particular case the information provided would be current stock levels and future consumption.

The second portal, the 'customer' portal, could be incorporated between the remanufacturer and the parent manufacturer to permit an improved information flow. The parent manufacturer would be able order the transmissions through this medium and make other enquiries relating to stock levels, invoices and the tracking of their orders. Whilst improving or suggesting an alternative communication infrastructure with the parent manufacturer was not an essential part of this case, it warrants a brief mention.

Alternatively, integration with both the manufacturer and the parent manufacturer could be achieved via XML. Both SAP and EFACS utilise XML for interfacing with external systems. SAP achieves this via the Business Connector (Refer to Chapter 4) whilst it is unclear as to the exact method that EFACS uses. Therefore figure 5.58, illustrates the EA-Based integration architecture for this case. It clearly demonstrates the portal and/or the SAP business connector enabling integration.

In terms of the generic architectures in Chapter 4, figure 5.58 had obvious similarities to the 'integrated operation' scenario. The SAP business connector is a focal point for the integration and this has been discussed extensively in Chapter 4. Also in figure 5.58, portals have been introduced so as to enhance supplier/customer integration. Portals permit integration to selected trading partners regardless of the tier in which they are situated. Therefore portals are significant in the development of a 'single instance' architecture.

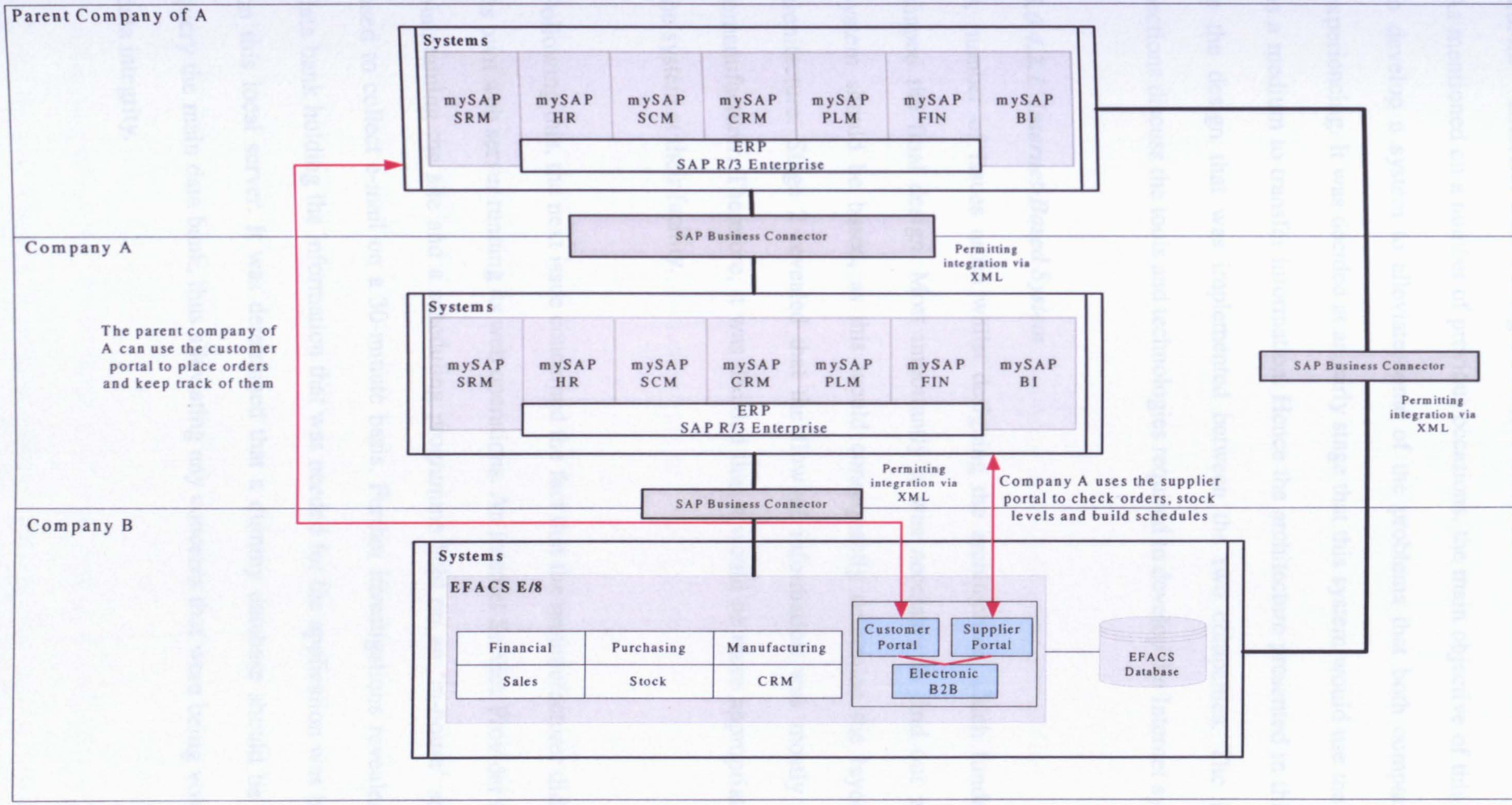


Figure 5.58 – EA-Based Integration Architecture

5.6.4.2 Internet-Based Integration Architecture

As mentioned on a number of previous occasions, the main objective of this case was to develop a system to alleviate some of the problems that both companies were experiencing. It was decided at an early stage that this system would use the Internet- as a medium to transfer information. Hence the architecture presented in this section is the design that was implemented between the two companies. The following sections discuss the tools and technologies required to develop the Internet system.

5.6.4.2.1 Internet-Based System

A number of issues arose whilst designing the architecture, which fundamentally shaped the final design. Most importantly it was necessary to find out where the system should be based, as this would consequently determine the layout of the architecture. Stage 2 revealed that the flow of information was mostly from the remanufacturer. Therefore, it was decided that it would be more appropriate to base the system at their facility.

Following this, the next issue concerned the fact that the remanufacturer did not have its own web server running its web operations. An Internet Service Provider (ISP) was maintaining the site and a scheduling programme held on an 'in-house' server was used to collect e-mail on a 30-minute basis. Further investigations revealed that the data bank holding the information that was needed for the application was being held on this local server. It was determined that a dummy database should be set up to query the main data bank, thus alleviating any concerns that were being voiced about data integrity.

Having located the data and determined how it could be maintained on the Internet it was then necessary to select the appropriate software and tools to extract and manipulate the data. A specific application could have been designed and coded using any number of different languages. However, taking the functionality and time span for the case into account it was decided that a rapid application development (RAD) tool such as Macromedia's ColdFusion software, which was already being used on site at the remanufacturer, was the most suitable option.

So the web application and database were developed using ColdFusion and loaded onto the ISP's server. The scheduling application used for e-mail was re-configured to send the dummy database to the ISP every 30 minutes. The web application aimed to provide real time data necessary for the larger transmissions company to respond to the requirements of its customer. There were six main elements to the application; a schedule, a shipping schedule, a shipment acknowledgement component, a monthly/daily forecast update page, a log and the ATR page.

In terms of functionality, the schedule, which provided a 10-day build forecast, with each day indicating quantities for demand, quantity shipped and arrears was the focal point of the application. The 'demand' was input by an employee at the remanufacturer and the 'shipped' was entered as and when the manufacturer decided to ship. The arrears were calculated on a daily basis depending on what was demanded and what was shipped. The third column across in schedule (refer to prototype section) indicated the stock level for a particular part.

The shipping schedule represented the exact same page as the schedule apart from it allowed the manufacturer to enter data when it had shipped parts. When parts have been shipped the shipment acknowledgement page became active by showing the data related to the shipment. Once the shipment has arrived it was checked off and the record was removed from the shipment acknowledgement page.

The monthly/daily forecast page was where the remanufacturer could input data as to what they planned to build over the coming months. This part of the application offered the facility for the user to enter values for daily quantities to be consumed or alternatively enter a monthly value, which was divided evenly over the working days in that month. The others components of the system included the log system that stored all of the information on a daily basis for future reference and the ATR page. Figure 5.59 illustrates the Internet-Based Integration Architecture for this case.

The application designed and developed for this case represents probably the most comprehensive Internet application of all those discussed thus far. In reference to Chapter 4, once again is it clear that the proposed architecture (figure 5.59) has a number of similarities to the Internet-based generic architecture version 1. The key components are the application server and web server are both present and the ColdFusion application is bespoke to the particular project.

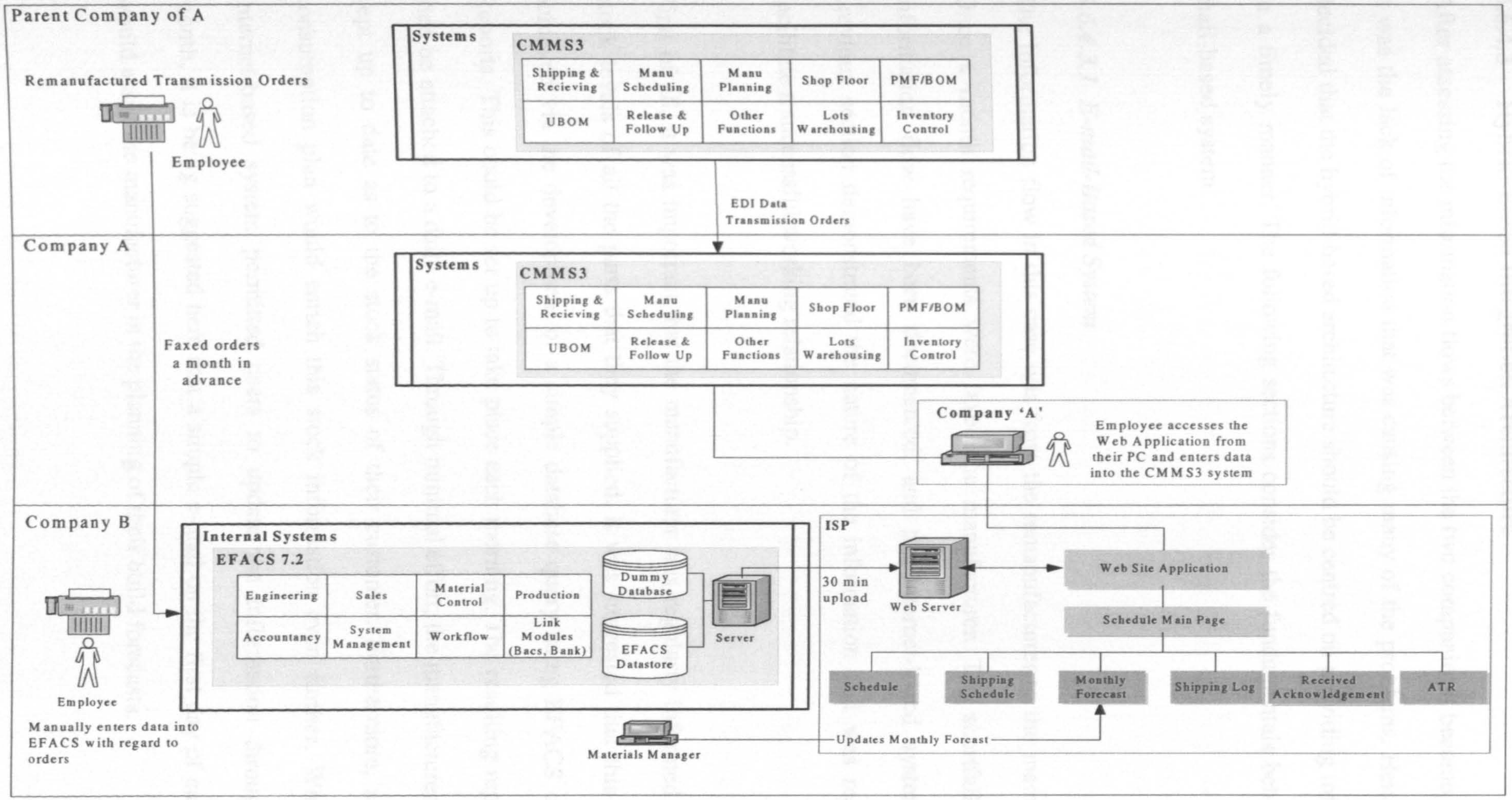


Figure 5.59 – Internet-Based Integration Architecture

5.6.4.3 Hybrid-Based Integration Architecture

After assessing the information flows between the two companies it became clear that it was the lack of information that was causing many of the problems. Hence, it was decided that the hybrid-based architecture should be centred on providing information in a timely manner. The following sections consider the fundamentals behind an e-mail-based system.

5.6.4.3.1 E-mail-Based System

The information flow in this case was from the remanufacturer to the manufacturer. Once a month requirements were faxed the manufacturer. The shortfalls of this information flow have been documented, and the Internet-based system in the previous section demonstrated the nature of the information that was required to facilitate a successful working relationship.

First of all, it was important that the manufacturer was regularly informed as to the stock levels of all the parts that they supplied. It was suggested that this could be achieved via the development of a simple database query using EFACS or Crystal Reports. This could be set up to take place each morning. The resulting report could then be attached to a daily e-mail. Through minimal effort, the manufacturer could be kept up to date as to the stock status of their customer. Furthermore, a monthly consumption plan would enrich this stock information even further. Whereas the Internet-based system permitted users to update the information throughout the month, it is being suggested here that a simple e-mail on the first day of each month would assist the manufacturer in the planning of their build forecasts.

Therefore, this hybrid-based architecture replicates the Internet-based system in a less sophisticated manner. More information would being supplied which would improve the current supply situation. Figure 5.60 shows the Hybrid-based integration architecture.

Figure 5.60 clearly demonstrates one of the simplest hybrid-based architectures within this Chapter. However, it was important to retain a sense of simplicity for this integration architecture. Fax was the primary method of communication prior to this case and with both companies having Internet access it seems the logical step to suggest e-mail as an alternative. In relation to the data required for this architecture it was important to convey to both sides the importance of data sharing. This architecture would be of no use if it was only used to transfer the same data as before. The Generic-based hybrid architecture in Chapter 4 has many similarities to figure 5.60 in that it offers e-mail as one of the options to communicate data between trading partners.

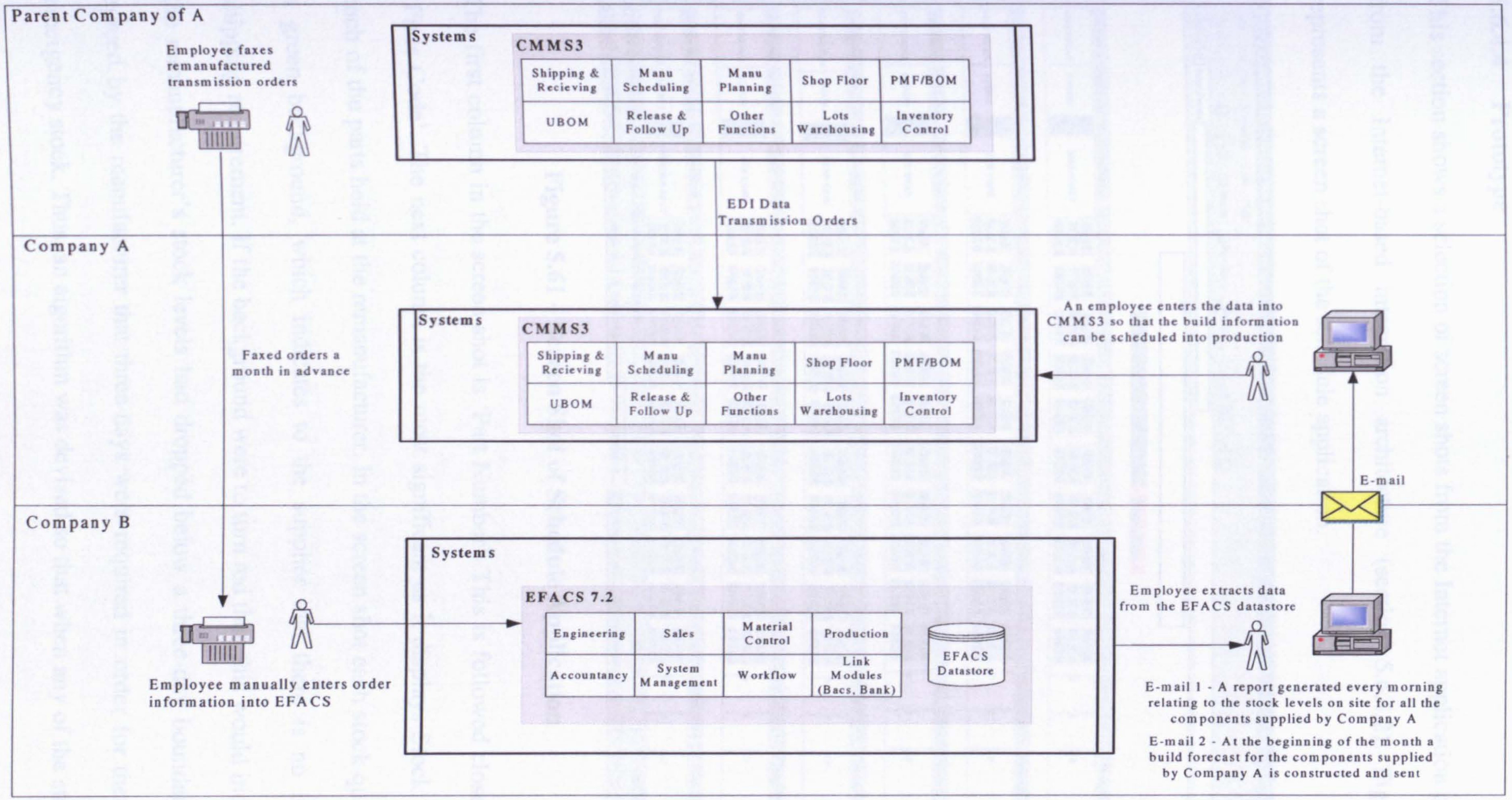


Figure 5.60 – Hybrid-Based Integration Architecture

5.6.4.4 Prototype

This section shows a selection of screen shots from the Internet application developed from the Internet-based integration architecture (section 5.6.4.2). Figure 5.61 represents a screen shot of the schedule application.

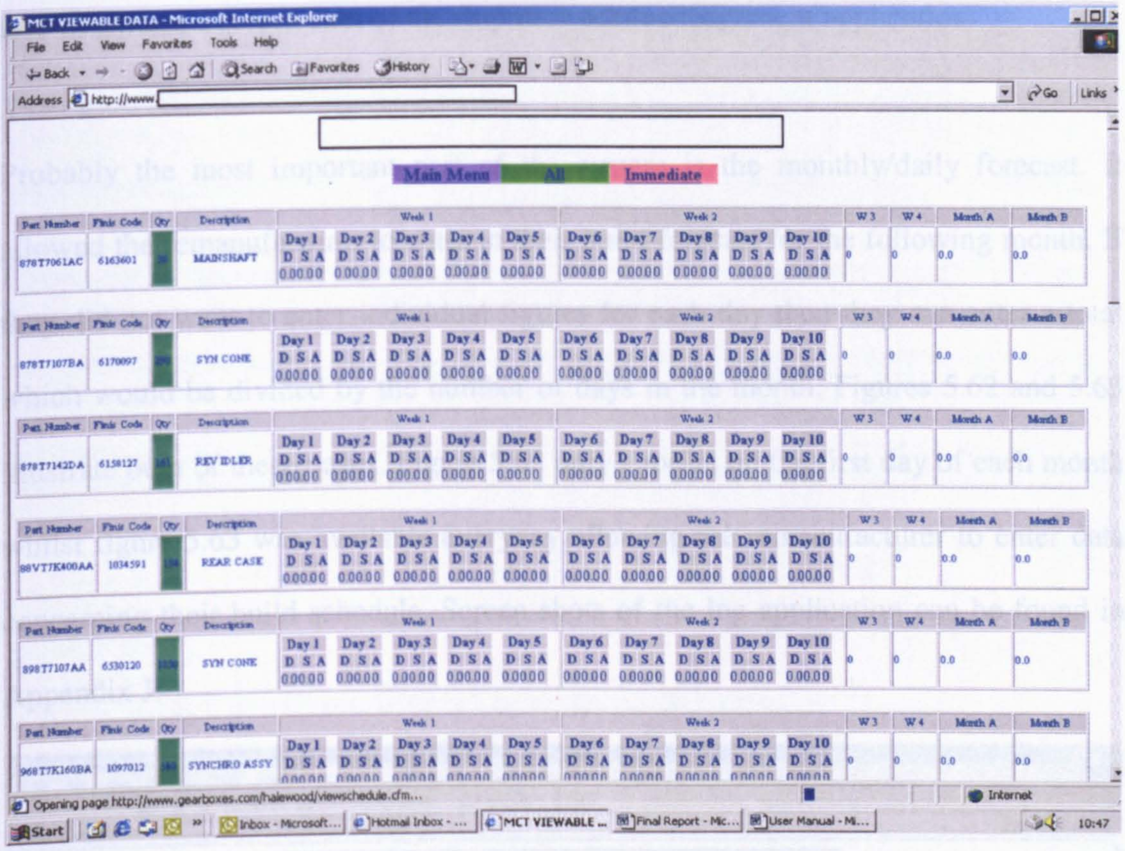


Figure 5.61 – Screen Shot of Schedule Application

The first column in the screen shot is 'Part Number'. This is followed closely by the 'Finis Code'. The next column is the most significant as it displays Stock levels for each of the parts held at the remanufacturer. In the screen shot each stock quantity has a green background, which indicates to the supplier that there is no immediate shipping requirement. If the background were to turn red then this would indicate that the remanufacturer's stock levels had dropped below a three-day boundary. It was agreed by the manufacturer that three-days were required in order for them to ship emergency stock. Thus, an algorithm was devised so that when any of the stock levels fall below three-days worth of demand it automatically flags it in the system. The shipping schedule side of the application is a duplicate of the schedule (figure 5.61) with the exception that it allows employees to enter the appropriate data as and when parts are shipped. A screen shot of this page can be found in Appendix J. Appendix J also illustrates a screen shot of the shipment acknowledgement application.

Probably the most important part of the system is the monthly/daily forecast. It allowed the remanufacturer to enter in their build forecast for the following month. If they did not want to enter individual figures for each day then they can enter a total which would be divided by the number of days in the month. Figures 5.62 and 5.63 illustrate both of these pages. Figure 5.62 only appears on the first day of each month whilst figure 5.63 was available everyday allowing the remanufacturer to enter data concerning their build schedule. Screen shots of the log application can be found in Appendix J.

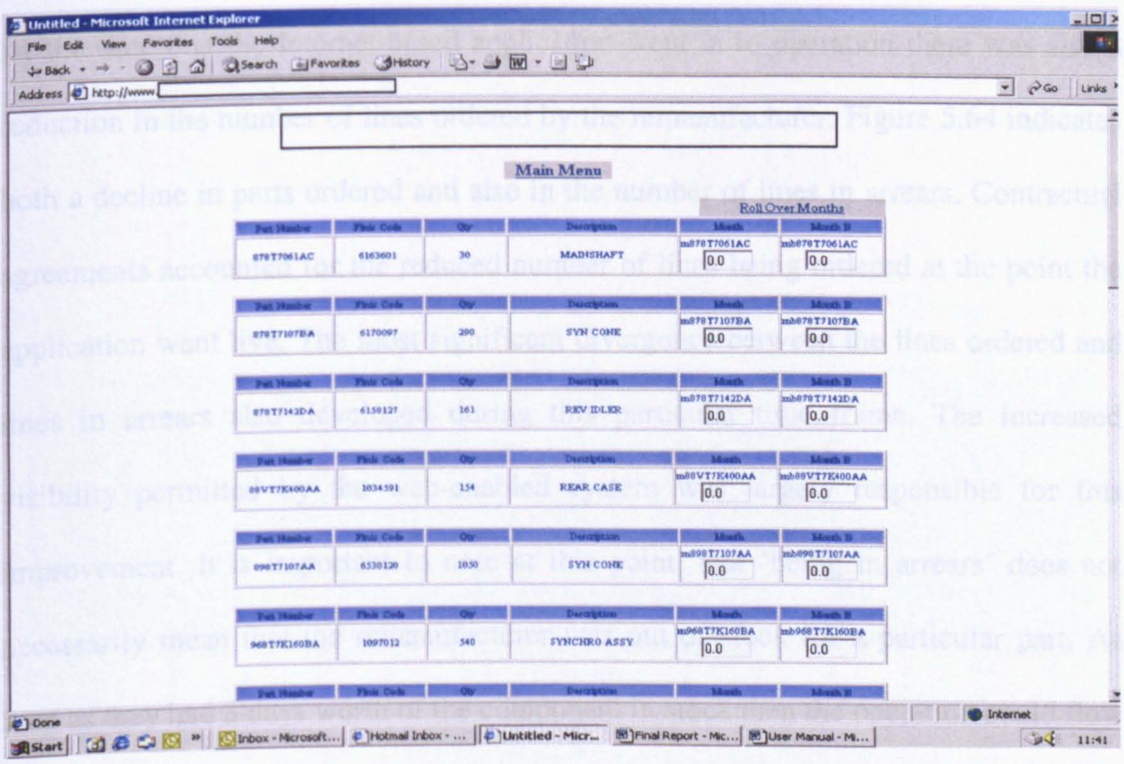


Figure 5.62 – Screen Shot of Monthly Forecast Application

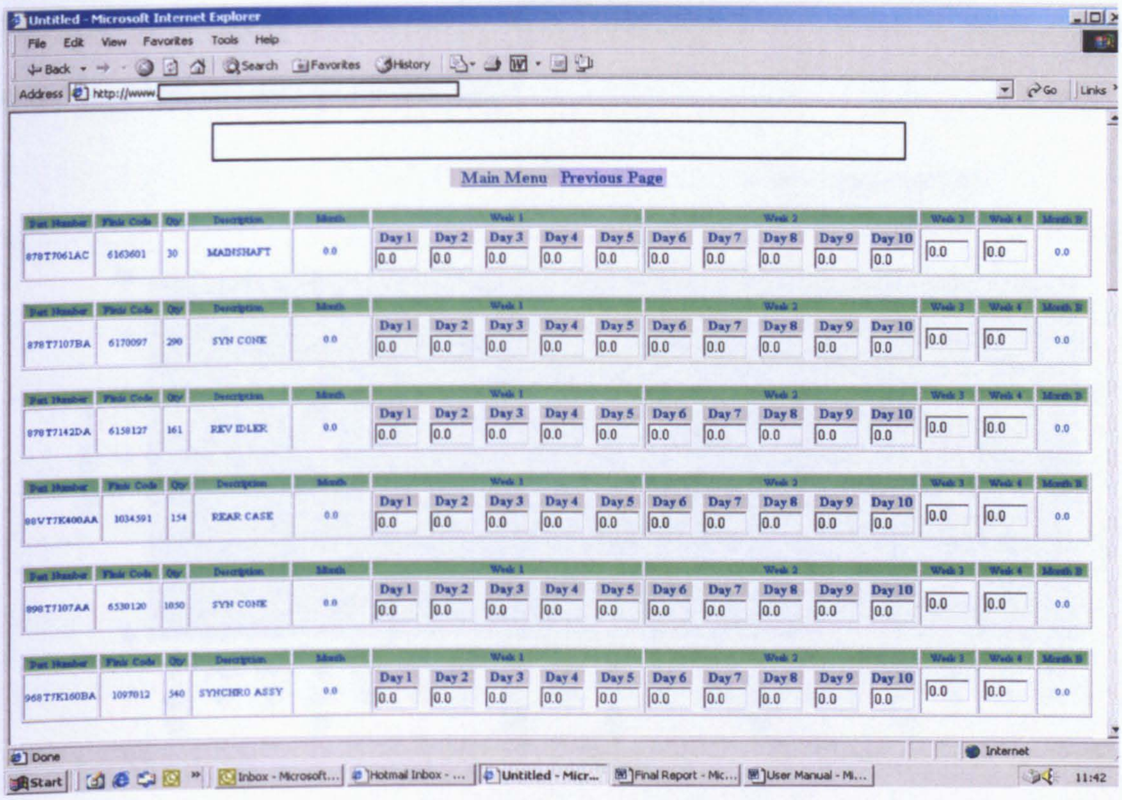


Figure 5.63 – Screen Shot of Daily Quantities

5.6.5 Stage 5 – Evaluation of Integrated Designs

At the time that the Internet-based application went in to operation there was also a reduction in the number of lines ordered by the remanufacturer. Figure 5.64 indicates both a decline in parts ordered and also in the number of lines in arrears. Contractual agreements accounted for the reduced number of lines being ordered at the point the application went live. The most significant divergence between the lines ordered and lines in arrears also developed during this particular time frame. The increased visibility permitted by the web-enabled system was largely responsible for this improvement. It is important to note at this point, that 'being in arrears' does not necessarily mean that the remanufacturer was out of stock for a particular part. As long as they had 3 days worth of the component in stock then the operation could flow smoothly. In fact, over a six-month analysis period it was estimated by the remanufacturer that they only had to stop/change their lines a total of 5 times due to reasons of late delivery (a 50 decline).

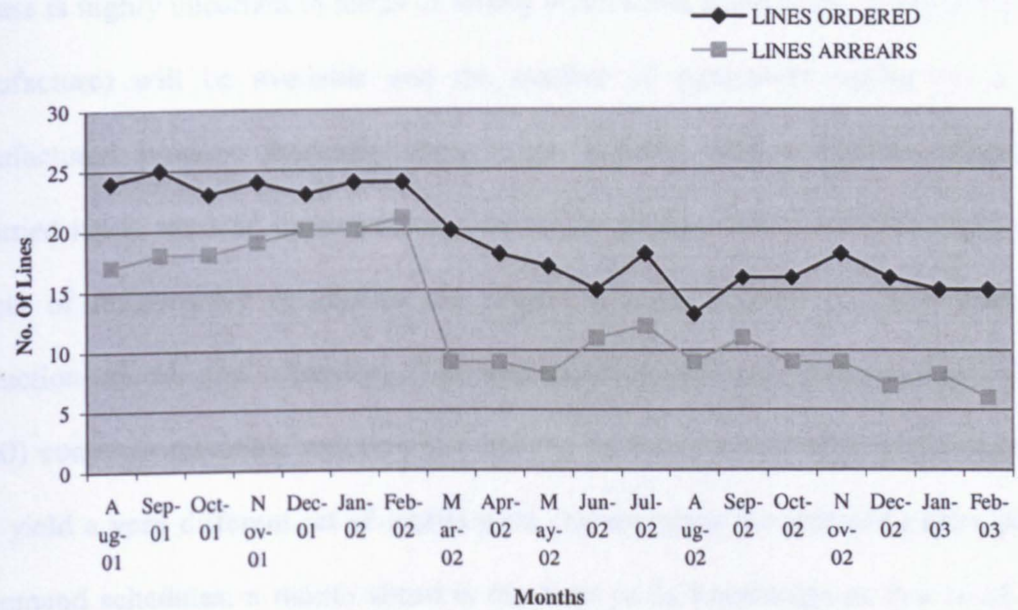


Figure 5.64 – Manufacturer Performance Analysis

Comparing the performance of the web-system with the systems that other automotive manufacturers incorporate (web or otherwise) there was a considerable different picture. Clearly the performance of the manufacturer was poor when compared to the other automotive suppliers as figure 5.68 indicates.

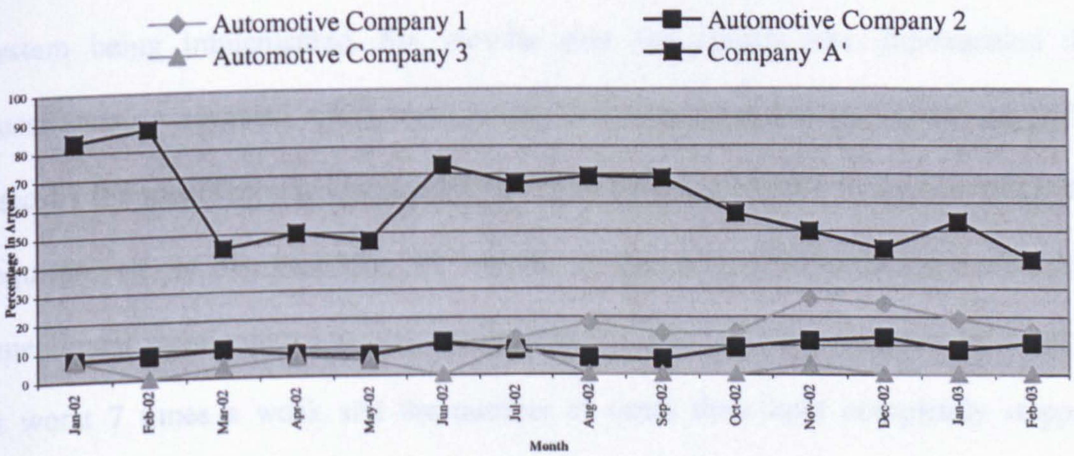


Figure 5.65 – Performance Comparison

However, a number of complicating factors common in re-manufacturing firms must be taken into consideration as identified by Guide (2000). The re-manufacturing process is highly uncertain in terms of timing when cores (transmissions requiring re-manufacture) will be available and the number of consumers opting for a re-manufactured product. Basically, there is no reliable, forward visible workload. Returned items must be disassembled prior to the product being fully restored. The effects of disassembly operations can impact a large number of areas such as production control and scheduling. The final issue of relevance discussed by Guide (2000) concerns materials recovery uncertainty, as two identical end items returned may yield a very different set of usable parts. Hence when the remanufacturer plans its demand schedules, a month ahead is the limit to its knowledge as that is all the information it receives from its customer (parent manufacturer). The volume of components re-manufactured for the parent manufacturer was considerably greater than those of the other three automotive companies present on the graph. This combined with the factors introduced by Guide are the principal reasons that the performance in figure 5.65 appeared to be so poor.

As discussed in Stage 3, questionnaires were conducted prior to and following the system being implemented. Six months after the system was implemented the questionnaires revealed a different picture. Premium freight shipping was yet to be used by the manufacturer and lines only had to be changed once to accommodate the requirements of its customer. In regard to the remanufacturer, build schedule amendment were reduced to between 2-6 times a month. Telephone calls were cut to at worst 7 times a week and the number of times their lines completely stopped diminished by half over the six-month period. Furthermore the working relationship between the two companies improved significantly.

5.6.6 Stage 6 – Evaluation of Integrated Designs

In conclusion, three integration architectures have been designed to improve the current remanufacturing scenario. The EA-based integration architecture offers a selection of advantages but would come at a considerable cost to the remanufacturer. The value of the products being manufactured is high and so the EA architecture might offer the best solution over the long term. The value of the remanufacturer's business to the transmissions manufacturer is relatively insignificant in comparison to its main line of work. However, supplying the remanufacturer was important in terms of the bigger picture and so they should agree to the adoption of a more integrated EA system.

The classification framework identified this case as being situated in an automotive reverse flow supply chain. Automatically an EA-based architecture would be considered due to the high value and moderate complexity of the final product. However, this case has considered a particular environment (reverse flow) that many EA products are not designed to facilitate. Furthermore, as stated above, the cost of a new EA-integration architecture would reside with remanufacturer. Therefore, it can be said that this case provides evidence to suggest that the Internet can provide a simple and cost-effective solution to significantly improve the information flow between two companies situated in a remanufacturing supply chain. The Internet-based integration architecture represented the best solution as neither company wanted to invest heavily to improve communication due to the costs involved. The components required to implement the EA and hybrid-based architectures along with the associated advantages have been discussed. However, it is the Internet-based solution that demonstrated significant benefit in this scenario.

The single interface that was developed for this project provides enhanced information quality and availability, which permits superior planning to take place. This planning in turn reduces the cost and time spent by the parties involved. The application overcomes the problems associated with legacy integration but acknowledges the further improvements that could be undertaken in this area. The system proved that large-scale investment in updated EA systems can be avoided in the short term.

Case 5 – High Volume Automotive Study

5.7.1 Stage 1 – Orientation

This project involved a total of five companies and represents the largest case study within this research. Situated in the automotive sector once again, the key challenges here were cross supply chain visibility (upstream) and legacy integration. Company A, was a major British Automotive vehicle manufacturer (VM), Company B a first tier sequenced seat supplier, companies C (a seat track manufacturer) and C1 (a Rear Centre Headrest (RCH) assembler) were second tier component suppliers, one of which was affiliated to the first tier sequenced seat supplier. Company D was a cloth supplier for the RCH assembler.

The VM recently redeveloped an exiting plant in order to introduce a new vehicle to their range. Along with the internal redevelopment of the facility there were also significant efforts made to create a 'Seamless Supplier Network'. The Industrial Park, where the VM resided had welcomed a number of first tier suppliers, who all now manufacture and supply components and sub assemblies to the production line.

This investigation represented a cross supply chain study. The aim was to look at the possibility of sending the information demand triggers from the VM to the first tier sequenced seat supplier and then simultaneously transmitting the demand triggers to the other companies involved in the study. The study involved extensive performance evaluation along with rigorous systems analysis. The value stream that formed the basis for this research can be viewed in Figure 5.66. The first tier seat supplier indicated in figure 5.66 is located within half a mile of the VM. In total this first tier supplier has 26 component suppliers all of which are based within Europe. The companies were selected for their location and also for their willingness to cooperate with the study.

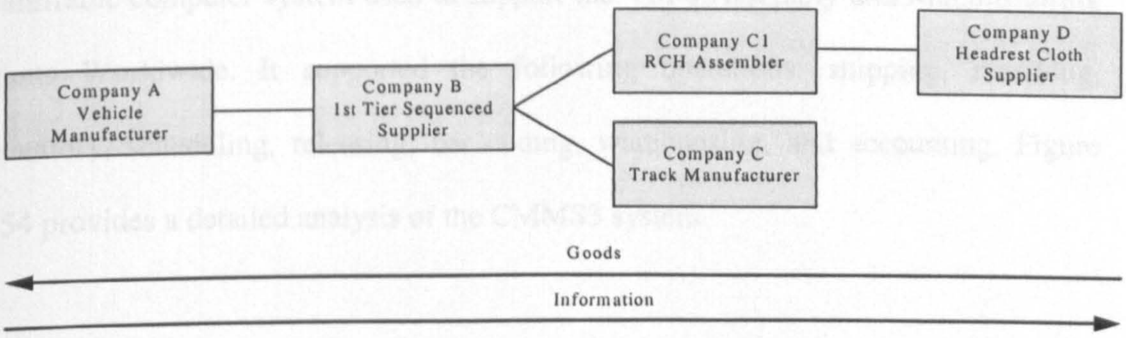


Figure 5.66 – Value Stream

5.7.2 Stage 2 – Value Stream and Information Flow Mapping

The main focus of this project related to the information originating at the VM. The VM had a range of systems in operation in order to complete its day-to-day functions. However, there were only a few systems of relative importance for this project. Their individual functions and the ways in which they interact are now discussed in greater detail. Appendix K provides an example of the questionnaire designed for this case.

- **ASRS**

The Automated Storage and Retrieval System is unique to the VM. It can be described as a large storage tower capable of storing 400 fully constructed painted bodies. Vehicles enter the ASRS as they exit the paint shop and are stored there until a particular vehicle order arrives on the Trim & Final Line. At this point, assuming the required colour and body configuration exist, the vehicles rejoins the main production line to be dressed and trimmed. This system resides on two HP-UX 9000 UNIX Servers.

- **CMMS3**

CMMS3 is a global system controlling material and component supply. It is a mainframe computer system used to support the VM's Assembly and Manufacturing Plants Worldwide. It supported the following operations: shipping, receiving, inventory, scheduling, releasing, bar coding, warehousing, and accounting. Figure 5.54 provides a detailed analysis of the CMMS3 system.

- **ILVS**

In-Line Vehicle Scheduling was particularly important in that it assisted PVS in controlling the movement of vehicles around the various construction areas of the plant - known as Zones. Each plant had its own Zone Model, which effectively mapped out the main production areas into a series of logical steps. While ILVS existed as a (VM developed) system in its own right, the majority of its information and data was received from PVS and other systems

- **MCIS**

Material Call in Server (MCIS) was a system for continuous broadcast to sequenced suppliers of vehicles entering Target Launch Sequence (TLS). It split vehicle orders in to component part information as required by the supplier.

- **OPCON**

Operational control was developed by the VM to control vehicles entering the final stages of production and leaving the plant. This was a VAX Mainframe System (VMS) and was newly implemented at the manufacturers site as part of the new vehicle program. It held important data relating to finished and unfinished vehicles. It also stored data pertaining to the particular batches of parts used on a vehicle and the body type of the vehicle.

- **Plant Vehicle Scheduling (PVS)**

PVS was one of the most important systems at the VM since it controlled the movement of vehicles throughout all stages of the production process from the minute a Vehicle Identification Number (VIN) was first stamped onto a metal plate.

Developed by the VM's parent company, PVS was particularly important to the whole manufacturing process because it was connected to the main automotive dealership systems from which customer orders were received and processed. The system itself was 30 years old and was situated on a VAX Mainframe System. While this type of system is no longer common place in today's technologically advanced society, its robustness, reliability and cost of a replacement meant it was likely to remain in place for some considerable time yet.

The systems discussed above combine to produce a number of signals that provide suppliers with the data they require as to when they should supply components. These signals are transmitted in the form of fax, EDI or e-mail. The following section considers each of the signals that were sent.

Figure 5.67 illustrates the demand signals that were transmitted from the VM to its suppliers.

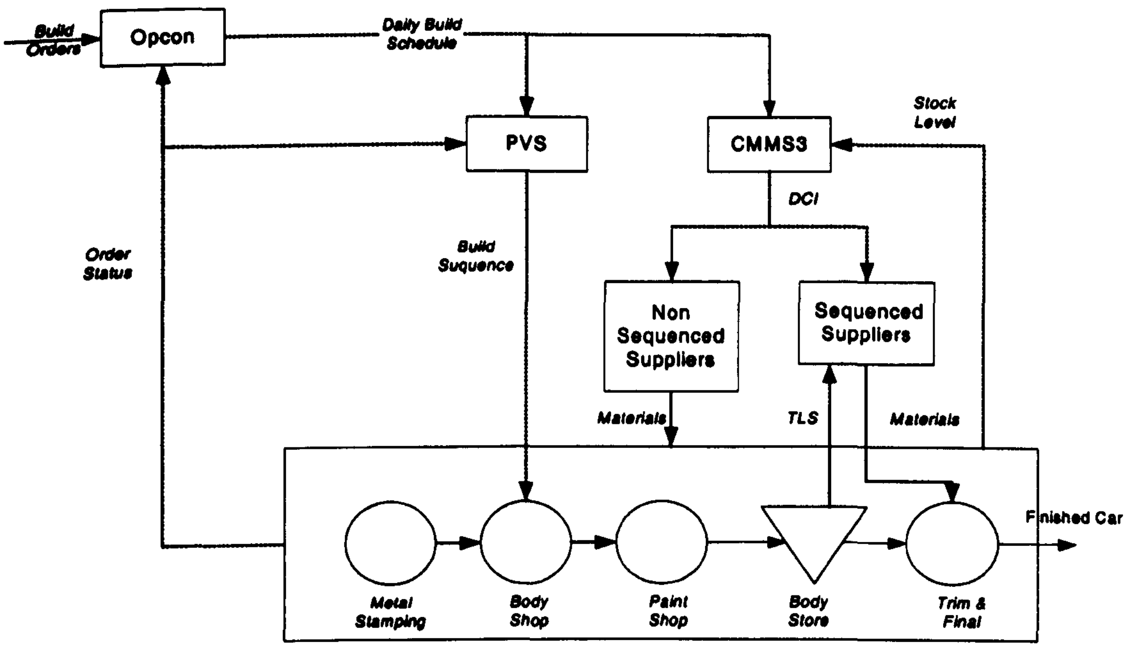


Figure 5.67 – Demand Signal from VM to Suppliers

The VM provided three material demand forecasts to its suppliers. They were:

- The Daily Call-In (DCI)
- The Target Launch Sequence (TLS)
- The Overlay (Unofficial Report)

Both the DCI and the TLS were transmitted to suppliers via an EDI link that was established at an early stage in the restructuring of VM's manufacturing plant. The DCI, which was generated from CMMS3, provided information regarding materials demand for the following ten days in daily quantities. It also offered a significantly longer time horizon, which allowed suppliers enough time to react to production capacity shifts. Combined with this, 'sequenced' parts suppliers received a continuous broadcast of the TLS approximately 8 to 12 hours prior to the launch of the vehicle into the Trim & Final process. 'Sequenced' parts suppliers delivered the materials to the Trim and Final assembly line according to the TLS broadcast, which included the parts required and the sequence of delivery.

The final information signal supplied by the VM was a seven-day production schedule known as the 'Overlay', that was sent out on a daily basis via e-mail. It provided information concerning all the cars that were to be built over the following seven days. Once the 'Overlay' had been sent, the suppliers had to interpret this information into materials requirements, which were then supplied to the VM. Figure 5.68 indicates exactly how the Overlay was generated. PVS sliced the Work in Progress (WIP) and committed orders within the production pipeline, depending on the daily build schedule, which was generated via OPCON. This process took place at the end of working hours each day. It should be noted that the 'Overlay' was provided to suppliers with the understanding that they accepted it was an unofficial report.

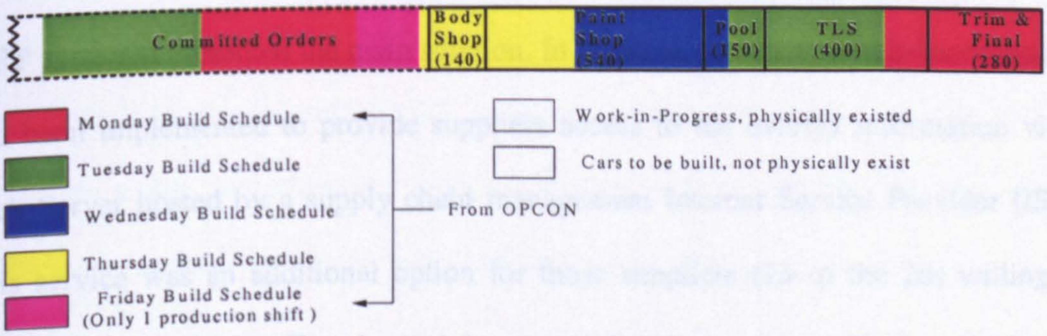


Figure 5.68 - Formation of the Overlay

Table 5.28 demonstrates the differences and similarities between the three information systems outlined above.

Features	DCI	TLS	Overlay
Forecast Horizon	10 working days	8-12 hours, depending on the production rate and build schedule	5-7 days, depending on the WIP and committed orders
Generated by	CMMS	PVS	PVS
Nature of Information	Material demand Forecast	Actual material demand in the Trim & Final Process	Daily Build Schedule
Receiver	All Suppliers	Sequenced-part suppliers	Some sequenced suppliers
Broadcast Frequency	Daily (After prod stops)	Continuous	Daily (After prod stops)

Table 5.28 - Analysis of DCI, TLS & Overlay

All of the demand information that was currently being supplied by the VM was very much under scrutiny in this research. In order to have a base point from which a new system(s) can be compared against, it was important to monitor the performance of the current systems. The accuracy and reliability of the DCI affected the suppliers as well as the VM and so this was the main focus of the analysis. Overlay, was also taken into account as from an early stage it became evident that many of the suppliers used the Overlay far more than the DCI. Examples of both the DCI and Overlay can be found in Appendix L.

In terms of the systems infrastructure at the seat supplier (Company B), the BPCS MRP system represented the main solution. In addition, however, a web-based system had been implemented to provide suppliers access to the overlay information via a Web Server hosted by a supply chain management Internet Service Provider (ISP). This service was an additional option for those suppliers (13 of the 26) willing to subscribe to the service. Faxed schedules were still sent regardless. The suppliers used this information to control both manufacture and shipping of seat components. Six (UK based) suppliers used the schedules for planning purposes only, whilst shipping was controlled via Kanban. Demand was monitored daily in order to fine-tune the number of Kanban cards in operation.

Essentially the interface from the vehicle assembly to seat assembly was demand driven. That is to say, the assembly of a unique seat set was triggered by the launch of its destination vehicle into the final assembly sequence. At which time the actual seat requirement was sent to the first tier supplier via the MCIS broadcast system. This link operated along the lines of Sequenced In Line Supply (SILS), i.e. seats are assembled and transported to point of fit in-line with the vehicle assembly sequence.

Before the MCIS broadcast, an aggregated daily seat requirement was communicated to the first tier supplier via a Daily Call In (DCI) file. Each day, the DCI revealed the next ten daily requirements, followed by a further forecast requirement in more tentative weekly and monthly buckets.

The seat supplier used this DCI information to drive its own internal BPCS ERP system. The DCI file was loaded each day, and once a week (Thursday PM) the ERP system was run. Supplier schedules were produced for each of the seat suppliers' 26 component suppliers. These were transmitted by Fax and normally contained daily requirements for the following week, as well as more tentative forecast requirements in weekly and monthly buckets. Figure 5.69 illustrates the IFD for this case. Figure 5.70 illustrates the VSM for the supply chain under analysis.

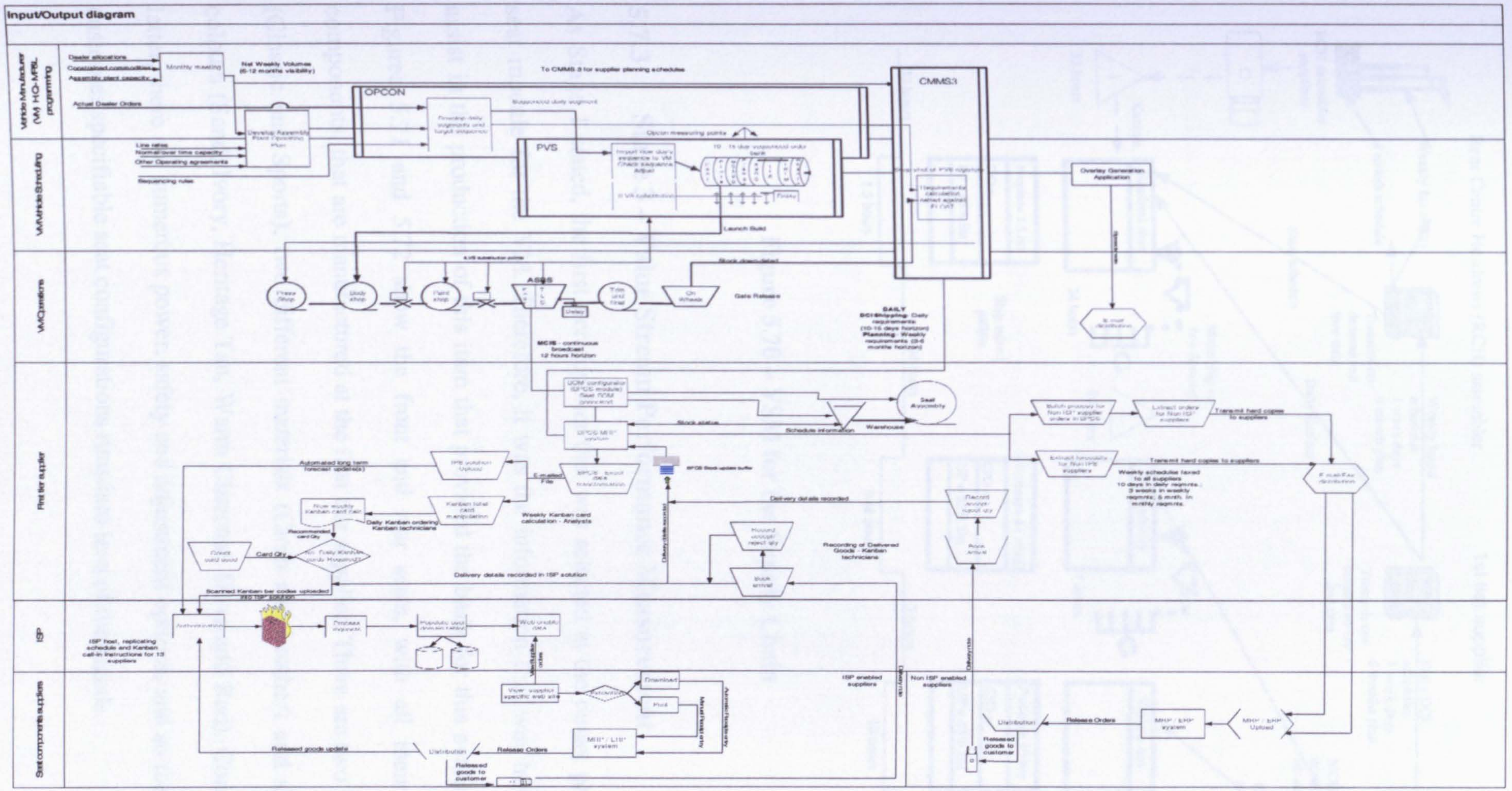


Figure 5.69 – IFD For Case 5

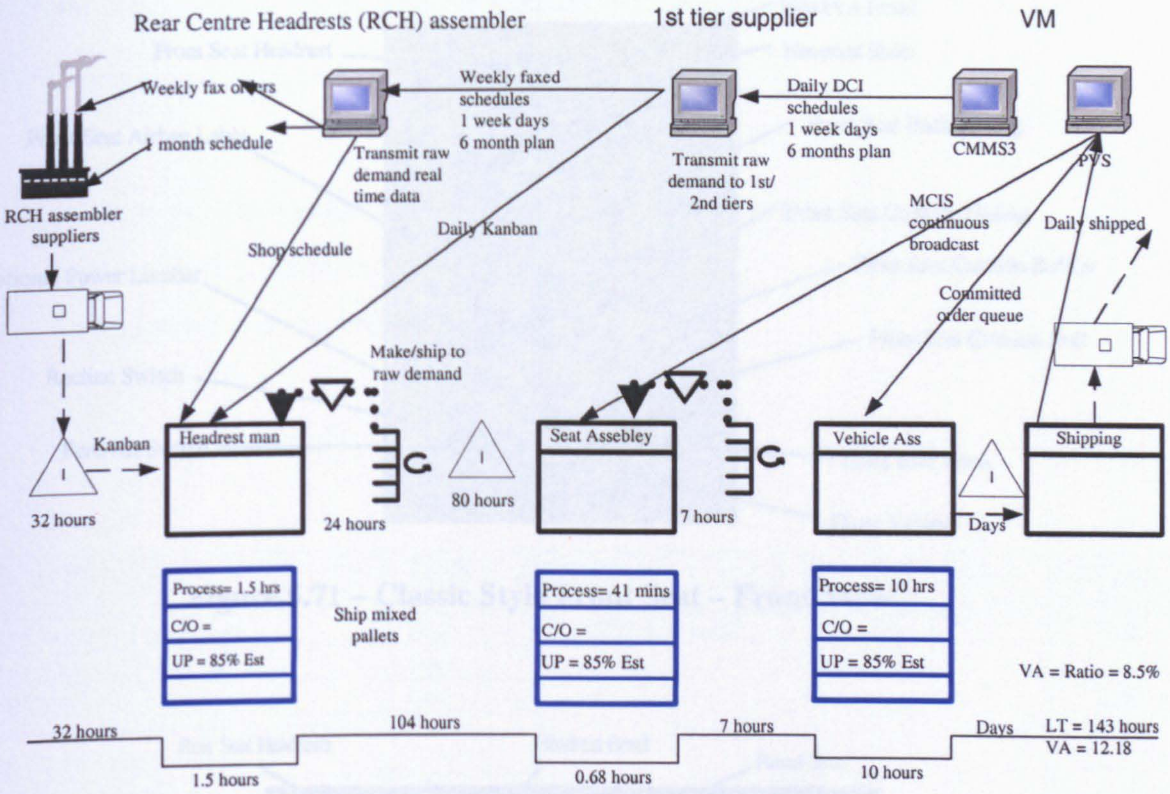


Figure 5.70 – VSM for the Supply Chain

5.7.3 Stage 3 – Value Stream Performance Measurement

As Stage 1 stated, the first tier supplier that was selected at the outset produced the seat module for the VM. Therefore, it was the information that was transmitted to assist in the production of this item that provided the basis for this evaluation stage. Figures 5.71 and 5.72 show the front and rear seats, with all their associated components, that are manufactured at the first tier supplier. There are two basic styles (Classic and Sports), two different materials (Cloth and Leather) and six different colours (Sand, Ivory, Heritage Tan, Warm Charcoal, Dove and Red). Combined with latter, there are numerous power, safety and adjustment options, and so the number of customer specifiable seat configurations runs into tens of thousands.

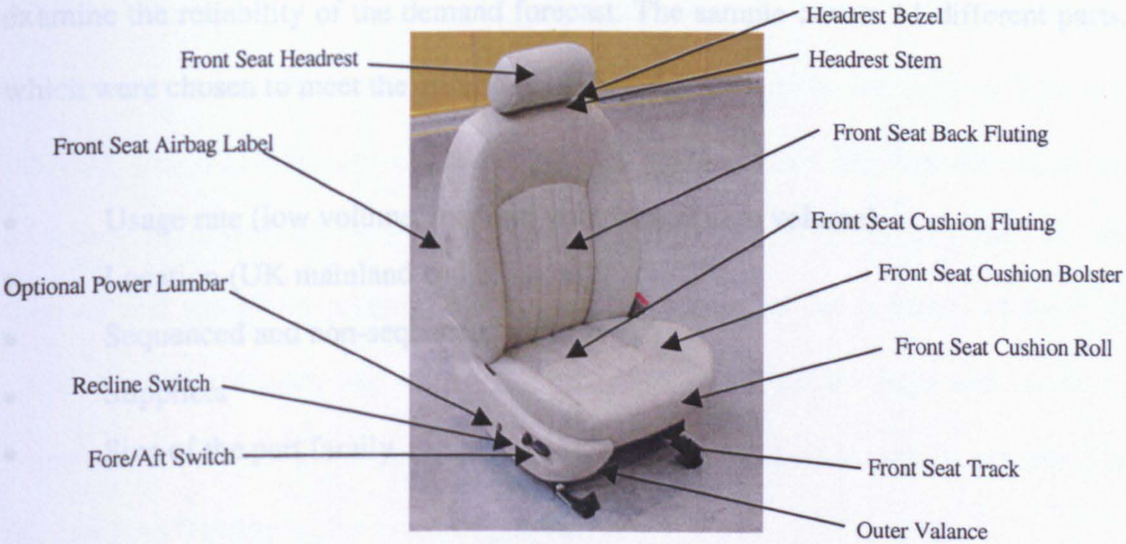


Figure 5.71 – Classic Style Front Seat – Front View

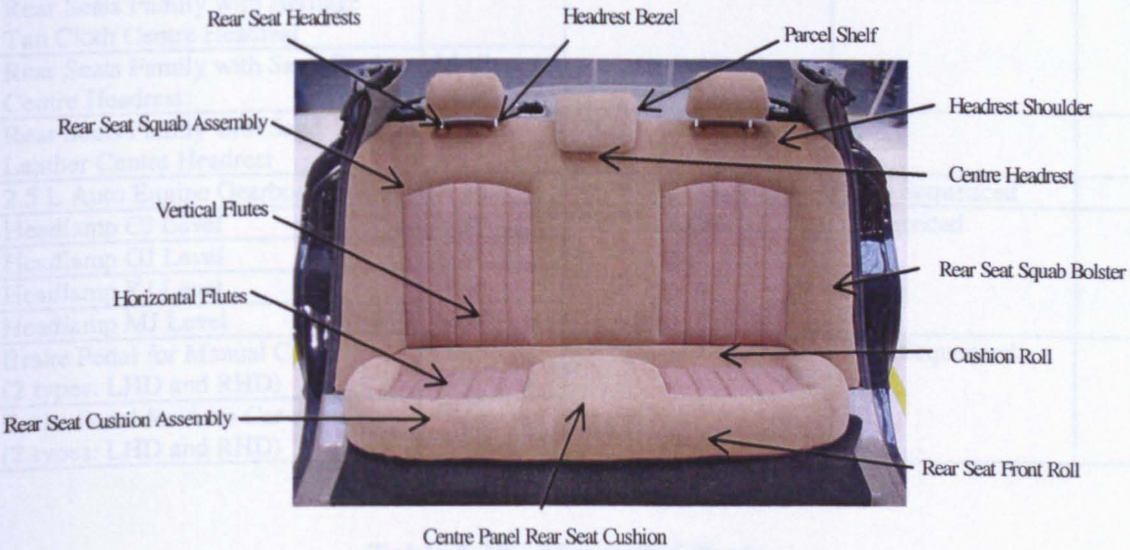


Figure 5.72 - Classic Style Rear Seat – Front View

Due to the vast number of suppliers and individual parts that were supplied to the VM on a daily basis, it was important that the evaluation of the DCI and Overlay should cover a mix of parts. The parts analysed ranged in their respective usage, i.e. high or low, and also in their variety. Table 5.29 indicates the parts that were monitored to examine the reliability of the demand forecast. The sample covers 11 different parts, which were chosen to meet the criteria listed below.

- Usage rate (low volume, medium volume and high volume)
- Location (UK mainland and offshore)
- Sequenced and non-sequenced parts
- Suppliers
- Size of the part family

Part Description	Usage Rate	Supplier	Remark	Part Variety
Sand Leather Front Seat	High	****(Halewood)	Sequenced	348
Ivory Leather Front Seat	High			
Heritage Tan Cloth Rear Seat	Low			119
Rear Seats Family with Heritage Tan Cloth Centre Headrest				
Rear Seats Family with Sand Cloth Centre Headrest	Medium			
Rear Seats Family with Sand Leather Centre Headrest				
2.5 L Auto Engine Gearbox	High	**** (Japan)	Non Sequenced	5
Headlamp CJ Level	High	***** (Banbury)	Sequenced	24
Headlamp GJ Level	Low			
Headlamp KJ Level	High			
Headlamp MJ Level	Low			
Brake Pedal for Manual Car (2 types: LHD and RHD)	High	*** (Scunthorpe)	Non Sequenced	4
Brake Pedal for Auto Car (2 types: LHD and RHD)	High			

Table 5.29 - Monitored Parts

For each of the parts listed in table 5.29, graphs were drawn up to illustrate the accuracy of the forecast provided by the Overlay and the DCI, by comparing them against the actual amount of cars constructed using that particular part. Appendix M provides a detailed analysis of how the graphs for each part deviate from the actual build.

5.7.3.1 Results

Immediately the analysis revealed a significant difference in the forecast accuracy between the DCI and the Overlay. Table 5.30 represents the forecast accuracy between DCI and Overlay, i.e. the MAD (Mean Absolute Deviation) between the forecast and the actual production. It should be noted that the accuracy of the DCI varied for different parts and suppliers as not all the parts had the same setting errors. Appendix M further illustrates the difference in the forecast accuracy between the DCI and the Overlay with a range of graphs.

Part	Average Daily Production Volume	Day 1		Day 2		Day 3		Day 4	
		Overlay	DCI	Overlay	DCI	Overlay	DCI	Overlay	DCI
Sand Leather Front Seat (ADX) *12 Feb - 19 Apr, 209 units*	209/44 = 4.75 unit/day	0.3182	11.6820	0.6364	4.8636	1.4545	4.8409	2.0909	5.0455
Ivory Leather Front Seat (NBD) *6 Feb - 19 Apr, 224 units*	224/45 = 4.98 unit/day	0.5333	12.1110	1.0667	5.5111	1.2667	5.4222	2.0889	5.2667
Heritage Tan Cloth Rear Seat (ADY) *4 Mar - 19 Apr, 15 units*	15/29 = 0.52 unit/day	0.0345	1.6207	0.2069	0.7586	0.2414	0.7241	0.1724	0.7586
Rear Seats with Sand Cloth Center Headrest (Part Family of 5) *12 Mar - 19 Apr, 469 units*	469/24 = 19.54 unit/day	1.6667	49.9630	2.4074	12.5930	2.6667	12.2590	3.0741	12.3330

MAD = Mean Absolute Deviation $\frac{\sum |Actual - Forecast|}{Sample \quad Size}$

Table 5.30 - Forecast Performance Analysis of Overlay and DCI in Mean Absolute Deviation

The Overlay clearly revealed a more accurate production schedule. All of the lines within the graphs (Appendix M) were positioned in close proximity to each other, which indicated that the part requirement forecast from the Overlay was more accurate. On the other hand, the analysis exposed the poor performance of the DCI. Therefore, further investigations were carried out in order to find out why a system of such strategic importance was not generating the appropriate information.

5.7.3.1.1 Reasons for DCI Poor Performance

The Cause-and-Effect diagram (figure 5.73), illustrates why the DCI produced such inaccurate forecasts. All of the factors documented in figure 5.73 could be categorised into 3 main groups.

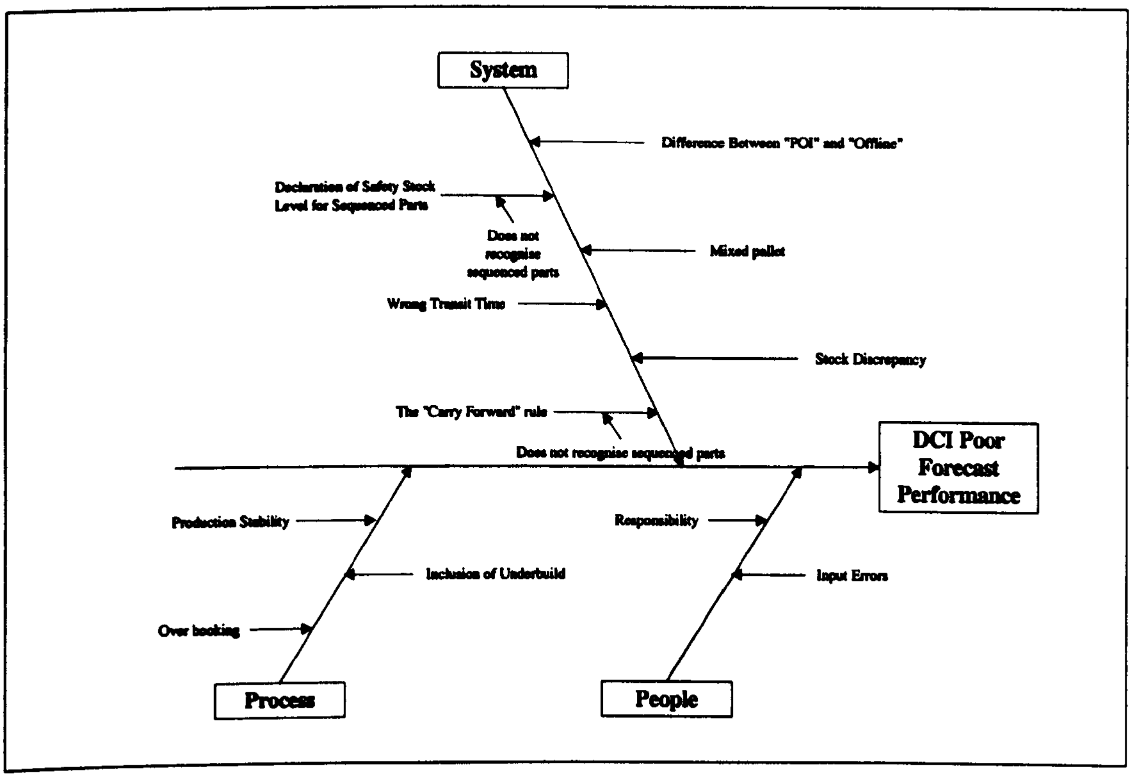


Figure 5.73 - Cause and Effect Diagram of DCI Poor Performance

- **People (Responsibility and Input Errors)**

The material supply analysts based at the VM generally overlooked DCI when planning schedules. This was mainly because sequenced suppliers always delivered according to the TLS, and not DCI. Effectively this meant that errors and problems in DCI had been overlooked. Furthermore, human error did contribute to poor DCI performance.

- **Process (Overbooking, Inclusion of Under-Build, Production Stability)**

Overbooking mainly occurred on sequenced parts and was due to a systems error. The inclusion of under-build caused a problem as the daily production schedule at the VM was full to capacity. Figure 5.74 shows that initially the under build for any particular week was simply added on to the top of the following days build schedule. Consequently, this meant was that the daily build quantity exceeded the daily build capacity. This had the domino effect of causing the DCI forecast to rise above the actual requirements. Once this problem had been identified, the production team formulated a solution whereby the build schedule was re-segmented everyday to include the under build jobs into the daily build schedule. This meant that each day the original schedule was pushed backwards which led to a change in the mix. Importantly, however, the build volume was not increased.

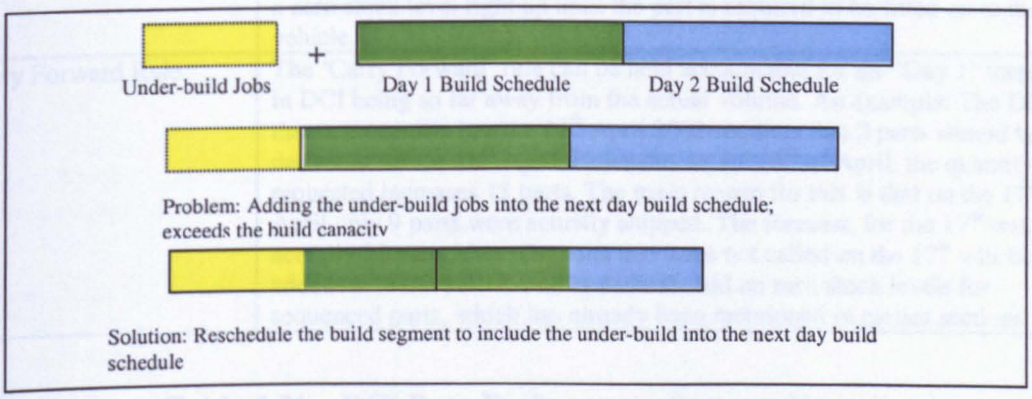


Figure 5.74 - The Inclusion of Under-Build

Production stability was also an issue with the plant being relatively new. As production volume changed frequently, demand forecast fluctuated to a greater extent. Systems and machinery breakdowns could be held accountable for most of these disruptions.

- **System**

There are a number of system errors associated to the poor DCI performance. Table 5.31 highlights the main themes.

Problem	**Description**
Declaration of Safety Stock Level on Sequenced Parts	CMMS3 does not recognise sequenced parts presently, and as a result, keeps a safety stock for all parts according to the standards defined when it was introduced (Usually this is 1 days worth of stock). Therefore, DCI always calls in the materials ahead of the schedule in order to maintain a safety stock.
Mixed Pallet	For example, the actual demand (overlay & TLS) for the headlamps is 20 units of A and 20 units of B. The supplier then ships 20 units of both headlamps in one pallet. DCI, however, will call for 40 units of each headlamp (as shown in Appendix N), as this is the minimum pallet size defined in CMMS3. Therefore, CMMS3 will think that there are excessive stocks in the plant and consequently does not order parts in the future.
Incorrect Transit Time	The current transit time residing in CMMS3 for Company B is 1.3 days, which is incorrect as they are situated within half a mile of A. Due to this DCI calls parts 2 days in ahead of schedule. Refer to Appendix O.
Stock Discrepancy	CMMS3 stores a higher stock level than is actually in stock for a number of parts at Company A. If the stock level for any particular part is reported to be above the safety stock level, then CMMS3 will not call for delivery. However, as far as sequenced parts are concerned, there should always be a zero stock level right up until the part is required to be fitted on to the vehicle.
Carry Forward Rule	The 'Carry Forward' rule can be held accountable for the 'Day 1' forecast in DCI being so far away from the actual volume. An example: The DCI that is transmitted on the 17th April 2002 requests that 2 parts should be delivered for the 18th April. However, on the 18th of April, the quantity requested increases 18 parts. The main reason for this is that on the 17th of April only 9 parts were actually shipped. The forecast, for the 17th was actually 21 parts, thus, the parts that were not called on the 17th will be added on to the 18th. In reality there should be zero stock levels for sequenced parts, which has already been mentioned in earlier sections.

Table 5.31 – DCI Poor Performance Systems Errors

5.7.3.1.2 Comparison of Overlay & DCI

From the analysis of Overlay and DCI, both had their pros and cons. Overlay was considerably accurate, but did not provide long-term visibility, and DCI was inaccurate but provided suppliers with future demand forecasts relating to what volumes the VM were looking to target. So from this it can be stated the main criteria affecting the performance of the forecast are its accuracy and its horizon.

An important outcome of this initial performance evaluation was to identify the most accurate information stream to transmit further down the supply chain under analysis. As the primary signal from the VM, the DCI's performance was less than satisfying. However a number of the problems identified in the previous section could be fixed to improve the DCI's performance. Thus, constraints such as safety stock, transit time and the carry forward rule were removed from the information gathered. Table 5.32 extends table 5.30 to reveal the results of the cleansed data. Graphs from this study can be found in Appendix P.

Part	Average Daily Production Volume	Day 1			Day 2			Day 3			Day 4		
		Overlay	DCI	Further Improved DCI	Overlay	DCI	Further Improved DCI	Overlay	DCI	Further Improved DCI	Overlay	DCI	Further Improved DCI
Sand Leather Front Seat (ADX) *12 Feb - 19 Apr, 209 units*	209/44 = 4.75 unit/day	0.3182	11.6820	2.7727	0.6364	4.8636	1.6364	1.4545	4.8409	1.8864	2.0909	5.0455	2.0909
Ivory Leather Front Seat (NED) *6 Feb - 19 Apr, 224 units*	224/45 = 4.98 unit/day	0.5333	12.1110	2.3111	1.0667	5.5111	2.1778	1.2667	5.4222	1.8444	2.0889	5.2667	2.0000
Heritage Tan Cloth Rear Seat (ADY) *4 Mar - 19 Apr, 15 units*	15/29 = 0.52 unit/day	0.0345	1.6207	0.4828	0.2069	0.7586	0.4828	0.2414	0.7241	0.5172	0.1724	0.7586	0.5517
Rear Seats with Sand Cloth Centre Headrest (Part Family of 5) *12 Mar - 19 Apr, 469 units*	469/24 = 19.54 unit/day	1.6667	49.9630	8.5200	2.4074	12.5930	7.4000	2.6667	12.2590	7.0800	3.0741	12.3330	7.6400

MAD = Mean Absolute Deviation $\frac{\sum |Actual - Forecast|}{Sample \quad Size}$

Further Improved DCI: No safety stock level, no transit time, No "Carry Forward" Rule

Table 5.32 - Forecast Performance Analysis of Overlay, DCI and Improved DCI in Mean Absolute Deviation

One can derive from the analysis above that the longer the forecast horizon, the further information can be passed down the supply chain. With this in mind the DCI, that provided a 10-day demand forecast along with quantities for future weeks and months would be the ideal platform to extract information for the new web-based system. However, the analysis above also revealed that the DCI's data was relatively inaccurate and so transmitting this data would be of little use.

Although the Overlay consists of a shorter forecast horizon, its data accuracy meant that it could be used to pass to second and third-tier suppliers with little worry of data corruption. Thus, in conclusion, it was decided that the Overlay should provide the basis for the three designs in Stage 4.

5.7.3.2 Scorecard

To illustrate the current performance of the supply chain using the scorecard, historical data was analysed on:

- OEM demand (VM) based on actual usage at the first tier supplier
- First tier demand based on the first tier supplier Kanban call off.
- Second tier demand based on deliveries from RCH assembler.
- Third tier demand based on deliveries from the cloth supplier.

The data was collected and analysed over a six-month period and provided an initial view of the performance of the supply chain under investigation. Data was collected and analysed at part number level. A sample of 4 out of the 10 Rear Centre Headrests, and 3 out of the 6 seat tracks were analysed. The part numbers for each component were selected to cover the usage range from runner to stranger. Scorecards were produced for each part number and the scores combined to give an overall measure for the supply chain. Table 5.33 displays the results.

The results in table 5.33 reveal a high bullwhip measure, low synchronisation index for second tier suppliers and negative the third tier supplier. A complete set of results for the Inventory analysis undertaken can be found in Appendix Q.

SUPPLY CHAIN BEHAVIOUR MEASURES	Current
Synchronisation index - overall (%)	**31.0**
First Tier	96.0
Second Tier	6.2
Third Tier	-9.4
Bullwhip measure (OEM - Tier 3)	**3.5**
RESPONSIVENESS MEASURES	
Supply chain cycle times - overall (days)	**10.0**
First Tier	3.0
Second Tier	3.8
Third Tier	3.1
Pipeline Inventory - overall (days of stock)	**8.9**
First Tier RM	2.6
Second Tier FG	1.5
Second Tier RM	2.0
Third Tier FG	2.8
Value adding/Non value adding (%)	12.2

Table 5.33 - Current Supply Chain Performance

5.7.4 Stage 4 – Design and Prototyping

Three designs are discussed in this section to facilitate improvement in both the supply chain and also the information systems infrastructure. Stage 1 of this case stated that this research aimed to e-enable the information demand triggers from the VM to the first-tier sequenced supplier. It was hoped that this information could simultaneously be transmitted to the other companies involved in the study. With this in mind, three architectures are presented in this Chapter that seek to demonstrate how the demand triggers can be made available to sub first tier suppliers.

5.7.4.1 EA-Based Integration Architecture

The EA-based architecture in this case was envisaged to possess similarities to the single instance generic architecture, as its specific aim was integrate with suppliers based in tiers one to three. The systems in place at the VM did not have the functionality of modern day ERP/SCM software and so in order to envision a situation whereby the OEM demand triggers are made visible to tiers two and three it was essential that a more sophisticated enterprise system be implemented.

The VM had entered into early negotiations with SAP to implement their solution throughout their manufacturing facility. Therefore it was decided that the SAP solution should provide the basis for the architecture in this section.

5.7.4.1.1 SAP

Having referred extensively to the SAP website it became evident that SAP had undertaken a number of projects within the Automotive industry in recent years. More specifically, the BMW group implemented the mySAP Automotive solution in order to achieve certain aims. Discussing this briefly, mySAP Automotive receives custom-configured manufacturing orders from BMW's planning system. The orders include all the parts required to build each car. mySAP Automotive generates the delivery schedules for each part to match BMW's assembly-line planning and sequencing directives.

BMW sends these long-horizon forecasts and short-horizon JIT delivery schedules to its suppliers. Larger suppliers receive the information via EDI. Other suppliers access the mySAP Automotive supplier portal, where BMW posts the requirements to provide up-to-date information on its delivery needs. Using an Internet browser, suppliers can view the information in real time, including release schedules, purchasing documents, invoices and engineering documents. When parts are shipped, suppliers send BMW advance shipping notifications (ASNs) to provide the car manufacturer with exact information on parts counts and delivery dates. Parts arriving at loading bay are received and transferred directly to the line. Once on the production line, mySAP Automotive monitors the production status in real time. The system registers production confirmation and parts consumption information every three minutes.

The situation at BMW is very similar to the scenario of this case as the aim here was to provide data to the first tier supplier along with a selected number of lower tier suppliers. Therefore EDI could be used to send the data to the first tier supplier, whilst the smaller supplier situated in tiers two and three could use the supplier portal to access the information relating to them. It was envisaged that the SAP system would produce far more accurate information than the multiple systems at the FM. Figure 5.75 illustrates the EA-based integration architecture for this case.

Due to the vast differences that would have to be made should an EA-based architecture come into operation, figure 5.75 ignored a number of the elements from the original systems map. The advanced functionality of the SAP system would replace the ineffective systems at the FM. The Supplier Portal enables those suppliers with access rights to obtain information relating to their operations. It would be beneficial if the SAP system could be configured with the bill of materials for the seat module so that when a seat is requested the appropriate suppliers are informed to replenish the first tier sequenced supplier. If this was implemented then there would be clear advantages for all involved. In terms of the generic architecture in Chapter 4, the supplier portal would enable multiple suppliers to become connected. Whilst it does not fit the exact requirements for the 'single instance' generic architecture it is clear that there are many similarities.

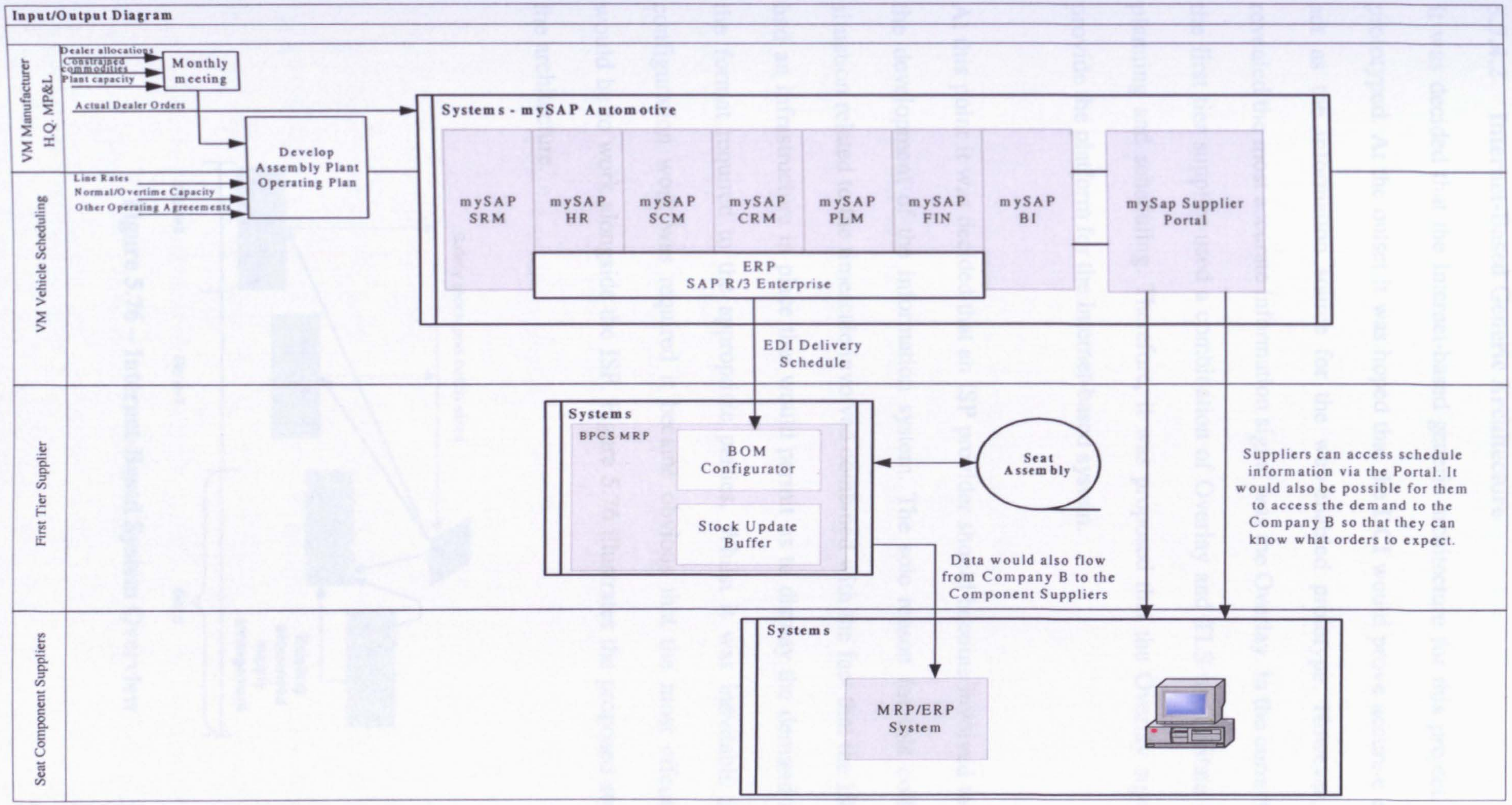


Figure 5.75 – EA-Based Integration Architecture

5.7.4.2 Internet-Based Generic Architecture

It was decided that the Internet-based generic architecture for this project would be prototyped. At the outset it was hoped that the DCI would prove accurate enough to act as the information source for the web-enabled prototype. However, Stage 3 revealed the most accurate information signal was the Overlay. In the current scenario the first tier supplier used a combination of Overlay and TLS to facilitate improved planning and scheduling. Therefore, it was proposed that the Overlay signal would provide the platform for the Internet-based system.

At this point it was decided that an ISP provider should become involved to facilitate the development of the information system. The sole reason for this collaborative situation related to the timescale involved combined with the fact that the ISP already had an infrastructure in place that would permit us to display the demand signals in the format required to the appropriate parties. Whilst it was inevitable that some configuration work was required it became obvious that the most effective route would be to work alongside the ISP. Figure 5.76 illustrates the proposed structure of the architecture.

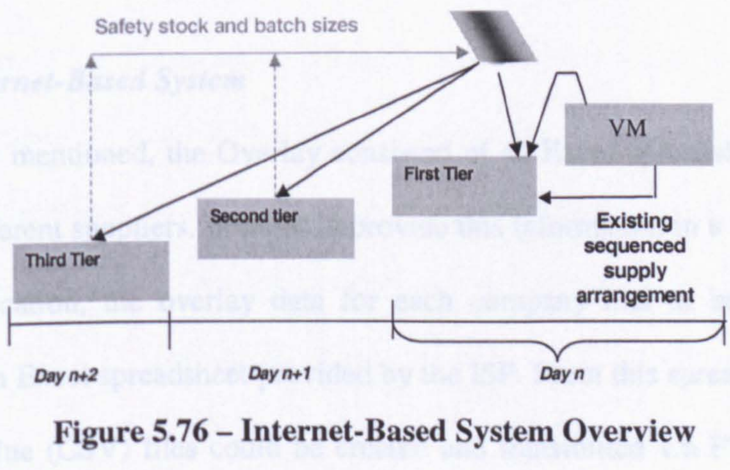


Figure 5.76 – Internet-Based System Overview

There were three principal components to the architecture of the web-enabled system: the information stream, the presentation platform and the viewer. Figure 5.77 illustrates the 3 main components.

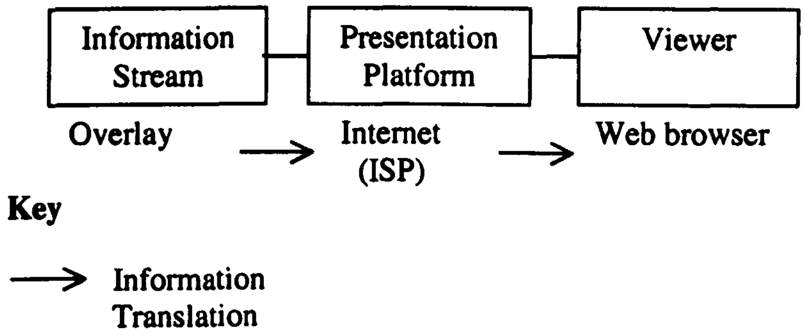


Figure 5.77 - Three Components of Web-enabled System

The Overlay was the first component of the three, and is the main source of information. The ISP provided the second web-based component for this architecture. Hosted online, their application could be configured to provide each company in the supply chain access to part quantities found in the Overlay. In order to do this the original Overlay data had to be filtered and segmented for the different suppliers. The final component was the Internet which each of the suppliers in the cluster required in order to view the information relevant to them.

5.7.4.2.1 Internet-Based System

As previously mentioned, the Overlay consisted of an Excel spreadsheet, segmented for all the different suppliers. In order to provide this information in a valid format for the ISP application, the overlay data for each company had to be extracted and relocated in an Excel spreadsheet provided by the ISP. From this spreadsheet, Comma Separated Value (CSV) files could be created and transmitted via FTP. Figure 5.78 reveals how the system functions.

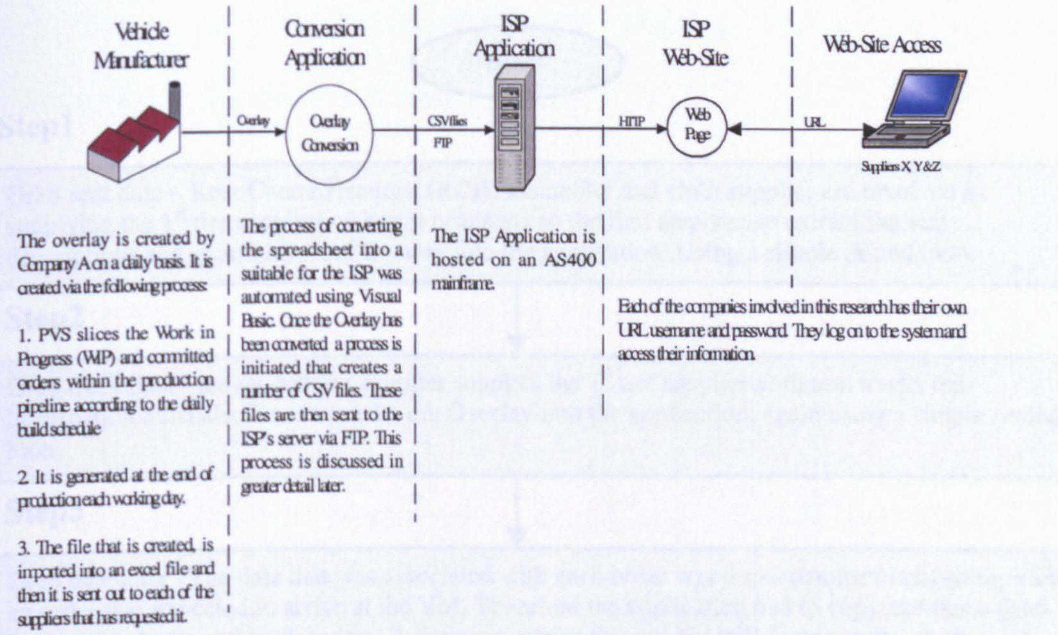


Figure 5.78 – System Overview

Figure 5.78 shows that there are 4 principal components. As previously mentioned, the Overlay was created in conjunction with PVS. The steps that were taken in creating the overlay have already been discussed. Following this the conversion application is required to translate the Overlay spreadsheet into a format suitable for the ISP spreadsheet. The flow diagram below (figure 5.79) demonstrates the conversion process.

Implementation of the conversion application started with a Visual Basic program to extract information for each of the companies concerned. The application took into account the current day, cloth quantities by style, totals leather quantities by style. It took a two-day lead-time offset for Companies and C and C1, a three day lead time offset for Company D. The result of this process is the population of the ISP's spreadsheet with data. Screen Shots for this application along with a sample CSV file are situated in Appendix R.

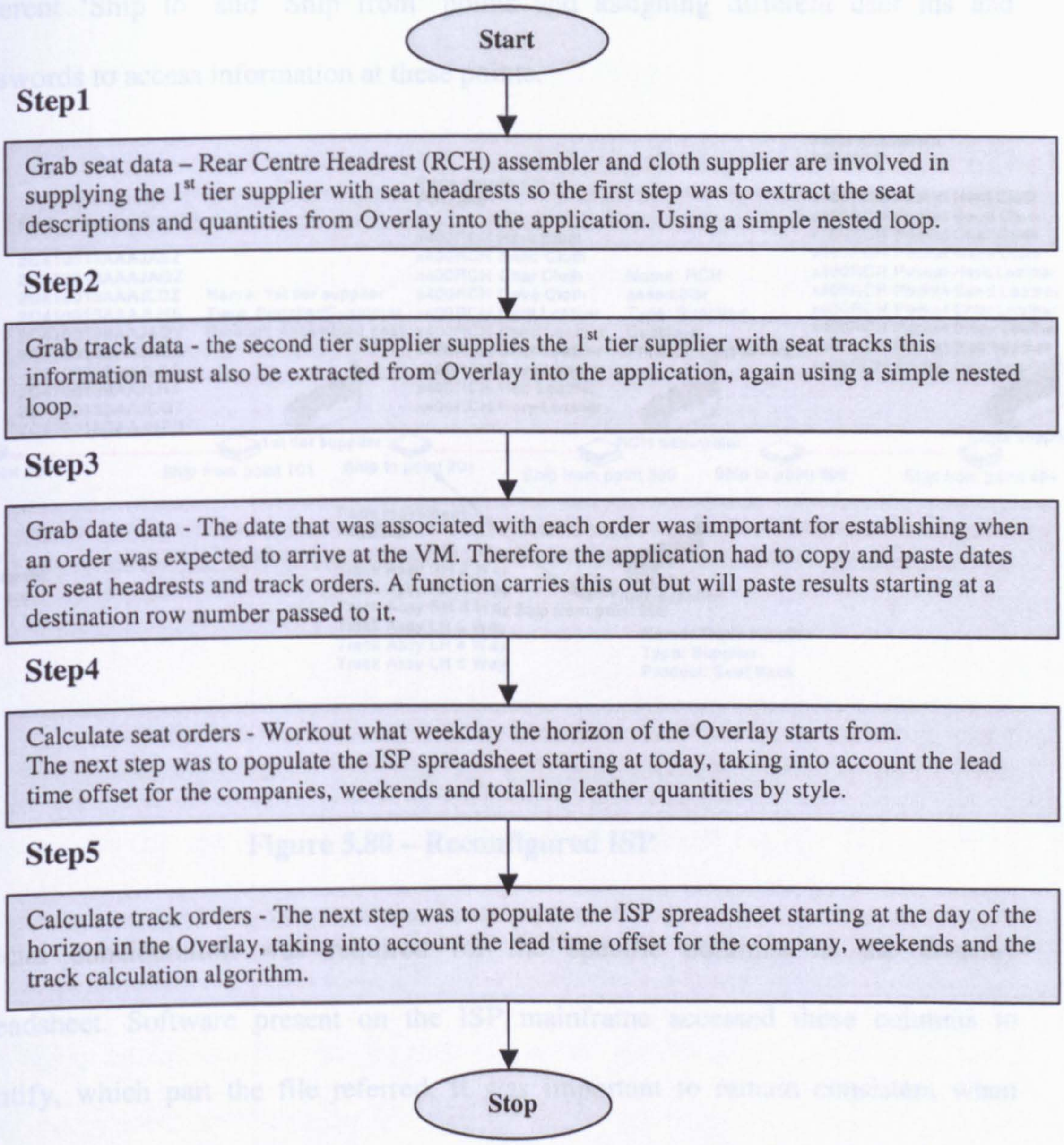


Figure 5.79 – Conversion Process

The ISP application (presentation platform) was hosted on a number of AS400 mainframes. All the companies were assigned a unique URL, username and password. For this project, the ISP allocated space on their servers for 5 different users, along with administrator rights. The application could then be configured to suit the particular supply scenario. However, a typical scenario revolved around shipments going to one source. This did not reflect the needs of the case. The resulting configuration demonstrated in figure 5.80 overcame this limitation by creating different 'Ship to' and 'Ship from' points and assigning different user ids and passwords to access information at these points.

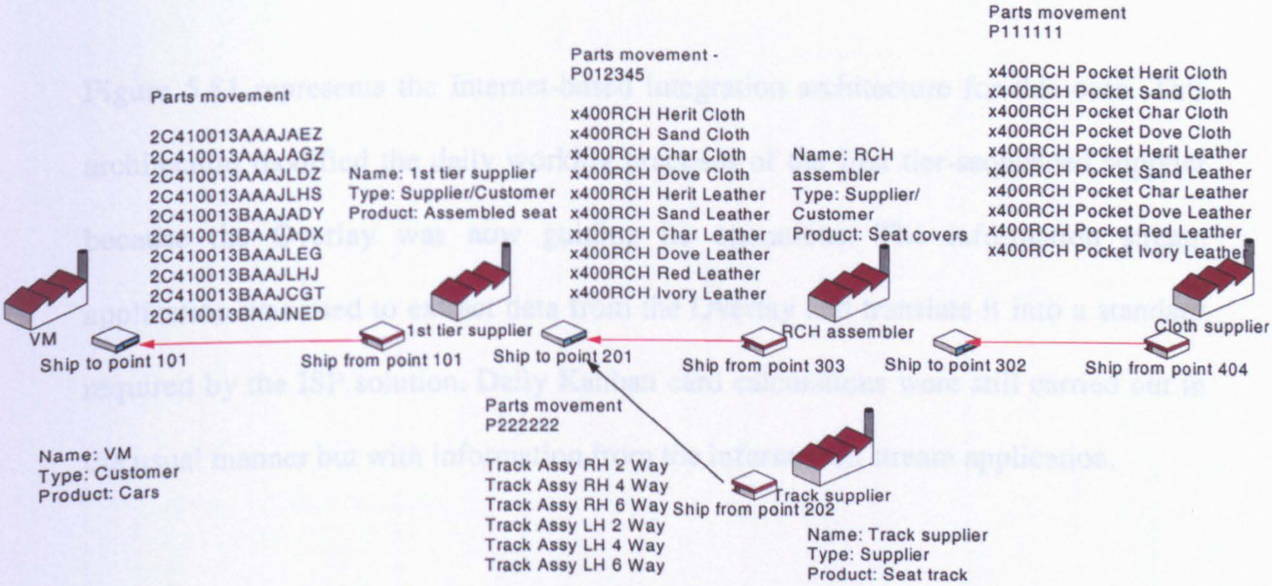


Figure 5.80 – Reconfigured ISP

Special consideration was required for the specific columns in the Overlay spreadsheet. Software present on the ISP mainframe accessed these columns to identify, which part the file referred. It was important to remain consistent when defining values for these variables, during the conversion and on the website, because inconsistencies would result in missing information.

Glass Pipeline experiments that were undertaken with the data sets resulted in another variation of the configuration shown in figure 5.80. The initial experiment displayed individual quantities of parts (GP 1), further experiments required more "Ship to" points to be added, in order to display batch quantities for GP 2 and GP 3. The Overlay conversion had to reflect these new "ship to" points and user ids and passwords had to be issued. The glass pipeline experiments are discussed in greater detail in the Prototype Section to follow along with Stage 5.

Figure 5.81 represents the Internet-based integration architecture for this case. This architecture modified the daily working practises of the first tier-sequenced supplier because the Overlay was now guiding its operations. The information stream application was used to extract data from the Overlay and translate it into a standard required by the ISP solution. Daily Kanban card calculations were still carried out in the usual manner but with information from the information stream application.

This architecture enabled the companies concerned to access requirement information via the Internet application. Confirmation of goods received was recorded in two locations (BPCS and the ISP solution). This was because of the first tier suppliers' insistence on continuing this practise.

Identifying similarities between the generic Internet architectures designed in Chapter 4 it was evident that Version 2 acted as the template for this case. From the configuration of the system it is clear that the vendor solution acted as a hub whereby multiple suppliers could access the information appropriate to them. As considered in Chapter 4, the ISP application had to be configured in the appropriate way to enable this scenario to take place. The benefits of this configuration are demonstrated in Stage 5.

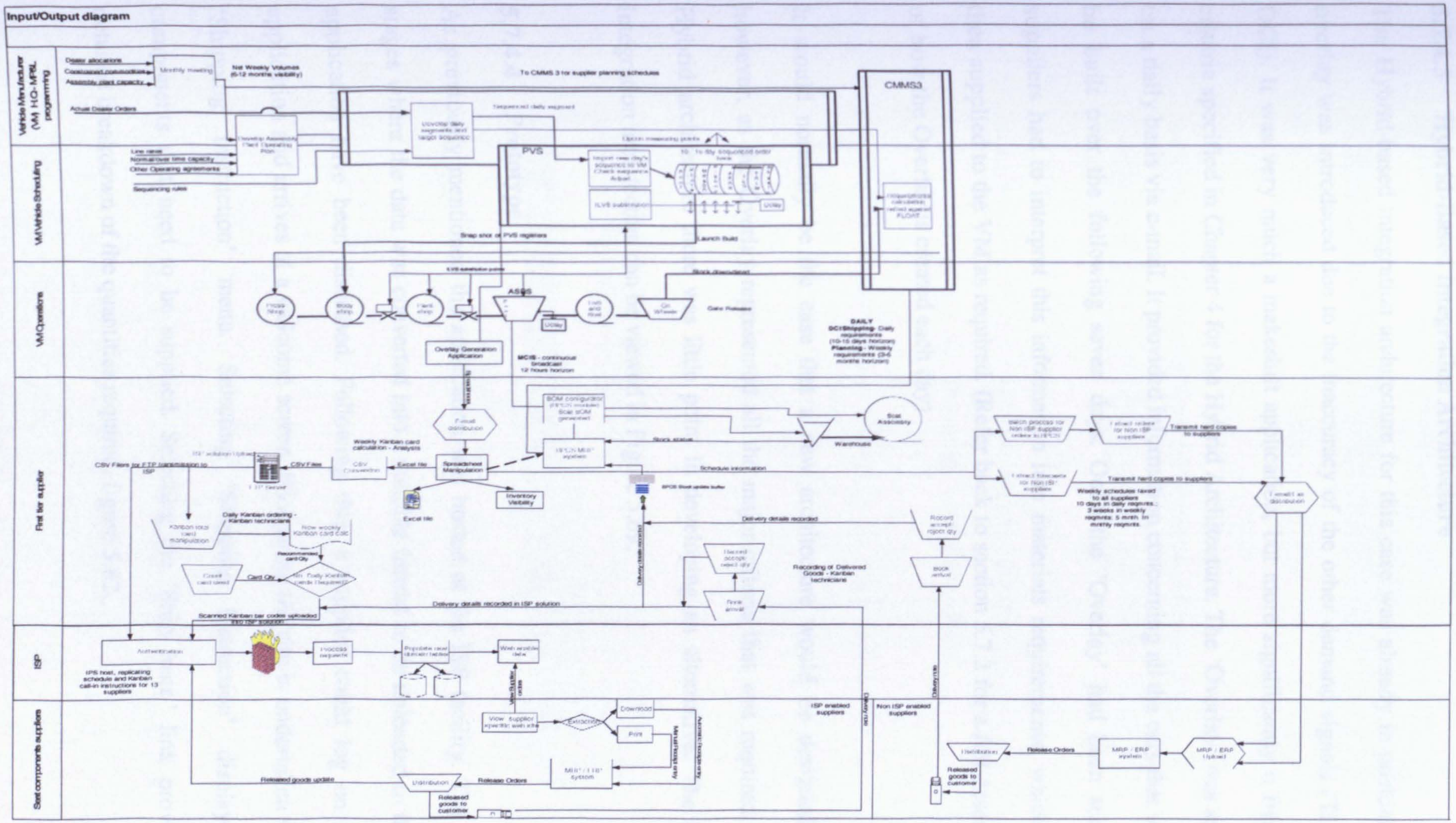


Figure 5.81 - Internet-Based Integration Architecture

5.7.4.3 Hybrid-Based Integration Architecture

The Hybrid-based integration architecture for this case was already in position. The overlay was introduced due to the inaccuracy of the other demand signals (TLS and DCI). It was very much a makeshift application, but more significantly it fitted the criteria specified in Chapter 4 for the Hybrid Architecture. The 'Overlay' was sent out on a daily basis via e-mail. It provided information concerning all the cars that were to be built over the following seven days. Once the 'Overlay' had been sent, the suppliers had to interpret this information into materials requirements, which were then supplied to the VM as required. (Refer back to section 5.7.2 for a full description of how the Overlay is created each day)

It would normally be the case that a new architecture would be designed here, however, as the Overlay represented all the major criteria that was required of the Hybrid architecture there was little point in developing an alternative. The hybrid integration architecture can be viewed in Figure 5.69.

5.7.4.4 Prototype

As previously mentioned the application was hosted at the ISP facility. The initial stages where the data was converted into a suitable format to be uploaded to the ISP application have been discussed. Following this, a supplier could log on to the application and arrives at a welcome screen. Navigating the site is undertaken via the 'Shipping Instruction' menu. Selecting 'Shipping Instruction' displays the components that need to be supplied. Selecting the 'Ship Instr.' link provides a detailed breakdown of the quantities required, figure 5.82.

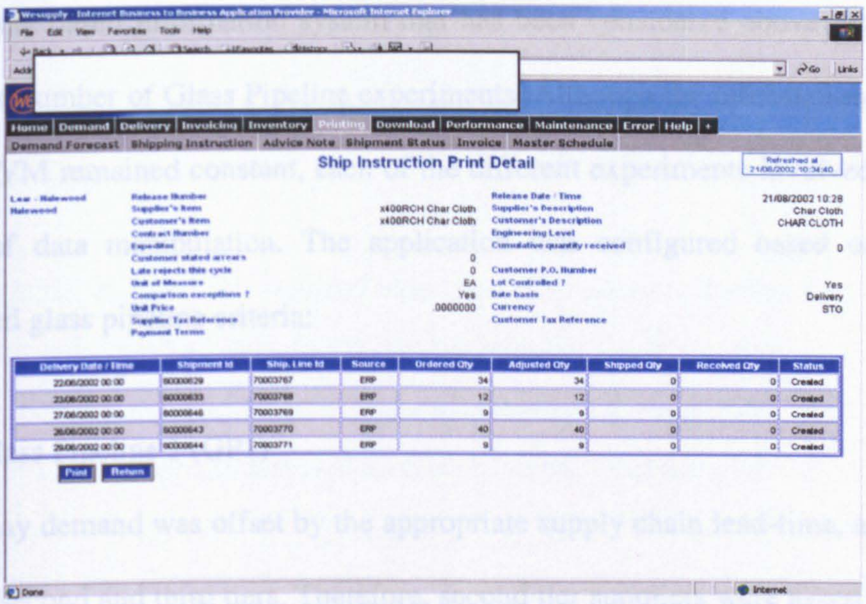


Figure 5.82 - Shipping Instruction Detail

Accessing the site as a customer and following the steps outlined above: will bring users to the supplier selection (figure 5.83). Here to view a projected delivery schedule, a user must select a supplier, from the list, followed by clicking the "Confirm" button.

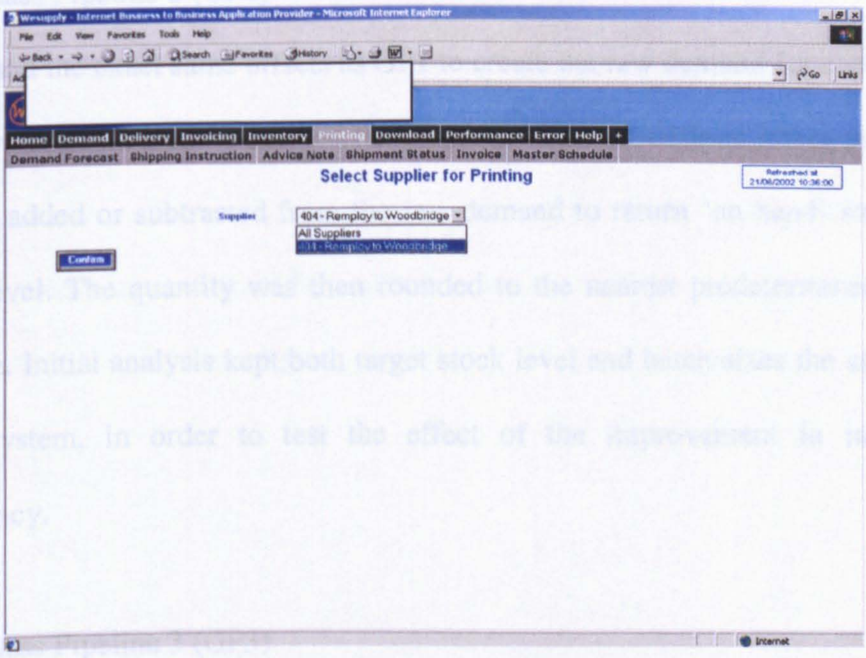


Figure 5.83 - Supplier Selection

The Internet-based information system that has been considered above provides the basis for a number of Glass Pipeline experiments. Although the information extracted from the VM remained constant, each of the different experiments involved a certain amount of data manipulation. The application was configured based on the pre determined glass pipeline criteria:

- Glass Pipeline 1 (GP1)

The overlay demand was offset by the appropriate supply chain lead-time, and passed on to the second and third tiers. Therefore, second tier suppliers were asked to deliver to the VM's requirements one full day before the scheduled build day. This reflects the current 1-day supply chain cycle time for first tier supplier to sequence, manufacture and delivery to the VM. Third tier suppliers were offset by a further day, being asked to deliver second tier requirements 3 days before the FM's build day.

- Glass Pipeline 2 (GP2)

GP2 utilised the exact same offsets as GP1 to create the raw demand for each tier on a given day. Then GP2 compared 'on hand' stock with a predefined safety stock target level and added or subtracted from the raw demand to return 'on hand' stock to the desired level. The quantity was then rounded to the nearest predetermined delivery batch size. Initial analysis kept both target stock level and batch sizes the same as the current system, in order to test the effect of the improvement in information transparency.

- Glass Pipeline 3 (GP3)

GP3 utilised the same principal as GP2, but rather than sampling stock, and updating the FM's demand weekly, GP3 used daily updates.

5.7.5 Stage 5 – Evaluation of Integrated Designs

Data for the glass pipeline experiments was collected over a six-month period. The data collected included:

- Vehicle Manufacturer demand based on actual usage at the first tier supplier
- First tier demand based on the first tier supplier Kanban call off
- Second tier demand based on deliveries from RCH assembler
- Third tier demand based on deliveries from the cloth supplier

A spreadsheet was developed in which the outputs from the 'real' (current) supply chain were input, next to the outputs from the Internet application (Overlay). The spreadsheet allowed different GP algorithms to be applied. GP1 and GP2 were posted on the web through the system. GP 3 was simulated and produced internally to the study for analysis against GP1 and GP2. To evaluate the GP experiments both against each other, and in relation to the existing ERP outputs, a scorecard was incorporated. Data collection, and evaluation of the prototype output was conducted over a six-month period (Table 5.34). Table 5.34 shows details of the data gathered during the survey period. Data was collected and analysed at part number level. A sample of 4 out of the 10 Rear Centre Headrests, and 3 out of the 6 seat tracks were analysed. Scorecards were also produced for each part number, but then the scores combined to give overall measures for each glass pipeline.

Data	Current	GP 1	GP 2	GP 3
VM demand	✓	-	-	-
1st tier supplier usage	✓	-	-	-
MRP schedule RCH assembler	✓	-	-	-
Kanban call RCH assembler	✓	-	-	-
MRP schedule track supplier	✓	-	-	-
Kanban call track supplier	✓	-	-	-
1st tier supplier Raw material stock	✓	-	-	-
RCH assembler deliveries	✓	-	-	-
RCH assembler Finished goods stock	[1]	-	-	-
RCH assembler raw materials	[1]	-	-	-
Track supplier Deliveries	✓	-	-	-
Track supplier Finished Goods stock	[1]	-	-	-
Track supplier Raw materials	[1]	-	-	-
Cloth supplier deliveries	✓	-	-	-
GP requirements and deliveries to RCH assembler	-	✓	✓	✓
GP requirements and deliveries to track supplier	-	✓	✓	✓
GP requirements and deliveries to cloth supplier	-	✓	✓	✓
1st tier supplier RM stock if GP was followed [2]	-	✓	✓	✓
RCH assembler RM stock if GP was followed [2]	-	✓	✓	✓

Table 5.34 - Data Collated During the Survey Period

5.7.5.1 Glass Pipeline Experiments

This section reveals the results from the analysis of the supply chain subset. Appendix S contains screen shots from the full set of results that included the analysis of the seat track supply chain. Table 5.35 presents a summary of the results for each of the optimised glass pipelines.

SUPPLY CHAIN BEHAVIOUR MEASURES	Current	GP 1	GP 2	GP 3
Synchronisation index - overall (%)	31.0	78.2	44.8	45.0
First tier	96.0	96.0	96.0	96.0
Second tier	6.2	69.2	35.2	35.0
Third tier	-9.4	69.2	3.2	4.1
Bullwhip measure (VM - Tier 3)	3.5	1.2	2.5	2.3
RESPONSIVENESS MEASURES				
Supply chain cycle times - overall (days)	10.0	6.1	7.6	6.7
Pipeline Inventory - overall (days of stock)	8.89	5.06	6.50	5.65

Table 5.35 - Summary RCH scorecard, optimised for GP 1-GP 5

[1] Stock not monitored, but average figure obtained from the company
[2] Simulated

GP1 represents a situation where the supply chain is highly synchronised. The existing sequenced supply link from the VM to the first tier-sequenced supplier exhibited a high degree of synchronisation. Furthermore, the second and third tier would manufacture and deliver in line with VM demand, with a synchronisation index of 69. The remaining 'lack of synchronisation' is accounted for by any discrepancies between overlay and VM actual demand.

Bullwhip was also reduced significantly and GP1 gives the lowest Bullwhip measure out of the 3 GP experiments. The level of Pipeline stock was determined primarily by the lags in the system. In the studied chain, whatever is delivered to second tier should be used the next day, and so stock should oscillate around a safety stock that is determined by the on-hand stock at the start of the analysis period. Hence, optimisation of GP1 was achieved by lowering the starting stock to a level that results in no stock-outs, but gives minimum pipeline stock. In practice this 'retrospective' optimisation would be impractical, and for GP1 to become operational, a more dynamic safety stock monitor would be required to guard against stock-out.

In order to optimise GP2, it was necessary to manipulate the safety stock targets. In the real supply chain, these are set at a multiple of the delivery batch size. (High usage items have a target of 2 * batch of 28 = 56, low usage have a target of 1*28=28). When safety stock targets are left at current system levels, there was some reduction in pipeline inventory, indicating that the information transparency alone brings some advantage. The real power in terms of inventory reduction, though, comes when the safety targets are reduced. This was feasible using the GP system, because of its ability to reduce amplifications, and hence peaks and troughs in demand.

Bullwhip was reduced, although not to the level of GP1. This was related to the fact that the algorithm for GP2 (and GP3) utilised a safety stock target. This combined with the unavoidable time lag, and (in the case of GP2 and GP3.) fixed batch sizes – meant that even with the information transparency, there are still some significant drivers for amplification.

Requirements in GP2 were sampled and transmitted once per week. This meant that any changes to VM demand in the course of the car's build week would not be passed on to the supplier. Consequently, this adversely affects the experiment, in terms of synchronisation, and ultimately inventory performance.

Requirements in GP3 were sampled and transmitted on a daily basis. This factor represented the single difference GP3 and GP2. However, the affect of the greater update frequency was revealed in a lower pipeline inventory, lower bullwhip, and higher synchronisation. It should be noted here that synchronisation for both GP2 and GP3 divulge lower than expected results. The analysis month had some very 'testing' conditions for the GP system, in that every Friday was a down day for the VM. In practice this meant that the system had to cope with a wildly fluctuating demand pattern from Thursday to Monday. Overall, GP3 gave the best performance. The behaviour of the supply chain is at an optimum, when compared with the implementation costs for the changes.

One of the most important tests for the different glass pipelines was the return on capital they generate. Figure 5.84 showed that ROI was at a maximum for GP 3. GP 2 exhibited the lowest implementation cost, but the extra cost savings from GP 3 outweighed this.

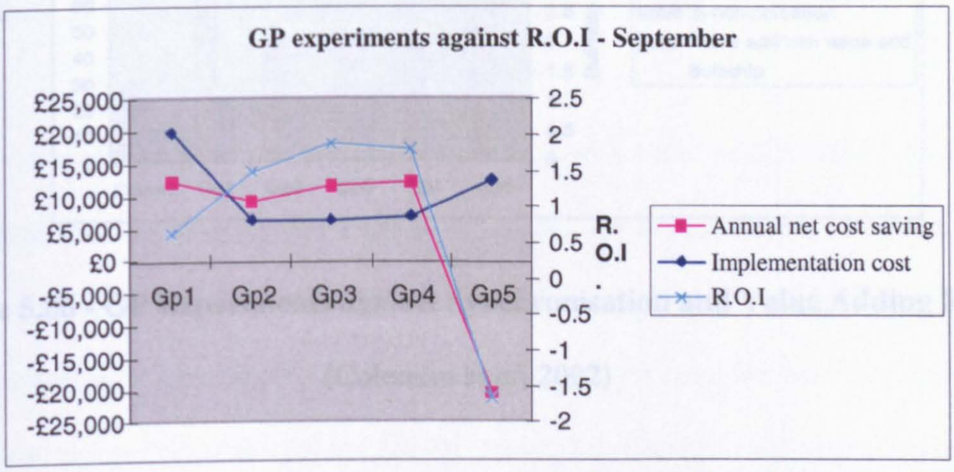


Figure 5.84 - GP Experiments against ROI (Coleman *et al*, 2002)

Looking in more detail at cost savings, it can be seen (figure 5.85) that GP5 generates the lowest pipeline inventory.

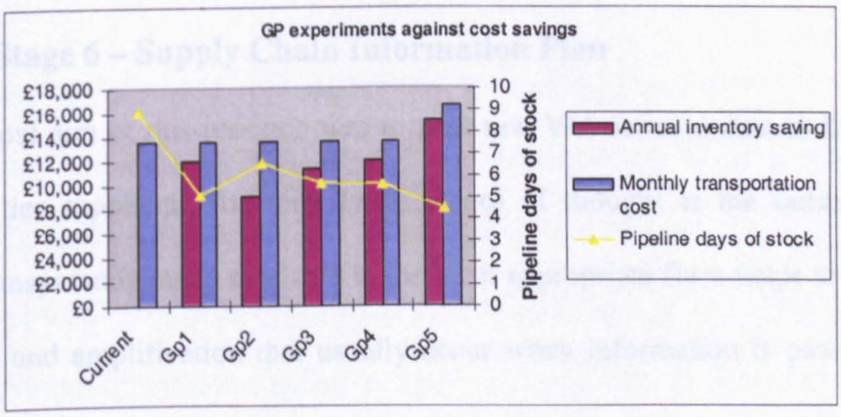


Figure 5.85 - GP Experiments against Cost Savings (Coleman *et al*, 2002)

Looking at the performance of the supply chain subset purely in terms of synchronisation and bullwhip, the best performance comes from GP1. However, the rest of the analysis clearly revealed that inventory reductions and cost savings do not necessarily follow in line with supply chain behavioural performance.

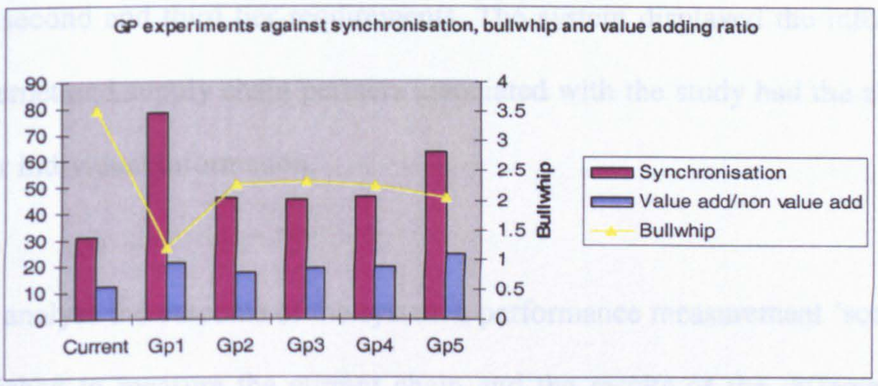


Figure 5.86 - GP Experiments against Synchronisation and Value Adding Ratio (Coleman *et al*, 2002)

Overall, GP3 was the experiment that showed the best trade-off between operating and implementation costs. A yearly saving on Rear Centre Headrest alone of some £11,500 on a total yearly spend of some £160,000 – (7% saving) – was demonstrated (Coleman *et al*, 2002).

5.7.6 Stage 6 – Supply Chain Information Plan

The principal aim of this research was to pass raw VM demand data to first, second and third tier suppliers. The underlying school of thought at the outset was that demand transparency made available in the most appropriate form helps to reduce the distortions and amplification that usually occur when information is passed down a chain in a step-by-step manner.

The research provided results based upon a sample supply chain (Vehicle Seats) in the Automotive Sector. Three integration architectures were designed in-line with the requirements of this research and the Internet-based system was prototyped to demonstrate the effects of implementing a system to integrate from OEM to tier 3. The Internet-based system provided an accurate 6-day vehicle build forecast and calculated second and third tier requirements. The system displayed the information via the Internet and supply chain partners associated with the study had the ability to access their individual information.

In order to analyse the outcome of the system a performance measurement 'scorecard' was established to measure the current chain and the results of the different Glass Pipeline experiments. This analysis revealed the existing chain to exhibit low levels of synchronisation in second and third tier, with high degrees of demand amplification. (Synchronisation 31%, Bullwhip 3.5 (> 1=amplification)). Further investigations revealed that if the supply chain was to operate with the Internet-based system, then synchronisation would have been improved by as much as 46% to 78% (for GP1). In turn, it was demonstrated that a reduction in raw materials inventory of 51% would be feasible.

The most appropriate integration architecture for this case would have characteristics similar to the 'Single Instance' EA-based integration architecture discussed in Chapter 4. However, with the probability of suppliers in an automotive supply chain relinquishing control of their internal planning systems being very slim, the Internet-based integration architecture offers a significant opportunity for first, second and third tier suppliers to synchronise with VM demand.

A number of barriers must be removed if the Internet-based system is to succeed and become fully operational in the future. Forecast accuracy was probably one of the most significant barriers for a number of reasons. Information transparency by its nature increases the response speed of the supply chain, (which is a positive outcome) and it means that lower tiers are manufacturing more closely to the demand data provided by the 'transparent system'. However, this means that it is very important that the demand data that drives the system is accurate, and stable for at least the cycle time that allows the lowest tier in the system to react.

The second issue relates to the Bills of Material (BOM). Products in this and other similar sectors have thousands of components. Permutations of the Bill Of Materials run into tens of thousands depending on the Finished Product Code. For the 'Glass Pipeline' system to become operational it needs to have a method of interpreting the finished product codes and deducing from these the components that second and third tier must contribute. For the trial system, this issue was avoided by choosing a supply chain subset where the trim colour and fabric alone determined the components required from second and third tier. Trim fabric and colour could be deduced with relative ease from the finished goods code.

In conclusion, the project as a whole, and the 'Glass Pipeline' prototype trials in particular have shown the potential for the Internet to be utilised as a worthy medium for permitting information transparency. The investigation took place in a complex sector and data emerged to endorse the premise that information transparency can be enhanced via an improvement in the flow of information. Three architectures were designed for this case, one of which was implemented to demonstrate a number of fundamental principals necessary to warrant the development of a more sophisticated system. Interesting technical and sociological issues to do with implementing information transparency in the sector have also been highlighted.

5.8 Chapter Summary

In summary, this Chapter presents five case studies situated in a range of different supply network environments. Each case has followed the SCICM format defined in Chapter 3. More importantly, three architectures have been designed for each case to fit with the main objectives of this research. The architectures are case specific and where possible, prototypes have supported the designs. The prototyped applications seek to demonstrate the validity of the proposed architectures whilst also adding real benefit to the companies involved. The following Chapter considers the conclusions that can be drawn based upon the case studies and the work undertaken in the other elements of this research.

6 CONCLUSIONS

6.1 Introduction

The research presented within this thesis validates three supply chain integration architectures to facilitate the next generation of manufacturing. Following an extensive review of the technologies and integration components available, three integration architectures were established based upon a pre-determined framework. The framework was developed to introduce the concepts of Enterprise Application (EA)-based, Internet-based and hybrid-based supply chain integration architectures to apply to a selection of case studies. In conjunction with this, the classification framework (Chapter 3) and the supply chain integration case methodology (SCICM) brought together the necessary elements to undertake five industry-based case studies. Empirical evidence of the applications and architectures that have been applied to actual supply chain scenarios is presented within the Case Study Chapter. Ultimately, this research enables companies to recognise the real benefits of information sharing, namely, reduced order cycle times, which in turn reduces inventory levels, improved efficiency in terms of forecasting (Lin *et al*, 2002) and reduced costs across the chain. In addition, companies can utilise this research to determine the most appropriate supply chain integration configurations for their particular situation.

This Chapter examines the findings of this research. Chapter 1 openly defined the research questions, hypotheses and objectives for this research. The sections to follow methodically respond to the research questions and hypotheses proposed at the outset. Following on from this, the contribution to knowledge is identified in order to portray the true value of this research. The further work section considers the themes that should be investigated in the future to maintain the momentum of the work undertaken here. A brief summary concludes this chapter.

6.2 Research Questions (Response)

The dialogue to follow represents a response to each of the research questions presented in Chapter 1.

Question 1

Which Enterprise Application (EA) and Internet systems and technologies are available to support supply chain strategies between trading partners situated at different levels of a supply chain?

There are a considerable number of technologies, both EA-based and Internet-based, available to support supply chain integration. Sections 4.2.2 and 4.3.2 of the Analysis Framework Chapter identified those technologies discussed in both academic and commercial circles that facilitate trading partner integration. Furthermore, the literature review revealed that there are three categories of commercial systems (ERP, SCM and Bespoke ISP) available to enable supply chain integration. ERP systems such as SAP and PeopleSoft emerged from the early MRP systems. Consequently until the arrival of SCM software much of their functionality was focussed upon internal processing. With the advent of SCM software such as i2 and Manugistics, ERP software was redesigned to encompass much of the functionality associated with the new and innovative SCM software. Thus, ERP vendors are clearly undergoing a period of transition as they are trying to keep pace with the developments in both technology and strategy. It became evident from the research undertaken that the markets for ERP and SCM products are gradually converging.

In terms of the Internet-based systems, many academics (Olafsson *et al*, 2001; Kokkinaki *et al*, 2001; Nurmilaakso *et al*, 2001; James *et al*, 2004) have reported on how the Internet and its associated technologies can combine to communicate information across company boundaries. On the other side of the coin, ISPs (WeSupply, VerticalNet) have emerged in recent years to offer bespoke applications to enhance supply network communication. WeSupply, for example, look to enhance supply chain operations by enabling real-time sharing of demand and fulfilment information. Within the ISPs that have been considered within this research, there was also a growing trend for them to offer hosted ERP and SCM software such as SAP and i2. However, the author feels that the true potential of this type of scheme has yet to be truly realised (refer to further work). For a complete evaluation of the systems available to support supply chain initiatives refer to Appendix A.

Question 2

Which components are required to support the integration of these systems?

From the Case Study Chapter, a selection of EA-based and Internet-based systems have been incorporated to facilitate a range of strategies. Focussing upon EA-based systems first, each case represents the unique configuration of a particular EA system. The Internet platform and its associated tools and technologies represent the primary integration tool for all the EA systems discussed in Chapter 5. More specifically, Case 1 illustrated how the particular ERP vendor had collaborated with an Internet supply chain integration product to enhance the services it offered to its customers. The ERP system did not possess the necessary components to facilitate a high degree of integration and so the collaborator was fundamental to enable integration. The system considered here did not represent the most comprehensive solution presented in the Case Study Chapter.

Case 2 highlighted Internet-based 'portal technology' as being the key component of the particular EA system to enable integration. The product incorporated portal technology to communicate with both suppliers and customers. The two portals considered within the case could be configured to enable the electronic exchange of trading documents with other systems via XML, EDIFACT, SAP IDOC and flat files via an XML standard. Whilst it is acknowledged that the Internet is the primary technology behind portals, it is the enterprise data and processes that are being transported across the company boundaries within this integration architecture that was important here.

The EA solution in Case 3 was determined by the VMI initiative in operation between the distributor and the manufacturer. With VMI becoming an increasingly popular initiative (Disney and Towill, 2003a, 2003b; Dong and Xu, 2002; Kuk, 2004; Waller *et al*, 1999;) the software vendor had developed two methods to facilitate this strategy. Whilst both integration architectures require the particular EA product to be present at both the supplier and the distributor, they do provide examples of a truly integrated approach to VMI. EDI represented the principal method for communication in both of the methods.

Case 4 highlighted a number of inadequacies of modern day EA solutions in regard to managing a remanufacturing environment. However, it was demonstrated that two software vendors could successfully control a remanufacturing environment by incorporating either portal technology or via a company developed EA integration tool.

The final case (Case Five) represented a more complex scenario. With a number of disparate systems combining to provide poor quality data for the first tier sequenced supplier, it was decided that a new EA-based system would alleviate a number of the problems surrounding the current integration setup. An EA integration tool specific to the product that was due to be implemented, along with EDI provided an enhanced level of integration. To enable integration with second and third-tier component suppliers, a portal was incorporated.

Many similarities exist between the Internet technologies that were applied throughout the cases. In Case 1, a database, application server and a web server combined to provide the basis of the system. JSPs were coded to extract and insert the data to and from the database. Case 2 introduced an XML-based design based upon the same platform as Case 1.

With Case 3, XML was once again the main focus of the integration architecture. With a particular XML standard developed for the office products industry it was deemed appropriate to incorporate to demonstrate how it could be applied to a real situation. As an alternative with this case, an ISP-based architecture was also presented to exhibit how and ISP could facilitate VMI. The ISP method had various connection and integration methods, all of which are discussed in Chapter 4. However, the Internet was the fundamental technology behind the ISP-based Integration Architecture.

Case 4 was unique in that an application was designed using a RAD software tool. The functionality of the system was coded in the particular tools distinctive language. A database and a scheduling program supported the front-end application. As with Case 3 the final case (case 5) required the involvement of an ISP. A visual basic program extracted the necessary data and formatted it for the ISP to display the requirements data to the appropriate parties.

In summary, there are evidently a range of components and configurations to support the integration of these systems. The Internet however, is one that remains constant throughout each of the cases.

Question 3

Based upon the identified technologies and systems, what would be the most appropriate supply chain information architectures?

Three integration architectures are presented in this research. The EA-based architecture provides the most integrated approach for companies in a supply chain/network. Within the EA-based theme, the 'Integrated Operation' configuration enables companies to synchronise their business processes across company boundaries. Furthermore, the concept of a 'Single Instance' configuration demonstrates a benchmark, which both software developers along with supply chain participants should be looking to attain. Within the EA-based architecture it is important to note that the application of the Internet has been the catalyst for the wealth of possibilities that have emerged for integration. The Internet has had a profound effect on the way EA systems have been developed, and with new technologies being developed frequently it is likely to be a sustainable platform for many years to come.

For those companies that do not have the resources to integrate their corporate systems exclusively, then the Internet-based integration architecture represents a valid alternative with a range of configurations. For example, collaborating with an ISP allows data to be displayed and acted upon in real time. Alternatively, as many of the prototypes in this research have demonstrated, an Internet application can be developed and maintained by single supply chain entity.

Thus, it is possible to derive a series of conclusions based upon the research undertaken. Firstly EA-based integration architectures offer the most comprehensive method to achieving total supply chain integration. Secondly, in achieving this, the Internet plays a vital role. Thirdly, for those smaller supply partners with limited resources, the Internet (ISP or Bespoke) provides the means for integration.

Question 4

What are the effects on the supply chain of implementing systems to support these strategies? i.e. what are the benefits? Do the benefits outweigh the potential costs?

This research demonstrates that there are clear benefits to implementing any one of the three integration strategies presented. The performance analyses revealed that an improvement in information flow between supply partners can reduce bullwhip, enhance synchronisation and remove many of the excess stock piles that were evident. In addition, trading partner relations were improved which led to a more willing attitude to share information.

It can only be decided on a case-by-case basis as to whether the benefits would outweigh the potential costs of an improved integration architecture. In shallow (low value) supply chains such as those discussed in Cases 1 and 2, the benefits of implementing an EA-based integration architecture might not justify the high costs involved. However, the Internet-based integration architecture offers a solution that does not generate costs in excess of the prospective benefits expected in these two Cases. Whilst it does not offer integration to the extent of the EA-based approach, it has demonstrated to supply enriched information that can be harnessed to the benefit of those involved. On the other hand, a shallow supply chain offers significant opportunities for complete integration across all trading partners. Therefore, as the food manufacturer in Case 2 was undertaking a systems upgrade at the time of this project there was an ideal opportunity to integrate with the retailer and possibly develop a more integrated situation with their suppliers via the EA-based integration architecture.

Case Three involved a retail VMI situation consisting of more valuable items than the previous two Cases. Here the performance evaluation illustrated high stock levels and poor working practice. The analysis revealed a cautious approach to stock management which was largely due to the lack of confidence in the current VMI procedure. The implementation of an EA-based integration architecture would have facilitated a more streamlined stock replenishment initiative and therefore permitted a reduction in the recommended safety stock levels. Also, it would have reduced the time spent by employees at both companies on the whole VMI initiative. A cost benefit analysis of implementing a new system against employee time at both companies over a period of time might well have supported a new EA-based integration architecture.

The final two Cases were situated within the automotive sector. Deep supply chains combining hundreds if not thousands of suppliers typify the main characteristics of this sector. In both Cases a more integrated information systems architecture would have removed considerable costs from the chain. In turn a more integrated information system means that a make-to-order strategy can be achieved. The cost of implementing the EA-based integration architecture would be considerably less than the benefits to the whole chain in this case. However, the cost of implementing a new system would not have been distributed across the whole chain. It is likely that there would be period of time before the benefits have propagated through the chain and returned via cost reductions and other such benefits. Therefore, it is also sufficient to say that the Internet-based integration architecture demonstrates a less expensive variation for the short-term.

Question 5

Does the classification (type) of the supply chain alter the configuration of the proposed integration architectures?

Each of the supply chains discussed in this research has different characteristics as highlighted in the classification framework (Chapter 3). The type of supply chain does affect the configuration proposed integration architectures. More specifically, the factors that determine the configuration of the integration architectures are the sector the companies operate within, their position within the supply chain, whether or not there is a specific supply chain strategy in operation and the value of the commodities in question.

In Case 1 the classification framework identified this case to be situated within the Process industries sector. This sector is characterised by shallow supply chains involving non-discrete products. In relation to integration, the characteristics of process industry supply chains along with this research suggest that ultimately an EA-based integration architecture would generate the most benefit as the lack of depth facilitates the possibility of deeper integration upstream. However, the particular item being produced/manufactured also has a significant role in determining the integration strategy. High value items are more likely to support the business case behind a EA-based integration architecture. In this case, with the value of the items being low, and with integration at a minimum already, the Internet-based integration architecture was the most suitable option.

Case 2 represented a fast moving consumer goods (FMCG) supply chain. In this sector profits are thin and demand visibility poor and retailers are reported to have much of the power within FMCG supply chains. Therefore, it is in the manufacturers best interests to achieve the highest degree of integration possible. The EA-based configuration would have permitted higher levels of integration which are ever more important in a fast moving supply chain involving perishable items. Whilst the supply chain in this case was also shallow, the Food Manufacturer (FM) could benefit significantly from integrating with the retailer to obtain improved visibility of actual consumer demand, or point of sale (POS) data as it is widely known. Thus, here the sector along with the product affected the proposed configuration.

In Case 3 the supply arrangement identified in the classification had a significant influence over the proposed integration architecture. VMI is an information driven initiative and thus integration is the key. It is possible to operate VMI using relatively simple methods of communication (e-mail, fax, telephone). However, to run VMI at it optimal settings whereby stocks are at a minimum then an EA-based integration architecture represents the best approach. Furthermore, if the company should want to expand its VMI initiative to incorporate a series of suppliers then an EA-based system provides the flexibility to facilitate this. However, with VMI becoming an increasingly popular initiative, ISP solutions also offer considerable advantages. Therefore in summary, is fair to say that the faster moving the supply chain the more integration is required to facilitate a competitive VMI operation. However, if VMI only represents a small part of the manufacturers whole business then an outsourced ISP solution represents the best option. Therefore the classification of the supply chain does have a role in determining the configuration of the proposed integration architecture.

Case 4 and Case 5 revealed some interesting findings in relation to this question. Whilst both cases were situated in the automotive sector, and therefore consisted of manufacturing complex products in high volumes, each case clearly supported an Internet-based Integration Architecture. In Case Four, the remanufacturing situation was clearly causing a number of problems for both parties. At the time this project was undertaken, remanufacturing was considered relatively new in terms of the systems that were available to support such an initiative. Consequently an Internet-based integration architecture was implemented which demonstrated how the situation could be improved via tools and technologies already in place at the host company.

Thus, the remanufacturing element identified in the classification isolated the Internet to be the only integration architecture for this case.

In Case 5, an EA-based system that could provide high quality information to a large number of suppliers would have represented the best selection. However, with this vision unlikely to be achieved for a number of reasons, and with each participant in the chain supporting their own planning system, an Internet-based integration architecture was once again deemed to be the best fit for this case. Here, the complexity of the automotive industry along with poor operational practise determined the configuration.

In summary, it is evident that the classification of the supply chain is critical in determining the configuration of the proposed architectures.

Question 6

Do the previous methods of communication become redundant as a result of presenting an innovative integration architecture?

From the research undertaken, the answer to this question is very much dependant on the particular case. In Case 1 the only communication media were fax and e-mail and so the Internet-based system removed the requirement for both these means of communication. In Case 2, EDI represented the main communication between the retailer and the food manufacturer. Whilst it was the recommendation of this research to implement an EA-based integration architecture in this case, it is likely that EDI or a variation of EDI (Web EDI) would remain the principal form of communication. The VMI scenario in Case 3 was currently undertaken via a series of manual processes involving the fax and telephone along with a final stage EDI process. With the implementation of a new system the manual processes would be eradicated and as a result, the manpower required to undertake these processes. EDI was likely to remain, however, the Internet-based integration architecture did demonstrate that XML was a viable alternative.

In case 4 the telephone and fax were the two communication methods in place at the outset. With the introduction of the web-based system the fax machine was made redundant immediately, whilst the telephone was still required although to a lesser extent. Case 5 was the most complex of all the cases. The means of communication ranged from EDI to e-mail to fax. The implemented Internet-based integration architecture provided visibility of the OEM demand down to the third tier. However, the other methods of communication would all remain in place with this architecture. Had an EA-based system been selected then it was envisaged that similar communications methods would have been incorporated. EDI/Web EDI would have still communicated the demand to first tiers.

In summary, it fair to say that as a general rule, the previous methods of communication become redundant or at least take place in the shadow of the improved integration architecture.

6.3 Contribution To Knowledge

There are a number of areas in which the work undertaken has made contributions to knowledge.

- The development of three generic integration architectures (EA-based, Internet-based and hybrid-based) centred upon the literature within both academic and commercial groups. The three architectures have been proven to be used as design templates to create a specific set of authentic supply chain integration architectures.

- Empirical analysis along with the developed prototypes has demonstrated the applicability and value of the templates as supply chain design aids. As stated in Chapter 1, the Internet has been widely acknowledged as a technology that can make a considerable contribution to supply chain communication (Cronin, 1995) and supply-chain excellence (E.I.U, 2000). The prototypes developed as part of this research support and enhance the previous statements. Each of the prototyped applications demonstrates that the Internet is an efficient, cost effective method of integrating supply chain partners, as hypothesis 1 stated.

- The development of a classification framework facilitated the identification of the case studies undertaken. The work of Carbonara *et al* (2002) provided the basic structure and variables for this classification. The authors put forward a list of variables that were grouped into the four dimensions (i.e. physical, technological, strategic, and organisational). The classification was tailored to fit with the aims of and objectives of this research. Following on from this, a case-based research approach was developed (SCICM) to fit needs of this study. More specifically, it was shaped out of a necessity to have a distinctive methodology to follow when applying the generic integration architecture templates to the particular case scenario.

- Finally, sufficient support to substantiate the hypothesis concerning modern day Enterprise Applications (EA) and their ability to integrate to such a level that simultaneous processes can take place has been provided (hypothesis 2). Furthermore, each case clearly illustrates how modern day supply chains are hindered by a lack of and quality of valuable information (hypothesis 3).

6.4 Further Work

This research has achieved the objectives that it set out to accomplish at the outset. However, a number of themes were identified throughout the duration of this research that would logically maintain the research undertaken thus far.

As mentioned earlier on in the Chapter, the author feels that ISPs providing hosted EA applications such as SAP offer a significant opportunity for supply chains. A number of authors have discussed how integrating enterprise systems has proven to be beneficial to the supply chain (Kulkami.2002; Davenport & Brooks, 2004). However, very few have considered the notion of a single enterprise system spanning multiple supply chain tiers. Business process synchronisation (BPS) across a number of tiers has been considered by Dabbiere (1999) who stated that BPS will take supply chain integration to the next level of efficiency. However, the author stated that it is very difficult to make discreet entities in the supply chain, each with their own agendas, function as a synergistic whole. In contrast to this research however, the author does not envision a single enterprise system to achieve this objective.

At present there is a growing trend for companies to outsource the complete systems operations. A report be Accenture (2002) identified that outsourcing can improve a company's ability to innovate. Based on this research the author feels that if an OEM were to follow a strategy such as this and a number of first and possibly second tiers agreed to run trials with an ISP then the improvements to the particular supply chain could be significant. If this were achieved then the information systems design would to some degree mimic the 'Single Instance' architecture whereby a single enterprise system controls a supply chain. Following on from this, a number of issues relating to the bill of materials (BOM) would have to be targeted. This represents a research opportunity on its own.

Moving away from ASPs, a research area that has grown increasingly important in recent years is remanufacturing. Lund (1998) revealed that there are estimated to be in excess of 73,000 re-manufacturing firms in the United States with a direct employment of 350,000 and total annual sales of $53 billion. Sun Microsystems, Hewlett-Packard, Kodak, Xerox are just a few of the companies that actively participate in re-manufacturing. With environmental issues very much at the forefront of many governments agendas it is likely that re-manufacturing will be forced upon many industries. Throughout this work it was identified that very few EA-based systems can support such initiatives. The literature did provide a selection of examples involving web-based systems to support remanufacturing, however, there needs to be more research in this area to develop strategies to integrate remanufacturing practices with typical manufacturing operations.

6.5 Chapter Summary

Thus, in conclusion, this chapter has clearly summarised the main findings of this research. The research questions have been answered comprehensively and the contribution to knowledge highlights the true value of this research. Future research is vital in order to sustain the work undertaken to date. If the UK is to sustain its already diminishing manufacturing sector then a considerable amount of work will need to be undertaken in the field of supply chain integration.

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Company Name/ Product	Core Functionality	Product Analysis	Publicised Customers
i2 Technologies/ i2-Six Product Family	**Fulfilment optimization** - Demand Fulfilment, Distributed Order Management, Inventory Management, Supply Chain Event Management, Financial Collaboration Manager, Discovery Knowledge Manager, Replenishment Planner, Service Budget Optimizer, Service Parts Planner. **Logistics optimization** - Supply Chain Strategist, Transportation Bid Collaboration, Transportation Planner, Transportation Manager, Transportation Modeller, Warehouse Manager. **Production optimization** - Supply Chain Strategist, Demand Manager, Demand Fulfilment, Factory Planner, Supply Chain Planner, Profit Optimization and Supply Collaboration. **Revenue and profit optimization** – Enterprise Business Planning Solutions, Pricing Solutions. **Spend optimization** – Spend Executions, Sourcing Planning and Analytics	Report by Nucleus Research looking at the ROI of the i2 SCM Product. Key Findings: 55% of i2 customers interviewed did not believe that they had achieved a positive ROI from their deployments after having used the product for an average of 2.2 years. Customers achieving benefits in 3 key areas: reductions in inventory costs, shortening of order-to-fulfilment and planning cycle time, and gains in employee productivity. 64% of customers reported reductions in inventory costs, however only 4 customer believed the inventory savings justified the investment. 50% reported some reduction in order-to-fulfilment cycle times. 27% reported some returns from increased employee productivity. Average 3 year cost f i2 deployment is $7.2 million, including the costs of software, hardware, consulting, training, and personnel.	3M, Alcoa, Inc., Apple Computer, Inc., AT&T Wireless Services, Inc., BAE SYSTEMS, Bali Company, Barnes & Noble, Bell Helicopter Textron, Best Buy, The Boeing Company, British American Tobacco, Caterpillar, Inc., Clorox Corporation, Coca-Cola Enterprises, Continental AG, Cooper Tire & Rubber, Corning, Inc., DaimlerChrysler, Dana Corporation, Del Monte Foods, Dell Computer Corporation, Dillard's Dole Asia, Ford Motor Company. MANY MORE.
Manugistics	**Supply Chain Management** - Fulfilment Management, Collaborative Vendor Managed Inventory (VMI), Sales and Operations Planning, Order Management, Manufacturing Planning and Scheduling, Supplier Collaboration, Procurement Management, Network Design and Optimization. **Logistics Management** - Global Logistics Management, Fleet Management, Global Logistics Sourcing, Freight Payment Management, Real-Time Visibility and Trading Partner Connectivity, Logistics Market, Bulk Replenishment. **Demand & Revenue Management** – Demand Management, Demand Classification, Lifecycle Pricing, Price Planning & Opt, Promotions Planning & Opt, Markdown Opt, Market Basket Analysis, Trade Promotions Management, Price Quotation Opt, Sector Revenue Management. **Service & Parts Management** – Service Network Planning, Service & Parts Pricing, Repair Demand and Parts Planning, Allocation Management, Resource Scheduling, Service Delivery Management, Reverse Logistics, Collaboration & Integration, Event Management & Analysis, Sourcing, content, and knowledge Management	-Report by Nucleus Research looking at the ROI of the Manugistics SCM Product. Key Findings: -80% of customers interviewed believed they had achieved positive ROI from their deployments. 11 of these believed the solution had paid for itself within 16 months. -Companies using Manugistics SCM and Revenue Opt solutions achieved benefits in 5 main areas: reduced inventory costs, reduced order-to-fulfillment cycle time, increased productivity, increased revenue and saving in operational costs. -64% reported a reduction in inventory costs.71% reported that they had shortened their order-to-fulfillment cycle time and 60% reported that the Manugistics SCM and Revenue Opt solutions had caused significant improvements in the productivity of staff -Those companies choosing to use the revenue and profit opt modules reported net revenue increases of 2.5-7.5% and 40% experienced significant reductions in operational costs – such as carrier costs, transportation spend and freight costs. -The average 3-year cost of a Manugistics deployment was $6,972,309. This included licences, maintenance, consulting, hardware, personnel, and training. -Consumer Goods Technology Magazine, in their January 2004 issue, named Manugistics the top SCP solution provider to the CPG industry for the second consecutive year.	Harley-Davidson, Nissan, Ford, Robert Bosch Corporation, Lufthansa, Publix Super Markets, Remy Cointreau, Tine BA, O2, L.L. Bean, ON Semiconductor, McCormick, H.J. Heinz, Bandag, Federated Department Stores, Bacou-Dalloz, CompUSA, PETRONAS, BEL Group, Black & Decker, Glazer's, Woolworths, Pechiney, GNER, HON INDUSTRIES, H-E-B Grocery Company, Kesped, Olympus, Coca-Cola Bottling Company Consolidated.

Company Name/ Product	Core Functionality	Product Analysis	Publicised Customers
IBS	**Application SoftWare (ASW)** - ASW Analyzer, ASW Asset Control, ASW Distribution, ASW Euro Currency Handling, ASW Financials, ASW Hotline, ASW Internet Connection ICe², ASW Inventory Control, ASW Output Solutions, ASW Production Control, ASW Purchase Support, ASW Sales & Marketing Support, ASW Service, ASW Telesales, ASW Warehouse Management. **e-business** – e-Business and IBS Internet Connection e², Web-Enabled Enterprise Applications, Web Customer Self Service, Supply Chain Integration. **Customer Relations Management (CRM)** – Sales and Customer Service & Order Management, Service and Warranty – After Sales Service, Marketing and Sales Support – Customer Care. **Business Intelligence & Financials** – Online Analysis, Financial Accounting and Asset Control. **Inventory and Distribution** – Warehouse Management, Inventory Control, Production and Value added Assembly	**November 26, 2003** - IBS received the Supply-Chain Council European Award for "Development Excellence" for developing and launching IBS Business Intelligence - a stand-alone software product for managing and analysing enterprise and supply chain performance based on the SCOR model. **November 12, 2001** - Two new international studies have recently ranked IBS as the no.1 supplier of supply chain execution solutions, i.e. software and services primarily for order fulfilment, inventory control, warehousing and logistics. The independent studies are based on revenue within each respective field, and were conducted by AMR Research and Frost & Sullivan. The studies referred to are AMR Research 2001, The Supplier Management Application Report 2000-2005, and Frost & Sullivan 2001 European Supply Chain Management Software Markets. The former covers the global market, and the latter the European market. Since 2001, ASW controls Roland's inventory and 57,000 possible parts combinations. Tied-up capital in inventory dropped millions of dollars within 12 months. Reduced transaction costs and warehouse space demands have allowed Roland to increase sales support staff and thereby increase sales.	ABB, Miele, Bergen Brunswig, Scheller Handel AG, Elektroskandia, Nintendo, Roland USA, Nautor's Swan, Mitsubishi, US Tire & Exhaust, Golden Eagle, Cartier, Timberline, Essers Group, Pioneer, Messer, Ray Mussay, Galexis, VitalAire, Brame Speciality, Cole Papers, Macfarlane Packaging, Ciba Vision, Galenica, Enesco
Manhattan Associates	**Trading Partner Management** – Supplier Enablement, Logistics Hub Management, Carrier Enablement, Customer/Store Enablement, Reverse Logistics Management **Transportation Management Systems** – Transportation Procurement, Transportation Planning & Execution, Carrier Management **Warehouse Management Systems** – Warehouse Management, Labour Management, Slotting Optimization, Billing Management **Performance Management** – Events, Analysis, Reporting **Enterprise Integration Services**	67% of Manhattan Associates customers interviewed achieved a positive ROI from their deployments. Key returns included increased employee productivity, increased inventory and shipping accuracy, improved customer management and retention, and reduced cost of operations. The average 3-year cost of a Manhattan Associates deployment was $2,834,177; the median 3-year cost was $1,696,200. The average software license maintenance charge was 17% of initial license price; the median was 16%. Companies devoted an average of 2.7 ongoing full-time personnel to support their deployments and more than half of the customers completed their deployments on time and within budget.	ARAMARK, Ryder System Inc., Sainsbury's, Pacific Sunwear, KBToys, Mikasa, American Eagle, Federated Department Stores, Cornerstone Brands, Cutter & Buck, Columbia Sportswear, Timberland, Sports Authority, Halfords, Briggs & Stratton, Lex Auto, P.A.M Transportation Services, Ewals Cargo Care, Kiabi.

Company Name/ Product	Core Functionality	Product Analysis	Publicised Customers
SAP/ mySAP	**Customer Relationship Mgmt** – Marketing, Sales, Service, Analytics, Field Application Support, E-commerce, Interaction centre operations and management, Channel management. **ERP** – Business Analysis, Financial and Management Accounting, Human Capital Management, Managing Operations, Managing Corporate Services. **Financials** – Strategic Enterprise Management, Business Analytics, Accounting, SAP Financial SCM, Corporate Services, Financials enabling solutions. **Human Resources** – Employee life-cycle management, Employee relationship management, Workforce Analytics, Employee Transaction Management. **Product Lifecycle Mgmt** – Life-cycle data management, Program and Project Management, Life-cycle collaboration, Quality management, Asset life-cycle management, Environment, health, and safety. **Supplier Relationship Mgmt** – Strategic Sourcing, Operational Procurement, Supplier Enablement, Content Management **Supply Chain Mgmt** – Planning, Execution, Coordination, Collaboration.	-57% of SAP customers interviewed did not believe that they had achieved a positive ROI from their deployments. On average, the companies surveyed had been using SAP for 2.8 years. -Nearly half of the companies studied reported that their implementations of various SAP applications exceeded the initial deployment budget. -Most companies that were under maintenance contracts with SAP were paying maintenance fees at the standard rate of 17 % of the original license price. Other vendors maintenance fees varied from 15-20 %, SAP appeared to be consistent. -The average SAP software license investment was $1,853,333, and the median license price was $1,000,000. -On average, the companies interviewed spent $3.64 million on consulting for their SAP deployments. The median consulting spend — driven by a need for customization, back-end system integration, and the development of user interfaces — was $850,000. -SAP deployments for which consulting costs amount to more than twice the cost of software are unlikely to deliver a positive ROI.	BMW, Mahindra & Mahindra Ltd, Porsche, Volvo CE, Atofina, BASF AG, Basell NV, Dequssa, Dow Corning, Dystar, Eastman Chemical Co., E.I. DuPont de Nemours and Co. Inc., Geneva Pharmaceuticals, K+S Group, MG Industries, Aarhus Olie, Atomic, Bertelsmann, Chuba Chups, Codorniu, Colgate-Palmolive Co, Conair, Melitta, Sagit, S.p.A., Spaipa S.A., Unilever, KAESER Kompressoren, HP Co., HP Germany, Sony Marketing Asia Pacific.
Oracle/ E-Buiness Suite	**Oracle Product Lifecycle Management** **Oracle Marketing** **Oracle Sales** **Oracle Order Management** **Oracle Supply Chain Planning** **Oracle Procurement** **Oracle Manufacturing** **Oracle Order Management** **Oracle Maintenance Management** **Oracle Service** **Oracle Human Resource Management** **Oracle Financials** **Oracle Projects** **Oracle Intelligence**	-Oracle E-Business Suite generated financial returns through a combination of cost savings, revenue enhancement, productivity improvement, and working capital reductions -The average ROI was 156%. The research found that company ROIs ranged from 446% to 10%, with a standard deviation of 116%.The average payback period was 1.74 years, which was significantly lower than the 2.25-year average payback period found by the Meta Group (1999). -Total profit and loss benefits realized from Oracle E-Business Suite ranged from $3.4 million to $12 million in annual recurring savings, and were typically captured over a five-year period post-implementation. The total implementation costs were found to be 28% less than the average $10.6 million found in the Meta Group study (1999), ranging between $500,000 and $28 million. -The annual financial benefit ranged from $3.4 million to $12 million. These benefits were calculated by aggregating the total P&L benefit net of costs over an average 5–year forward-looking investment period. -For 5 of the most successful cases, using Oracle Consulting as their partner, implementation of Oracle E-Business Suite was completed in 9 months or less.	American Power Conversation (APC), Atari, C-COR Corp., EMC, Intersil Corporation, John I. Haas, Pella, POSCO, Qualcomm, TATA Teleservices Limited (TTSL), Al Ghurair Group, American Tower, Amercian Trans Air, Anugrah Argon Medica (AAM), BAE Systems, Best Buy, Boehringer Ingelheim, Cabot Microelectronics Corp., Dragon Air, Compass Group, eSilicon, Fuji Xerox Asia Pacific, General Dynamics UK, Liverpool City Council.

Company Name/ Product	Core Functionality	Product Analysis	Publicised Customers
PeopleSoft	**Asset Lifecycle Management** - Advanced Real Estate Forecasting, Capital Asset Management, Real Estate Management, Resource Assignments **CRM** - Advanced Configurator, Customer Self Service, Integrated Field Service, Marketing, Mobile Sales, MultiChannel Interaction Manager, Partner Relationship Management, Sales, Support. **Financial Management** -Accounts Payable, Accounts Receivable, Advanced Cost Accounting, Cash Accounting, Expense Management, Financial Planning & Budgeting, Financial Reporting, Fixed Asset Accounting, General Ledger. **Human Capital Management** - Employee Self Service, Human Resources Management, Manager Self Service, Payroll Processing. **Project Management** - Change Management, Contract Service Billing, Homebuilder Management, Project Costing. **Supplier Relationship Management** - Procurement and Subcontract Management, Supplier Self Service. **SCM** - *Advanced Planning* - Demand Consensus & Forecasting, Production & Distribution Planning, Production Scheduling (Discrete & Process), Strategic & Tactical Network Opt. *Customer Order Management* - Advanced Pricing, Agreement Management, Order Promising, Product Variants, Sales Order Management. Logistics - Advanced Inventory Management, Bulk Stock Logistics, Inventory Management Base, Transportation Management, Warehouse Management. *Manufacturing* – Quality, Requirements Planning.	**LAS VEGAS -- October 7, 2003** -- At the APICS International Conference and Exposition 2003, PeopleSoft, Inc. today announced that according to Gartner Dataquest's recently published North American license revenue market share statistics, the combination of PeopleSoft and J.D. Edwards & Company created the largest ERP supply chain vendor in North America. **ANAHEIM, Calif. - Sept. 15, 2003** - At its Connect 2003 conference, PeopleSoft, Inc. today announced that an independent research study completed by Forrester Research found that PeopleSoft scored highest overall in Forrester's Application Ownership Satisfaction Index. The survey of more than 600 business and IT users is a comparative, multi-vendor study assessing the software ownership experience across five phases of the application lifecycle: engage, implement, use, maintain, and evolve. PeopleSoft outscored SAP, Oracle, and Siebel in the overall ability to deliver a superior enterprise application ownership experience.	Aegis Comms Goup, Allianz Dresdner, AON, AXA Corporate Solutions, Beers Skanska, Bausch & Lomb, Burda Ciscom, Cargill S.A., Capital One, CNT, DaimlerChrysler, Edward Keller Group, ENSCO, Expedia-FMS, Ford Motor Company, France Telecom, Hewlett-Packard, Hilton, Kirkpatrick & Lockhart,
SSA BAAN	**SSA Baan ERP** - Enterprise Planning, Manufacturing, Finance, Warehousing, Freight, Purchasing, Sales, Service, Project. ***SSA Baan ERP Extensions…*** **SSA CRM** - Sales Management, Marketing Management, Service Management, Collaborative Order Management. **SSA SRM** - Spend Analysis, Tendering, Advanced Auctions, Contract Management, eProcurement, Supplier Collaboration **SSA CPM** - Enterprise Planning, Enterprise Scorecarding, Enterprise Business Intelligence **SSA PLM** - Lifecycle Data Management, Configuration Management, Management & Tracking of Documents, Collaboration Management, Analysis and Reporting Tools. **SSA SCM** – Demand & Order Planning, Production Planning & Scheduling, Inventory Planning, Supply & Replenishment Planning, Logistics & Transportation Planning, Warehouse Mngt. **SSA ERP** – Manufacturing Solutions, Lean Manufacturing, Order Management, Project Management, Service Management, Financial Management, Distribution. **SSA Financial Management** – General Ledger, Accounts Payable, Accounts Receivable, Fixed Assets, Project Accounting, Fund Accounting, Draft Services, Currency, Cost Accounting. **SSA Human Capital Management** – Human Resources, Payroll, Flexible Benefits, Training Admin, Self Service.	Since SSA acquired BAAN a number of changes have taken place in terms of the company and product structure. They intend to avoid the upper end of the market were companies SAP, PeopleSoft and Oracle are fighting it out, according to SSA Global CEO. Now after Baan's acquisition, SSA can leverage Baan's expertise in verticals like manufacturing. Post acquisition, SSA Global now has the largest customer base in manufacturing in the world. SSA's ability to integrate technologies from its recent Baan and EXE Technologies acquisitions will largely determine the success of its strategy	KLM,

Appendix A - ISP SCM Components

Company Name/ Product	Core Functionality	Product Analysis	Publicised Customers
WeSupply Solution Framework: wesupply.com	**Intelligent Process Agents** - Enables collaborative business processes across a corporation, its customers and its trading partners. As the Agents sit within the Wesupply Dynamic Framework, organisations can select the most appropriate Agents to match their supply processes. Examples include: Collaborative Demand Management, Dynamic Inventory Optimisation, Multi-mode Fulfilment, Network Inventory Visibility, Invoice Management, Supplier Performance Monitor, Partner Solutions. **Collaborative Database** - The Collaborative Repository captures and retains all the relevant data required to support a process from all supply chain participants. **Dynamic Event Management** - Dynamic Event Management (DEM) provides workflow, alerting and process milestone management for all supply chain participants. Based on user defined business rules, Wesupply's DEM allows individuals to concentrate on running the business while it works proactively to address day to day issues, report exceptions and automatically resolve issues. **Rapid Integration Service** – This feature of the supply chain solution concerns its ability to rapidly and simultaneously integrate with disparate systems and technologies.	Wesupply by contrast claims to be able to implement a system in 90 days At Lear Corporation, they helped increase inventory turns on some operations from 45 to 160 a month. Provides standard interfaces not just with established EDI value-added networks (VAN's) but also with proprietary systems from suppliers such as SAP, Oracle and Manugistics.	Lear Jewson TI Group plc Colt Corp Lion Nathan SC Johnson, Marshalls, ICI, Castle Cement, WYKO, Cott, bpi, Valliant, TRW Automotive, Pattonair, Motorola, The Duckworth Group, LINPAC, Norgen, IFF, eybl, Compstock, AMCOR, FIBRAL
Verticalnet Solutions Verticalnet	**Supply Strategy** - Spend Analysis, Sourcing Analysis and Sourcing Advisory Services. **Supply Selection** – Reverse Auction, eRFX, Advanced Sourcing and Optimization. **Supply Execution** – Supply Planning, Contract Management, Contract Activation and eProcurement. **Supply Performance** – Supplier Scorecards, Supplier Corrective Action Request and Category Business Centres. **Supply Chain Optimization**	Global Logistics & Supply Chain Strategies Magazine (2003) named Verticalnet in its Top 100 list based on customer nominations. (2002) AMR Research, a leading technology research firm, named Verticalnet as the functionality leader in a report offering a detailed analysis of 17 strategic sourcing vendors, including some of the largest ERP and supply chain companies. The report is based on an evaluation of the top 17 vendors in the space against 200 functional requirements and more than 80 interviews with current adopters of the technology. Verticalnet's product suite is actually a combination of products from its acquisition of Atlas Commerce According to AMR, needing improvement are reverse auctions, contract authoring, the somewhat non-intuitive and inconsistent user interface, and the complete integration of the Verticalnet and Atlas Commerce products. The company names Consumer Products, Retail, High-Tech and Electronics, Transportation, and Industrial Products as its top five target industries.	Blyth, Cadbury-Schweppes, H.J. Heinz Company, Johnson & Johnson, Kraft Foods, PepsiCo, Sara Lee Corporation, Valvoline, Unilever, Federal-Mogul, Georgia Pacific, Illinois Tool Works Inc., Joy Global Inc., Kennametal Inc, MasterBrand Cabinets, Rohm and Haas, Thermo Electron Corporation, Bayer AG, Bristol-Myers Squibb, Eli Lilly, Pharmacia, Premier, Inc., Wyeth

Appendix A - ISP SCM Components

Company Name/ Product	Core Functionality	Product Analysis	Publicised Customers
elcom Inc/ PECOS elcom	**PECOS Internet Procurement Manager** ("PECOS.ipm") - is the eProcurement configuration of PECOS™ that automates the procurement process from supplier product content through financial settlement. Additional functionality: access to external eMarketplaces, multi-organizational "tiered" capabilities, flexible approval routing, electronic forms routing, receiving, financial settlement using corporate purchasing cards, Excel spreadsheet routing based on label (cell) amounts and electronic invoicing or evaluated receipt settlement. **PECOS Internet Commerce Manager** ("PECOS.icm") - is the eDistribution configuration version of PECOS™ that automates the online selling process from product information through financial settlement. **PECOS Internet Marketplace Manager** ("PECOS.imm") - is the eMarketplace system that allows a client to create its own electronic marketplace, enabling it to act as a market-maker for buyers and sellers of products with transactions and catalogue content managed by the Company. **elcom, inc.'s Dynamic Trading System** - provides "eNegotiation" capabilities for organizations and will allow organizations to negotiate goods and services not covered by existing electronic catalogues **eCommerce Network** - is a component-based technology platform which powers the Company's eProcurement, eDistribution and eMarketplace offerings. Hosted on a non-stop, high availability hardware platform it enables enterprises of all sizes to outsource their eProcurement, eDistribution and eMarketplace initiatives to.	-Analysis undertaken by the Aberdeen Group: UNICCO implementation of PECOS System. -e-Procurement system has shown UNICCO lowered administration costs, improved data gathering, increased purchasing contract compliance, reduced requisition cycles and improved systems integration. -In hard-dollar savings, UNICCO was able to recoup $500,000 in product cost savings from better commodity analysis and aggregate spending with just 25 suppliers. The system has allowed the firm to better manage its spend and negotiate reductions above its normal preferred vendor discounts. -The biggest internal plus for UNICCO has been improved transaction management, dropping administrative costs 40% per purchase order. Cycle times have decreased dramatically as well — while in the past requisition process times varied from site to site, the worst case scenario has gone from "months and weeks" to receive goods, to "days and hours." -In addition, PECOS.ipm now gives UNICCO better data on what is being spent and where. In the past, the little purchasing data that was captured in the enterprise resource management (ERP) wasn't coded correctly and it couldn't be analyzed accurately.	CBS Corp., TVA, Plascon, Palace Entertainment, Entergy, Cricket, Harbinger, UNICCO, Renfrewshire Council, Stockport Metropolitan Council, Canam Steel, Yale New Haven Health Systems, Galaxy Control Systems
SupplyWorks SupplyWorks	**SupplyWorks® SOURCE™** - provides manufacturers with the visibility and tools they need to understand, analyze, and manage component and materials costs across multiple plants and procurement centres. SupplyWorks SOURCE supports strategic sourcing on three levels: (1) **RFQ/Bid Analysis** - streamlines the quoting process. (2) **"What if" Costing Scenarios** - allows users to instantly create and compare different sourcing scenarios. (3) **Contract Management** - Contract management closes the loop on sourcing and insures that the goals of implementing a supply chain strategy are realized. **SupplyWorks® MAX™** - helps discrete manufacturers optimize the flow of parts and materials and manage their relationships with key suppliers by combining procurement execution, planning, and management in one integrated application. It incorporates the following 3 processes: (1) **Supply Chain Visibility and Synchronization** - creates real-time visibility for both manufacturers and suppliers on critical parts and materials. (2) **Efficient Procurement Execution** - functions are focused on assisting and automating transactions between buyers and suppliers. (3) **Collaborative Supply Chain Planning** - features enable manufacturers to coordinate their production plans with the capabilities of their suppliers.	Article: **Global Logistics & Supply Chain Strategies (August, 2003) "SPECIAL ISSUE: 100 Great Supply Chain Partners"** ImagePoint completed installation of SupplyWorks MAX in December 2002. Production buyers and planners can now coordinate purchases and inventory across multiple locations, to maximize the efficiency of direct materials usage and further improve cycle times and internal scheduling accuracy. Using SupplyWorks MAX, ImagePoint is planning to automate over 25 percent of the purchasing group's line volume. The project is on track to achieve 10 percent savings in ImagePoint's annual direct material spend, which amounts to a savings of over $10m per year. In 2001/2002 SupplyWorks made the top 100 for e-business According to AMR Research.	BorgWarner Morse TEC, Hussmann Corp., ImagePoint, Barnes & Noble, Associated Spring, Ingersoll-Rand

Appendix B – Part One

Information Flow Questionnaire

This questionnaire is intended to identify the main information flows between Intelicoat, TDG Runcorn and InteliCoat's customers. The questionnaire is also aimed at uncovering the main Information Technology (IT) systems that interpret, process and transmit/make available these information flows to your suppliers and operational staff. Thank you for taking the time to complete the Questionnaire.

- Customer Related Questions

1. Identify and list the main information exchanges between yourself and your customers?

2. How regularly do you receive these information flows?

3. Are any of these information flows directly integrated into internal systems? Please state which.

4. Identify and list the systems that process these, information flows?

- Internal Questions

5. At which point(s) in the shop floor processes, described above, are they monitored/interact with IT systems?

- Supplier Related Questions (TDG Runcorn)

6. Identify and list the main information flows between yourself and your supplier?

7. How regularly does your supplier transmit information to yourselves?

8. Identify and list the system(s) that your supplier has in place to transmit/provide information?

9. Is there the facility to integrate the information your supplier sends into the target systems or is manual intervention required?

Before answering the next section complete **Table 1.** In the table define how your organisation communicates with its customers/suppliers, both through automated or manual methods and at which tier. (Do not need to list all customers and suppliers, just a range).

How are incoming requirements from your customers processed? State if the process is Automated or manual, and in both cases describe: • Name of the system? • How the data is processed? • What output is generated? • What purpose of the information generated? • How often is the information generated?

How are your requirements to your suppliers generated?
State if the process is Automated or manual, and in both cases describe:

- Name of the system?
- The origin of the data used to generate the requirements?
- How the data is processed?
- The output generated?
- How often is the information generated?

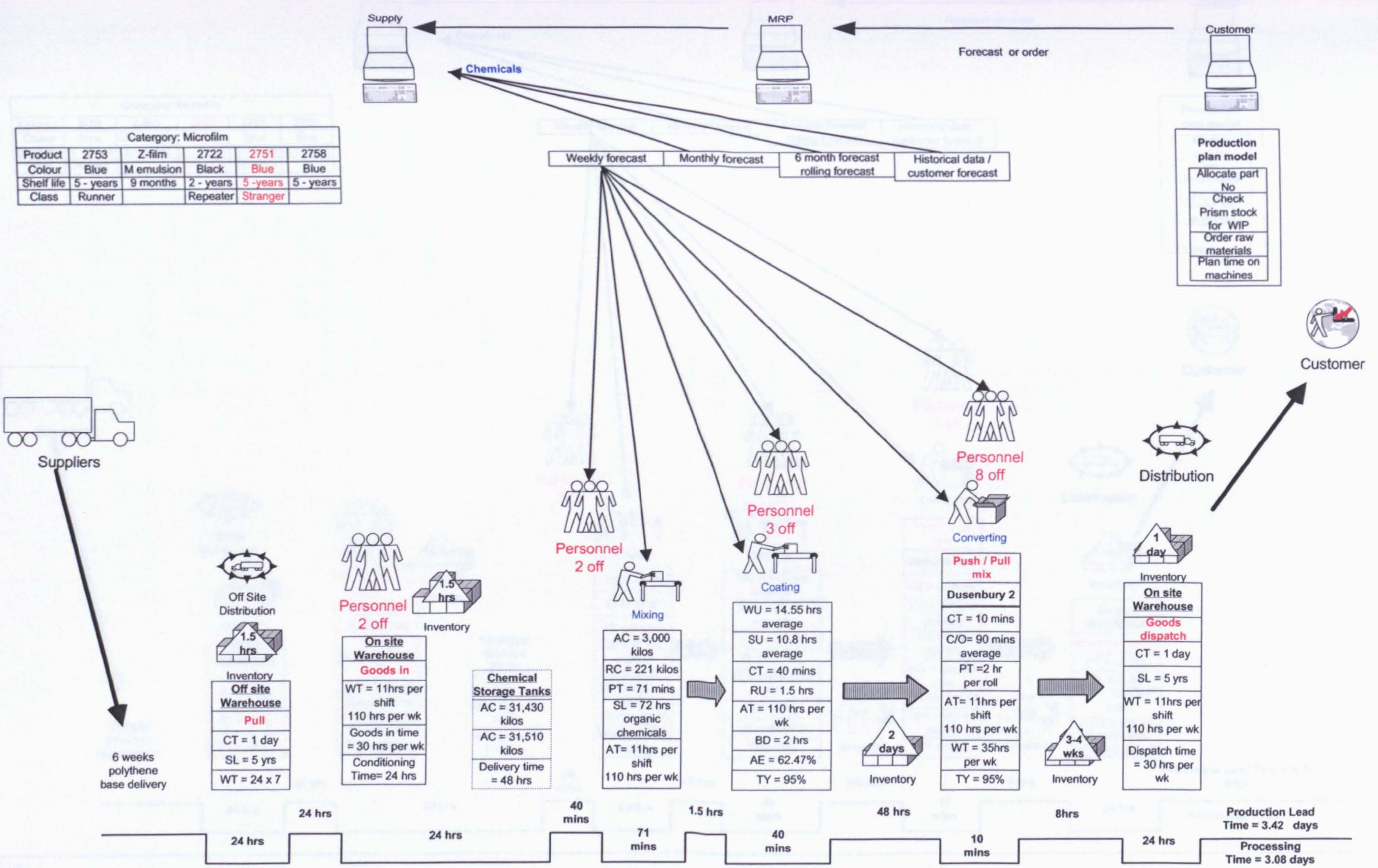
How do you communicate your requirements to your suppliers?
State if the process is Automated or manual, and in both cases describe:

- Name the system used?
- How often is the information transmitted?
- When is the information transmitted?
- Are any third parties involved and what is there role?

Table 1

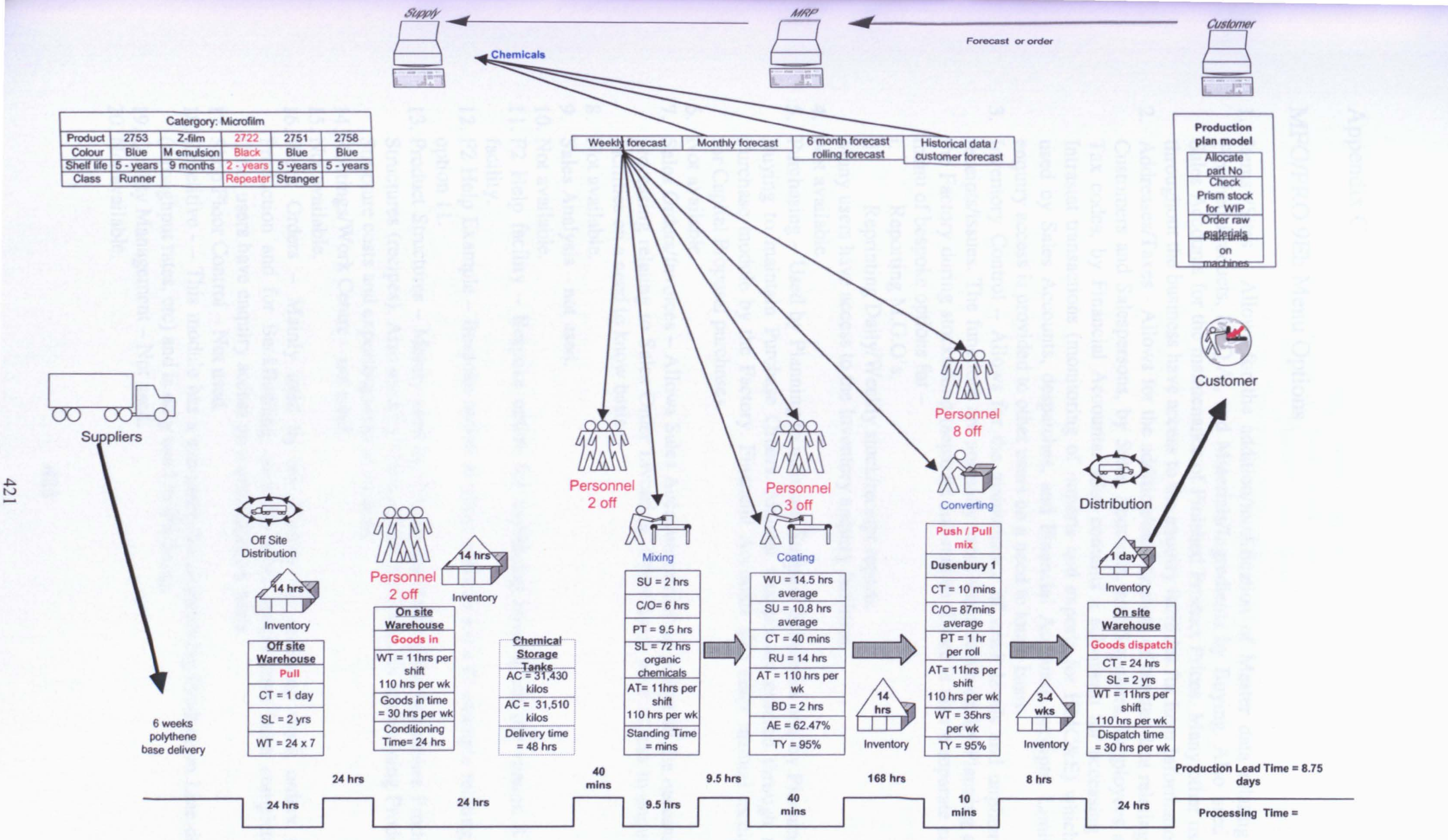
	Communication method (Tick and name method)	
Customer/Supplier - Please state which (Name and Tier)	Automated	Manual

Catergory: Microfilm					
Product	2753	Z-film	2722	2751	2758
Colour	Blue	M emulsion	Black	Blue	Blue
Shelf life	5 - years	9 months	2 - years	5 -years	5 - years
Class	Runner		Repeater	Stranger	



Key::
Push or pull kanban. Scheduling. Time line. WU = Wash Up Time
C/T Cycle time (time between coated rolls coming off the coater).C/O change overtime UT = Up time (on-demand machine up-time) EPE (production batch size). Number of operators Number of product variations Pack size PU = Process Upsets RU = Running Time
WT = Working time (minus breaks) Scrap rate. SL = Shelf life Size change PT = Process time SU = Set up time Clean down time AT = Available time RC = Required capacity AC = Available capacity BD = Breakdown Time TY = Target Yeild AE = Average machine efficiency

VSM Current State Microfilm Stranger



Key::
Push or pull kanban. Scheduling. Time line. WU = Wash up time
C/T Cycle time (time between coated rolls coming off the coater).C/O change overtime UT = Up time (on-demand machine up-time) EPE (production batch size). Number of operators Number of product variations Pack size PU = Process Upsets RU = Running Time
WT = Working time (minus breaks) Scrap rate. SL = Shelf life Size change PT = Process time SU = Set up time Clean down time AT = Available time RC = Required capacity AC = Available capacity BD = Breakdown Time TY = Target Yeild AE = Average machine efficiency

VSM Current State Repeater

Appendix C

MFG/PRO 9Eb Menu Options

1. Items /Sites – Allows for the addition/modification of Master data relating to Finished Products, by Q.A., and Materials/Ingredients by Buying. Also used by Sales Accounts for the maintenance of Finished Product Prices. Many other users throughout the business have access to the enquiry facilities for Item Information.
2. Addresses/Taxes - Allows for the addition/modification of Master data relating to Customers and Salespersons, by Sales Accounts, and Suppliers, Employees and Tax codes, by Financial Accounts. Also contains a sub-menu for accessing all Intrastat transactions (monitoring of imports and exports for HMC&E) which is used by Sales Accounts, despatches, and Financial Accounts, receipts. Limited enquiry access is provided to other users on a need to know basis.
3. Inventory Control – Allows for the maintenance of stock levels and unplanned receipts/issues. The functions are normally used, when required, by Planning and the Factory during stocktaking (separate sub-menu). There is also a separate sub-menu of bespoke options for –
   i. Reporting M.G.O's.
   ii. Reprinting Daily/Weekly stock/receipt reports.

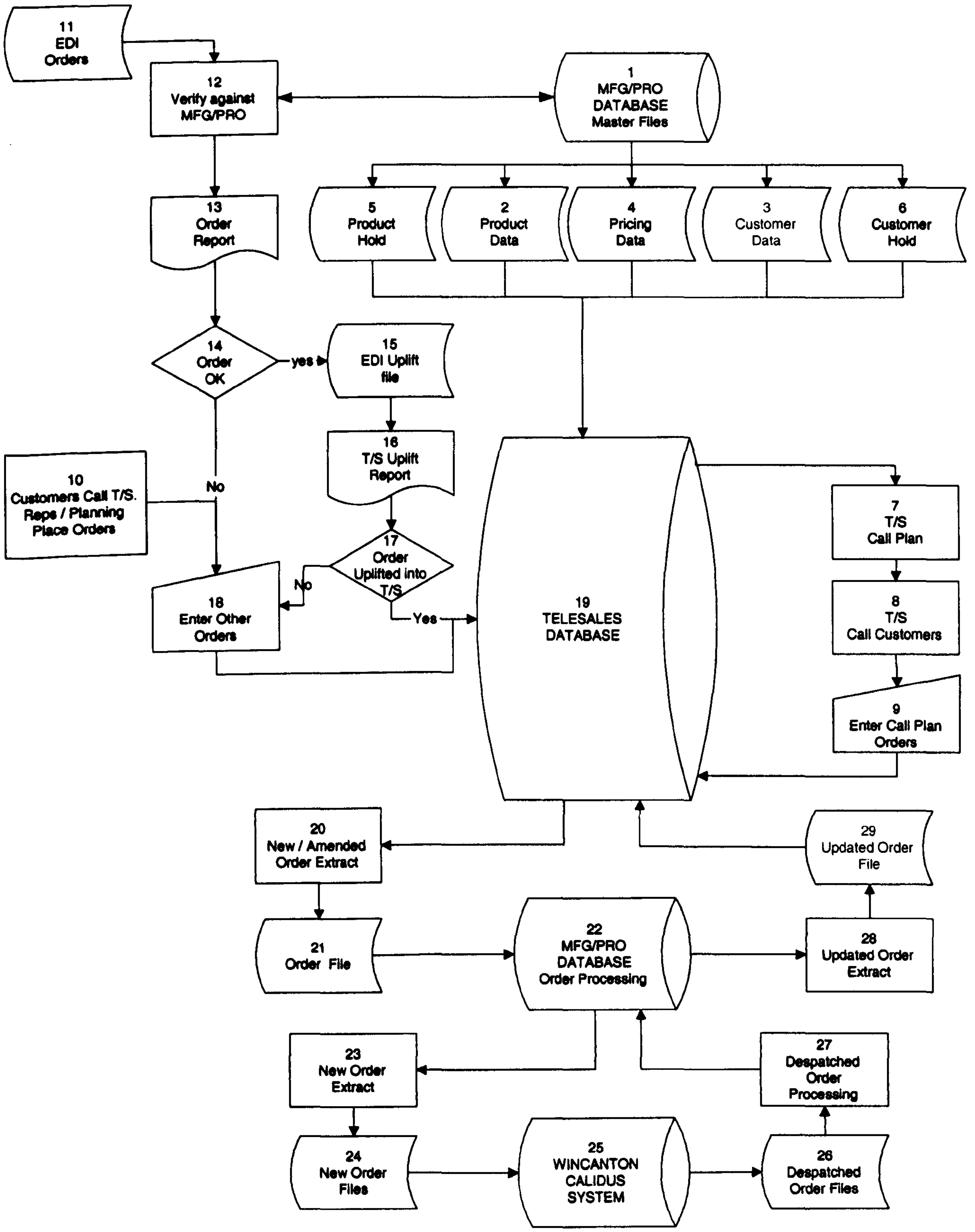
   Many users have access to the Inventory enquiry facilities.
4. Not available.
5. Purchasing – Used by Planning to maintain Supplier Schedules and by Planning / Buying to maintain Purchase Orders. Manual receipts are entered through the Purchase module by the Factory. Financial Accounts also enter manual receipts for Capital Proposal purchases.
6. Not available.
7. Sales Orders/Invoices – Allows Sales Accounts section to action all the necessary processing relating to Sales Order Invoicing. Other users have access to enquiry facilities on a need to know basis.
8. Not available.
9. Sales Analysis – not used.
10. Not available.
11. F2 Help facility – Bespoke option for explaining how to use the version 8 f2 facility.
12. F2 Help Example – Bespoke option to allow users to see a f2 example relating to option 11.
13. Product Structures – Mainly used by QA for maintaining the businesses Product Structures (recipes). Also used by Management Accounts for maintaining Product Structure costs and exporting same to Abacus.
14. Routings/Work Centre – not used.
15. Not available.
16. Work Orders – Mainly used by the Factory for releasing work orders for Production and for Backflushing once the work orders have been completed. Other users have enquiry access on a need to know basis.
17. Shop Floor Control – Not used.
18. Repetitive - – This module has a sub-menu for maintaining Production Line data (throughput rates, etc) and is only used by Planning.
19. Quality Management – Not used.
20. Not available.

21. Not available.
22. Forecast/Master Plan – Mainly used by the Forecasting section and Planning to maintain the Finished Product Sales Forecasts, including loading the forecasts from Proplan. Also used by Planning for Logistics reporting and monitoring changes/accuracy of Sales Forecasts. Also allows Planning to generate a 3rd Party Forecast file for a specific supplier. In standard MFG there are a number of enquiry facilities provided for a Planning section to monitor forecasts/sales, usage etc and check future stock forecasts. These are used infrequently in the business as they have been superseded by two bespoke options, 22.3 & 22.5.8, which are the Planners worksheets.
23. Materials Requirements Plan – Used only by Planning for executing MRP.
24. Not available.
25. General Ledger – Used only by Financial Accounts for maintaining budgets, inputting journals and maintaining the General Ledgers and reporting. The GL Report Writer is also provided as a sub-menu but has strictly limited access. Access to individual options in this module is strictly controlled.
26. Multiple Currency – Used by a limited number of employees in Financial Accounts for maintaining currencies and exchange rates.
27. Accounts Receivable – Allows Sales Accounts to control all of AC's customer accounts for Invoices outstanding, payments made and corrections. Allows the entry of Debit/Credit memos and printing of same. Produces various Ageing reports to monitor bad debtors and provides various Dunning letters.
28. Accounts Payable – The main purpose of this module is to allow Financial Accounts to input the Suppliers' invoices and obtain authorisation for payment. Reports are available for monitoring ageing of creditors and supplier accounts.
29. User Utilities – This contains a sub-menu, by department, of bespoke options for additional enquiries. One of the sub-menus is for I.T. and contains useful reports for identifying menu/transaction security issues because the standard MFG/PRO package provides inadequate information on this topic (this sub-menu is strictly controlled). A further option provides access to DSS (QAD's Decision Support System). DSS can be seen as a number of hierarchies where each hierarchy is a multidimensional spreadsheet. Within the business information is collected on a weekly or book-month basis for –
    i. Order data (passed to Eureka weekly) - Sales Order quantities, Despatch quantities, Invoice quantities and Sales in terms of Invoice Value, GSV, NSV, PPR's, TPR's, Accruals, NPS and Margin per customer, per order, per product, per week.
    ii. Green Tax data – Invoice Quantity, Material Usage, Material Usage by Weight, Production Weight and Total Weight per Bill-to, per Item, per Material Type, per Material Code, per book-month.
    iii. Actual Production – Production Quantity in units per Factory, per Production Line, per Item, per Work Order, per book-month.
    iv. M.G.O's (passed to Abacus weekly) – Quantity in units and Value per Item, per Reason Code, per week.

    Additional options are provided for reporting on these hierarchies the majority of which are for extracting Production data and Green Tax reports for Total Yearly business usage of Materials, Customer usage and Supplier Usage.
30. Cost Management – Mainly used by Management Accounts for maintaining Material and Finished Product costs.
31. Cash Management - Only available to the Financial Accounts Manager.

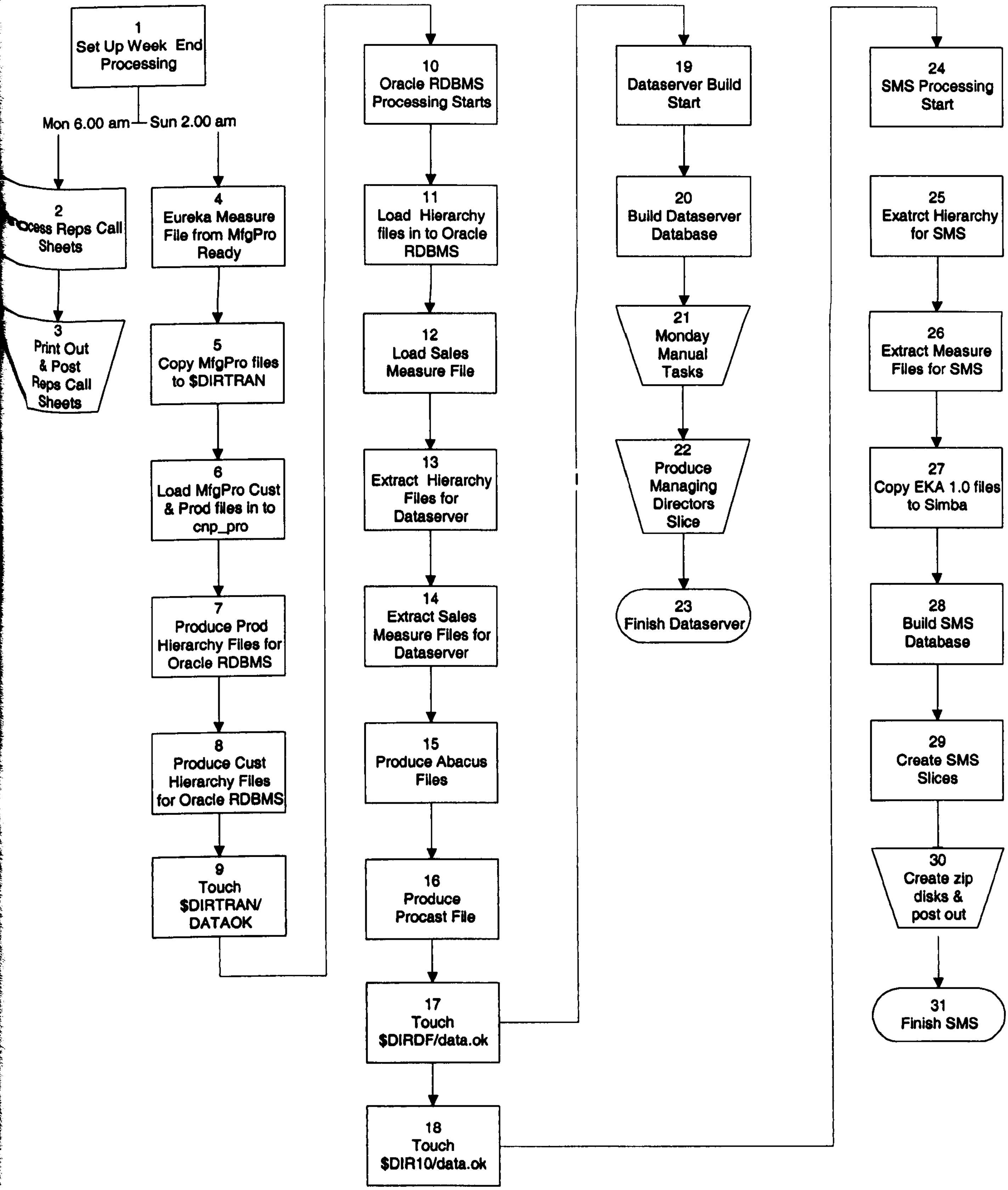
32. Fixed Assets – the system used is a heavily modified version of software supplied by Hindustan Lever which, in itself, was a heavily modified version of the standard QAD Fixed Assets software. As well as enabling Fixed Assets processing the system caters for Capital Proposal monitoring. This is the most "at risk" module of the businesses processing.
33. Enterprise Operations Plan – Used only by Planning to schedule work orders to the Production lines.
34. Not available.
35. EDI – The business conducts EDI business for orders, invoices and prices through MFG/PRO. The only users who are involved with this are Sales Accounts and I.T.
36. Manager Functions – Miscellany of functions for controlling the operation of MFG the majority of which are only available to I.T. Other users do have access to some options such as audit queries and all users have access to one transaction enabling each user to change their own password

Appendix D



Telesales Flow Diagram

Appendix E – Part One



Eureka Flow Diagram

Eureka Narrative

1 Set Up Week End Processing

Each week the Dataserver Meta Files are manually edited to include the current week's file names. Once this is completed the weekend's batch jobs are scheduled using the Unix at command. If it is the week after Book month end the Cost measures from Abacus are manually loaded into the Eureka RDBMS and extracted ready for the Dataserver processing. The progess database fms_pro is backed up, if processing fails this database needs to be restored. Other than this task, the Eureka processing is totally re-runable.

2 Process Reps Call Sheets

Prior to the weekend processing Sales Accounts input the Reps Call Code required to generate the weeks Call Sheets. On the Monday morning (6am) of the processing weekend, a file containing the individual Reps Call Sheets based on the Reps Call Code is produced. The processing here is a combination of Unix scripts and Progress programs accessing the Eureka RDBMS database. The unix script $REP/rep_load is the first script to run.

3 Print Out & Post Reps Call Sheets

On the Monday morning(9am) of the processing weekend, Sales Accounts checks with IT to ensure that the Call Sheets are ready to print and that they match the relevant Call Code. Once all is well the Call Sheets are printed off in Sales Accounts and posted out.

4 Eureka Measure File from MFG/PRO Ready

Sales transactions from MFG/PRO are aggregated into DSS & then extracted into files ready for EUREKA.

5 Copy MFG/PRO files to $DIRTRAN

Prior to having MFG/PRO as an ERP system, the EUREKA processing expects the sales measure files to be in $DIRTRAN. To maintain consistancy the DSS sales measure files are copied in $DIRTRAN.

6 Load MFG/PRO Customer & Product files in to cnp_pro

cnp_pro is an AC bespoke progress database which is populated from files generated from MfgPro, including ac_cust, ACPROD, ac_cot and ac_rep. ac_cust contains Customer Master data from Mfgpro and ACPROD contains Product Master data. This data is loaded in to cnp_pro via progress Programs.

7 Produce Prod Hierarchy Files for Oracle RDBMS

A Progress program extracts the Product Master data from cnp_pro to produce the Product Hierarchy files for Oracle RDBMS.

8 Produce Cust Hierarchy Files for Oracle RDBMS

A progress program extracts the Customer Master data from cnp_pro to produce the Customer Hierarchy files for Oracle RDBMS.

9 Touch $DIRTRAN/DATAOK

The hierarchy files and the sale measure files are now ready to be loaded into the Oracle RDBMS. The presence of the file $DIRTRAN/DATAOK indicates this..

10 Oracle RDBMS Processing Starts

The unix script $DIRAUTO/dir_loadext is the first script to run in this section of the processing. Its first task loop round and look for $DIRTRAN/DATAOK. Once it is present the load & extract into the Oracle RDBMS processing starts.

11 Load Hierarchy files in to Oracle RDBMS

The Customer & Product hierarchy files are loaded in to Oracle RDBMS. This is done via UNIX scripts & Oracle SQL.

12 Load Sales Measure File

The current weeks Sales measure file from DSS is loaded in to the MI_EKA_1 table of the Oracle RDBMS. This is done via UNIX scripts & Oracle SQL.

13 Extract Hierarchy Files for Dataserver

The hierarchy data in Oracle RDBMS is extracted in the correct format for the dataserver processing and placed in the $DIRDF Directory.

14 Extract Sales Measure Files for Dataserver

The current week sales measures for the processing week in Oracle RDBMS are extracted in the correct format for the dataserver processing and placed in the $DIRDF Directory.

15 Produce Abacus Files

A weekly sales measure file and a monthly sales measure file at the level of Pack Code and Division is produced for Abacus. Note: the month file is only produced at book month end.

16 Produce Procast File

A monthly file with containing despatches at the level of Pack Code and Division is produced for Procast.

17 Touch $DIRDF/data.ok

The hierarchy files and the sale measure files are now ready for the Dataserver Processing. The presence of the file $DIRDF/data.ok indicates this.

18 Touch $DIR10/data.ok

The hierarchy data and sales measures now in Oracle RDBMS can be extracted in the old format for the SMS(Eureka 1.0) processing. The presence of the file $DIR10/data.ok indicates this.

19 Dataserver Build Start

The UNIX script $DIRDF/sa_build is the first script to run in this section of the processing. Its first task is to loop round and look for $DIRDF/data.ok. Once it is present Dataserver build processing starts.

20 Build Dataserver Database

Sale Analyser is the client software that people associate with Eureka. Behind this client is the Oracle OLAP database on a UNIX platform. This is called the dataserver database or the MDB or the Oracle Express Server database. Using the Metafiles, the hierarchy files, the sales measure files for each week and the Abacus Cost files for each month the dataserver database is now built.

21 Monday Manual Tasks

On the Monday morning 8.30am the UNIX files, which makes up the Dataserver database are copied into pre-determined directory structures. Using the Eureka 2.5 dba client a shell (This contains only Product Customer Hierarchies and pointers to the sales measures in the UNIX dataserver database) is created on the R: Drive. Eureka is now ready to be used. As a control the audit reports from the weekends processing are checked, distributed and filed.

22 Produce Managing Directors Slice

A Sales Analyser slice is produced for the MD, which can be downloaded to his PC, is manually produced.

23 Finish Dataserver

Dataserver processing is complete.

24 SMS Processing Start

The UNIX script $DIR1.0/eka_build is the first script to run in this section of the processing. Its first task is to loop round and look for $DIR10/data.ok. Once it is present SMS processing starts.

25 Extract Hierarchy for SMS

The hierarchy data in Oracle RDBMS is extracted in the old Eureka format for the sms processing.

26 Extract Measure Files for SMS

The Sales Measures in Oracle RDBMS is extracted in the old Eureka format for the sms processing. AS well as the current month all previous months-sales data is extracted.

27 Copy EKA 1.0 files to Simba

The hierachy files and Sales measure files are copied to Simba

28 Build SMS Database
The SMS MDB is created on UNIX (Simba).

29 Create SMS Slices

Although the SMS MDB database is created every week. Remote users only require SMS Slices at month end.

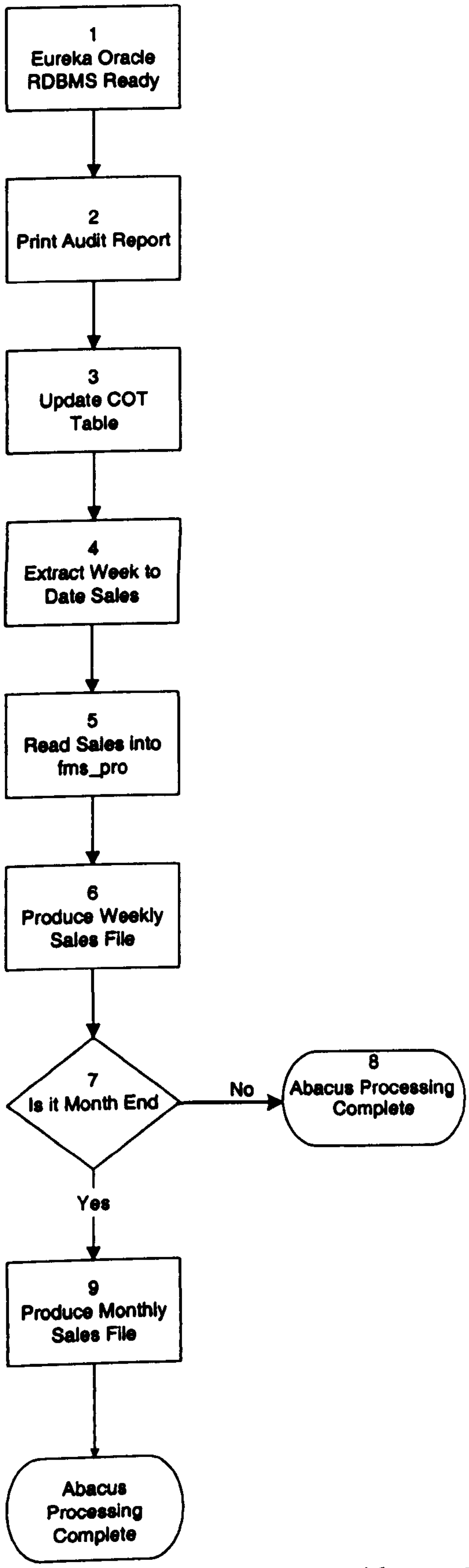
30 Create zip disks & post out

Slices are manually copied on to zip disks and posted out to the remote users.

31 Finish SMS

SMS Processing is complete

Appendix E – Part Two



Abacus Flow Diagram

Abacus Narrative

1 Eureka Oracle RDBMS Ready

At this stage of the processing the Customer & Product Hierarchy files are in Oracle RDBMS along with the current weeks sales measures. We are now in a position to produce the Abacus files. The unix script $FMS/fms_ext is the first step in the process and is called from $DIRAUTO/dir_loadext. The Abacus processing involves UNIX scripts, Oracle SQL, Progress programs and a Progress database.

2 Print Audit Report

An audit report records the week's sales measures totals in the Oracle database. On the Monday after the processing is complete this is compared to a DSS Audit report and the totals in Sales Analyser to reconcile the three systems. It is also passed on to the Management Accountants so that they can reconcile Abacus to Eureka and by default MfgPro DSS.

3 Update COT Table

Unilever provides the EUREKA RDBMS Database. In order to facilitate the Abacus processing, AC has created a COT(Class of Trade) table. This links deliver point number with COT then classifies the Delivery Point number into a Division.

4 Extract Week to Date Sales

The file $FMS/upwk.lst is extracted from the Oracle RDBMS. This contains Sales Measures at the Customer COT level & the Product Pack Code Level. Time is Week to date for the current year.

5 Read Sales into fms_pro

The file $FMS/upwk.lst is quoted to produce $FMS/upwk.dat and this is loaded in to fms_pro. Abacus can not re-solve previous month's sales history. For this reason to allow for movements of Delivery Points from one Division from an other Abacus is fed sales measures on a This Week to date minus Last Week to date basis for the weekly sales measure file. And a This Month to date minus Last Month to date basis for the monthly Sales Measure file (i.e. any changes in history is reflected in the current week or the current month).

To facilitate this, there is a Progess database fms_pro which holds: this week/month and last week/month sales measures at Customer Class of Trade level and the Product Pack code level. The progess database fms_pro is backed up on the Friday before processing begins. If processing fails this database needs to be restored before any re-run.

6 Produce Weekly Sales File

Once the Sales measures are in fms_pro. A Progress program will produce the weekly file for Abacus. This file is then copied to k3 ready for the Monday morning when it is loaded in to Abacus.

7 Is it Month End

The files $FMS/bookmoth.lst & $FMS/month.lst are produced by the early stages of the processing. The file $FMS/bookmonth.lst contains a flag Y or N to indicate whether its book month end. The file $FMS/month.lst contains the name of the Current Bookmonth.

The processing checks $FMS/bookmoth.lst is establish if it Bookmonth End.

8 Abacus Processing Complete

If it is not Bookmonth End the Abacus processing is complete and control is returned back to $DIRAUTO/dir_loadext.

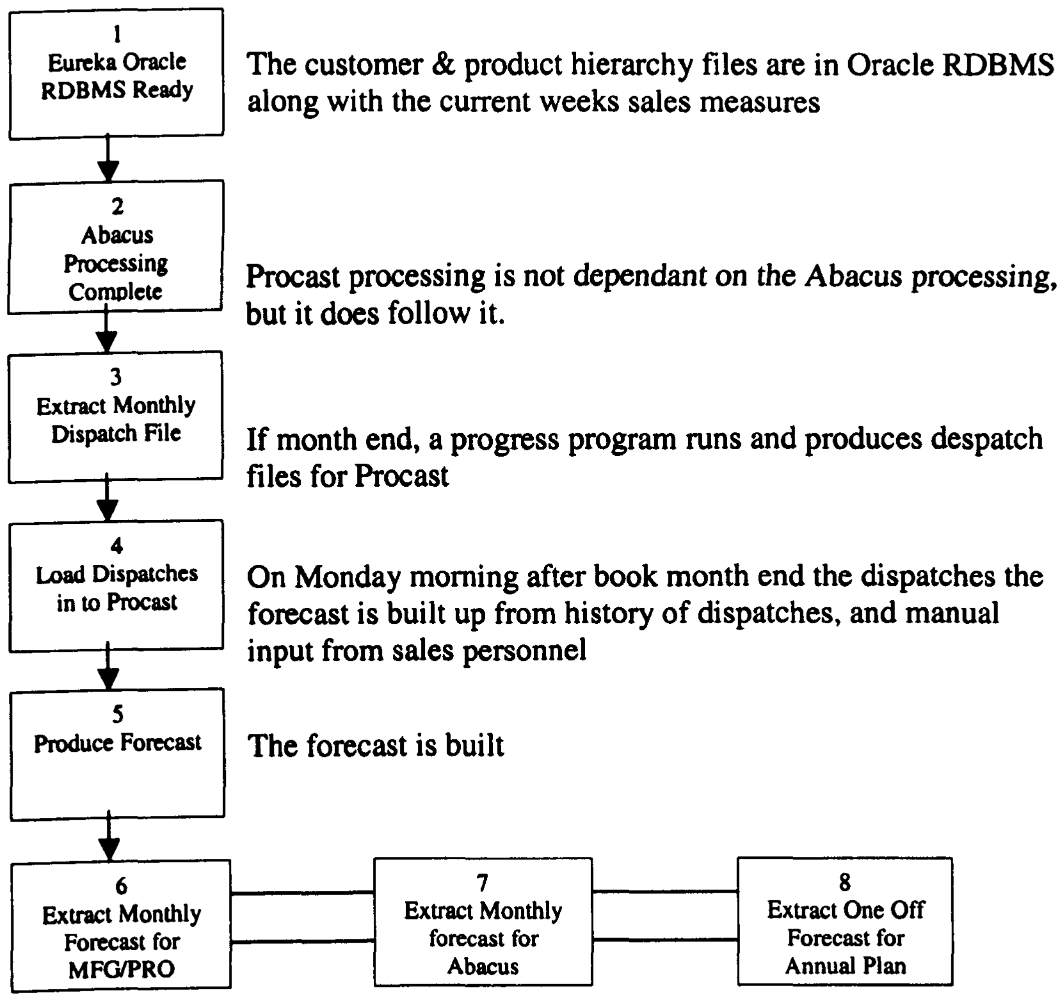
9 Produce Monthly Sales File

A Progress program will produce the monthly sales file for Abacus. This file is then copied to k3 ready for the Monday morning when it is loaded in to Abacus.

11 Abacus Processing Complete

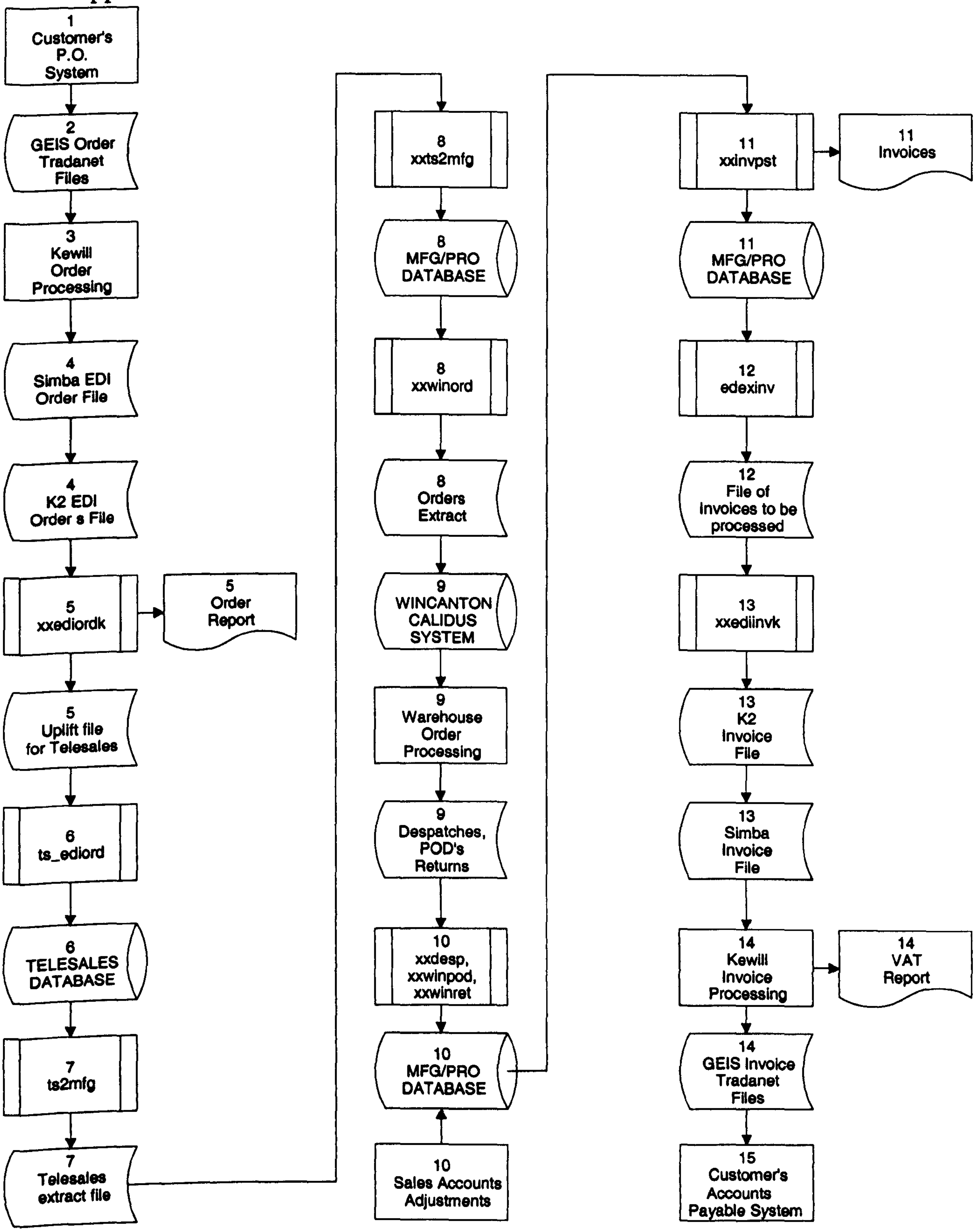
The Abacus processing is complete and control is returned back to $DIRAUTO/dir_loadext.

Appendix E - Part Three



Procast Flow Diagram and Interfaces

Appendix E – Part Four



EDI Lifecycle Flow Diagram

EDI Process

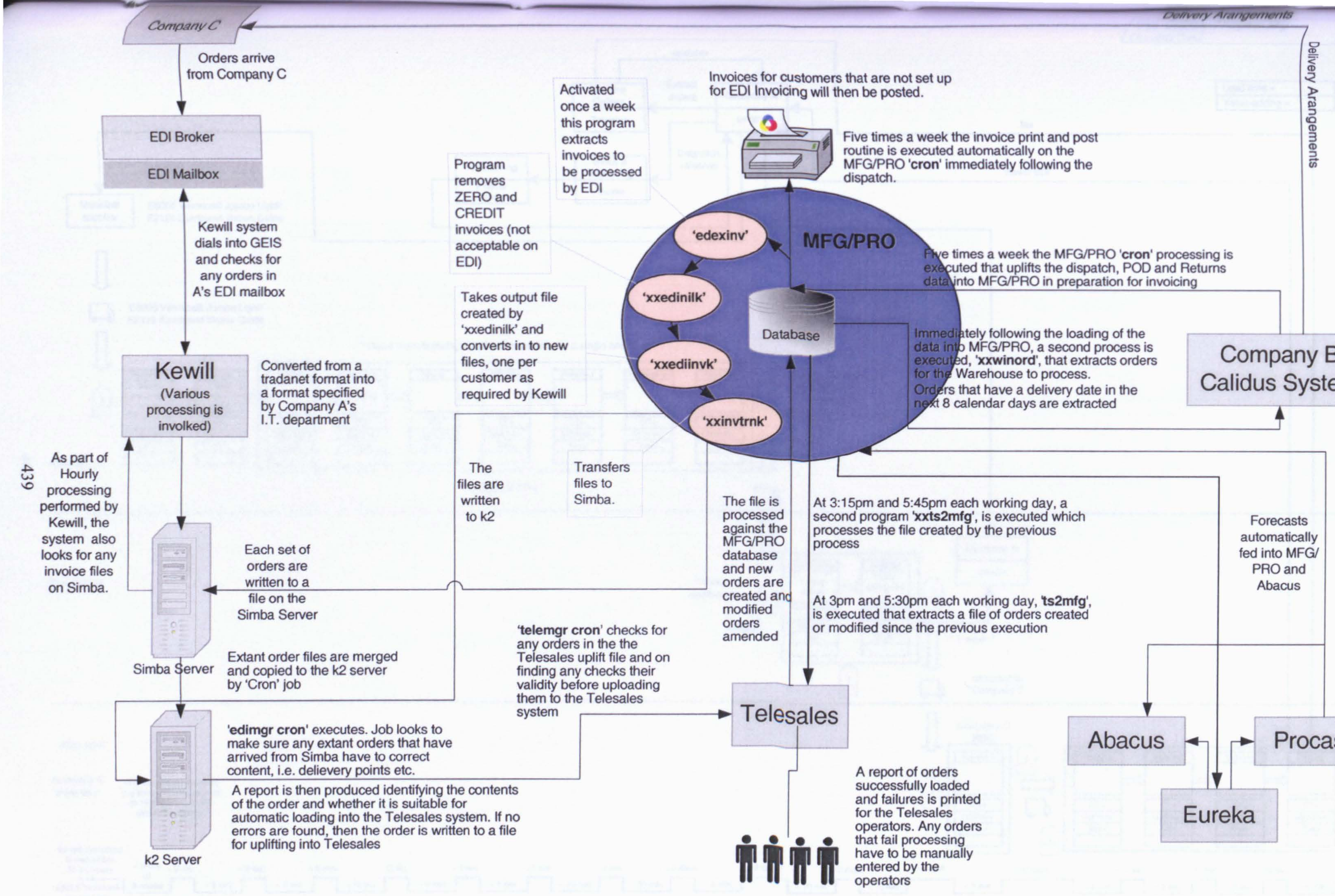
The process of EDI takes place in the following sequence. When a retailer requires a product, the order details will be placed into a Purchase Order system. The retailer will have various means of extracting the purchase orders for EDI but will usually have an automatic method of invoking this. The purchase orders in EDI tradanet format are then be transmitted to an EDI broker.

GEIS is similar to a BACS system (Banks Automated Clearing System) except it processes various types of EDI messages rather than bank payments. Each trading partner (customer or supplier) has various tradanet identifications, which they can use to grant/request permission to transfer EDI messages to another trading partner. If permissions are in place then the message will be transferred from the transmitters post box into the receivers' mailbox and will remain there until it is collected. All messages have a specific format although, in practice, they will vary because some fields are mandatory and some optional.

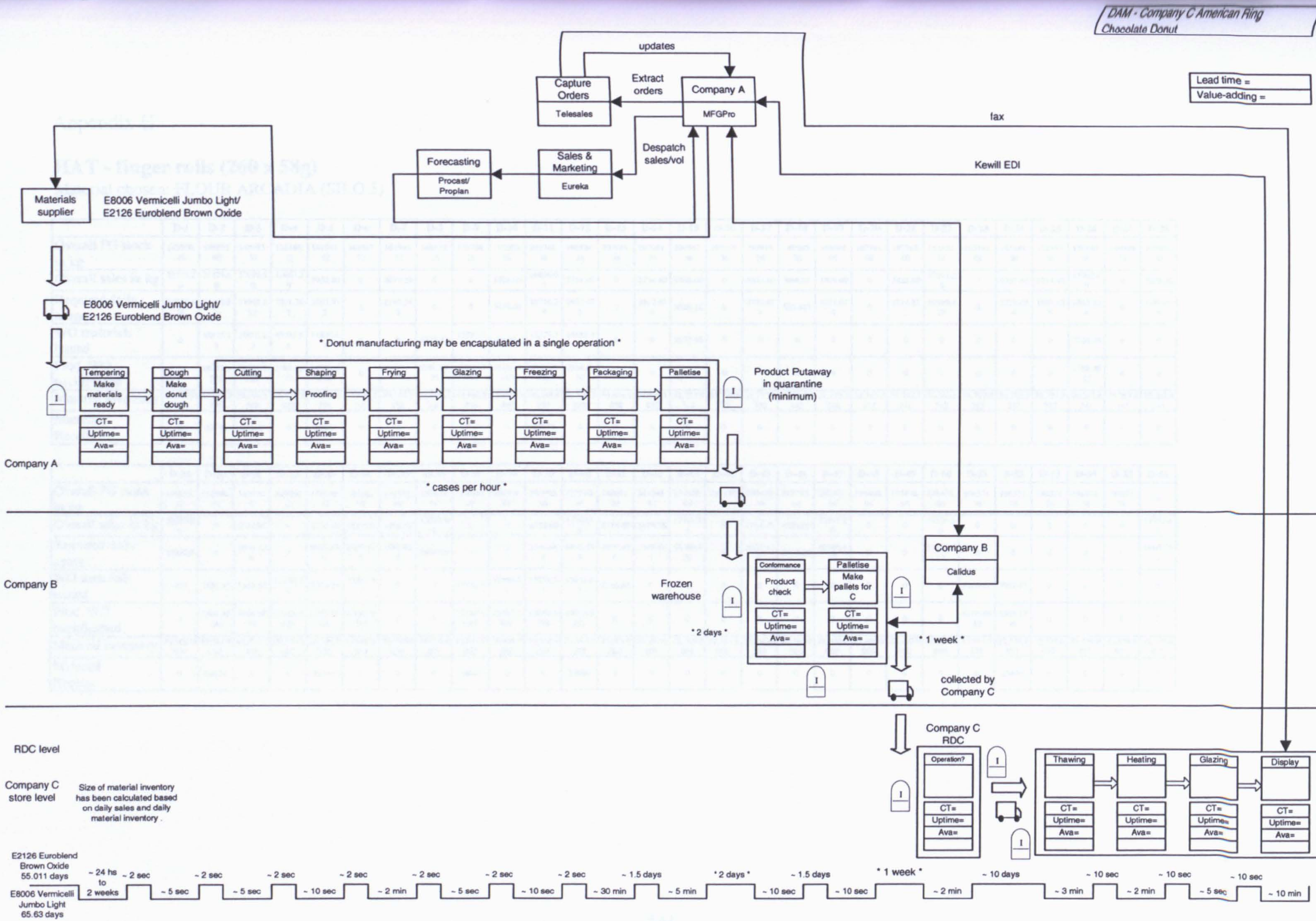
Company A uses a PC system called Kewill for processing EDI data. Once an hour, between 8am and 8pm, the Kewill system will dial into GEIS and check to see if there are any messages in the appropriate mailbox. All messages will be collected and pulled into the Kewill system where, depending on the message type, various processing will be invoked. A customer may have transmitted multiple orders in one transmission and each customer's orders will be in a separate message from other customers. Similarly, if a customer has transmitted more than once, then each transmission will be treated separately. For the orders, the system will then check that they are from customers configured in the Kewill system along with checking that each order satisfies the expected format for that customer. The orders will then be converted from a tradanet format into a format specified by Company A's I.T. department. Each set of orders in the order files will be processed this way and each set will be allocated a unique number as part of the file extension. Each set will then be written to a file on the Simba server for further processing.

The next stage involves the Simba EDI Order File and k2 EDI Orders files. On Simba there is a 'cron' job that is executed on a regular basis each hour between 8am and 8pm that looks for extant order files that haven't been processed. A second job originating on the k2 server known as 'edimgr cron' also executes regularly each hour between 8am and 8pm. This job looks for any extant order files transmitted from Simba. On locating a file of this type, each order is processed by checking the data content for legitimate customer delivery points, dates and products. A report is produced for Telesales identifying the contents of the order and whether it is suitable for automatic loading into the Telesales system (i.e. no errors). If no errors are found, then the order is written to a file for uplifting into Telesales.

The third job that executes each hour between 8am and 8pm on k2 is the 'telemgr cron' job which looks for any orders in the Telesales uplift file. On finding orders, checks are undertaken for accuracy against the Telesales database. Assuming there are no problems the orders are loaded into the Telesales system. Any orders that fail processing either at this stage or during the previous stage have to be manually processed by the operators using the same screens as they would to enter other orders. At 3pm and 5:30pm each working day, a program, 'ts2mfg', is executed that extracts a file of orders created or modified since the previous execution. Following this at 3:15pm and 5:45pm each working day, a second program 'xxts2mfg', is executed which processes the file created by the previous process. The file is processed against the MFG/PRO database and new orders are created and modified orders amended. Orders remain in MFG/PRO until they are invoiced. Immediately following the loading of the data into MFG/PRO, a second process is executed, 'xxwinord', that extracts orders for the Warehouse to process.



Companies A,B and C System Map and Information Flows



DAM - Company C American Ring Chocolate Donught

Appendix H

HAT - finger rolls (260 x 58g)

Material chosen: FLOUR ARCADIA (SILO 5)

	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12	D-13	D-14
Overall FG stock in kg	143350.48	136835.92	146185.52	124168.72	141661.52	161868.72	161868.72	168172.16	178728.16	192300.16	201348.16	196824.16	207681.76	207681.76
Overall sales in kg	21715.20	24429.60	37096.80	12667.20	9952.80	0.	3619.20	0	0	4524.00	18096.00	2714.40	0	2714.40
Required daily usage	12859.488	14466.924	21968.292	7501.368	5893.932	0	2143.248	0	0	2679.06	10716.24	1607.436	0	1607.436
WO materials issued	0	18805.23	18805.23	10491.96	11820.43	0	0	6878.87	13395.39	10180.5	12323.76	11682.44	0	0
Prod. WO backflushed	0	18753.5521	18753.5521	5697.5077	11787.9470	0	0	8930.2629	13395.3944	10180.4997	12323.7628	7304.9551	0	0
Material inventory	23,000.0000	24,334.7730	32,969.5460	22,477.5823	35,677.1539	35,677.1539	35,677.1539	28,798.2839	43,102.8896	32,922.3899	46,318.6271	34,636.1850	34,636.1850	34,636.1850
Material Receipt	0	20140	27440	0	25020	0	0	0	27700	0	25720	0	0	0

	D-15	D-16	D-17	D-18	D-19	D-20	D-21	D-22	D-23	D-24	D-25	D-26	D-27	D-28
Overall FG stock in kg	204967.36	195919.36	195919.36	189585.76	188680.96	187761.08	187761.08	182332.28	165141.08	165141.08	162577.48	159863.08	148070.52	148070.52
Overall sales in kg	9048.00	0	6333.60	904.80	1809.60	0	5428.80	17191.20	0	6333.60	2714.40	11762.40	0	7238.40
Required daily usage	5358.12	0	3750.684	535.812	1071.624	0	3214.872	10180.428	0	3750.684	1607.436	6965.556	0	4286.496
WO materials issued	2922.65	0	0	0	0	0	0	0	0	0	0	2768.38	0	0
Prod. WO backflushed	0	0	0	0	0	0	0	0	0	0	0	2768.3815	0	0
Material inventory	31,713.5312	31,713.5312	31,713.5312	31,713.5312	31,713.5312	31,713.5312	31,713.5312	31,713.5312	31,713.5312	31,713.5312	31,713.5312	30,267.4343	30,267.4343	30,267.4343
Material Receipt	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	D-29	D-30	D-31	D-32	D-33	D-34	D-35	D-36	D-37	D-38	D-39	D-40	D-41	D-42
Overall FG stock in kg	140832.12	132990.52	148070.52	160436.12	175516.12	183161.68	179542.48	185122.08	186630.08	201710.08	216790.08	225536.48	243964.24	241249.84
Overall sales in kg	22620.00	0	2714.40	0	2714.40	3619.20	1809.60	13572.00	0	0	6333.60	11762.40	2714.40	3619.20
Required daily usage	13395.3	0	1607.436	0	1607.436	2143.248	1071.624	8037.18	0	0	3750.684	6965.556	1607.436	2143.248
WO materials issued	-468	7501.42	9108.87	12323.76	8037.24	12046.92	0	0	17146.1	13395.39	12859.58	12035.61	2106.67	0
Prod. WO backflushed	0	7501.4208	9108.8682	12323.7628	8037.2366	12046.9247	0	0	17146.1048	13395.3944	12859.5786	10028.6852	0	0
Material inventory	31,468.0000	50,586.5792	41,477.7110	29,153.9482	46,556.7116	34,509.7869	60,040.0000	34,510.0000	42,803.8952	29,408.5009	16,548.9223	26,593.3077	23,100.0000	23,100.0000
Material Receipt	0	26620	0	0	25440	0	0	0	25440	0	0	22080	0	0

	D-43	D-44	D-45	D-46	D-47	D-48	D-49	D-50	D-51	D-52	D-53	D-54	D-55	D-56
Overall FG stock in kg	237630.64	220439.44	220439.44	217725.04	213201.04	198498.04	198498.04	198498.04	196371.76	196371.76	196371.76	196371.76	196371.76	0
Overall sales in kg	17191.20	0	2714.40	4524.00	17191.20	0	0	23524.80	0	0	0	0	0	11762.40
Required daily usage	10180.428	0	1607.436	2679.06	10180.428	0	0	13931.112	0	0	0	0	0	6965.556
WO materials issued	0	0	0	0	0	0	0	0	9108.87	7091.43	0	0	0	0
Prod. WO backflushed	0	0	0	0	0	0	0	0	9108.8682	3563.1749	0	0	0	0
Material inventory	23,100.0000	23,100.0000	23,100.0000	23,100.0000	23,100.0000	23,100.0000	23,100.0000	23,100.0000	13,991.1318	32,539.6977	32,539.6977	32,539.6977	32,539.6977	32,539.6977
Material Receipt	0	0	0	0	0	0	0	0	0	25640	0	0	0	0

HAT - finger rolls (260 x 58g). Material chosen: FLOUR ARCADIA (SILO 5)

GP1 Trials – supplier deliveries and material inventory at Company A.

	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12	D-13	D-14	D-15	D-16	D-17	D-18	D-19	D-20	D-21	D-22	D-23	D-24	D-25	D-26	D-27	D-28
Material supplier deliveries (kg)	14466.92	21968.29	7501.37	5893.93	0	2143.25	0	0	2679.06	10716.24	1607.44	0	1607.44	5358.12	0	3750.68	535.81	1071.62	0	3214.87	10180.43	0	3750.68	1607.44	6965.56	0	4286.50	13395.30
Material inventory level at A (kg)	16376.36	23877.73	9410.81	7803.37	1909.44	4052.69	1909.44	1909.44	4588.50	12625.68	3516.88	1909.44	3516.88	7267.56	1909.44	5660.12	2445.25	2981.06	1909.44	5124.31	12089.87	1909.44	5660.12	3516.88	8875.00	1909.44	6195.94	15304.74

	D-29	D-30	D-31	D-32	D-33	D-34	D-35	D-36	D-37	D-38	D-39	D-40	D-41	D-42	D-43	D-44	D-45	D-46	D-47	D-48	D-49	D-50	D-51	D-52	D-53	D-54	D-55	D-56
Material supplier deliveries (kg)	0	1607.44	0	1607.44	2143.25	1071.62	8037.18	0	0	3750.68	6965.56	1607.44	2143.25	10180.43	0	1607.44	2679.06	10180.43	0	0	13931.11	0	0	0	0	0	6965.56	
Material inventory level at A (kg)	1909.44	3516.88	1909.44	3516.88	4052.69	2981.06	9946.62	1909.44	1909.44	5660.12	8875.00	3516.88	4052.69	12089.87	1909.44	3516.88	4588.50	12089.87	1909.44	1909.44	15840.55	1909.44	1909.44	1909.44	1909.44	1909.44	8875.00	

RM starting stock: 14768.93 kg equal to 4 days of stock

GP2 Trials – supplier deliveries and material inventory at Company A.

	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12	D-13	D-14	D-15	D-16	D-17	D-18	D-19	D-20	D-21	D-22	D-23	D-24	D-25	D-26	D-27	D-28
Material supplier deliveries (kg)	18000	21000	0	20000	1000	9000	0	0	2000	8000	0	3000	3000	0	0	9000	0	1000	0	4000	0	0	14000	0	7000	0	6000	2000
Material inventory level at A (kg)	19909.44	26442.52	4474.22	16972.86	12078.92	21078.92	18935.68	18935.68	20935.68	26256.62	15540.38	16932.94	19932.94	18325.50	12967.38	21967.38	18216.70	18680.89	17609.26	21609.26	18394.39	8213.96	22213.96	18463.28	23855.84	16890.29	22890.29	20603.79

	D-29	D-30	D-31	D-32	D-33	D-34	D-35	D-36	D-37	D-38	D-39	D-40	D-41	D-42	D-43	D-44	D-45	D-46	D-47	D-48	D-49	D-50	D-51	D-52	D-53	D-54	D-55	D-56
Material supplier deliveries (kg)	0	13000	0	1000	1000	1000	0	2000	8000	3000	4000	0	6000	6000	0	7000	1000	9000	0	3000	9000	0	5000	0	0	0	7000	
Material inventory level at A (kg)	7208.49	20208.49	18601.06	19601.06	18993.62	17850.37	16778.75	10741.57	18741.57	21741.57	21990.88	15025.33	19417.89	23274.64	13094.22	20094.22	19486.78	25807.72	15627.29	18627.29	27627.29	13696.18	18696.18	18696.18	18696.18	18696.18	25696.18	

RM desired level of stock: 18461.15 kg equal to 5 days of stock
Batch size: 1000 kg
RM starting stock: 14768.93 kg equal to 4 days of stock

HAT - finger rolls (260 x 58g). Material chosen: FLOUR ARCADIA (SILO 5)

GP3 Trials – supplier deliveries and material inventory at Company A.

	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12	D-13	D-14	D-15	D-16	D-17	D-18	D-19	D-20	D-21	D-22	D-23	D-24	D-25	D-26	D-27	D-28
Material supplier deliveries (kg)	18000	21000	0	20000	1000	9000	0	0	2000	8000	0	3000	3000	4000	0	9000	0	1000	0	4000	7000	0	14000	0	7000	0	6000	9000
Material inventory level at A (kg)	19909.44	26442.52	4474.22	16972.86	12078.92	21078.92	18935.68	18935.68	20935.68	26256.62	15540.38	16932.94	19932.94	22325.50	16967.38	25967.38	22216.70	22680.89	21609.26	25609.26	29394.39	19213.96	33213.96	29463.28	34855.84	27890.29	33890.29	38603.79

	D-29	D-30	D-31	D-32	D-33	D-34	D-35	D-36	D-37	D-38	D-39	D-40	D-41	D-42	D-43	D-44	D-45	D-46	D-47	D-48	D-49	D-50	D-51	D-52	D-53	D-54	D-55	D-56
Material supplier deliveries (kg)	0	13000	0	1000	1000	1000	9000	2000	8000	3000	4000	0	6000	9000	0	7000	1000	9000	0	3000	14000	0	5000	0	0	0	7000	
Material inventory level at A (kg)	25208.49	38208.49	36601.06	37601.06	36993.62	35850.37	43778.75	37741.57	45741.57	48741.57	48990.88	42025.33	46417.89	53274.64	43094.22	50094.22	49486.78	55807.72	45627.29	48627.29	62627.29	48696.18	53696.18	53696.18	53696.18	53696.18	60696.18	

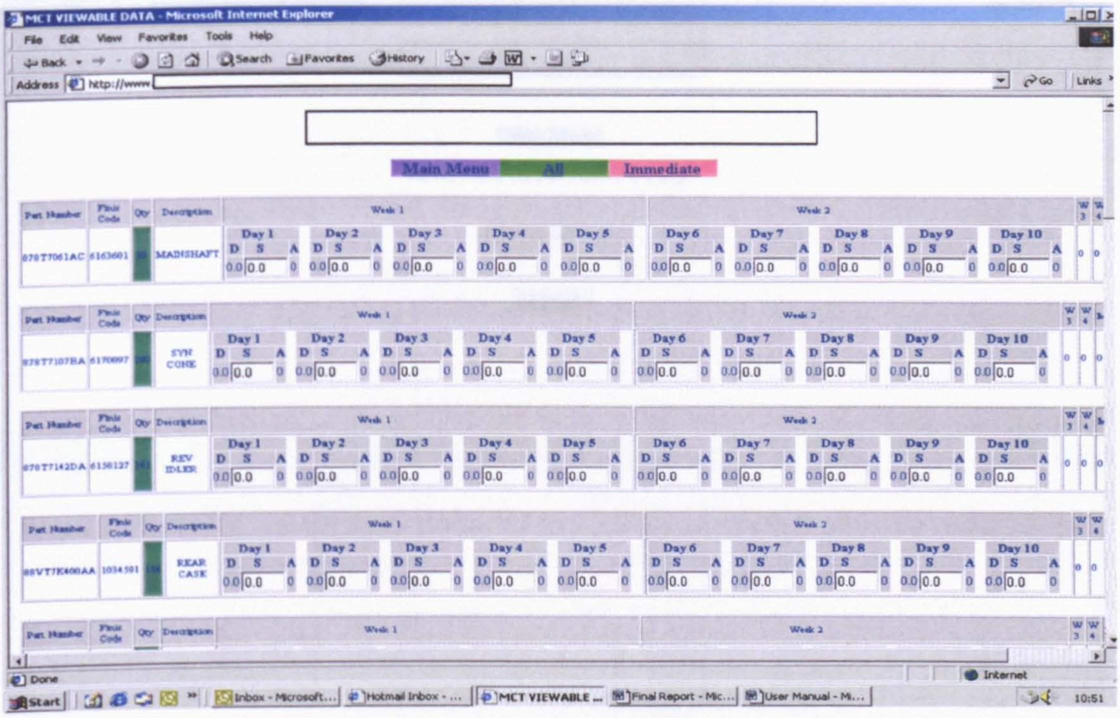
RM desired level of stock: 18461.15 kg equal to 5 days of stock
Batch size of material deliveries: 1000 kg
RM starting stock: 14768.93 kg equal to 4 days of stock

Appendix I – CMMS3 Screenshots

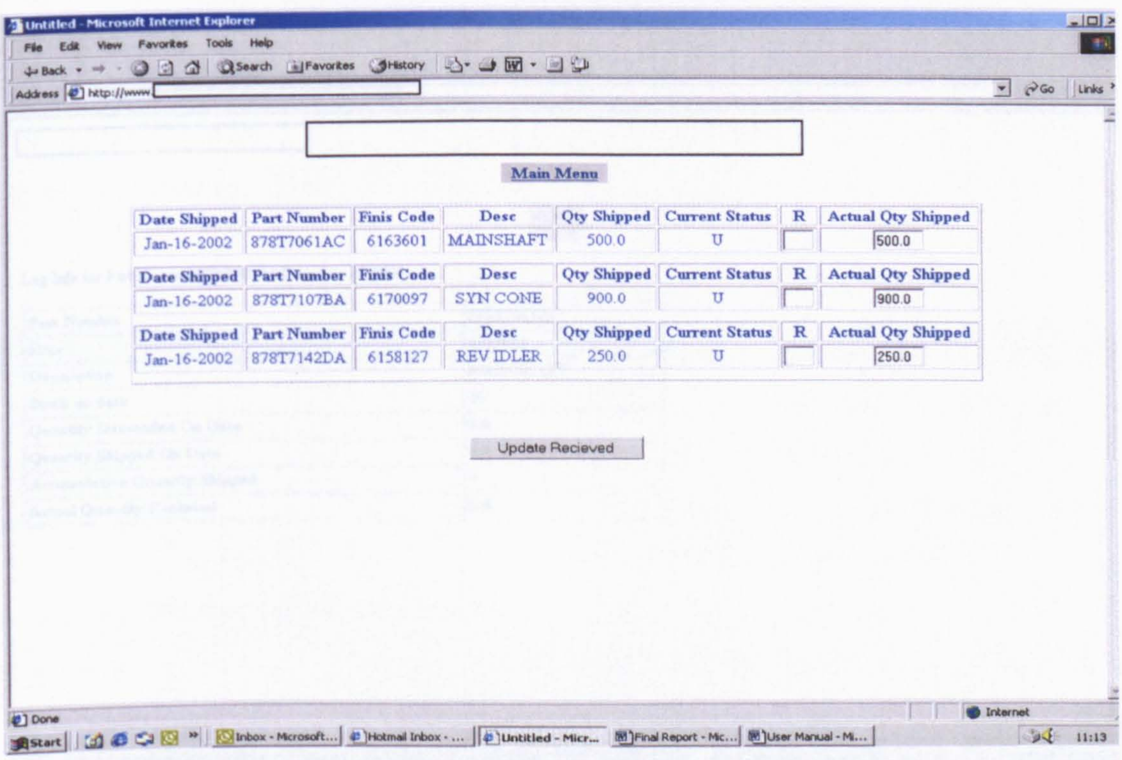
```
CMMSBGHA    CUSTOMER RELEASE REQUIREMENTS MAINTENANCE     19/08/02 11:01:53
==> ________ ____________________________________________ PLT 0122A TF__
PART:  988T-   7015-DA_________ CUST CODE: D03TA  RLSE DATE: 19/08/2002
Ref: ___________________________ Name: MS MITCHELL   REC TYPE: P  E/M: M#
Desc: SHAFT ASY-TRANS INPUT     Rls Eff: 02/08/02 Rlse No: _______ N/C: C
Shp To: D03TA  Name: MS MITCHELL   Ship Code: 41__  Rlse Stat: _  Note: N
AC DATE        Net   Accum   Plant Last Ship   Customer  Rlse Keep: N
- ---------- -------- --------- Dte: 12/08/2002 __________   Commitment
  19/08/2002   250   1630   Qty:      22       0  Fab: _______
  26/08/2002   0     1630   Cum:     1402      0  Raw: ________
  02/09/2002   500   2130   Contact: ___________________________
  09/09/2002   0     2130   Pr Cum:    1380  Offset:    0
  16/09/2002   0     2130   Rlse Type: 830  Block 862: N  Part Stat: C
  23/09/2002   0     2130   Rlse Load Status: LOAD COMPLETE
  30/09/2002   0     2130   LAST CHANGED BY: W#MK19
  07/10/2002   0     2130
  14/10/2002   0     2130
  21/10/2002   0     2130
  28/10/2002   0     2130
  04/11/2002   0     2130
  11/11/2002   0     2130
F1=Help  F2=Net/Cum  F4=NxtPart F5=NxtCust F6=NxtErr  F9=NxtWarn  F10=NxtKeep
F11=NxtSusp F13=Load F14=PrvDte F15=NxtDte F16=PrvPart F17=PrvCust F18=Daily
MORE RECORDS AVAILABLE                                   W#MK19
```

```
CMMSEMHA              MPS PART DETAIL              19/08/02 11:03:08
==> ________ ____________________________________________ PLT 0122A TF__
PART:  988T-   7015-DA_________  Live Boh:    0 Frozen Boh:    0
              Cust Rlse #s: NONE   NONE   667-05  667-03  667-13
    Liv/Frz Liv/Frz  Liv/Frz
A         Cum     Cum     Ship ------------ Net Requirements ------------
C CUST    Ship    Req   Status 19/08/02 20/08/02 21/08/02 22/08/02 23/08/02
- ----- -------- ------- -------- -------- -------- -------- -------- --------
 DA0NA    700     700      0       40       40       40       40       40
          700     700      0
 D03TA   1402    1380     22      250        0        0        0        0
         1402    1380     22
 0095A    164     196    32-        0        0        0        0        0
          164     196    32-
 0143A    259     329    70-       60        0        0        0        0
          259     329    70-
 0160A    371     416    45-       12        0        0        0        0
          371     416    45-
        -------- ------- -------- -------- -------- -------- -------- --------
 Total   2896    3021   125-      362       40       40       40       40
         2896    3021   125-
F1=Help (Field)  F4=Next Part  F5= Next Left  F6= Next Right
F10= Plng Grp Detail          F11= Plng Grp Menu
NO MORE RECORDS AVAILABLE - FROZEN VALUES AS OF 18/08/02 21:33:13     W#MK19
```

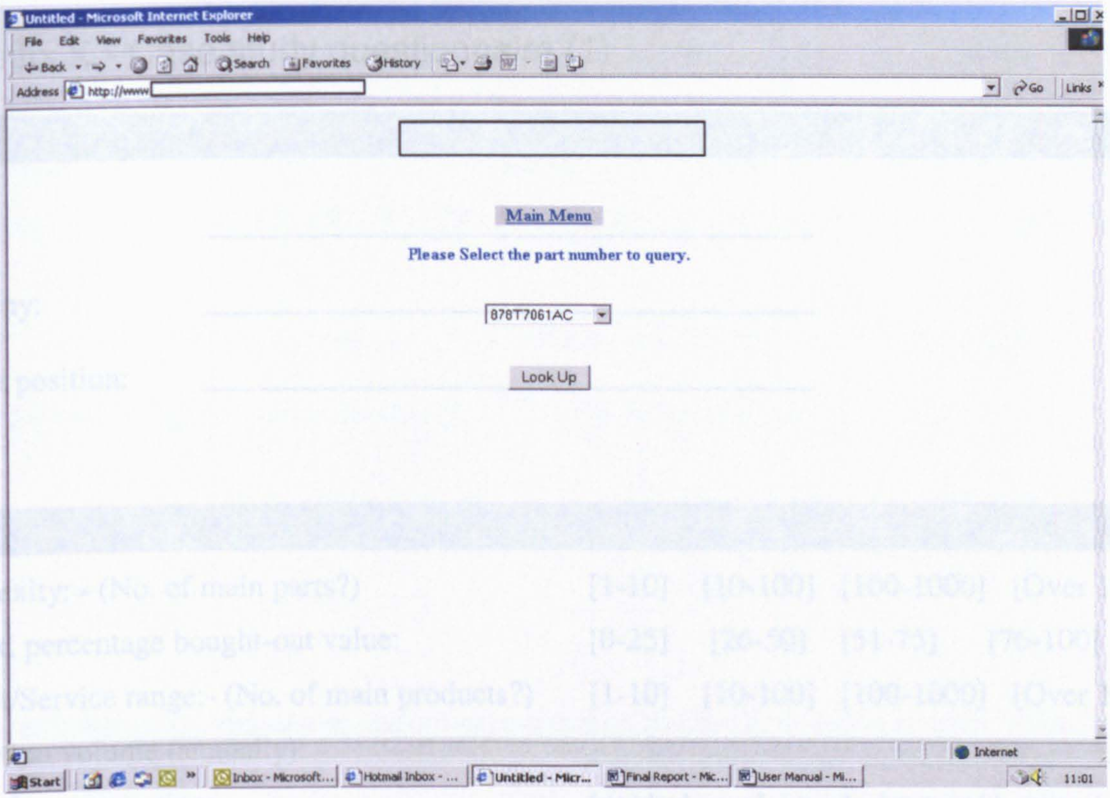
Appendix J - Screen Shots of the Internet Application (Case 4)



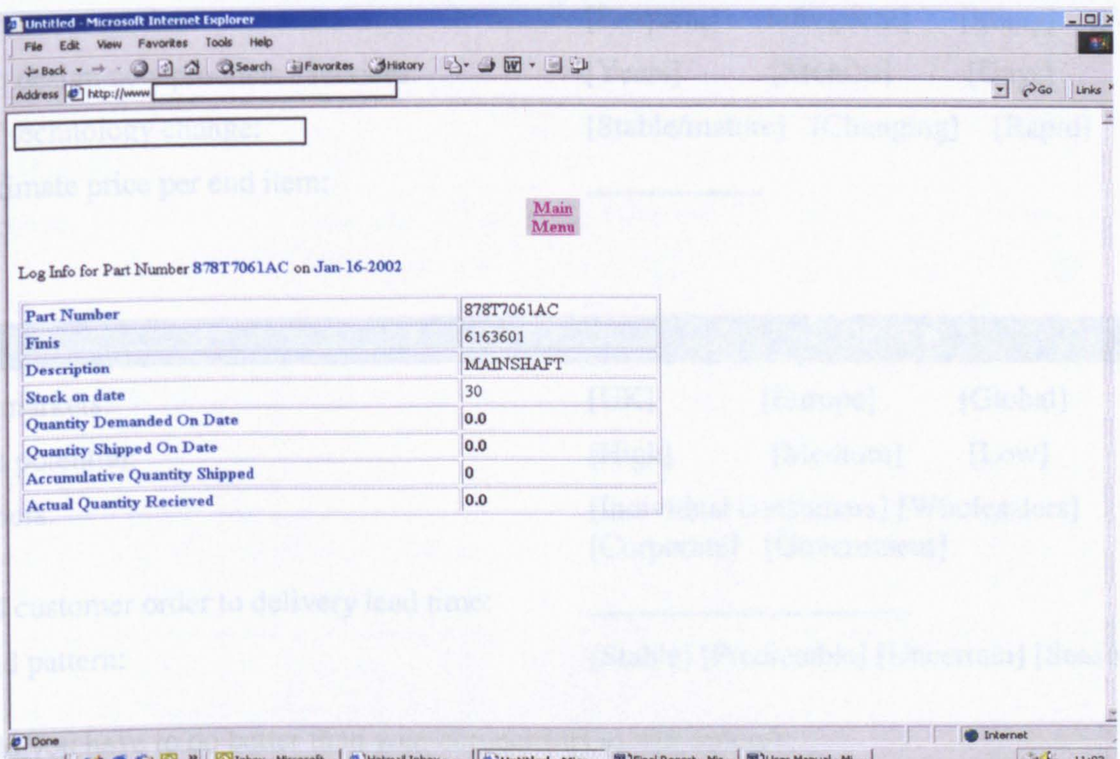
Screen Shot of Shipping Schedule



Screen Shot of Shipment Acknowledgement Application



Screen Shot of Log Application Query Page



Screen Shot of Log Application Results Page

Appendix K - Case study questionnaire (1)

1. Respondent Company contact:

Name: ______________________

Company: ______________________

Current position: ______________________

2. Product(s) or service(s):

Complexity: - (No. of main parts?)	[1-10] [10-100] [100-1000] [Over 1000]
Approx. percentage bought-out value:	[0-25] [26-50] [51-75] [76-100]
Product/Service range:- (No. of main products?)	[1-10] [10-100] [100-1000] [Over 1000]
Production volume (annually):	______________________
Level of customisation:	[standard range] [standard range with options] [some design work per order] [design to order]
Product life cycle (time between 'new models'):	Length: ______________________
New products/services:	[Frequent] [Infrequent] [Many] [Few]
Time to design new products / services:	[Years] [Months] [Days]
Pace of technology change:	[Stable/mature] [Changing] [Rapid]
Approximate price per end item:	____________

3. Markets / customers

Target markets:	[UK] [Europe] [Global]
Growth potential:	[High] [Medium] [Low]
Customers:	[Individual consumers] [Wholesalers] [Corporate] [Government]
Typical customer order to delivery lead time:	______________________
Demand pattern:	[Stable] [Predictable] [Uncertain] [Seasonal]

What do you have to do better than your competitors to win orders?:

[Price] **[Delivery speed]** **[Delivery reliability]** **[quality]**

[Availability] **[Innovative product]** **[Innovative process]**

4. Key competitors

Number: [Many] [Few]

Relative size: [Larger] [Same] [Smaller]

On average do you perform better/about the same/worst than your competitors in the following areas:

[Price] **[Delivery speed]** **[Delivery reliability]** **[quality]**

[Availability] **[Innovative product]** **[Innovative process]**

5. Financial performance

Annual turnover (£M): __________ Profit margin (%): ________

6. Human resources

No. of employees in : Manufacture: ___________ Support: __________

Organisation structure: [Product oriented] [functionally oriented] [Matrix]

7. Plant and process

No. of factories / facilities: _____________

Layout: [Functional] [cells] [line] [combination]

Process Route:

Description	**Time and frequency**	**Stock or order?**	**Operation** ●	**Transport** ➡	**Delay** D	**Inspection** ■	**Storage** ▼
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							

Delivery frequency to customer:

Delivery frequency from main suppliers:

Technology for manufacture / provision of service: [Low tech] [high tech] [changing]

Sourcing policy (for majority of parts): Single / Dual / Multiple sources

No. of suppliers:

Quality system:

8. Scheduling / material control

Customer orders:

Frequency: (continuous, hourly, daily etc)________________________

Fixed horizon: ________________________

Tentative horizon: ________________________

Actual fixed – normal time after which no customer order changes take place:__________

Means (Internet, EDI, Fax etc): ________________________

Percentage of orders changed by customer after fixing point:________________________

Materials planning system:

Customer orders loaded directly? ________________ [Manually] [Automatically]
Frequency:

Planning and Control System details (type – used for what?):________________________

____

Supplier scheduling:

Frequency: (continuous, hourly, daily etc): ________________________

Means (Internet, EDI, Fax etc): ________________________

Length of fixed horizon: ___________ how are these quantities calculated? _______

Length of tentative horizon: ___________ how are these quantities calculated? _______

Percentage of orders changed by you after fixing point:: ________________________

Actual fixed – latest time that you would demand an order change: ________________

9. Performance measures:-

Inventory investment:

Raw material (days or value): ____________

WIP (days or value): ____________

Finished Goods (days or value): ____________

Delivery Performance:

Delivery Schedule adherence: ____________

(Percentage of product delivered according to customer schedule)

Delivery lead time: ____________

Responsiveness:

Response time to customer requests: ____________

% work demand driven: ____________

Quality performance:

Scrap: ____________

Re-work: ____________

Returns: ____________

Appendix L

▪ Example of Daily Call-In (DCI)

```
CMMSAAIA                SUPPLIER RELEASE - 1                  17/05/02 12:06:54
==> ________  ________________________________________________ PLT 02641 JH__
PART:     1X43-    600C14-AGN0ADX_____       SUPP: BPVKA       830/862 (P/S):  S
PROG START DATE: 13/05/02 PROG NO. 664-55_  Send (F,R): _   Process Status: S
Date    TW % Adj   Quantity      Cum Pend Amnd:   Amnd Type:     Strik Prot:
------ -  - -     ------------------- Ship Freq: 11              Final Rlse:
PRIOR                           374 Part Desc: FRONT SEAT KIT
170502              28          381 Supplier:  LEAR CORP UK LTD
180502               0          381 Issue Dte: 17/05/02     Thcknss:       0.0000
190502               0          381 Pct Bus:   100          Width:          0.000
200502              35          416 Part Stat: C            Length:          0.00
210502              40          456 R/F/G:  RF7 K02         T&G:
220502              48          504 Ship/Del:  S            Stl Comm:
230502              23          527 Trn Dy/Sr:  0.0         Thck Dsc:
240502              32          559 862 Code:  D            S/B:
250502               0          559 Last No:   051602        PO. No.: IA4291
260502               0          559 Last Date: 17/05/02     Rel Type: A
270502              28          587 Last Qty:          21     Buyer Name/Phone #
280502              31          618 Cum Rec+IT        353   N J GASSOR
290502              17          635                            +44-2476-202805
300502               3          638 Ship To:                Bill To:  02641
```

- **Example of Overlay**

	WARNING THIS IS ONLY A GUIDE SEQUENCES MAY CHANGE								
	GRAND TOTAL	17-May	20-May	21-May	22-May	23-May	24-May	27-May	REST
ALL JAGUARS	0	0	0	0	0	0	0	0	0
==============	3766	158	384	384	384	384	158	384	1530
VISTEON REPORT	0	0	0	0	0	0	0	0	0
==============	0	0	0	0	0	0	0	0	0
CHAR/CHAR LHD	755	61	79	58	71	74	13	22	377
CHAR/CHAR RHD	232	14	28	26	14	5	5	22	118
SAB/IVORY LHD	812	8	119	65	35	56	29	100	400
SAB/IVORY RHD	9	0	1	3	4	0	0	1	0
SAB/SAND LHD	1221	45	63	150	176	175	95	182	335
SAB/SAND RHD	303	14	55	36	42	22	5	24	105
CHAR/IVORY LHD	1	0	1	0	0	0	0	0	0
CHAR/IVORY RHD	2	0	0	1	0	0	0	1	0
CHAR/DOVE LHD	21	1	0	1	2	8	0	0	9
CHAR/DOVE RHD	30	0	2	4	2	3	1	4	14
CHAR/SAND LHD	18	2	1	1	2	11	0	0	1
CHAR/SAND RHD	51	1	8	7	1	1	3	6	24
GRAN/DOVE LHD	160	6	4	5	16	23	4	14	88
GRAN/DOVE RHD	151	6	23	27	19	6	3	8	59
=============	0	0	0	0	0	0	0	0	0
WOOD SHOP REP	0	0	0	0	0	0	0	0	0
=============	0	0	0	0	0	0	0	0	0
ALL ENTRY LEVEL	481	26	73	52	53	56	25	51	145
ALL SPORT LEVEL	297	13	25	28	23	60	12	27	109
ALL EXEC LEVEL	2988	119	286	304	308	268	121	306	1276
ALL LHD	2988	123	267	280	302	347	141	318	1210
ALL RHD	778	35	117	104	82	37	17	66	320
AUTO G/BOX	2887	120	288	298	290	291	122	293	1185
MANUAL G/BOX	879	38	96	86	94	93	36	91	345
ALL AUTO GREY	101	6	4	10	4	45	6	5	21
ALL AUTO BRONZE	2786	114	284	288	286	246	116	288	1164
ALL LHD GREY	96	7	0	4	11	51	3	0	20
ALL RHD GREY	178	6	20	23	7	7	7	25	83
ALL LHD BRONZE	2892	116	267	276	291	296	138	318	1190
ALL RHD BRONZE	600	29	97	81	75	30	10	41	237
=============	0	0	0	0	0	0	0	0	0
TRW STEERING WHEELS	0	0	0	0	0	0	0	0	0
=============	0	0	0	0	0	0	0	0	0
AGOAEK SABLE BASE	129	6	16	8	13	19	13	25	29
AGOLEG CHARCOAL BASE	106	5	11	4	6	16	5	18	41
AGOLGP GRANITE BASE	58	3	8	5	7	7	1	4	23
CFOAEK SABLE ICE	7	1	0	0	0	5	0	1	0

CFOLEG CHARCOAL ICE	2	0	0	1	0	0	1	0	0
CFOLGP GRANITE ICE	1	0	0	0	0	1	0	0	0
DGOAEK SABLE BOTH	2157	55	204	238	234	224	116	281	805
DGOLEG CHARCOAL BOTH	690	59	81	63	59	25	4	8	391
DGOLGP GRANITE BOTH	240	9	19	19	27	21	5	18	122
HB CHARCOAL SPORT NON	161	4	13	21	14	12	7	19	71
JB CHARCOAL WITH ICE	23	0	4	3	2	2	2	3	7
KB CHARCOAL WITH BOTH	110	9	7	4	7	45	3	5	30
EAOAEK SBL BASE W/L	7	1	5	1	0	0	0	0	0
EAOLEG CHAR BASE W/L	5	0	0	0	0	2	0	1	2
EAOLGP GRAN BASE W/L	0	0	0	0	0	0	0	0	0
FAOAEK SBL ICE W/L	0	0	0	0	0	0	0	0	0
FAOLEG CHAR ICE W/L	0	0	0	0	0	0	0	0	0
FAOLGP GRAN ICE W/L	0	0	0	0	0	0	0	0	0
GAOAEK SBL BOTH W/L	45	4	13	7	10	5	0	0	6
GAOLEG CHAR BOTH W/L	13	2	3	2	4	0	0	1	1
GAOLGP GRAN BOTH W/L	12	0	0	8	1	0	1	0	2
CHILD SPLIT	2489	98	213	236	220	231	103	269	1119
CHILD N/R	236	4	14	13	35	56	14	25	75
LEG	969	72	104	80	85	76	18	42	492
LHN	51	1	2	5	4	11	1	4	23
LHP	69	3	9	8	3	12	3	6	25
LHM	18	3	3	4	0	3	0	2	3
LGJ	3	0	1	1	0	0	0	1	0
ADZ	1524	59	118	186	218	197	100	206	440
AES	821	8	120	68	39	56	29	101	400
LHH	311	12	27	32	35	29	7	22	147
ALL RHD	778	35	117	104	82	37	17	66	320
ALL LHD	2988	123	267	280	302	347	141	318	1210
=============	0	0	0	0	0	0	0	0	0
ALL 2.0 LITRE	441	13	52	42	47	38	18	45	186
2LTR AUTO	113	4	11	11	10	12	4	12	49
2LTR MANUAL	328	9	41	31	37	26	14	33	137
ALL 2.5 LITRE	2517	111	254	259	261	223	107	263	1039
ALL 2.5 MANUAL	430	22	44	44	45	36	18	46	175
ALL 2.5 AUTO	2087	89	210	215	216	187	89	217	864
ALL 3.0 LITRE	763	34	78	83	76	78	33	76	305
3.0 LTR AUTO	665	27	67	72	64	70	29	64	272
3.0 LTR MANUAL	98	7	11	11	12	8	4	12	33
=============	0	0	0	0	0	0	0	0	0
ALL MOON ROOF	2549	106	228	252	228	232	105	268	1130
=============	0	0	0	0	0	0	0	0	0
ALL 70/30 SPLIT	3110	127	305	328	322	291	130	323	1284
=============	0	0	0	0	0	0	0	0	0
ALL SPOILER	297	13	25	28	23	60	12	27	109
=============	0	0	0	0	0	0	0	0	0
ALL LEAPER	2668	93	225	252	247	274	113	280	1184
=============	0	0	0	0	0	0	0	0	0
ALL GROWLER	1098	65	159	132	137	110	45	104	346
=============	0	0	0	0	0	0	0	0	0
ALL FEDERAL	2661	91	225	249	246	274	113	280	1183
=============	0	0	0	0	0	0	0	0	0

ALL GERMAN	74	12	8	7	9	16	11	9	2
=============	0	0	0	0	0	0	0	0	0
GT BRITAIN	691	20	109	100	67	24	12	51	308
=============	0	0	0	0	0	0	0	0	0
ALL JAPAN	1	0	1	0	0	0	0	0	0
=============	0	0	0	0	0	0	0	0	0
ALL AUTOMATIC	2887	120	288	298	290	291	122	293	1185
ALL MANUAL	879	38	96	86	94	93	36	91	345
=============	0	0	0	0	0	0	0	0	0
ALL SPORT	297	13	25	28	23	60	12	27	109
ALL NON SPORT	3469	145	359	356	361	324	146	357	1421
=============	0	0	0	0	0	0	0	0	0
IVD LHD	416	26	27	34	43	77	21	35	153
IVD RHD	34	7	10	3	4	1	5	1	3
=============	0	0	0	0	0	0	0	0	0
JAGUAR GREEN	3	0	0	0	0	1	0	0	2
EBONY	26	0	0	0	0	5	0	0	21
ALL RACE GRN	439	15	14	47	51	92	28	89	103
ALL ZIRCON	220	6	25	28	27	9	5	24	96
ALL TOPAZ	393	5	9	67	94	56	45	48	69
ALL QUARTZ	455	12	21	68	23	33	20	40	238
ALL CARNIVAL	184	6	21	11	12	8	15	17	94
ALL ANTHRACITE	2	0	0	1	0	0	0	0	1
ALL EMERALD	0	0	0	0	0	0	0	0	0
ALL PACIFIC	305	8	64	22	26	52	11	32	90
ALL PLATINUM	1055	64	161	88	101	50	8	75	508
ALL ADRIATIC	274	13	24	14	15	11	6	12	179
ALL WHITE	278	16	28	16	23	62	19	43	71
ALL PH/RED	132	13	17	22	12	5	1	4	58
SPORT RACE GRN	21	3	0	0	0	9	1	2	6
SPORT W/MINSTER	0	0	0	0	0	0	0	0	0
SPORT TOPAZ	2	0	0	1	0	1	0	0	0
SPORT TITANIUM	0	0	0	0	0	0	0	0	0
SPORT CARNIVAL	10	0	2	3	2	0	0	0	3
SPORT ANTHRACITE	1	0	0	1	0	0	0	0	0
SPORT EMERALD	0	0	0	0	0	0	0	0	0
SPORT PACIFIC	32	1	6	2	3	1	3	5	11
SPORT PLATINUM	99	4	6	10	11	24	2	11	31
SPORT ADRIATIC	19	1	3	1	3	1	0	2	8
SPORT WHITE	0	0	0	0	0	0	0	0	0
SPORT PH/RED	23	1	4	0	0	4	1	3	10
ALB LESS IVD	450	33	37	37	47	78	26	36	156
SPORT RHD	190	6	23	23	8	7	8	27	88
SPORT LHD	107	7	2	5	15	53	4	0	21
W/S A	852	47	115	99	102	94	32	87	276
W/S B	40	4	10	10	7	0	2	4	3
W/S C	1250	54	89	141	109	138	55	120	544
W/S D	121	5	20	17	14	3	7	9	46
W/S E	10	2	3	1	0	1	0	1	2
W/S F	1493	46	147	116	152	148	62	163	659
LOW	3745	153	377	379	382	383	158	384	1529
HIGH	21	5	7	5	2	1	0	0	1

JAPAN VICS	1	0	1	0	0	0	0	0	0
PIR401	0	0	0	0	0	0	0	0	0
PIR402	13	2	5	2	4	0	0	0	0
PIR403	65	3	9	17	15	4	2	5	10
PIR404	0	0	0	0	0	0	0	0	0
PIR405	62	0	3	1	10	13	5	14	16
PIR406	274	10	37	30	24	24	4	8	137
PIR407	0	0	0	0	0	0	0	0	0
PIR408	48	11	6	7	9	4	0	3	8
PIR409	321	25	69	44	42	29	12	22	78
PIR410	60	5	10	10	8	5	4	0	18
PIR411	145	8	9	13	15	14	10	29	47
PIR425	44	1	0	0	1	30	0	0	12
PIR426	0	0	0	0	0	0	0	0	0
PIR412	2	0	0	1	0	0	1	0	0
PIR413	58	1	1	1	7	13	7	23	5
PIR423	0	0	0	0	0	0	0	0	0
PIR424	0	0	0	0	0	0	0	0	0
PIR414	0	0	0	0	0	0	0	0	0
PIR415	0	0	0	0	0	0	0	0	0
PIR416	0	0	0	0	0	0	0	0	0
PIR417	0	0	0	0	0	0	0	0	0
PIR418	0	0	0	0	0	0	0	0	0
PIR419	0	0	0	0	0	0	0	0	0
PIR420	0	0	0	0	0	0	0	0	0
PIR421	1217	20	92	111	115	132	36	165	546
PIR422	137	12	25	30	24	4	2	0	40
PIR427	12	1	1	2	0	3	0	0	5
PIR428	45	1	9	7	4	1	0	0	23
PIR436	0	0	0	0	0	0	0	0	0
PIR435	664	37	53	54	56	42	52	52	318
PIR434	0	0	0	0	0	0	0	0	0
PIR433	599	21	55	54	50	66	23	63	267
PIR430	0	0	0	0	0	0	0	0	0
PIR429	0	0	0	0	0	0	0	0	0
PIR431	0	0	0	0	0	0	0	0	0
PIR432	0	0	0	0	0	0	0	0	0
FLINT RHD	315	15	38	38	17	9	9	33	156
FLINT LHD	795	64	81	60	75	93	13	22	387
SABLE RHD	312	14	56	39	46	22	5	25	105
SABLE LHD	2033	53	182	215	211	231	124	282	735
GRANITE RHD	151	6	23	27	19	6	3	8	59
GRANITE LHD	160	6	4	5	16	23	4	14	88
CHARCOAL TRAY	987	75	107	84	85	79	18	44	495
HEADLAMP WASH	166	12	32	29	22	22	6	7	36
CHARCOAL	949	72	104	76	83	76	17	40	481
DOVE	362	13	29	37	39	40	8	26	170
SAND	1593	62	127	194	221	209	103	212	465
HERITAGE	18	3	3	4	0	3	0	2	3
IVORY	824	8	121	69	39	56	29	102	400
RED	20	0	0	4	2	0	1	2	11
=============	0	0	0	0	0	0	0	0	0

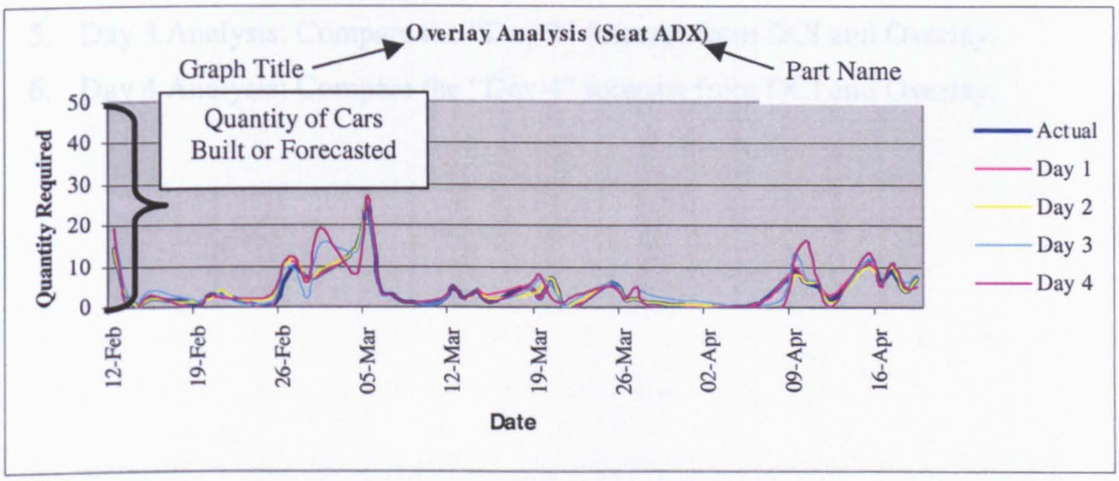
SEAT SPORT	0	0	0	0	0	0	0	0	0
=============	0	0	0	0	0	0	0	0	0
SPORT C/COAL	152	8	13	9	14	38	7	14	49
SPORT DOVE	49	1	2	5	4	9	1	4	23
SPORT SAND	70	3	9	8	3	13	3	6	25
SPORT HERITAGE	3	1	0	1	0	0	0	0	1
SPORT IVORY	3	0	1	1	0	0	0	1	0
SPORT RED	20	0	0	4	2	0	1	2	11
=============	0	0	0	0	0	0	0	0	0
POWER SEATS	0	0	0	0	0	0	0	0	0
=============	0	0	0	0	0	0	0	0	0
4-2W SEAT RH	362	17	50	33	19	20	9	44	170
8-2W SEAT RH	0	0	0	0	0	0	0	0	0
8-8W SEAT RH	398	14	64	68	62	17	8	22	143
10-2W SEAT RH	0	0	0	0	0	0	0	0	0
10-10W SEAT RH	18	4	3	3	1	0	0	0	7
4-2W SEAT LH	133	7	9	4	14	36	19	31	13
8-2W SEAT LH	1436	44	143	114	144	126	60	160	645
8-8W SEAT LH	170	18	27	23	39	34	9	7	13
10-2W SEAT LH	0	0	0	0	0	0	0	0	0
10-10W SEAT LH	1224	53	88	139	104	134	53	120	533
CTR HEADRESTS (NON FE	0	0	0	0	0	0	0	0	0
=============	0	0	0	0	0	0	0	0	0
BENCH NO AREST	263	18	47	22	19	28	9	21	99
NEW SPORT SEAT	153	2	18	20	3	5	5	23	77
CHAR CLOTH+REST	29	1	3	0	1	3	3	13	5
SAND CLOTH+REST	46	1	2	0	6	12	9	11	5
DOVE CLOTH+REST	15	1	1	0	4	4	1	2	2
IVORY CLOTH+REST	819	8	119	68	39	56	29	100	400
HERT CLOTH+REST	1	0	0	0	0	1	0	0	0
HERT LEATH+REST	5	0	1	1	0	2	0	1	0
CHAR CLOTH+SPLIT	27	1	2	0	1	3	3	12	5
SAND CLOTH+SPLIT	44	1	2	0	6	11	9	10	5
DOVE CLOTH+SPLIT	15	1	1	0	4	4	1	2	2
IVORY CLOTH+SPLIT	784	8	112	65	38	52	29	90	390
HERT CLOTH+SPLIT	1	0	0	0	0	1	0	0	0
HERT LEATH+SPLIT	5	0	1	1	0	2	0	1	0
CHAR CLOTH	92	3	7	2	5	15	4	18	38
CHAR SP 1/2 LEATH	57	3	11	2	7	4	3	7	20
CHAR LEATH	122	14	23	16	14	7	5	5	38
CHAR SP LEATH	59	4	2	7	7	7	4	7	21
DOVE CLOTH	45	3	7	4	4	7	1	3	16
DOVE SP 1/2 LEATH	0	0	0	0	0	0	0	0	0
DOVE LEATH	136	5	19	26	25	5	5	7	44
DOVE SP LEATH	33	1	2	5	3	3	1	4	14
SAND CLOTH	94	5	17	6	7	12	9	14	24
SAND SP 1/2 LEATH	30	0	5	5	2	2	1	2	13
SAND LEATH	348	21	55	46	56	41	9	27	93
SAND SP LEATH	32	3	4	3	1	3	2	4	12
HERIT CLOTH	7	0	2	1	0	1	0	1	2
HERIT SP 1/2 LEATH	1	0	0	1	0	0	0	0	0
HERIT LEATH	8	2	1	2	0	2	0	1	0

HERIT SP LEATH	2	1	0	0	0	0	0	0	1
IVORY LEATH	16	2	3	4	5	1	0	1	0
IVORY SP LEATH	3	0	1	1	0	0	0	1	0
RED SP 1/2 LEATH	7	0	0	2	0	0	0	2	3
RED LEATH	0	0	0	0	0	0	0	0	0
RED SP LEATH	13	0	0	2	2	0	1	0	8
NO COL CLOTH	0	0	0	0	0	0	0	0	0
NO COL SP 1/2 LEATH	0	0	0	0	0	0	0	0	0
NO COL LEATH	0	0	0	0	0	0	0	0	0
NO COL SP LEATH	0	0	0	0	0	0	0	0	0
=============	0	0	0	0	0	0	0	0	0
CD AUTO CHANGER	1039	42	118	115	125	92	52	87	408
JAPAN NAV	1	0	1	0	0	0	0	0	0
W/CHAR CLOTH	92	3	7	2	5	15	4	18	38
CHR SPT H/LEA	57	3	11	2	7	4	3	7	20
W/CHARC LEATHE	705	61	84	65	64	23	6	8	394
W/CHAR SPT LE	95	5	2	7	7	34	4	7	29
DOVE CLOTH	45	3	7	4	4	7	1	3	16
DOVE SPT H/LE	0	0	0	0	0	0	0	0	0
DOVE LEATHER	266	9	20	28	31	22	6	19	131
DOVE SPORT LE	51	1	2	5	4	11	1	4	23
SAND CLOTH	94	5	17	6	7	12	9	14	24
SAND SPT H/LE	30	07	5	5	2	2	1	2	13
SAND LEATHER	1430	54	101	180	211	185	91	192	416
SAND SPORT LE	39	3	4	3	1	10	2	4	12
HERITAG CLOTH	7	0	2	1	0	1	0	1	2
HERI SPT H/LE	1	0	0	1	0	0	0	0	0
HERITAGE LEAT	8	2	1	2	0	2	0	1	0
SPORT HERI LE	2	1	0	0	0	0	0	0	1
IVORY LEATHER	821	8	120	68	39	56	29	101	400
SPT IVOR F/LE	3	0	1	1	0	0	0	1	0
SPT H/RED LE	7	0	0	2	0	0	0	2	3
RED LEATHER	0	0	0	0	0	0	0	0	0
RED SPORT LE	13	0	0	2	2	0	1	0	8
CLOTH NO COL	0	0	0	0	0	0	0	0	0
SPT H/LE NO C	0	0	0	0	0	0	0	0	0
LE NON COLOUR	0	0	0	0	0	0	0	0	0
SPT LE NO COL	0	0	0	0	0	0	0	0	0
BOTH PWR 10 HEATED	545	7	18	53	34	61	32	25	315
2.5/3.0 PERF	243	12	15	19	19	58	12	27	81
3.0LTR AUTO	674	27	67	72	64	79	29	64	272
2.5 AUTO430AA	2092	89	210	215	216	192	89	217	864
STEEL WHEELS	60	1	1	2	7	13	8	23	5
600C14AGM0NED	203	0	39	33	9	13	8	39	62
600C14AGM0ADX	292	12	15	31	36	44	13	49	92
600B01AG0ADY	6	0	2	1	0	0	0	1	2
SHNN 29/30-CJ	1682	61	141	161	153	179	69	164	754
SXNA 29/30-MJ	979	30	84	88	93	95	44	116	429
SHYN 29/30-KJ	0	0	0	0	0	0	0	0	0
SXYA 29/30-GJ	0	0	0	0	0	0	0	0	0
ALL FEDERAL	2661	91	225	249	246	274	113	280	1183
ALL HID	1087	39	102	104	110	114	46	121	451

=============	0	0	0	0	0	0	0	0	0
FLOOR CARPETS (RHD)	0	0	0	0	0	0	0	0	0
=============	0	0	0	0	0	0	0	0	0
2.0l FLINT	101	1	14	13	3	1	0	0	69
2.5l FLINT	150	10	16	16	10	1	2	26	69
3.0l FLINT	64	4	8	9	4	7	7	7	18
2.0l SABLE	137	1	19	9	9	17	3	12	67
2.5l SABLE	149	12	37	23	27	5	2	10	33
3.0l SABLE	26	1	0	7	10	0	0	3	5
2.0l GRANITE	58	2	4	7	1	1	1	2	40
2.5l GRANITE	75	4	18	15	13	3	0	6	16
3.0l GRANITE	18	0	1	5	5	2	2	0	3
=============	0	0	0	0	0	0	0	0	0
CONSOLES (RHD)	0	0	0	0	0	0	0	0	0
=============	0	0	0	0	0	0	0	0	0
MAN FLINT	239	9	25	17	8	5	1	26	148
AUTO FLINT	76	6	13	21	9	4	8	7	8
MAN SABLE	133	3	21	8	4	4	2	14	77
AUTO SABLE	179	11	35	31	42	18	3	11	28
MAN GRANITE	77	3	6	6	1	5	2	7	47
AUTO GRANITE	74	3	17	21	18	1	1	1	12
BENCH RR SEAT	656	31	79	56	62	93	28	61	246
SPLIT RR SEAT	3110	127	305	328	322	291	130	323	1284
=============	0	0	0	0	0	0	0	0	0
5 SPOKE ALLOY	78	5	14	19	19	4	2	5	10
7 SPOKE ALLOY	336	10	40	31	34	37	9	22	153
10 SPOKE ALLOY	1723	68	192	192	190	169	50	190	672
7x17" ALLOY	306	16	29	32	28	53	14	29	105
STEEL WHEELS	60	1	1	2	7	13	8	23	5
ALL XTYPE	3766	158	384	384	384	384	158	384	1530
JCX43DPB03	238	11	33	13	16	35	14	36	80
JCX43DPB01	540	28	65	67	60	81	23	42	174
JCX43DPB020	2988	119	286	304	308	268	121	306	1276
JCX43DPB03LEG	92	3	7	2	5	15	4	18	38
JCX43DPB03LHJ	45	3	7	4	4	7	1	3	16
JCX43DPB03ADX	94	5	17	6	7	12	9	14	24
JCX43DPB03ADY	7	0	2	1	0	1	0	1	2
JCX43DPB01LEG	194	15	26	13	15	38	11	14	62
JCX43DPB01LHJ	78	2	6	9	9	12	3	6	31
JCX43DPB01ADX	199	6	14	34	34	28	8	19	56
JCX43DPB01ADY	5	2	1	1	0	0	0	0	1
JCX43DPB01CGT	20	0	0	4	2	0	1	2	11
JCX43DPB01NED	44	3	18	6	0	3	0	1	13
JCX43DPB02LEG	663	54	71	61	63	23	2	8	381
JCX43DPB02LHJ	239	8	16	24	26	21	4	17	123
JCX43DPB02ADX	1300	51	96	154	180	169	86	179	385
JCX43DPB02ADY	6	1	0	2	0	2	0	1	0
JCX43DPB02CGT	0	0	0	0	0	0	0	0	0
JCX43DPB02NED	780	5	103	63	39	53	29	101	387
HEATED SEATS	1281	45	66	108	113	130	57	109	653
NON-HEAT SEAT	2485	113	318	276	271	254	101	275	877

Appendix M: DCI and Overlay Performance Analysis

The graphs below and its associated notes give a brief explanation as to how the graphs in Appendix M took shape.



Explanation of Graphs

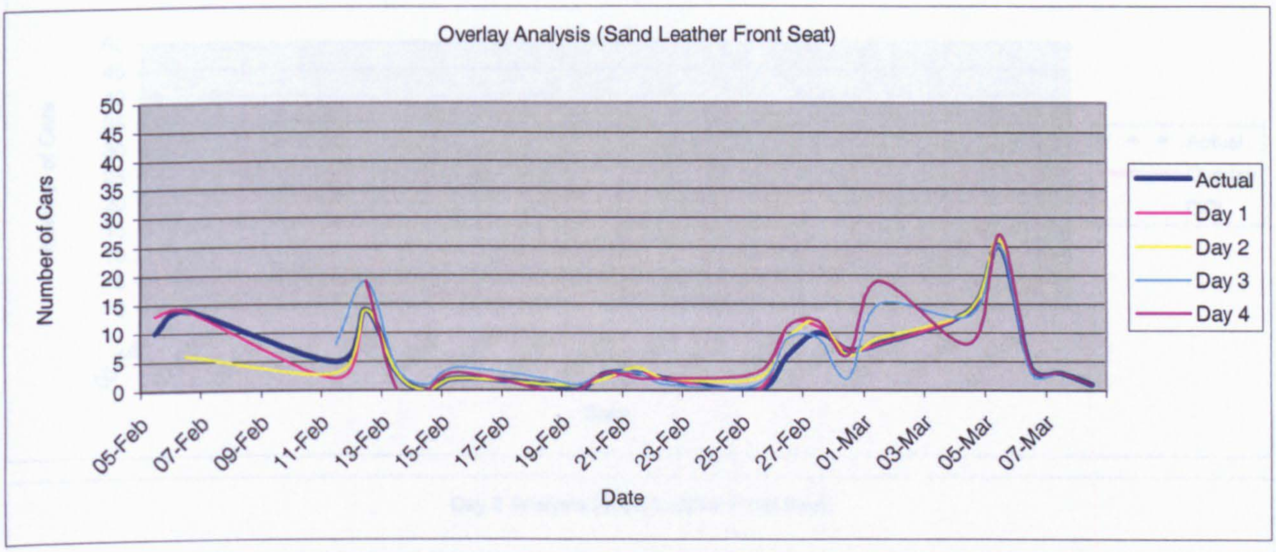
The following key explains what each of the terms in the graphs are

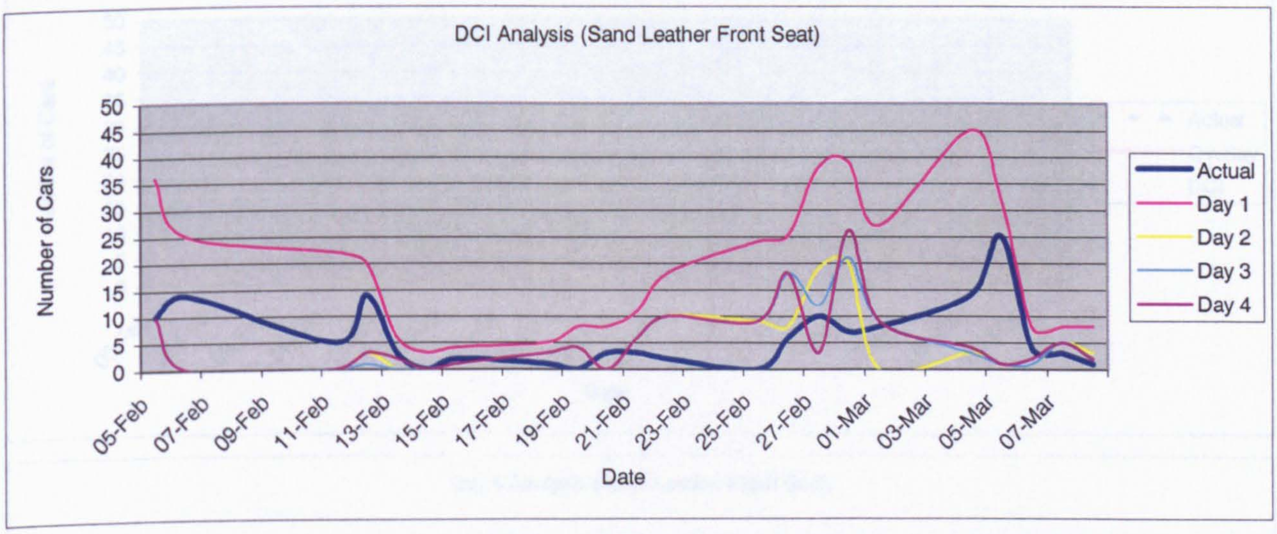
- 'Actual' refers to the actual amount of cars that have been built with the monitored parts fitted within that production day.
- 'Day 1' is the forecast given 1 day in advance. For example in Figure 10 above 'Day 1' forecast for the 8^{th} March is generated on the 7^{th} March (After production has ceased).
- Day 2' is the forecast given 2 days in advance. For example in Figure 10 above 'Day 2' forecast for the 8^{th} March is generated on the 6^{th} March (After production has ceased).

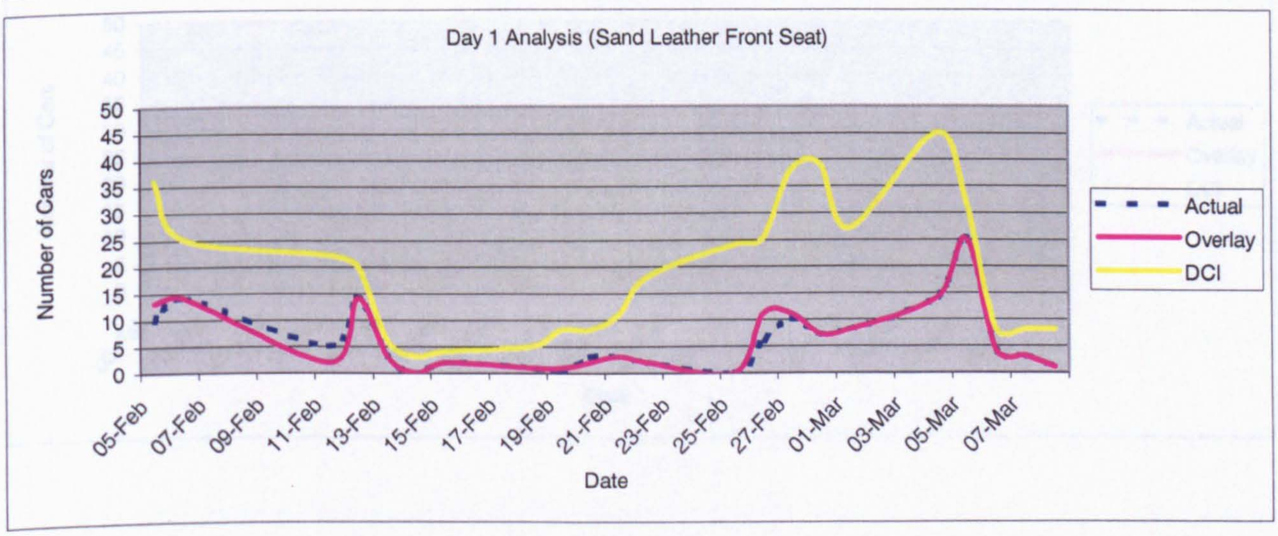
This key continues in the same fashion as above for days 3 and 4. The DCI and Overlay forecasts for these parts are compared against the real materials requirements. The comparison is made from 6 different perspectives:

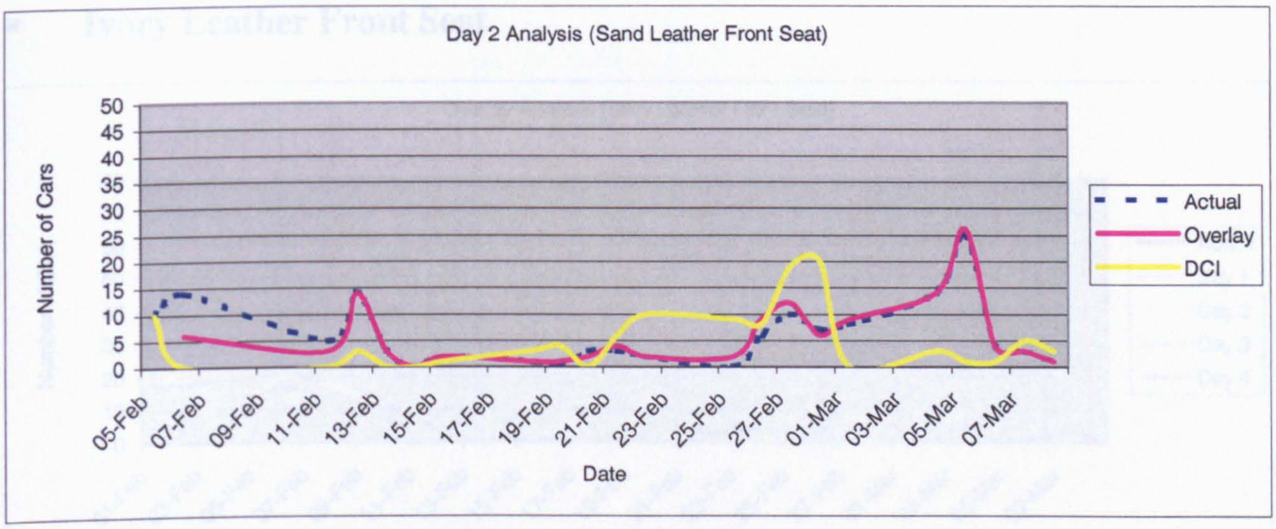
1. Overlay Analysis: Comparing the Overlay's forecasts from different time horizons
2. DCI Analysis: Compare the DCI's forecasts from different time horizons
3. Day 1 Analysis: Compare the "Day 1" forecast from DCI and Overlay.
4. Day 2 Analysis: Compare the "Day 2" forecast from DCI and Overlay.
5. Day 3 Analysis: Compare the "Day 3" forecast from DCI and Overlay.
6. Day 4 Analysis: Compare the "Day 4" forecast from DCI and Overlay.

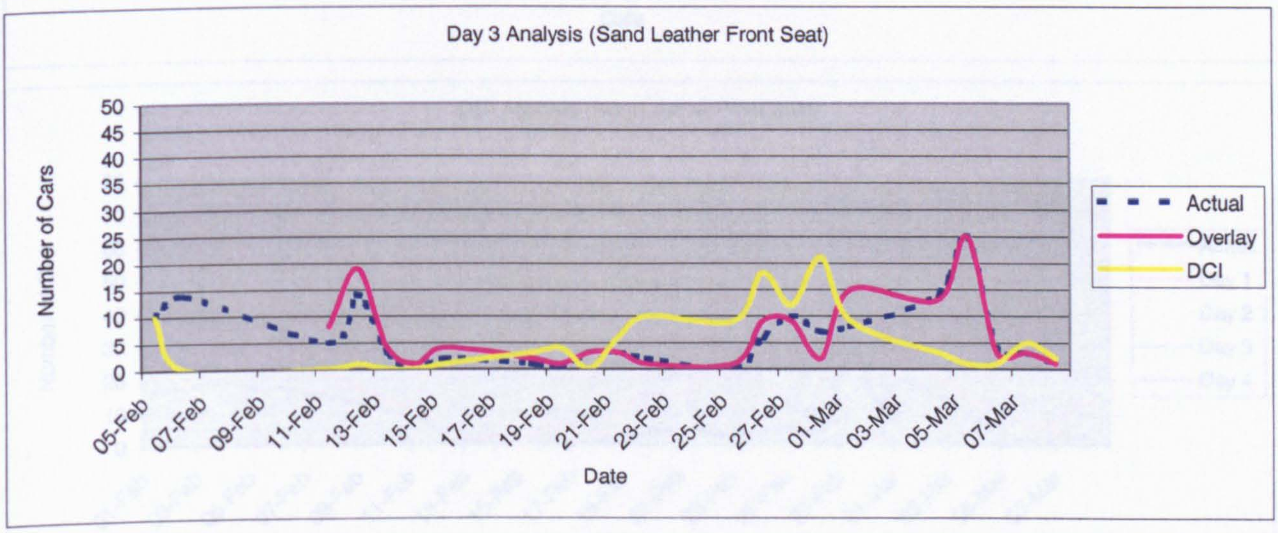
- **Sand Leather Front Seat**

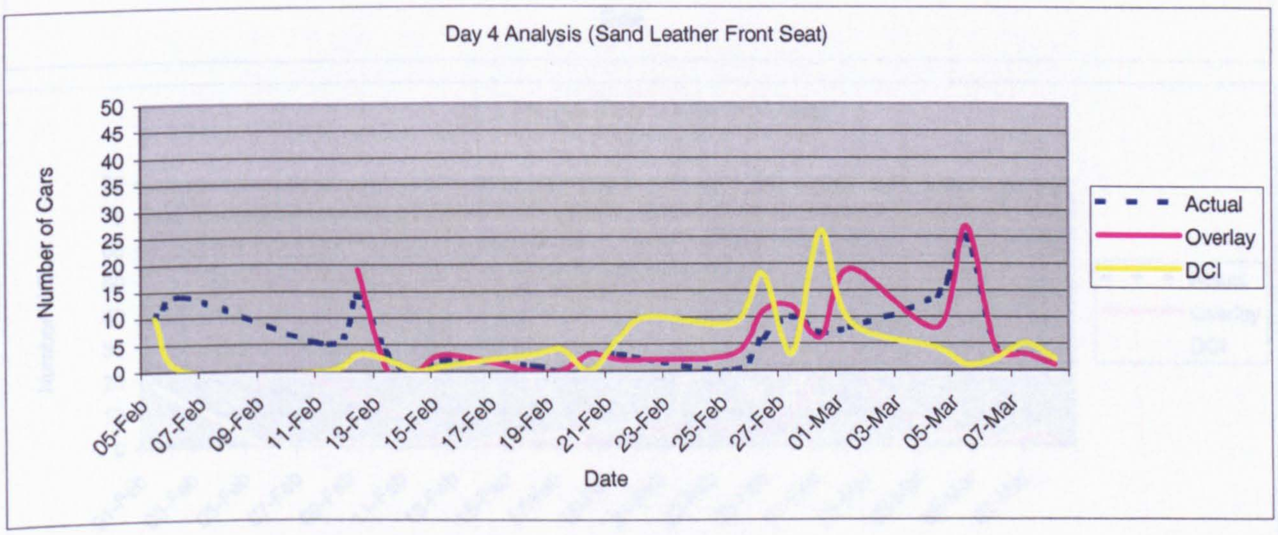




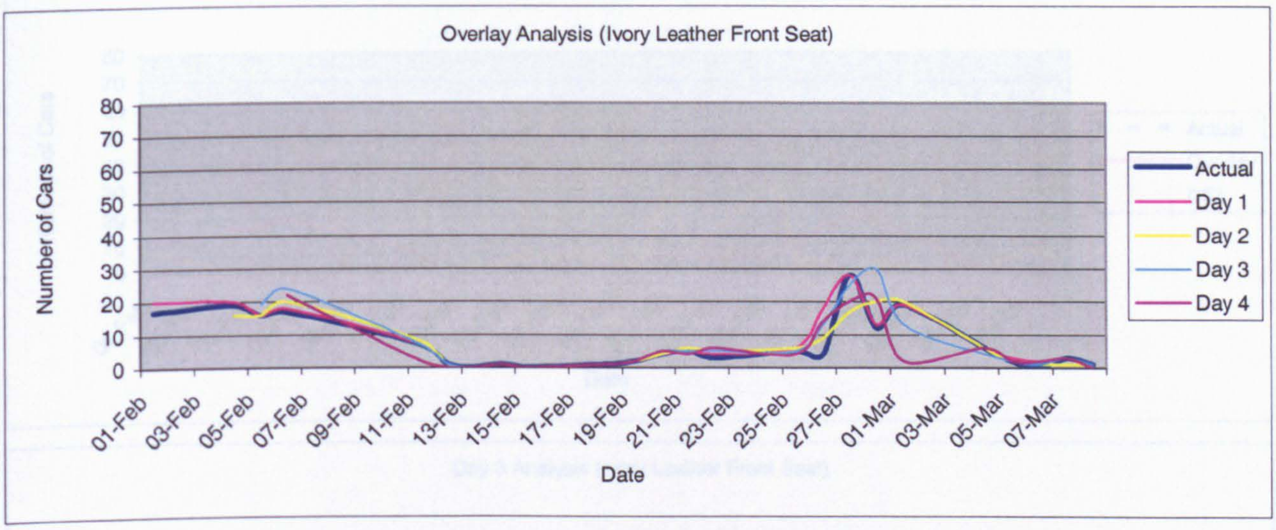


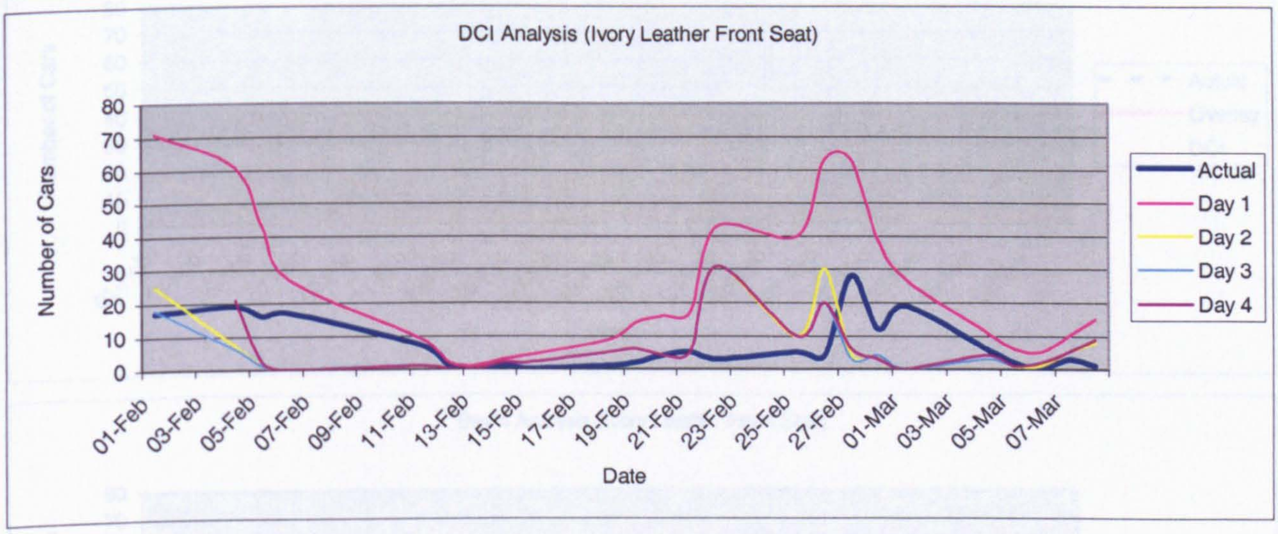

Day 2 Analysis (Sand Leather Front Seat)
Number of Cars
Date
Actual
Overlay
DCI

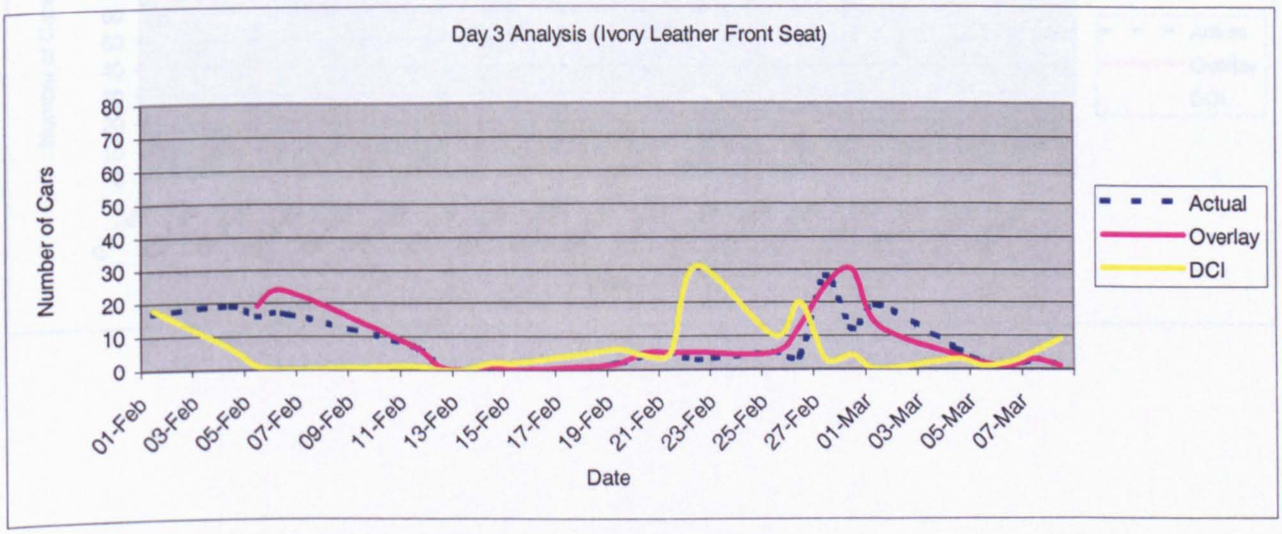

Day 3 Analysis (Sand Leather Front Seat)
Number of Cars
Date
Actual
Overlay
DCI

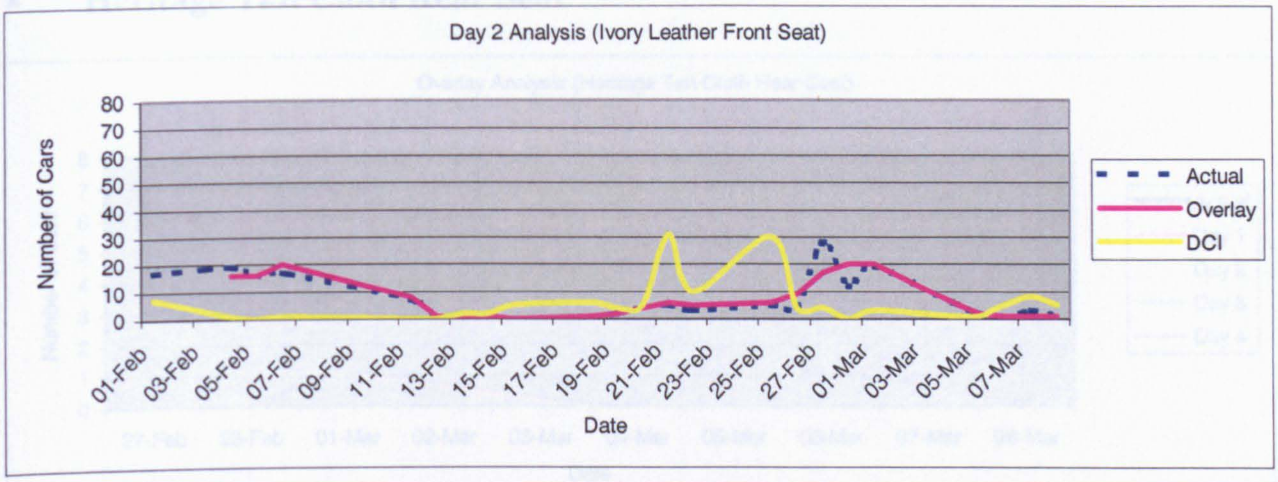

Day 4 Analysis (Sand Leather Front Seat)
Number of Cars
Date
Actual
Overlay
DCI

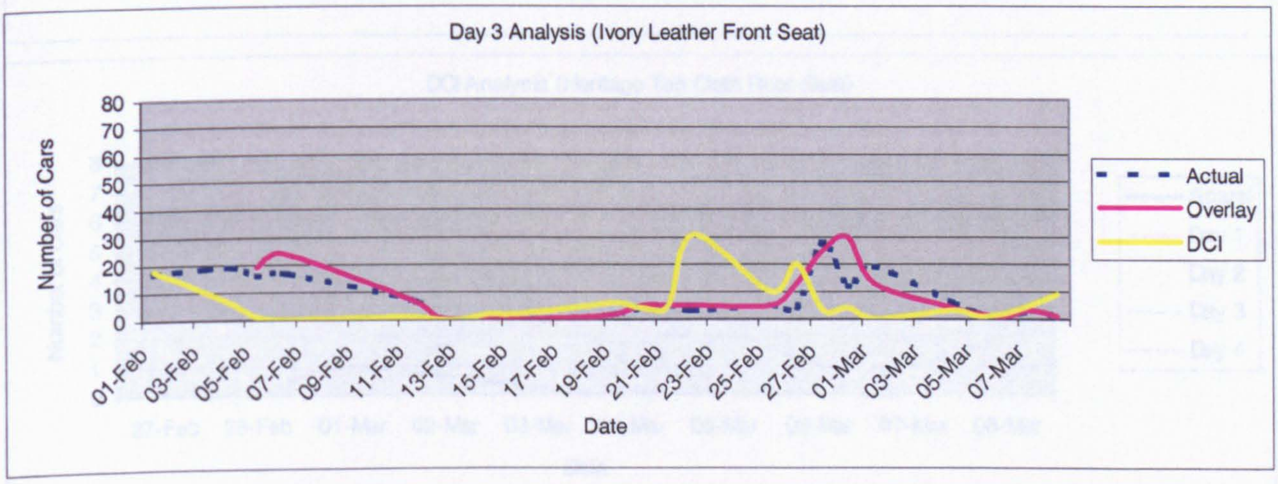
- **Ivory Leather Front Seat**

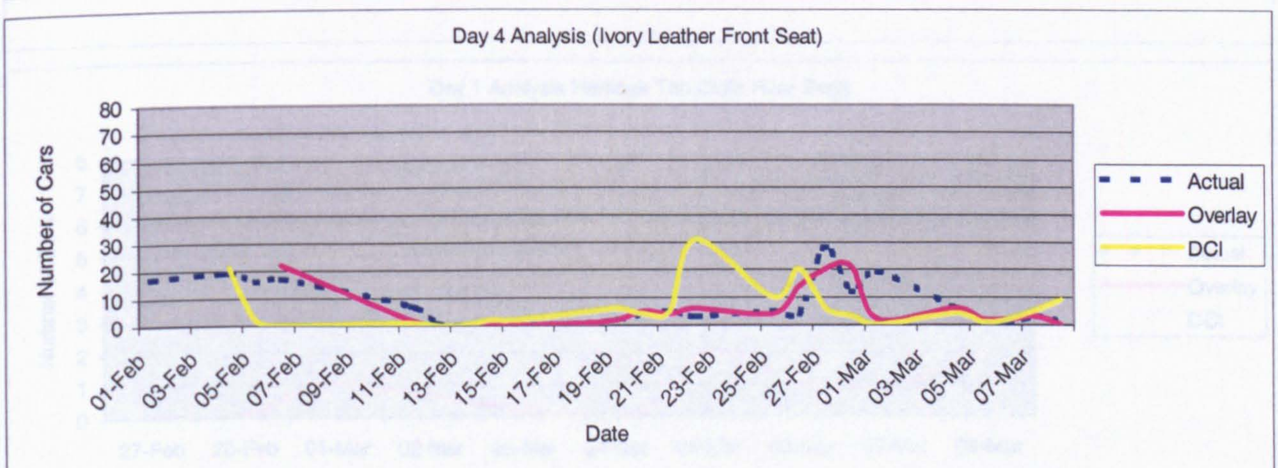




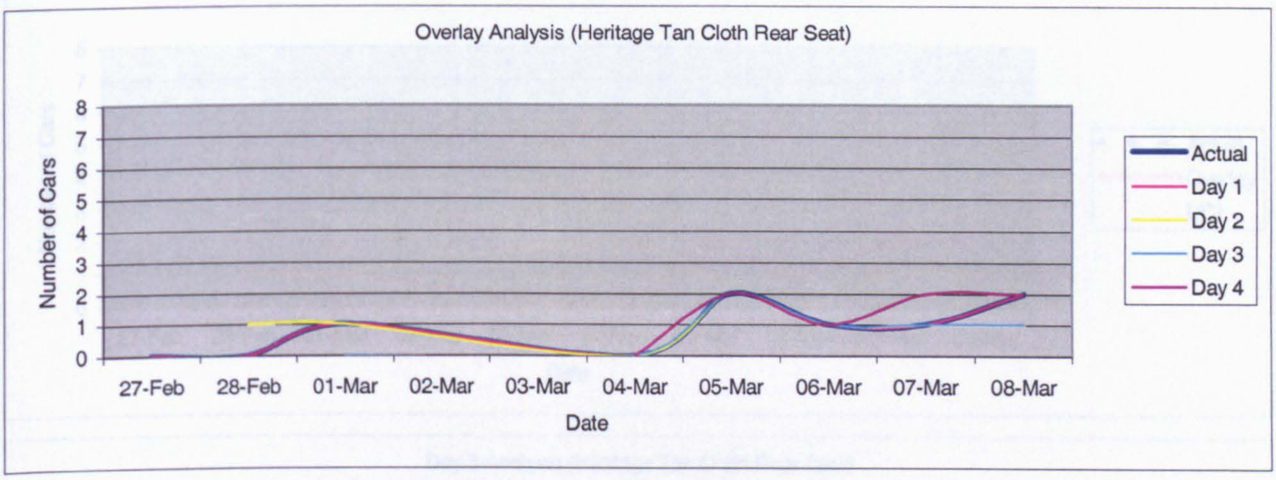


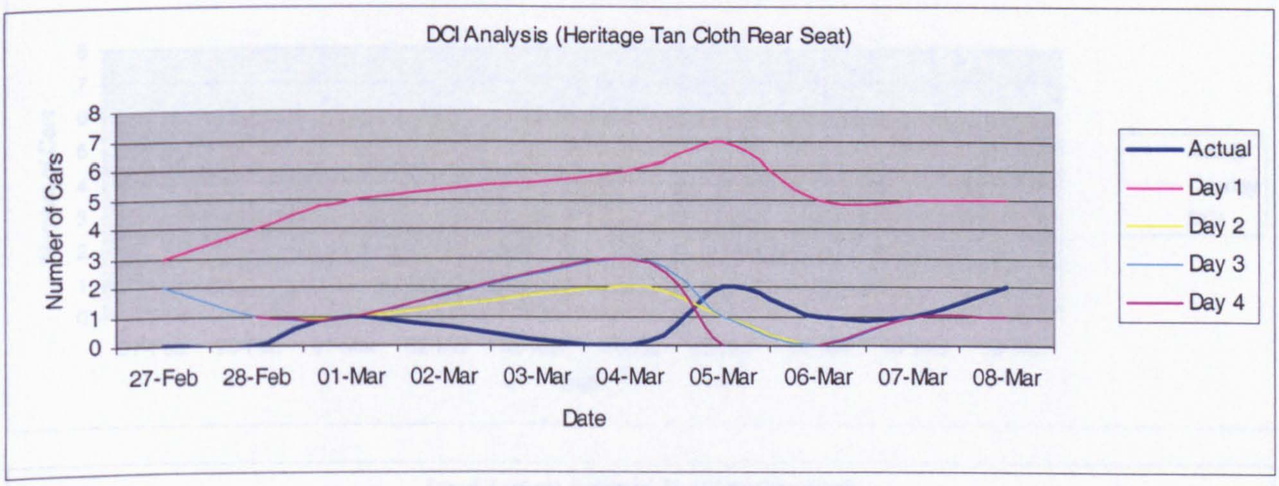

Day 2 Analysis (Ivory Leather Front Seat)
Number of Cars
0
10
20
30
40
50
60
70
80
01-Feb
03-Feb
05-Feb
07-Feb
09-Feb
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

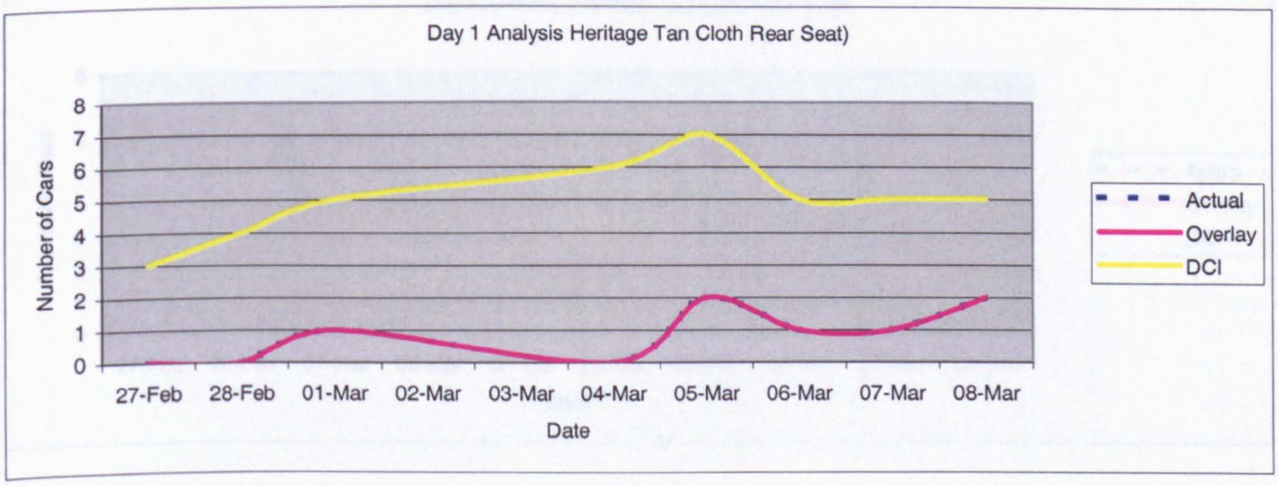

Day 3 Analysis (Ivory Leather Front Seat)
Number of Cars
0
10
20
30
40
50
60
70
80
01-Feb
03-Feb
05-Feb
07-Feb
09-Feb
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

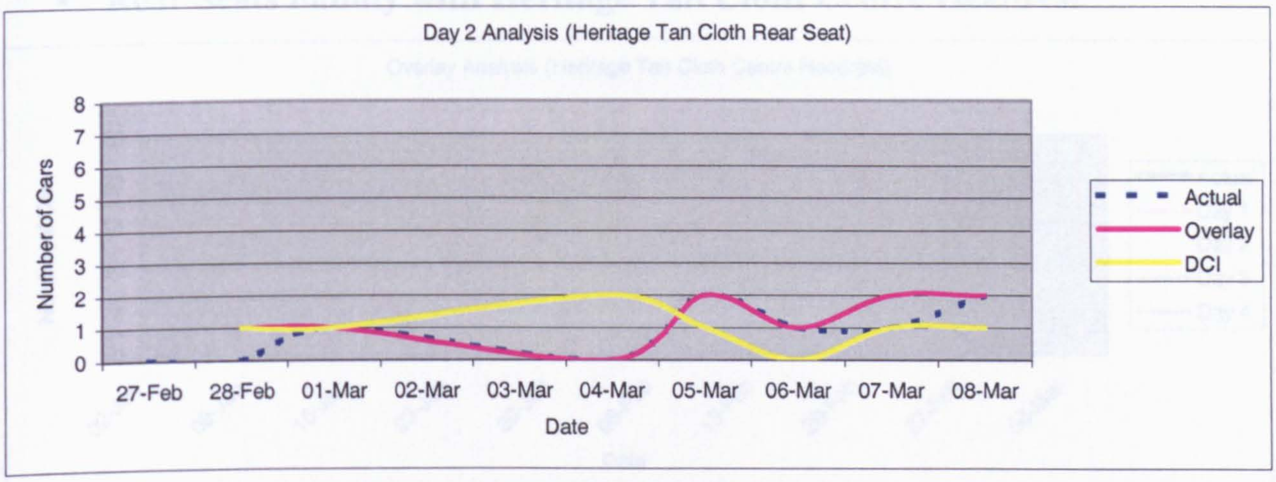

Day 4 Analysis (Ivory Leather Front Seat)
Number of Cars
0
10
20
30
40
50
60
70
80
01-Feb
03-Feb
05-Feb
07-Feb
09-Feb
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

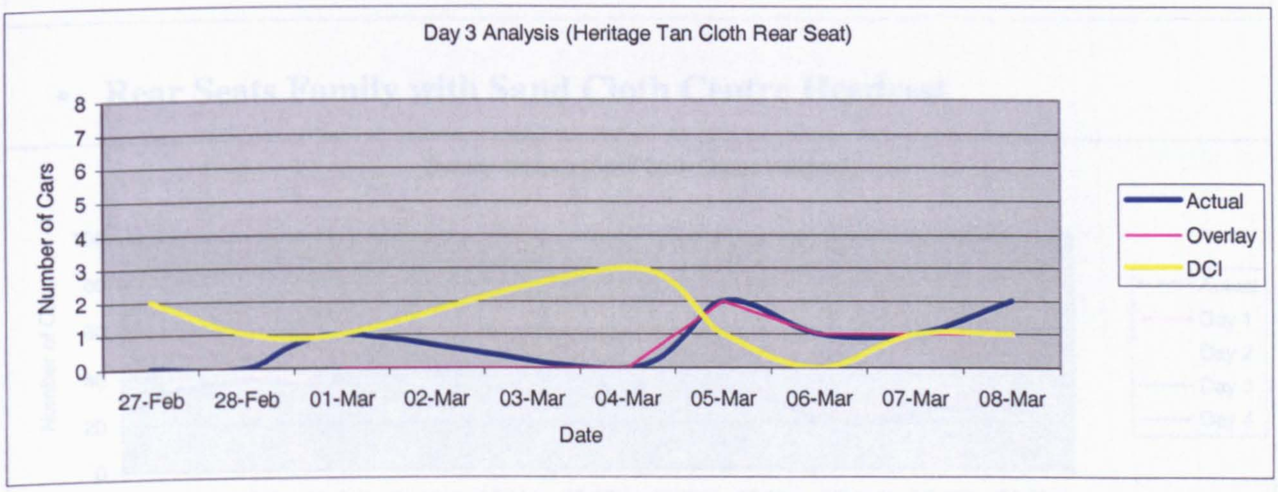
- # Heritage Tan Cloth Rear Seat

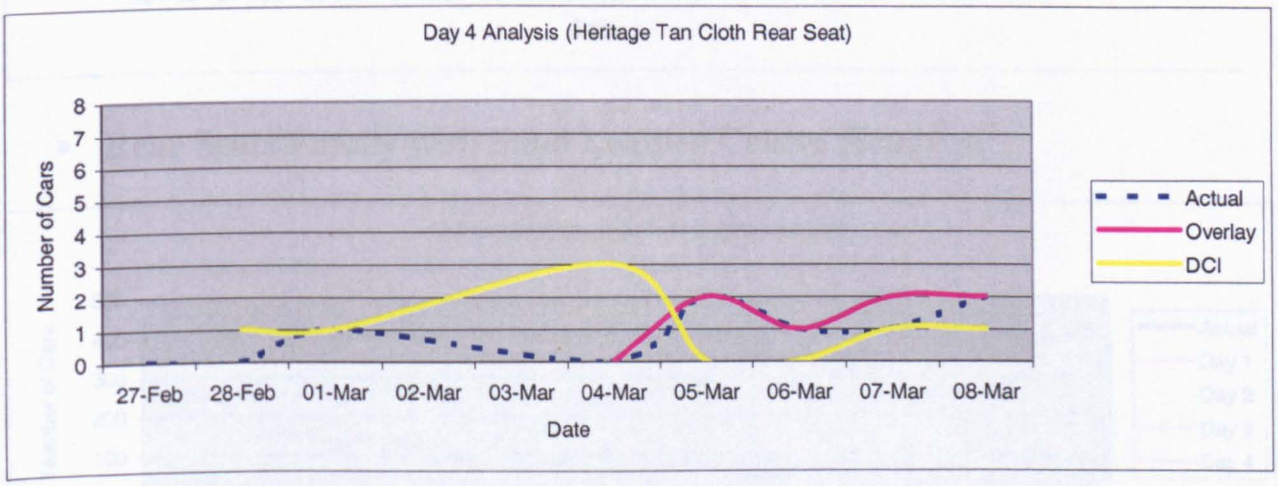




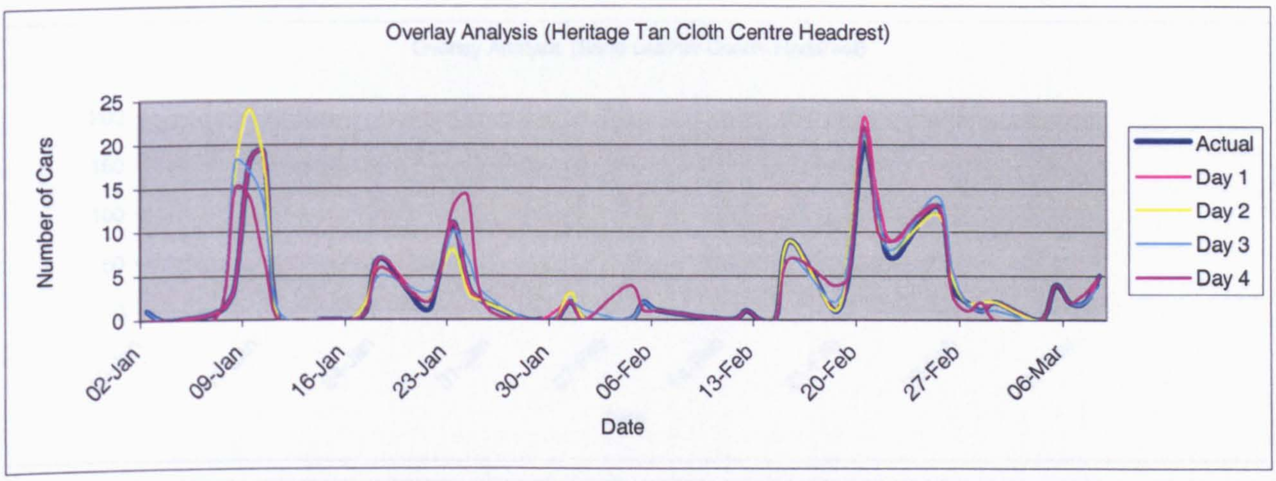



Day 2 Analysis (Heritage Tan Cloth Rear Seat)
Number of Cars
8
7
6
5
4
3
2
1
0
27-Feb
28-Feb
01-Mar
02-Mar
03-Mar
04-Mar
05-Mar
06-Mar
07-Mar
08-Mar
Date
Actual
Overlay
DCI

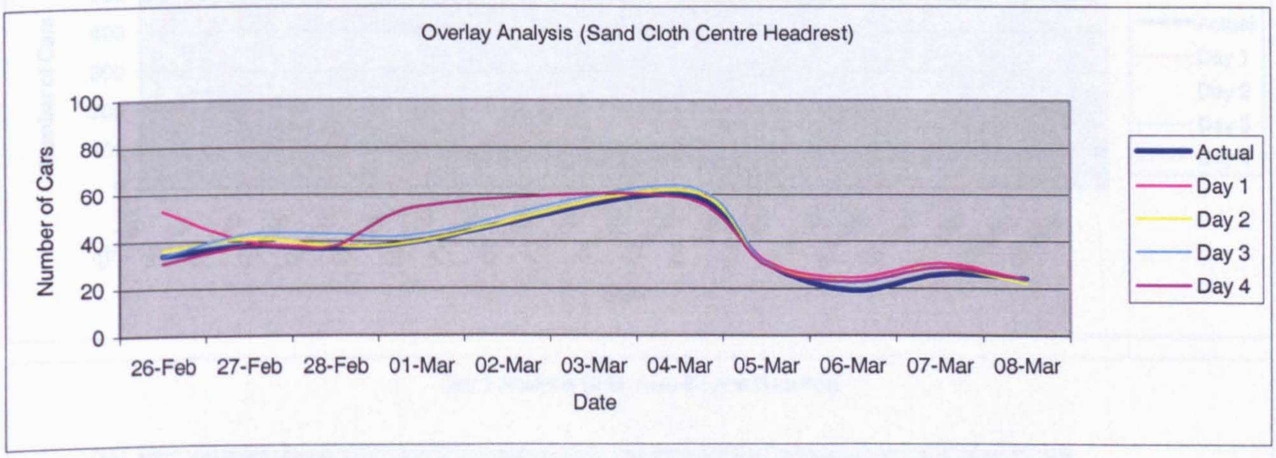

Day 3 Analysis (Heritage Tan Cloth Rear Seat)
Number of Cars
8
7
6
5
4
3
2
1
0
27-Feb
28-Feb
01-Mar
02-Mar
03-Mar
04-Mar
05-Mar
06-Mar
07-Mar
08-Mar
Date
Actual
Overlay
DCI


Day 4 Analysis (Heritage Tan Cloth Rear Seat)
Number of Cars
8
7
6
5
4
3
2
1
0
27-Feb
28-Feb
01-Mar
02-Mar
03-Mar
04-Mar
05-Mar
06-Mar
07-Mar
08-Mar
Date
Actual
Overlay
DCI

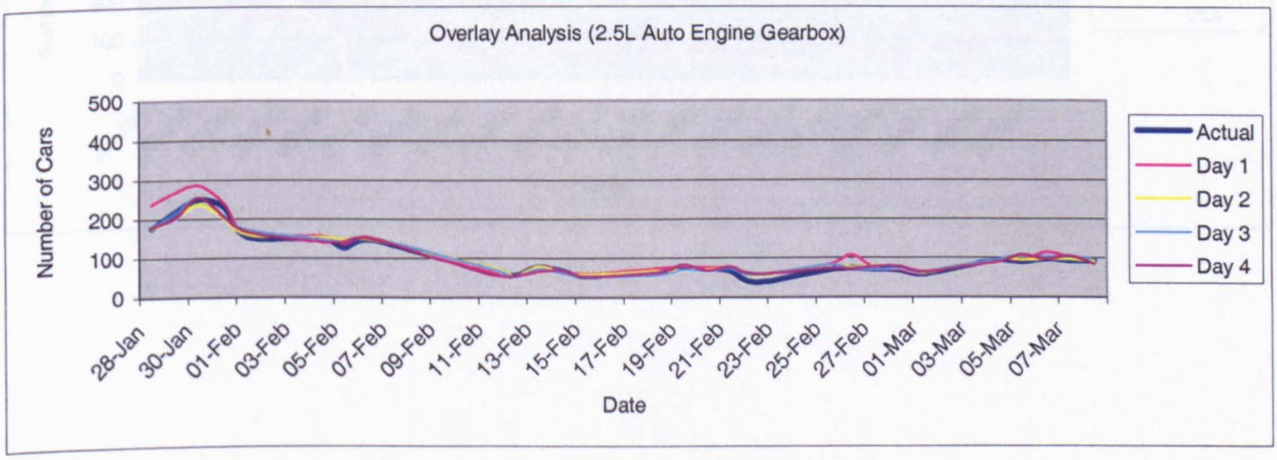
- **Rear Seats Family with Heritage Tan Cloth Centre Headrest**



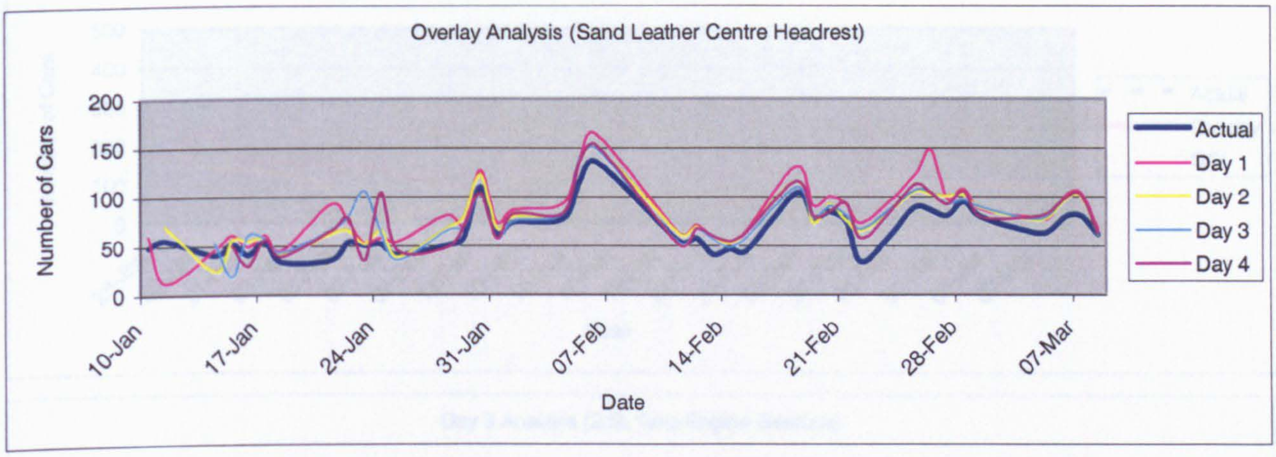
- **Rear Seats Family with Sand Cloth Centre Headrest**

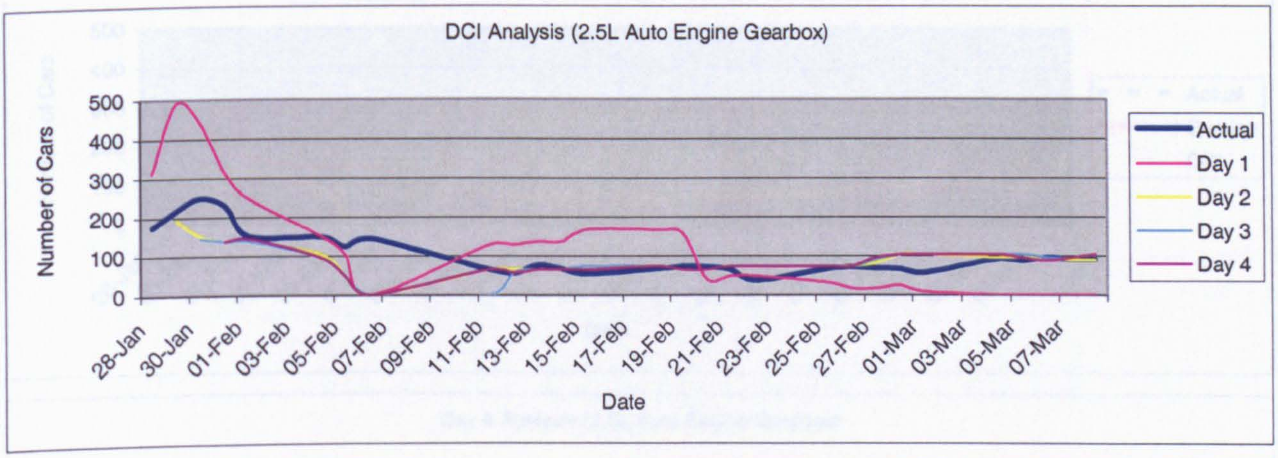


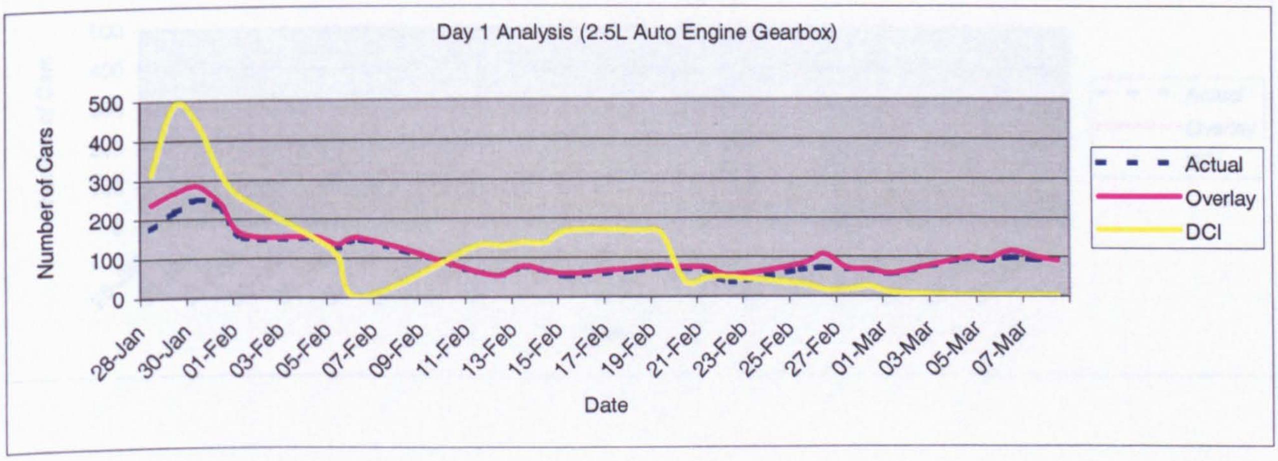
- **Rear Seats Family with Sand Leather Centre Headrest**

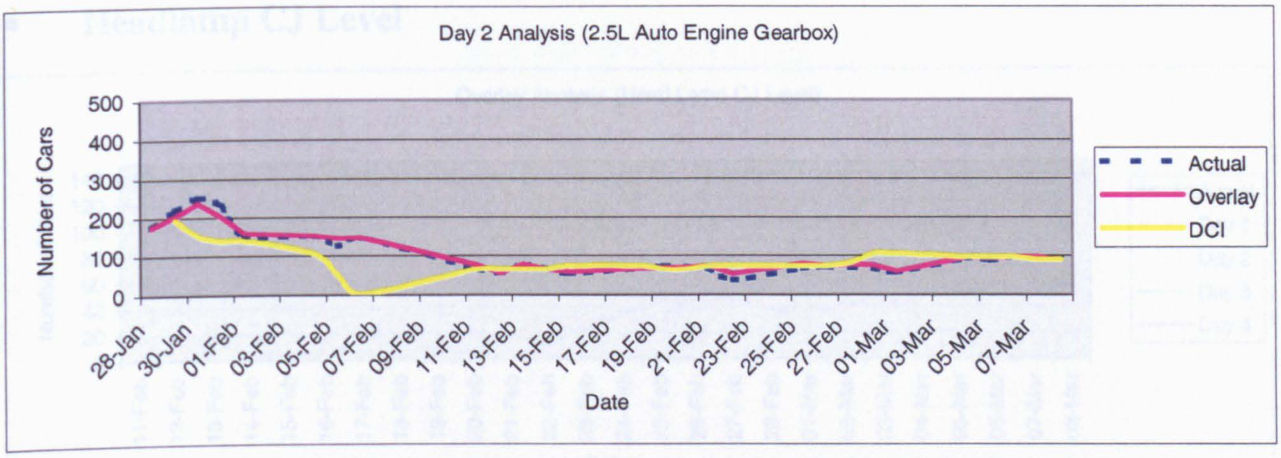


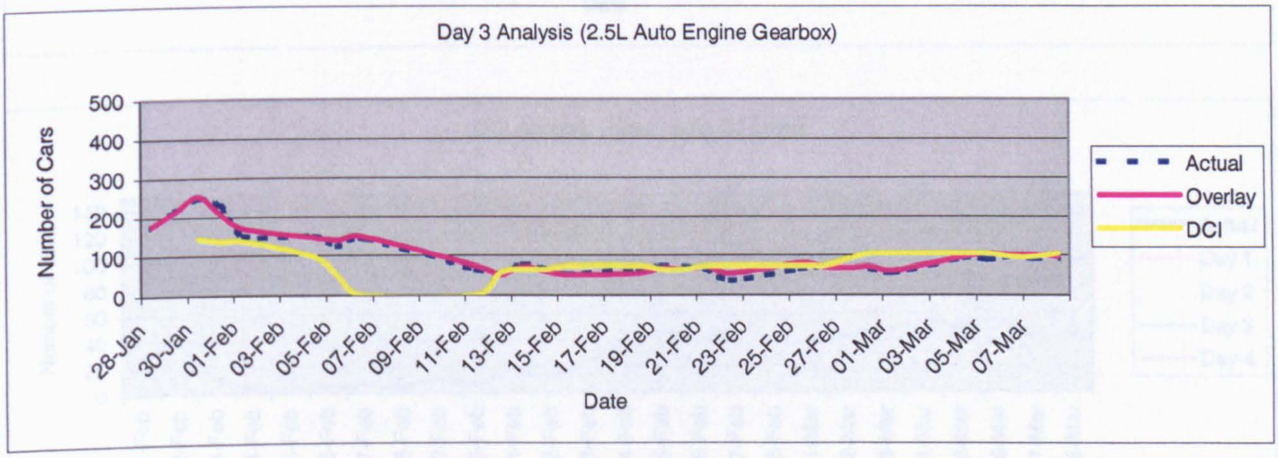
- **2.5 L Auto Engine Gearbox**

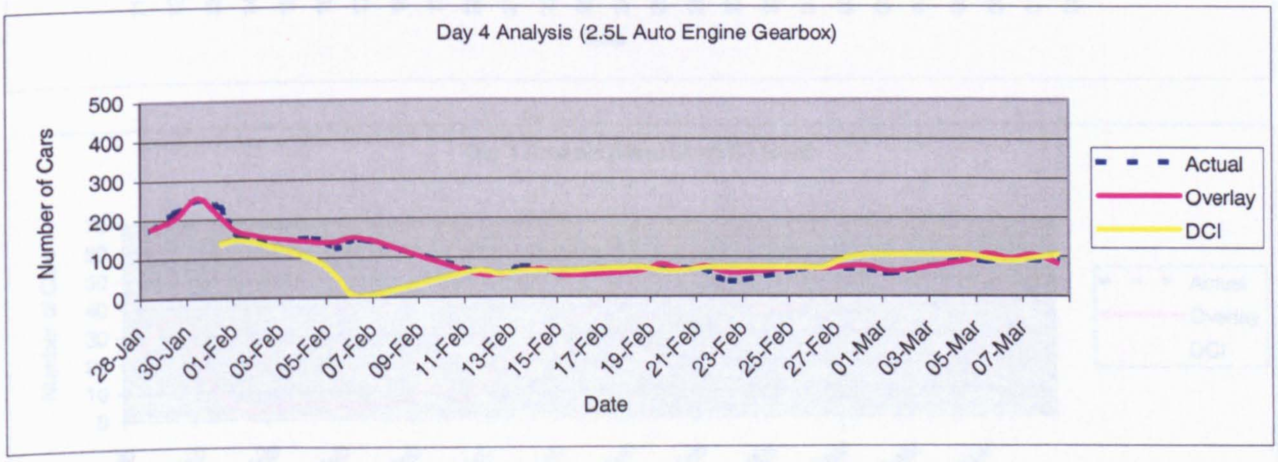




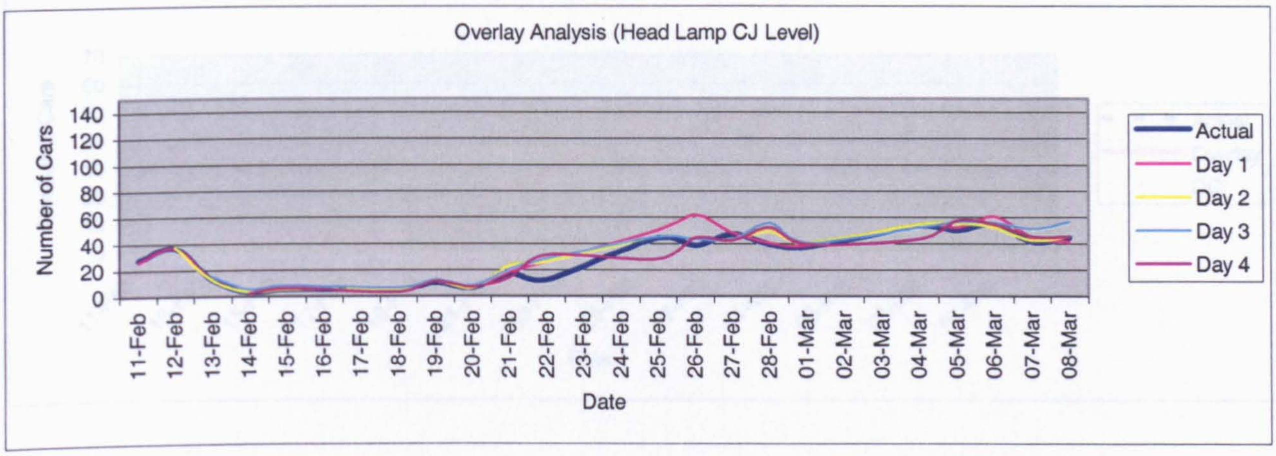


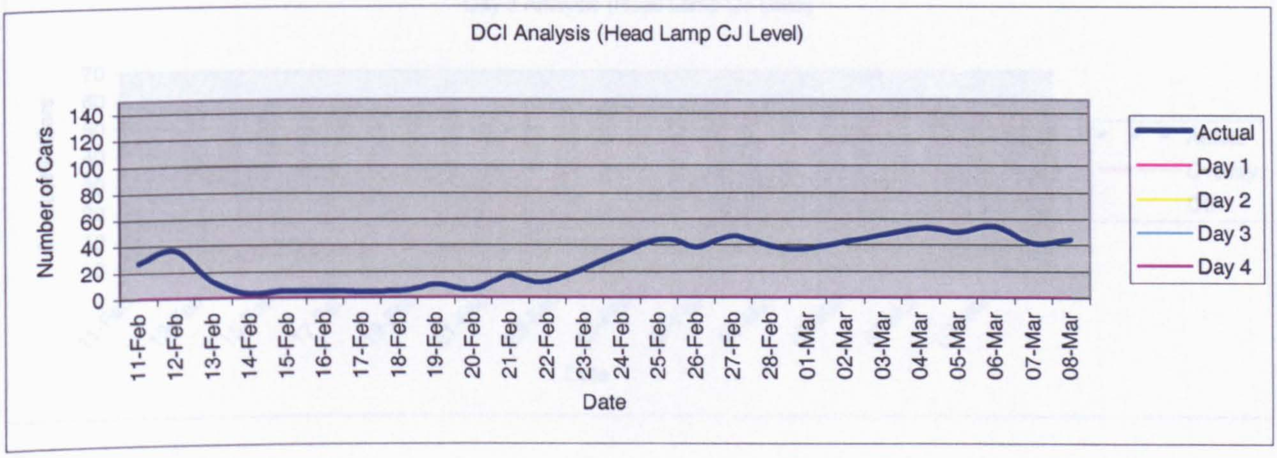

Day 2 Analysis (2.5L Auto Engine Gearbox)
Number of Cars
500
400
300
200
100
0
28-Jan
30-Jan
01-Feb
03-Feb
05-Feb
07-Feb
09-Feb
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

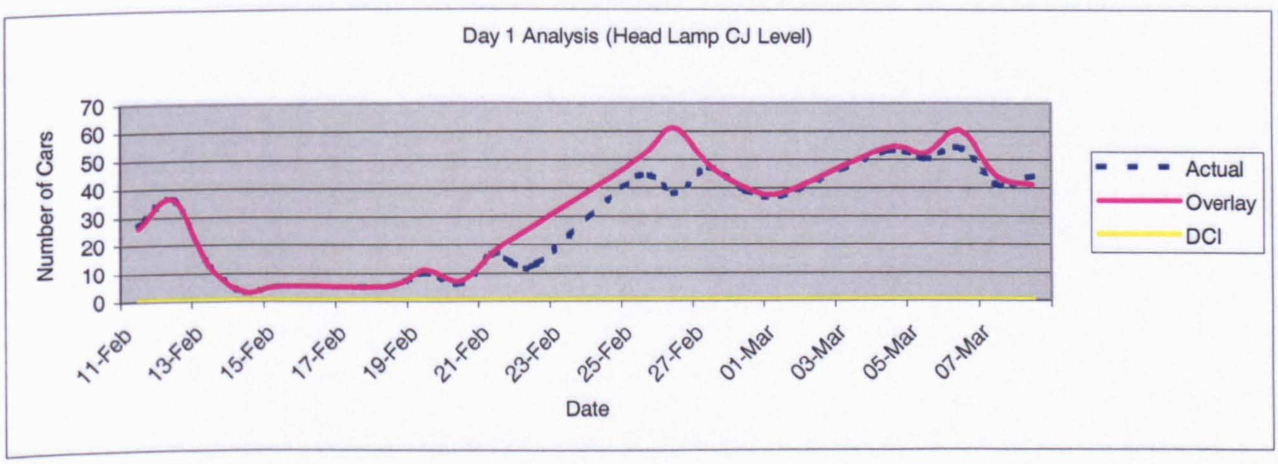

Day 3 Analysis (2.5L Auto Engine Gearbox)
Number of Cars
500
400
300
200
100
0
28-Jan
30-Jan
01-Feb
03-Feb
05-Feb
07-Feb
09-Feb
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

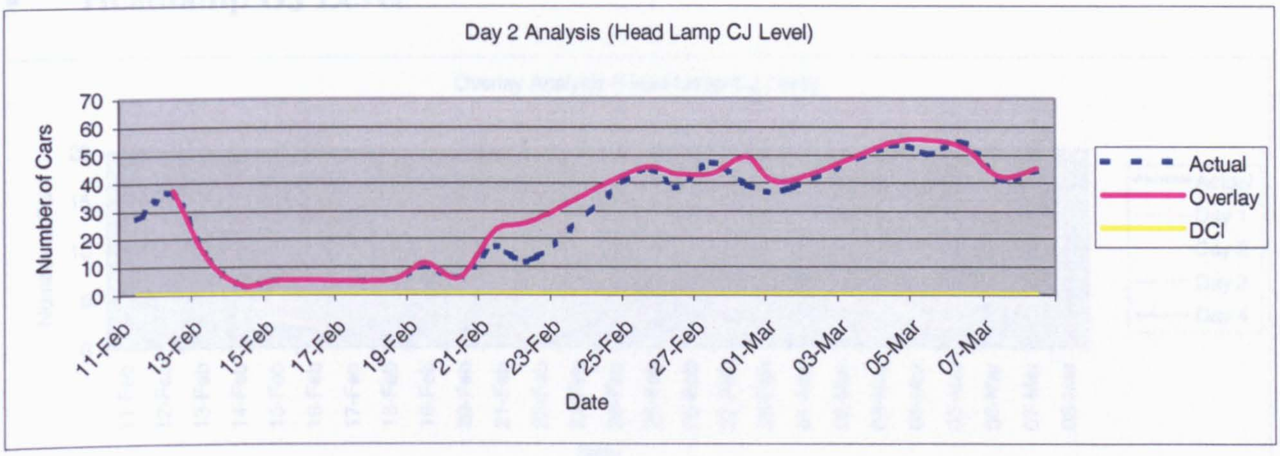

Day 4 Analysis (2.5L Auto Engine Gearbox)
Number of Cars
500
400
300
200
100
0
28-Jan
30-Jan
01-Feb
03-Feb
05-Feb
07-Feb
09-Feb
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

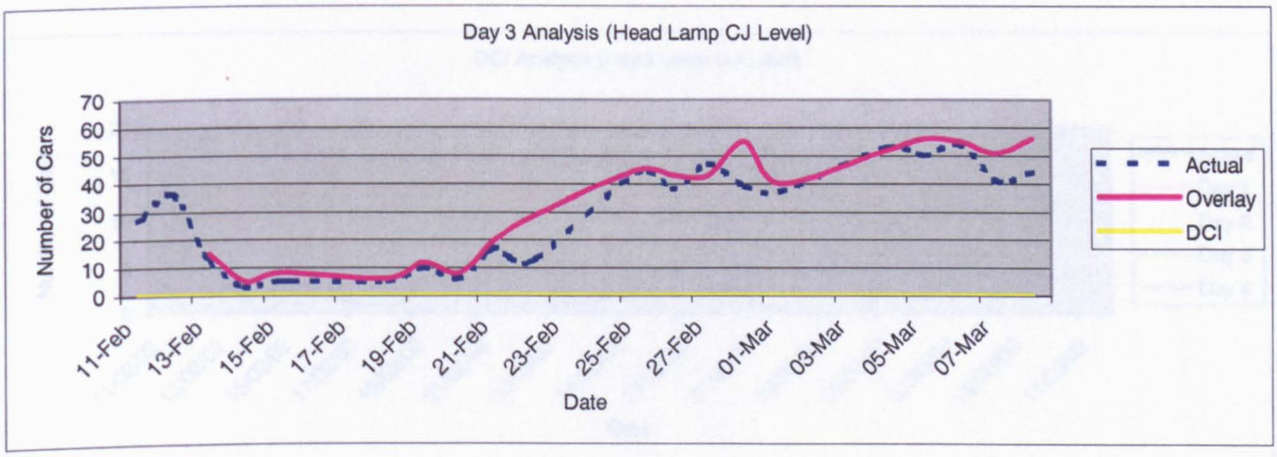
- **Headlamp CJ Level**

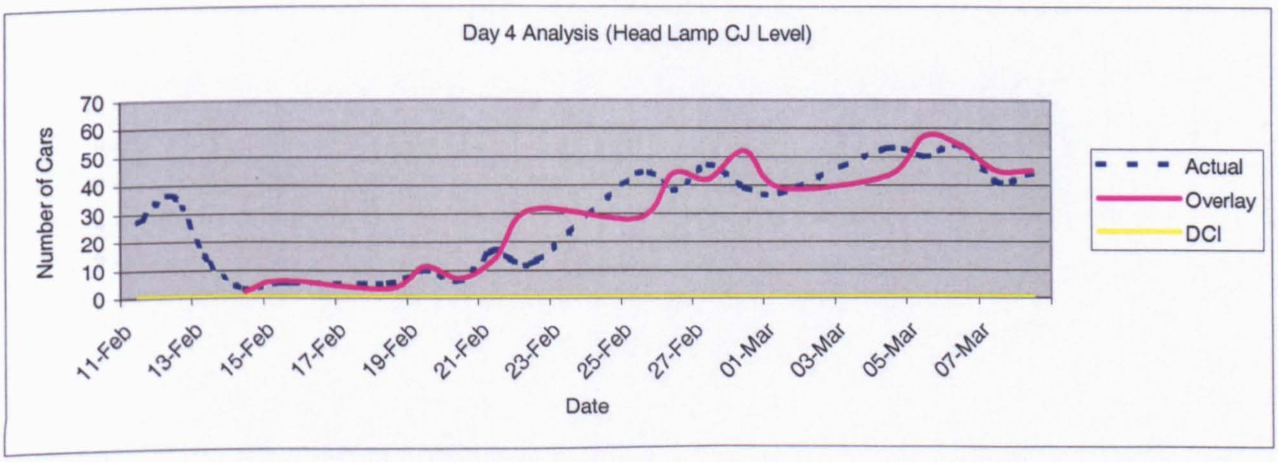




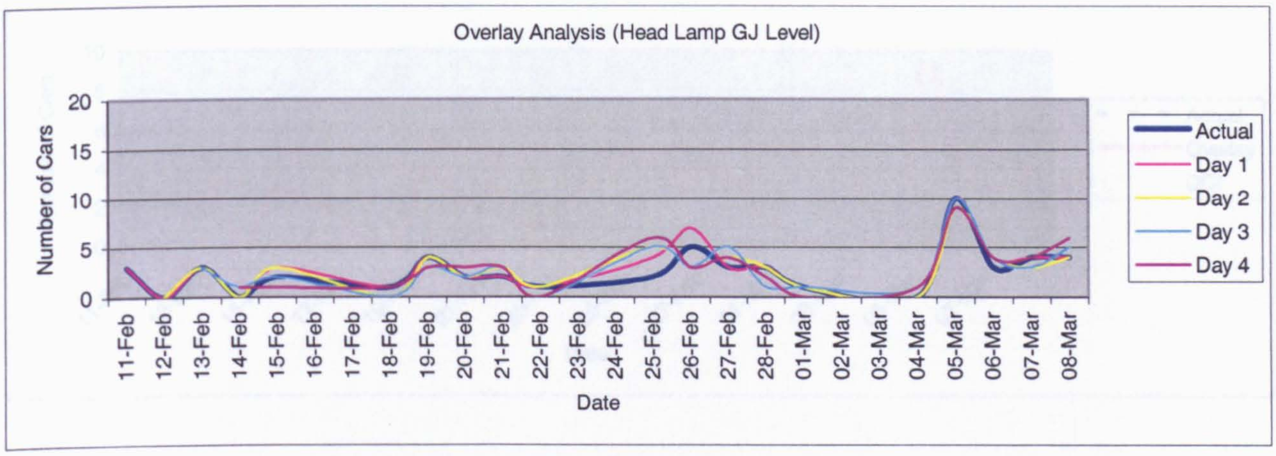


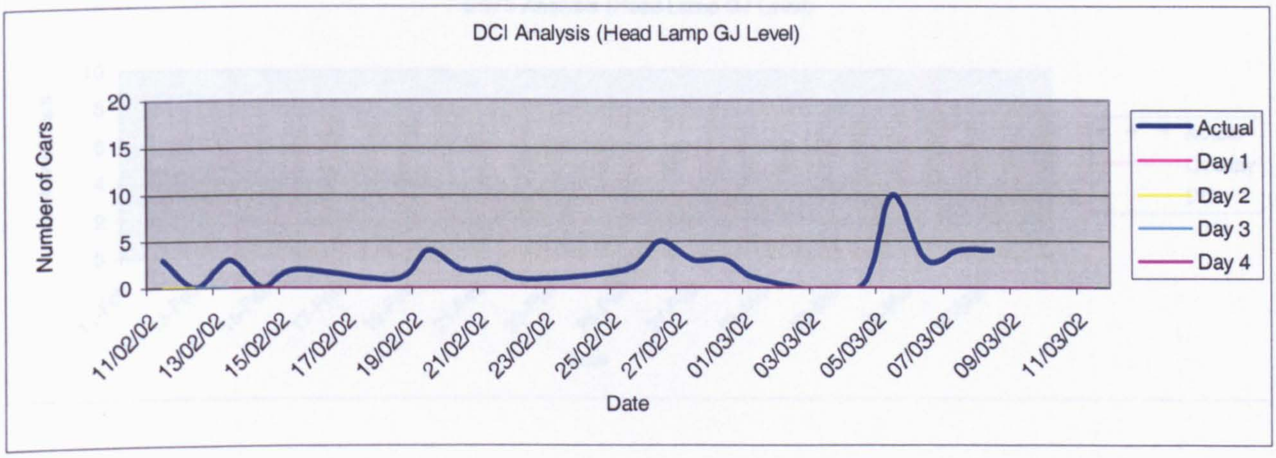

Day 2 Analysis (Head Lamp CJ Level)
Number of Cars
70
60
50
40
30
20
10
0
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

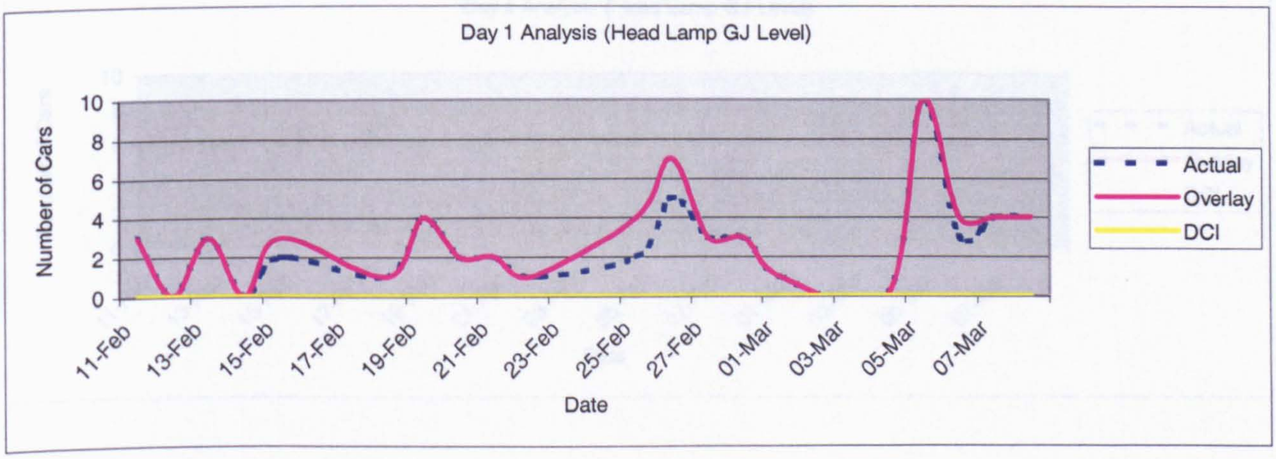

Day 3 Analysis (Head Lamp CJ Level)
Number of Cars
70
60
50
40
30
20
10
0
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

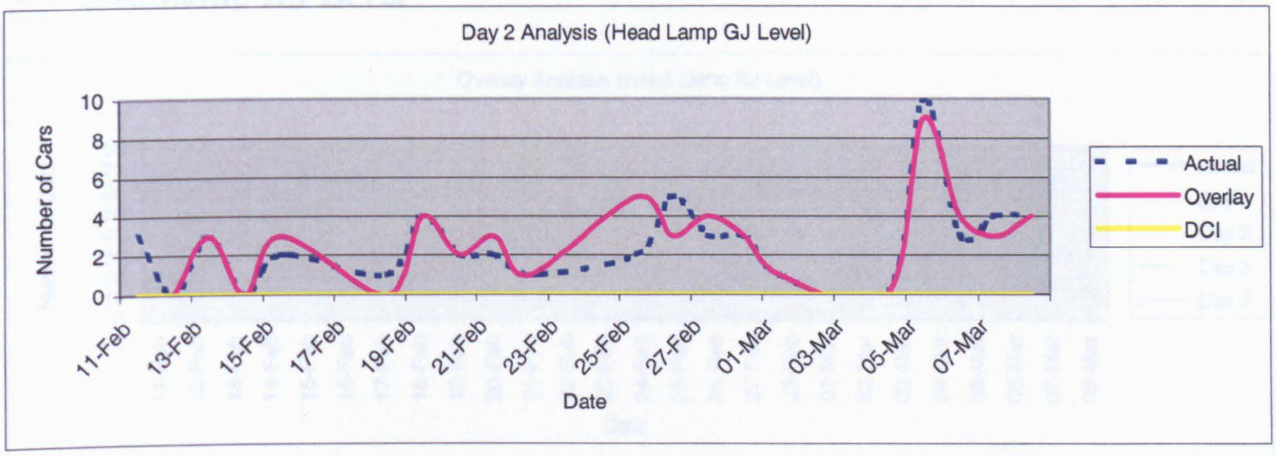

Day 4 Analysis (Head Lamp CJ Level)
Number of Cars
70
60
50
40
30
20
10
0
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

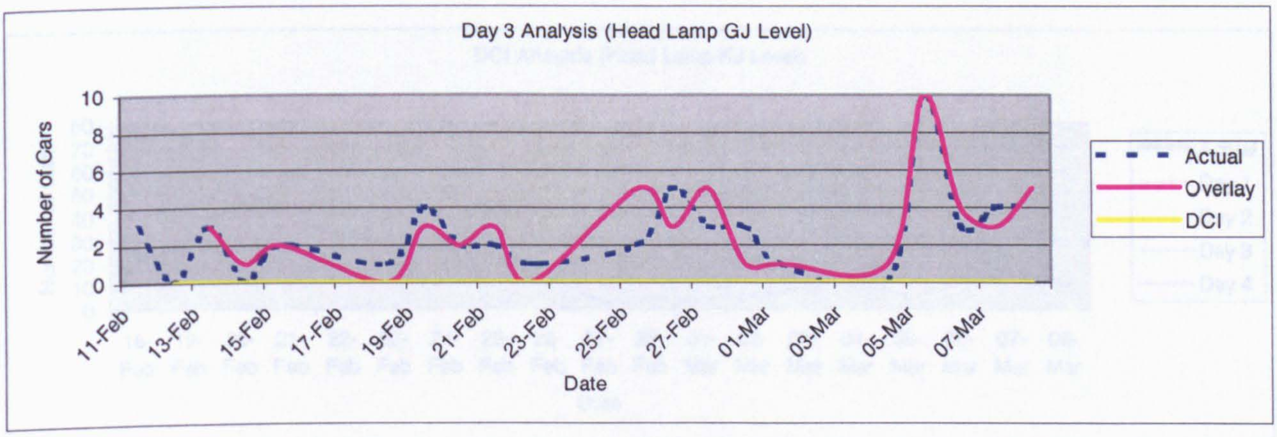
- **Headlamp GJ Level**

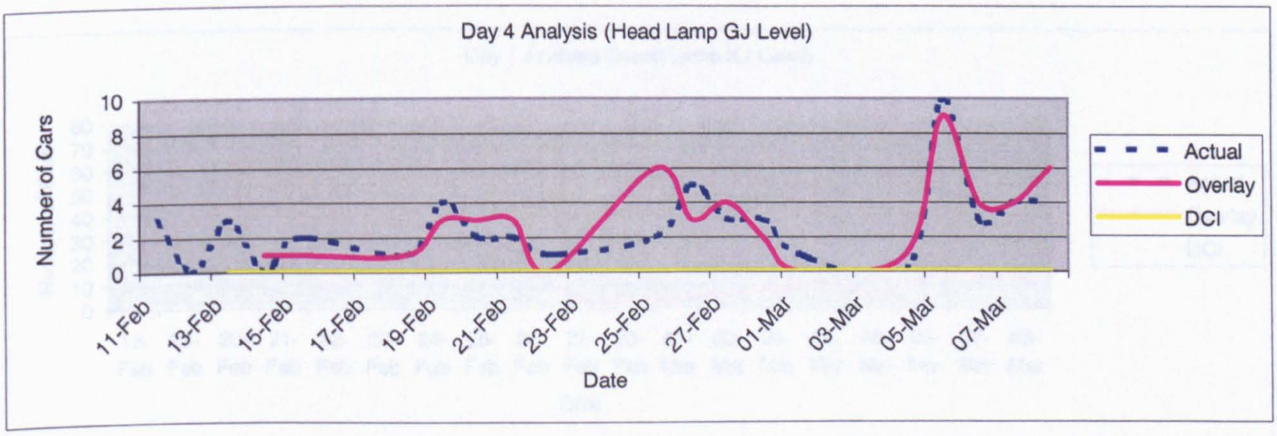




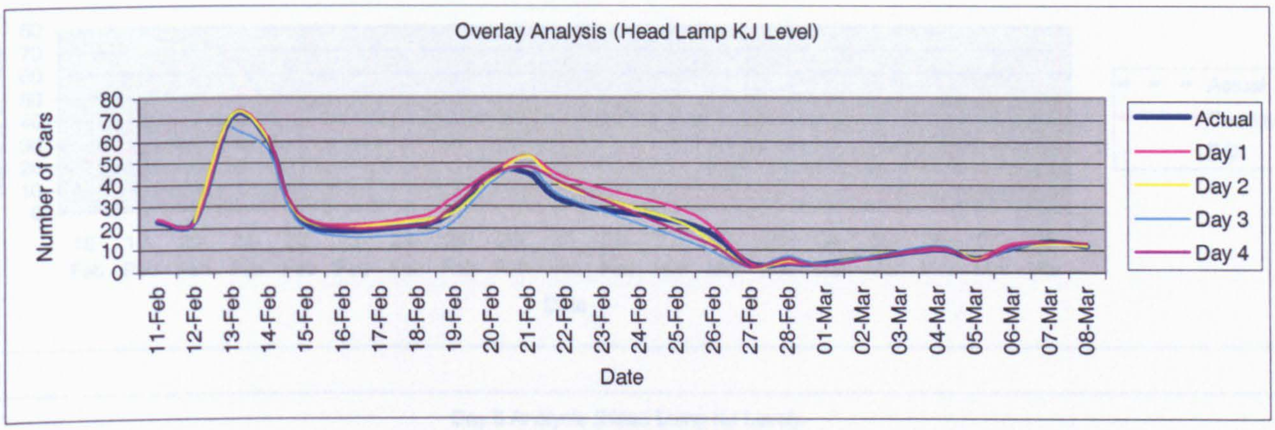


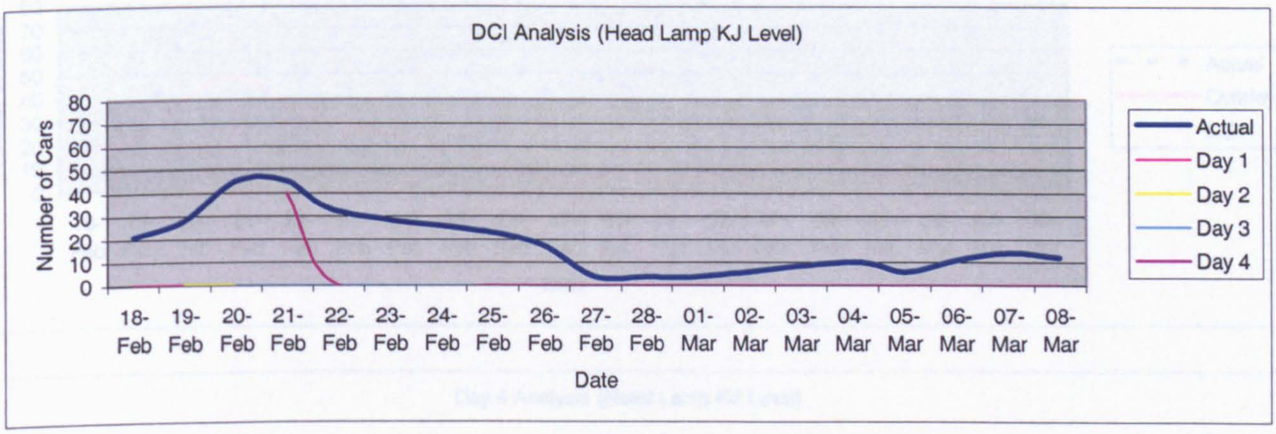

Day 2 Analysis (Head Lamp GJ Level)
Number of Cars
Date
Actual
Overlay
DCI

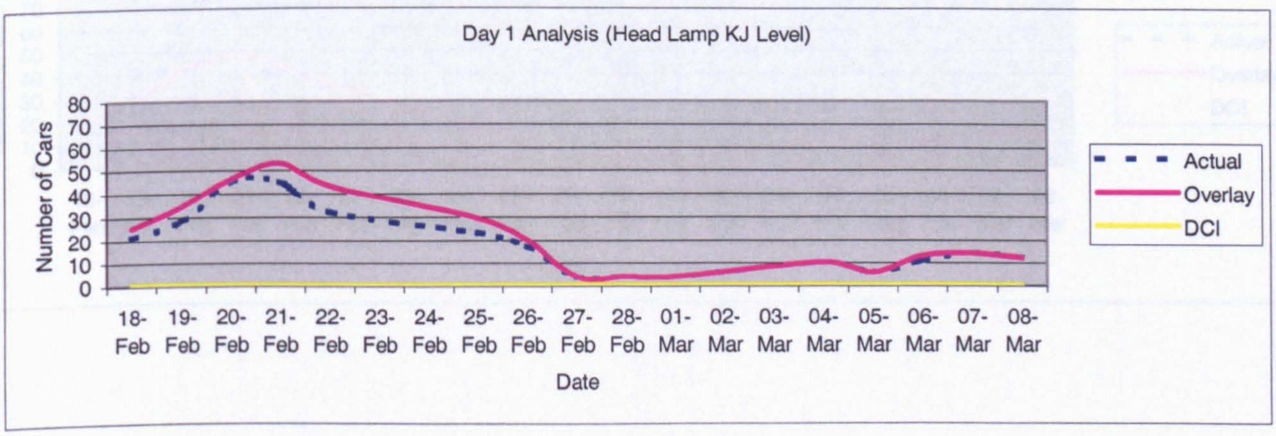

Day 3 Analysis (Head Lamp GJ Level)
Number of Cars
Date
Actual
Overlay
DCI

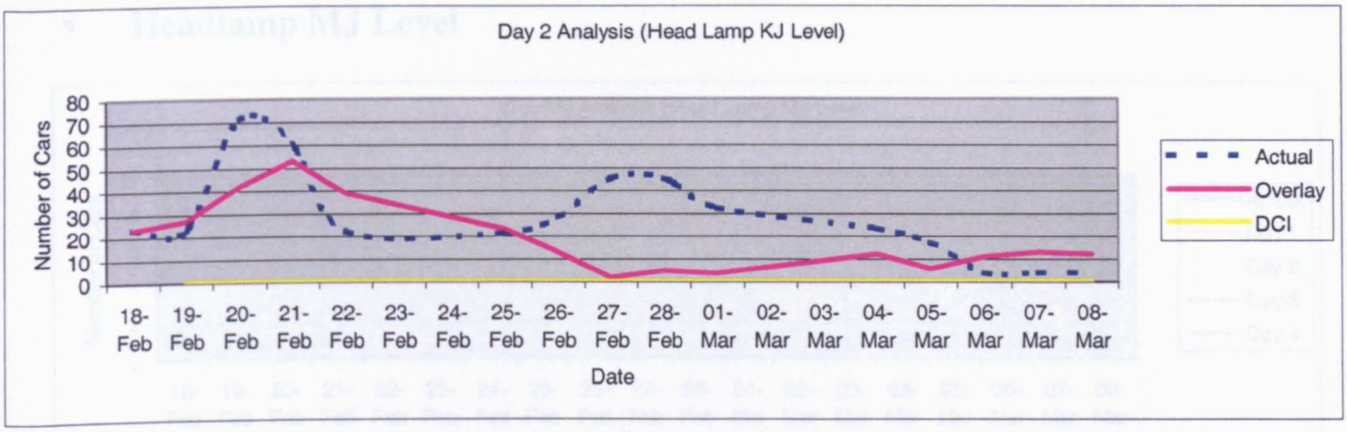

Day 4 Analysis (Head Lamp GJ Level)
Number of Cars
Date
Actual
Overlay
DCI

- **Headlamp KJ Level**

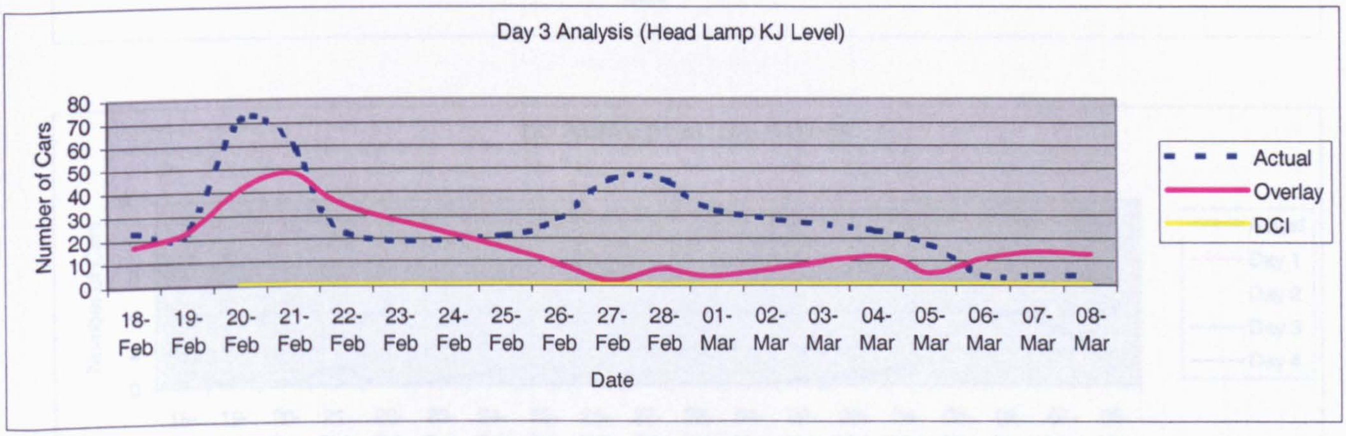




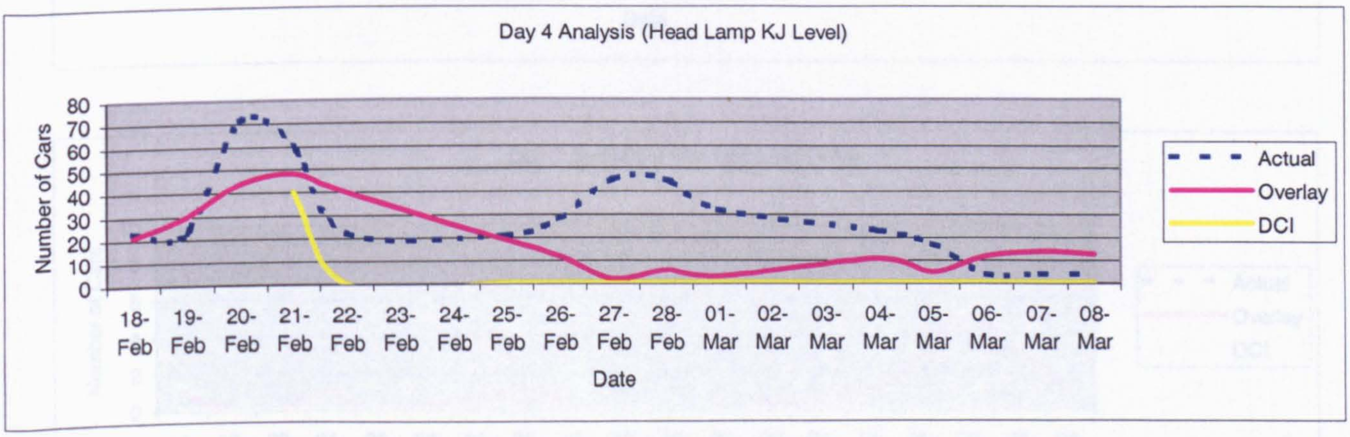




Day 2 Analysis (Head Lamp KJ Level)
Number of Cars
80
70
60
50
40
30
20
10
0
18-Feb 19-Feb 20-Feb 21-Feb 22-Feb 23-Feb 24-Feb 25-Feb 26-Feb 27-Feb 28-Feb 01-Mar 02-Mar 03-Mar 04-Mar 05-Mar 06-Mar 07-Mar 08-Mar
Date
Actual
Overlay
DCI

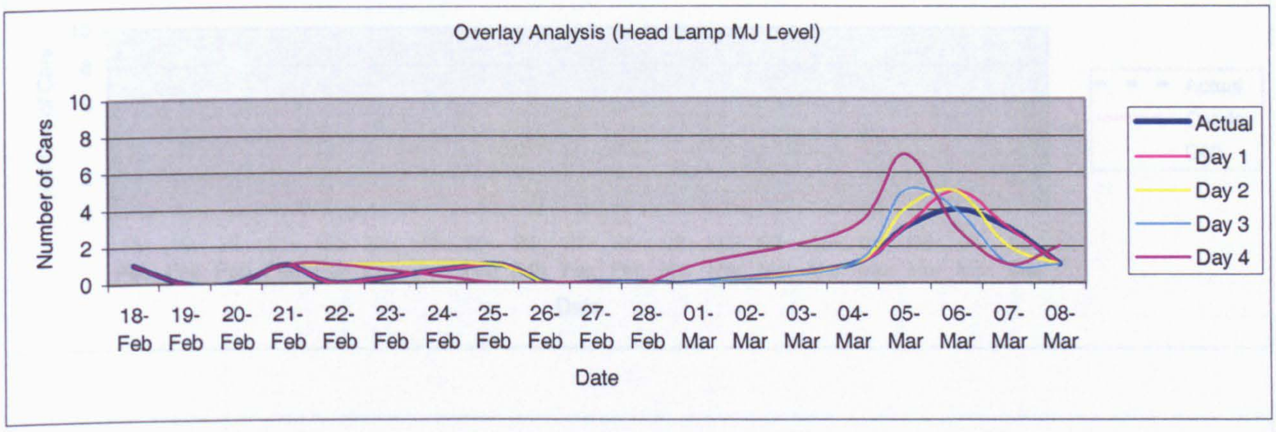


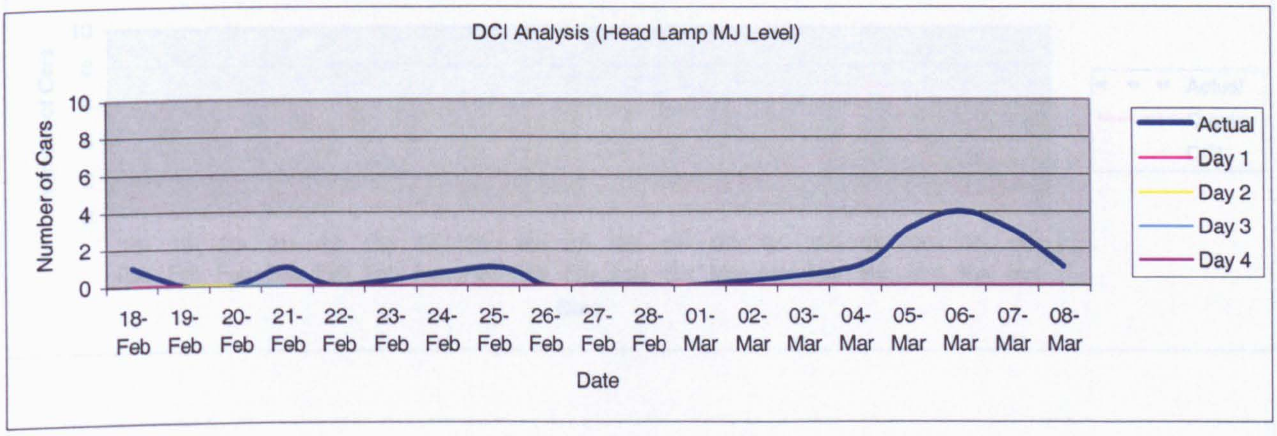
Day 3 Analysis (Head Lamp KJ Level)
Number of Cars
80
70
60
50
40
30
20
10
0
18-Feb 19-Feb 20-Feb 21-Feb 22-Feb 23-Feb 24-Feb 25-Feb 26-Feb 27-Feb 28-Feb 01-Mar 02-Mar 03-Mar 04-Mar 05-Mar 06-Mar 07-Mar 08-Mar
Date
Actual
Overlay
DCI

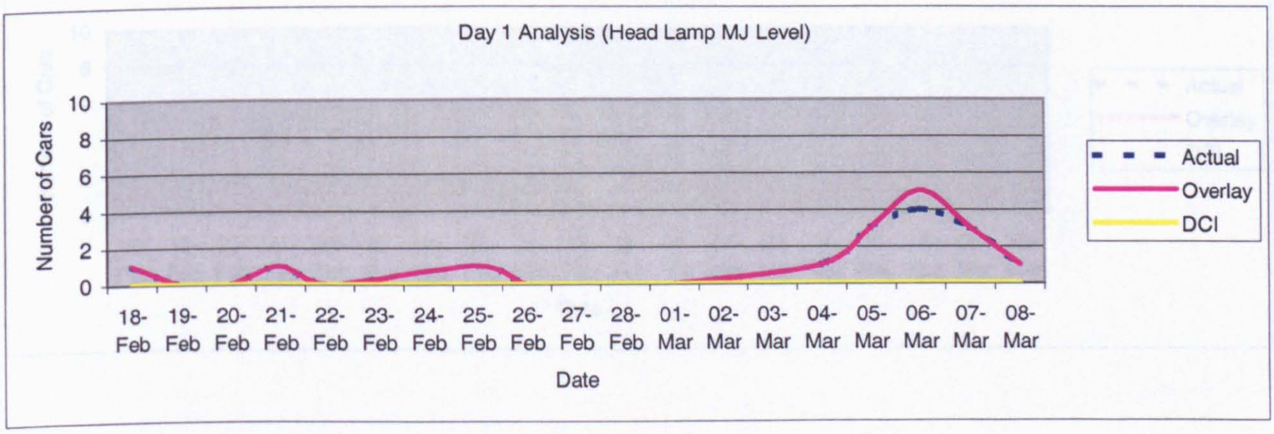


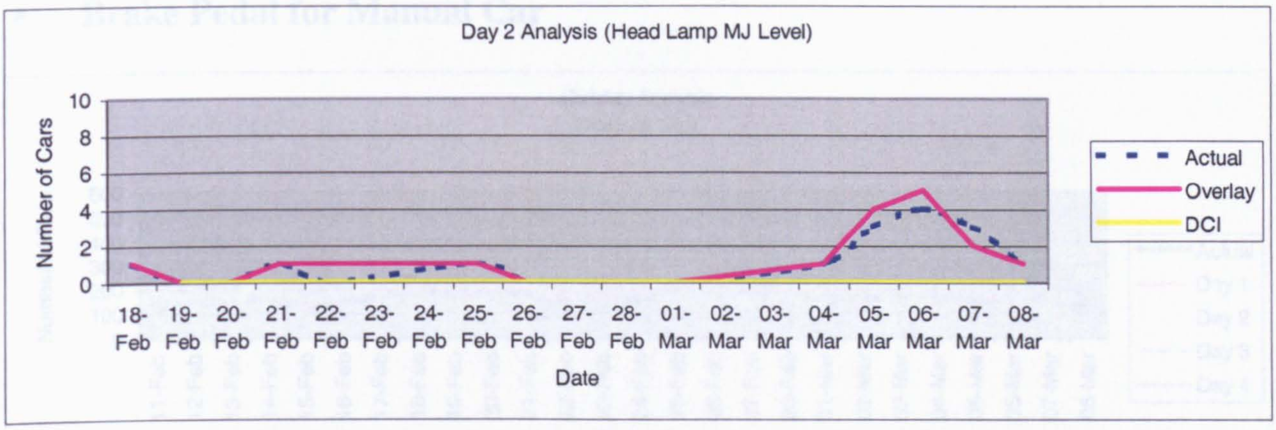
Day 4 Analysis (Head Lamp KJ Level)
Number of Cars
80
70
60
50
40
30
20
10
0
18-Feb 19-Feb 20-Feb 21-Feb 22-Feb 23-Feb 24-Feb 25-Feb 26-Feb 27-Feb 28-Feb 01-Mar 02-Mar 03-Mar 04-Mar 05-Mar 06-Mar 07-Mar 08-Mar
Date
Actual
Overlay
DCI

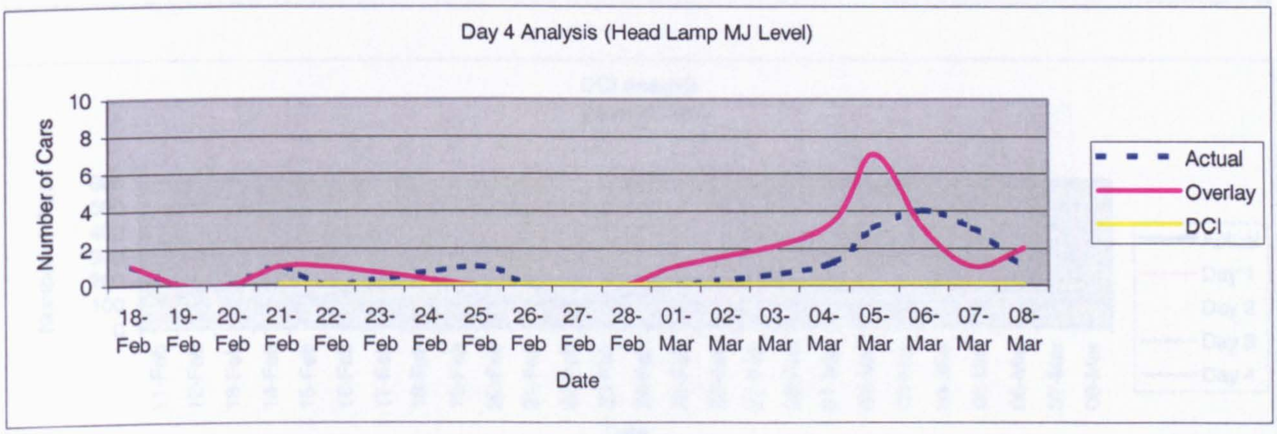
- **Headlamp MJ Level**

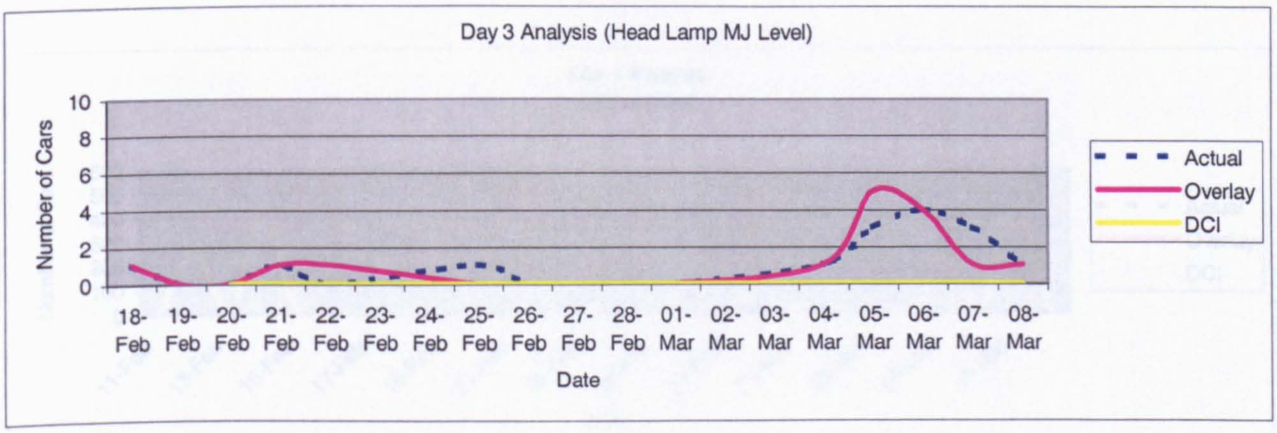




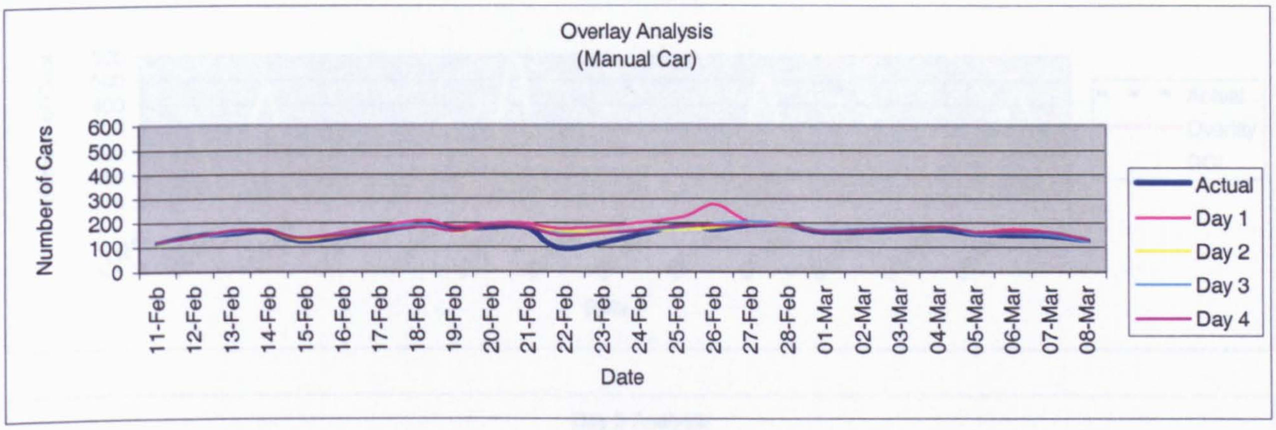


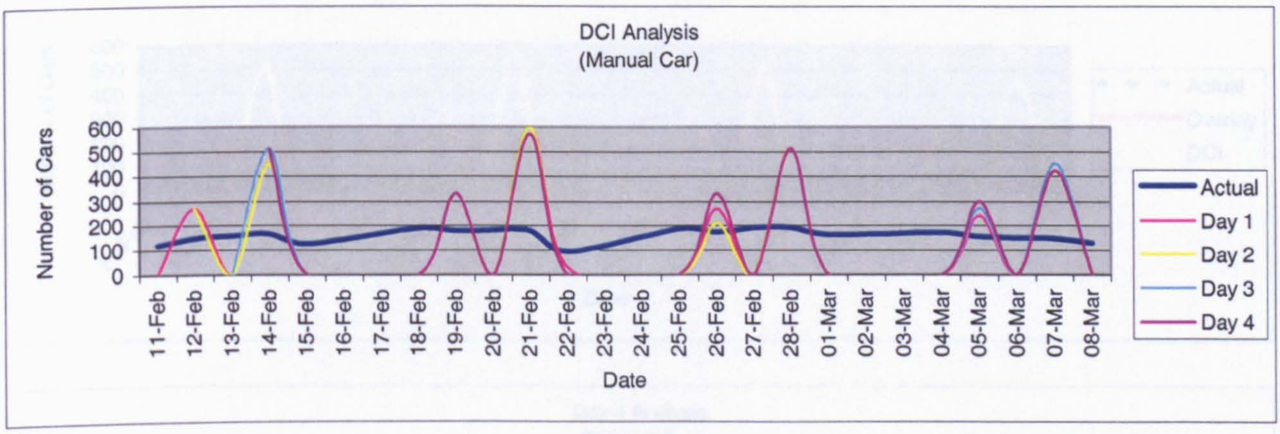

Day 2 Analysis (Head Lamp MJ Level)
Number of Cars
10
8
6
4
2
0
18-Feb 19-Feb 20-Feb 21-Feb 22-Feb 23-Feb 24-Feb 25-Feb 26-Feb 27-Feb 28-Feb 01-Mar 02-Mar 03-Mar 04-Mar 05-Mar 06-Mar 07-Mar 08-Mar
Date
Actual
Overlay
DCI

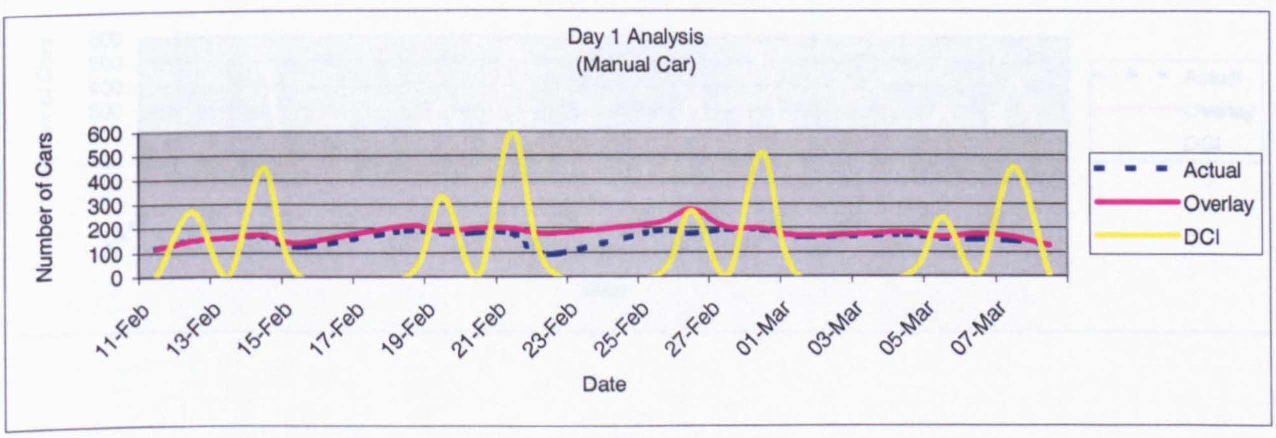

Day 4 Analysis (Head Lamp MJ Level)
Number of Cars
10
8
6
4
2
0
18-Feb 19-Feb 20-Feb 21-Feb 22-Feb 23-Feb 24-Feb 25-Feb 26-Feb 27-Feb 28-Feb 01-Mar 02-Mar 03-Mar 04-Mar 05-Mar 06-Mar 07-Mar 08-Mar
Date
Actual
Overlay
DCI

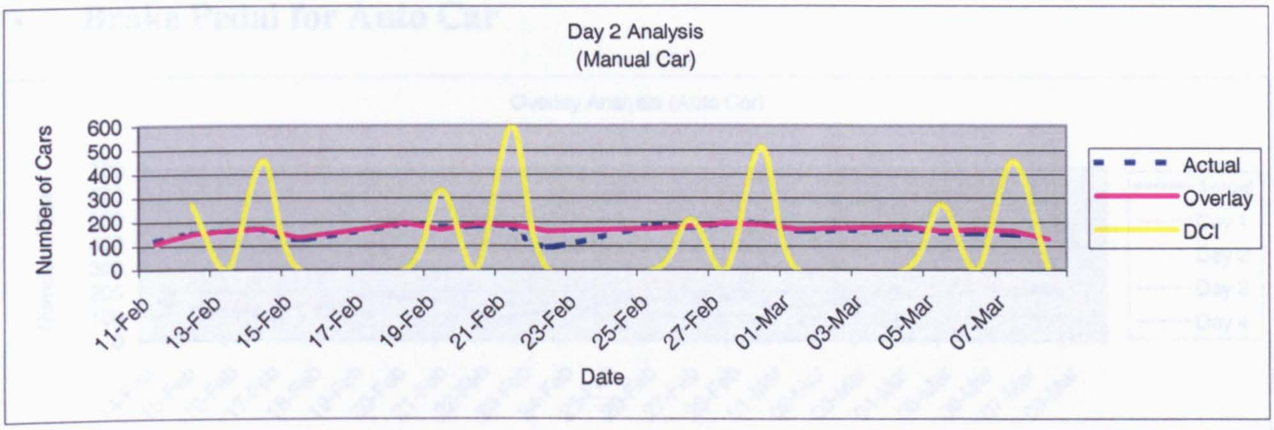

Day 3 Analysis (Head Lamp MJ Level)
Number of Cars
10
8
6
4
2
0
18-Feb 19-Feb 20-Feb 21-Feb 22-Feb 23-Feb 24-Feb 25-Feb 26-Feb 27-Feb 28-Feb 01-Mar 02-Mar 03-Mar 04-Mar 05-Mar 06-Mar 07-Mar 08-Mar
Date
Actual
Overlay
DCI

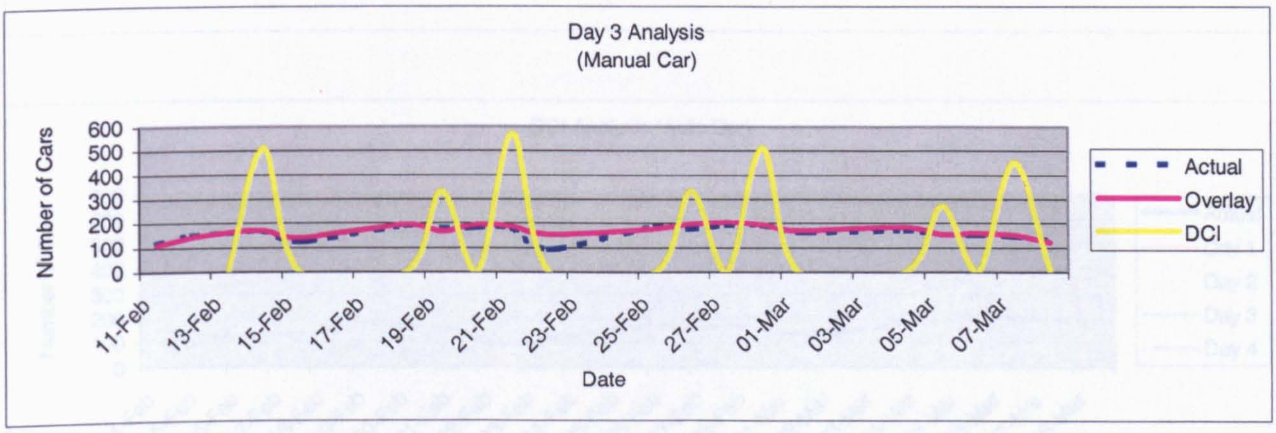
- **Brake Pedal for Manual Car**

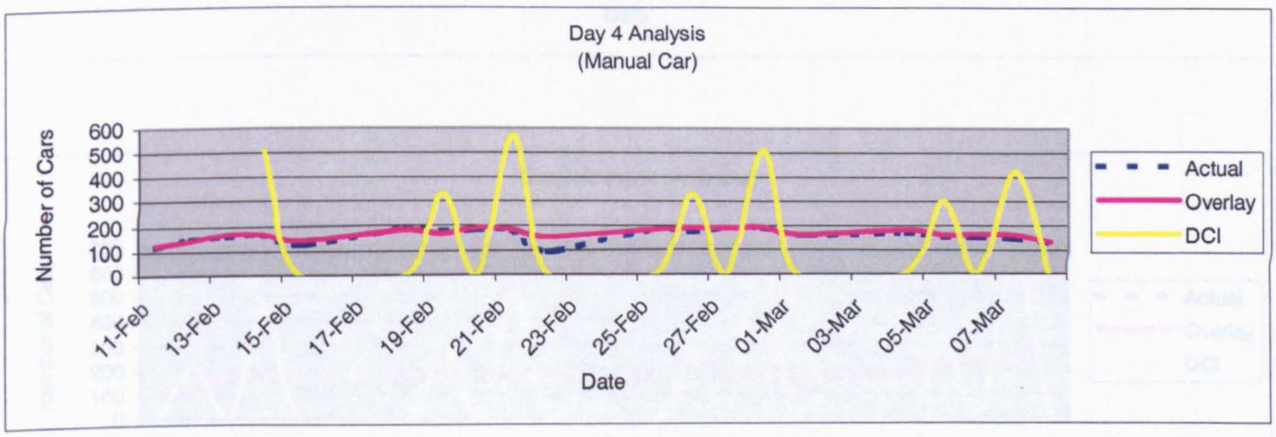




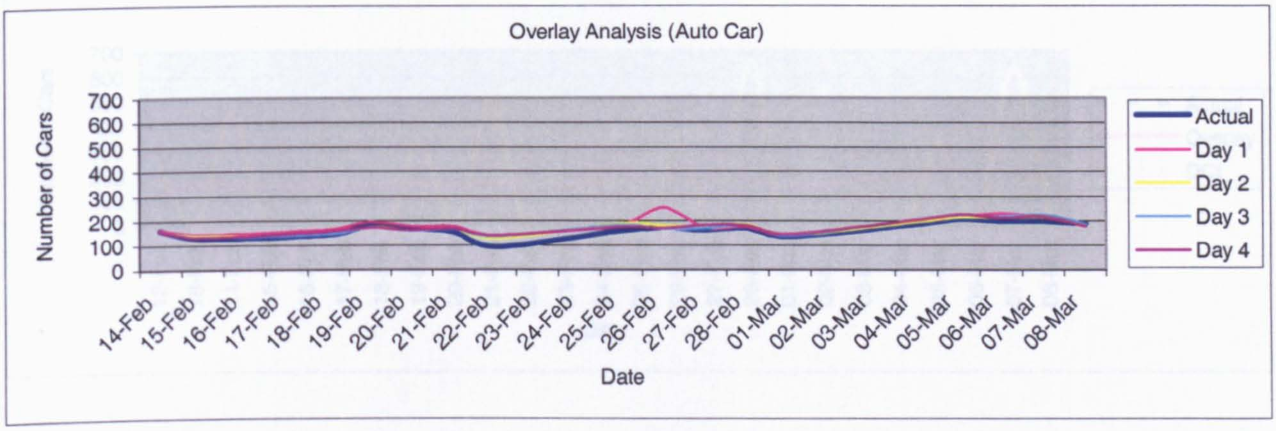


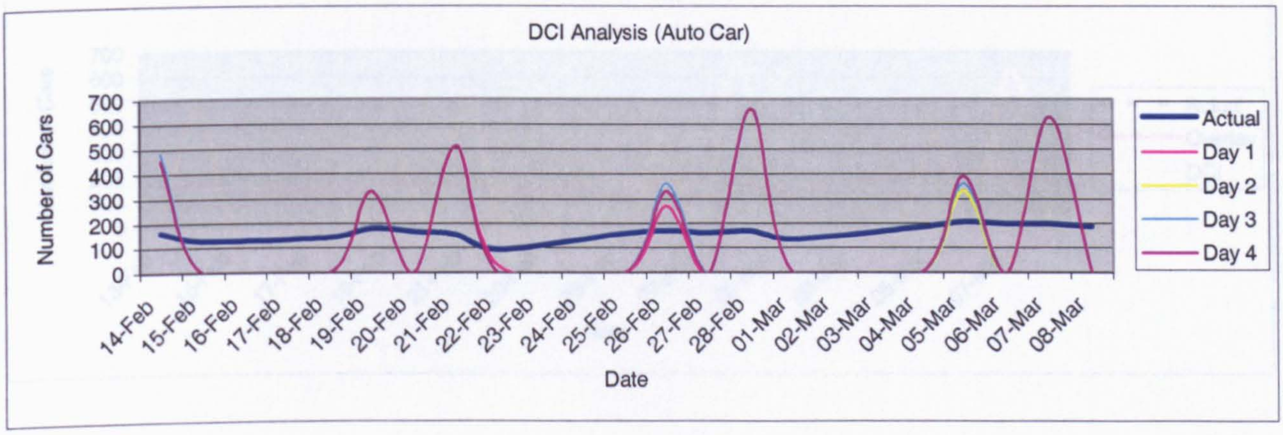

Day 2 Analysis
(Manual Car)
Number of Cars
600
500
400
300
200
100
0
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

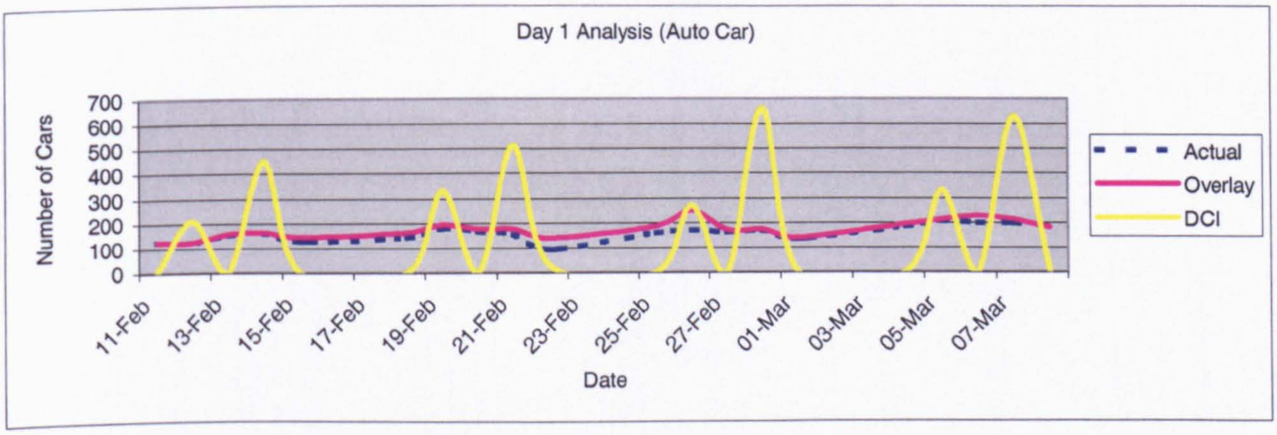

Day 3 Analysis
(Manual Car)
Number of Cars
600
500
400
300
200
100
0
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

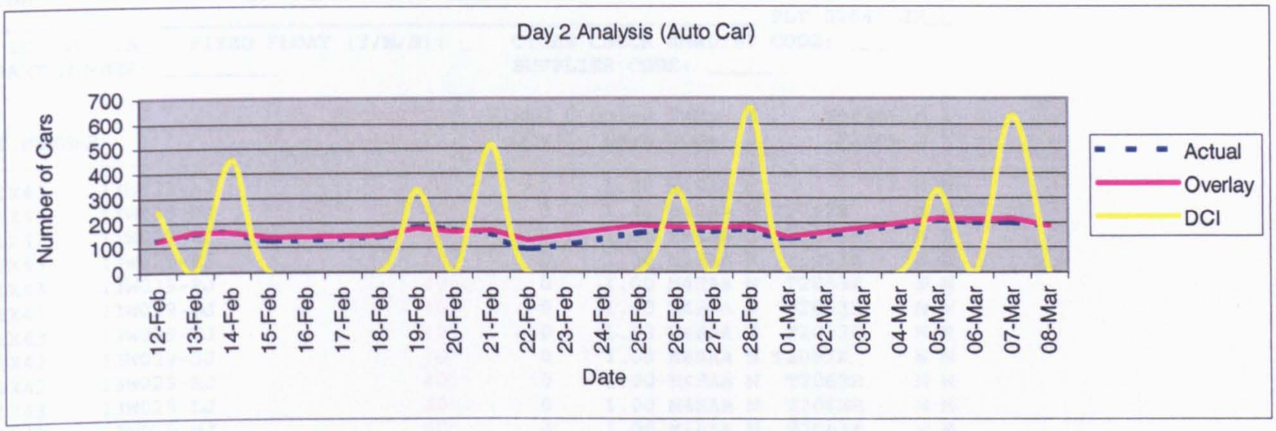

Day 4 Analysis
(Manual Car)
Number of Cars
600
500
400
300
200
100
0
11-Feb
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

▪ **Brake Pedal for Auto Car**

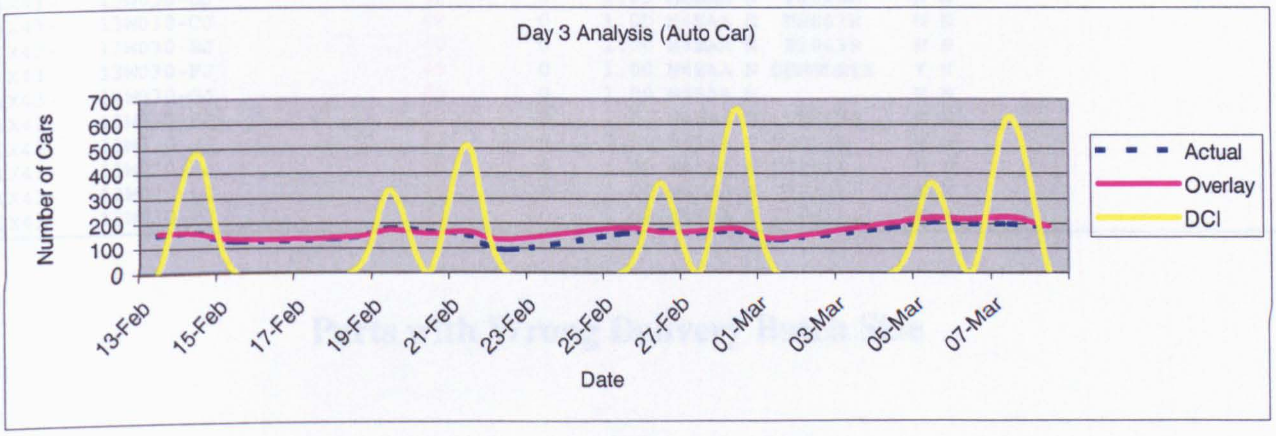








Day 2 Analysis (Auto Car)
Number of Cars
700
600
500
400
300
200
100
0
12-Feb
13-Feb
14-Feb
15-Feb
16-Feb
17-Feb
18-Feb
19-Feb
20-Feb
21-Feb
22-Feb
23-Feb
24-Feb
25-Feb
26-Feb
27-Feb
28-Feb
01-Mar
02-Mar
03-Mar
04-Mar
05-Mar
06-Mar
07-Mar
08-Mar
Date
Actual
Overlay
DCI



Day 3 Analysis (Auto Car)
Number of Cars
700
600
500
400
300
200
100
0
13-Feb
15-Feb
17-Feb
19-Feb
21-Feb
23-Feb
25-Feb
27-Feb
01-Mar
03-Mar
05-Mar
07-Mar
Date
Actual
Overlay
DCI

Appendix N

```
CMMSEJNA                  SMF FIXED FLOAT ENTRY                    05/04/02 15:17:14
==> ________ ____________________________________________________ PLT 02641 JH__
FLOAT ID: 663-1B_  FIXED FLOAT (Y/N/B): _   CYCLE CHECK ANALYST CODE: ___
BASE PART NUMBER: ________                  SUPPLIER CODE: _____

A                                   Packaging  Fixed B Opres Supp  M      Market M I
C PART NUMBER                        Quantity    Qty I  Days Code  S       Place L V
- ---------------------------------------------------------------------------- - -
    1X43-    13W029-AJ                40        0     1.00 M4EAA N                N N
    1X43-    13W029-BJ                40        0     1.00 M4EAA N T2063R         N N
    1X43-    13W029-CJ                40        0     1.00 M4EAA N  T2063R        N N
    1X43-    13W029-EJ                40        0     1.00 M4EAA N  T2053R        N N
    1X43-    13W029-FJ                40        0     1.00 M4EAA N  T2053R        N N
    1X43-    13W029-GJ                40        0     1.00 M4EAA N  T2053R        N N
    1X43-    13W029-HJ                40        0     1.00 M4EAA N  T2053R        N N
    1X43-    13W029-JJ                40        0     1.00 M4EAA N T2053R         N N
    1X43-    13W029-KJ                40        0     1.00 M4EAA N  T2063R        N N
    1X43-    13W029-LJ                40        0     1.00 M4EAA N  T2063R        N N
    1X43-    13W029-MJ                40        0     1.00 M4EAA N  T2063R        N N
    1X43-    13W030-AJ                40        0     1.00 M4EAA N T2063R         N N
    1X43-    13W030-BJ                40        0     1.00 M4EAA N  T2063R        N N
    1X43-    13W030-CJ                40        0     1.00 M4EAA N  T2063R        N N
    1X43-    13W030-EJ                40        0     1.00 M4EAA N  T2063R        N N
    1X43-    13W030-FJ                40        0     1.00 M4EAA N OBSOLETE       Y N
    1X43-    13W030-GJ                40        0     1.00 M4EAA N                N N
    1X43-    13W030-HJ                40        0     1.00 M4EAA N  T2063R        N N
    1X43-    13W030-JJ                40        0     1.00 M4EAA N T2061L         N N
    1X43-    13W030-KJ                40        0     1.00 M4EAA N T2061L         N N
    1X43-    13W030-LJ                40        0     1.00 M4EAA N T2061L         N N
    1X43-    13W030-MJ                40        0     1.00 M4EAA N T2061L         N N
```

Parts with Wrong Delivery Batch Size

Appendix O: Parts with Wrong Transit Time

```
CMMSAAIA                  SUPPLIER RELEASE - 1                 05/04/02 11:54:29
==> _________ ____________________________________________________ PLT 02641 JH__
PART:     1X43-    600C14-AGN0ADX_____       SUPP: BPVKA      830/862 (P/S):  S
PROG START DATE: 01/04/02 PROG NO. 663-35_  Send (F,R): _   Process Status: S
Date    TW % Adj   Quantity         Cum Pend Amnd:   Amnd Type:     Strik Prot:
------ -  - -    --------- ---------  Ship Freq: 11                 Final Rlse:
PRIOR                               119 Part Desc: FRONT SEAT KIT
050402                      19      129 Supplier:  LEAR CORP UK LTD
060402                       0      129 Issue Dte: 05/04/02    Thcknss:       0.0000
070402                       0      129 Pct Bus:    100        Width:          0.000
080402                       4      133 Part Stat: C           Length:          0.00
090402                       4      137 R/F/G:  RF7 K02        T&G:
100402                       6      143 Ship/Del:  S           Stl Comm:
110402                      10      153 Trn Dy/Sr:  1.3        Thck Dsc:
120402                      11      164 862 Code:  D           S/B:
130402                       0      164 Last No:    032802      PO. No.: IA4291
140402                       0      164 Last Date: 29/03/02    Rel Type: A
150402                       3      167 Last Qty:            1   Buyer Name/Phone #
160402                       4      171 Cum Rec+IT          110 N J GASSOR
170402                       5      176                            +44-2476-202805
180402                       2      178 Ship To:               Bill To: 02641
```

```
CMMSAAIA                  SUPPLIER RELEASE - 1                 05/04/02 11:57:06
==> _________ ____________________________________________________ PLT 02641 JH__
PART:     1X43-    600C14-AGN0NED_____       SUPP: BPVKA      830/862 (P/S):  S
PROG START DATE: 01/04/02 PROG NO. 663-35_  Send (F,R): _   Process Status: S
Date    TW % Adj   Quantity         Cum Pend Amnd:   Amnd Type:     Strik Prot:
------ -  - -    --------- ---------  Ship Freq: 11                 Final Rlse:
PRIOR                               113 Part Desc: FRONT SEAT KIT
050402                      10      119 Supplier:  LEAR CORP UK LTD
060402                       0      119 Issue Dte: 05/04/02    Thcknss:       0.0000
070402                       0      119 Pct Bus:    100        Width:          0.000
080402                      22      141 Part Stat: C           Length:          0.00
090402                       3      144 R/F/G:  RF7 K02        T&G:
100402                       4      148 Ship/Del:  S           Stl Comm:
110402                       8      156 Trn Dy/Sr:  1.3        Thck Dsc:
120402                       8      164 862 Code:  D           S/B:
130402                       0      164 Last No:    032702      PO. No.: IA4291
140402                       0      164 Last Date: 28/03/02    Rel Type: A
150402                       6      170 Last Qty:            5   Buyer Name/Phone #
160402                       4      174 Cum Rec+IT          109 N J GASSOR
170402                       0      174                            +44-2476-202805
180402                       0      174 Ship To:               Bill To: 02641
```

```
CMMSAAIA                  SUPPLIER RELEASE - 1                 05/04/02 11:57:44
==> _________ ____________________________________________________ PLT 02641 JH__
PART:     1X43-    600B01-AH0ADY_____       SUPP: BPVKA      830/862 (P/S):  S
PROG START DATE: 01/04/02 PROG NO. 663-35_  Send (F,R): _   Process Status: S
Date    TW % Adj   Quantity         Cum Pend Amnd:   Amnd Type:     Strik Prot:
------ -  - -    --------- ---------  Ship Freq: 11                 Final Rlse:
PRIOR                                 3 Part Desc: REAR SEAT KIT
050402                       0        3 Supplier:  LEAR CORP UK LTD
060402                       0        3 Issue Dte: 05/04/02    Thcknss:       0.0000
070402                       0        3 Pct Bus:    100        Width:          0.000
080402                       0        3 Part Stat: C           Length:          0.00
090402                       3        6 R/F/G:  RF7 K03        T&G:
100402                       0        6 Ship/Del:  S           Stl Comm:
110402                       0        6 Trn Dy/Sr:  1.3        Thck Dsc:
120402                       0        6 862 Code:  D           S/B:
130402                       0        6 Last No:    032702      PO. No.: HW9100
140402                       0        6 Last Date: 28/03/02    Rel Type: A
150402                       0        6 Last Qty:            1   Buyer Name/Phone #
160402                       0        6 Cum Rec+IT            3 N J GASSOR
170402                       0        6                            +44-2476-202805
180402                       0        6 Ship To:               Bill To: 02641
```

```
CMMSAAIA                  SUPPLIER RELEASE - 1              05/04/02 11:58:19
==> _________ _________________________________________________ PLT 02641 JH__
PART:    1X43-   600B01-AH0ADX______        SUPP: BPVKA     830/862 (P/S):  S
PROG START DATE: 01/04/02 PROG NO. 663-35_  Send (F,R): _   Process Status: S
Date    TW % Adj  Quantity         Cum Pend Amnd:   Amnd Type:     Strik Prot:
------ -  - -   --------- --------- Ship Freq: 11               Final Rlse:
PRIOR                          112 Part Desc: REAR SEAT KIT
050402                29       120 Supplier:  LEAR CORP UK LTD
060402                 0       120 Issue Dte: 05/04/02  Thcknss:       0.0000
070402                 0       120 Pct Bus:   100       Width:          0.000
080402                 8       128 Part Stat: C         Length:          0.00
090402                 9       137 R/F/G:  RF7 K03      T&G:
100402                 6       143 Ship/Del:  S         Stl Comm:
110402                 9       152 Trn Dy/Sr:  1.3      Thck Dsc:
120402                13       165 862 Code:  D         S/B:
130402                 0       165 Last No:   032802     PO. No.: HW9100
140402                 0       165 Last Date: 29/03/02  Rel Type: A
150402                 7       172 Last Qty:           7   Buyer Name/Phone #
160402                 5       177 Cum Rec+IT         91  N J GASSOR
170402                 7       184                         +44-2476-202805
180402                 5       189 Ship To:             Bill To:  02641
```

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CMMSAAIA                  SUPPLIER RELEASE - 1              05/04/02 11:58:38
==> _________ _________________________________________________ PLT 02641 JH__
PART:    1X43-   600B01-BH0ADX______        SUPP: BPVKA     830/862 (P/S):  S
PROG START DATE: 01/04/02 PROG NO. 663-35_  Send (F,R): _   Process Status: S
Date    TW % Adj  Quantity         Cum Pend Amnd:   Amnd Type:     Strik Prot:
------ -  - -   --------- --------- Ship Freq: 11               Final Rlse:
PRIOR                            4 Part Desc: REAR SEAT KIT
050402                 1         4 Supplier:  LEAR CORP UK LTD
060402                 0         4 Issue Dte: 05/04/02  Thcknss:       0.0000
070402                 0         4 Pct Bus:   100       Width:          0.000
080402                 0         4 Part Stat: C         Length:          0.00
090402                 0         4 R/F/G:  RF7 K03      T&G:
100402                 0         4 Ship/Del:  S         Stl Comm:
110402                 0         4 Trn Dy/Sr:  1.3      Thck Dsc:
120402                 3         7 862 Code:  D         S/B:
130402                 0         7 Last No:   032702     PO. No.: HW9113
140402                 0         7 Last Date: 28/03/02  Rel Type: A
150402                 0         7 Last Qty:           1   Buyer Name/Phone #
160402                 0         7 Cum Rec+IT          3  N J GASSOR
170402                 0         7                         +44-2476-202805
180402                 1         8 Ship To:             Bill To:  02641
```

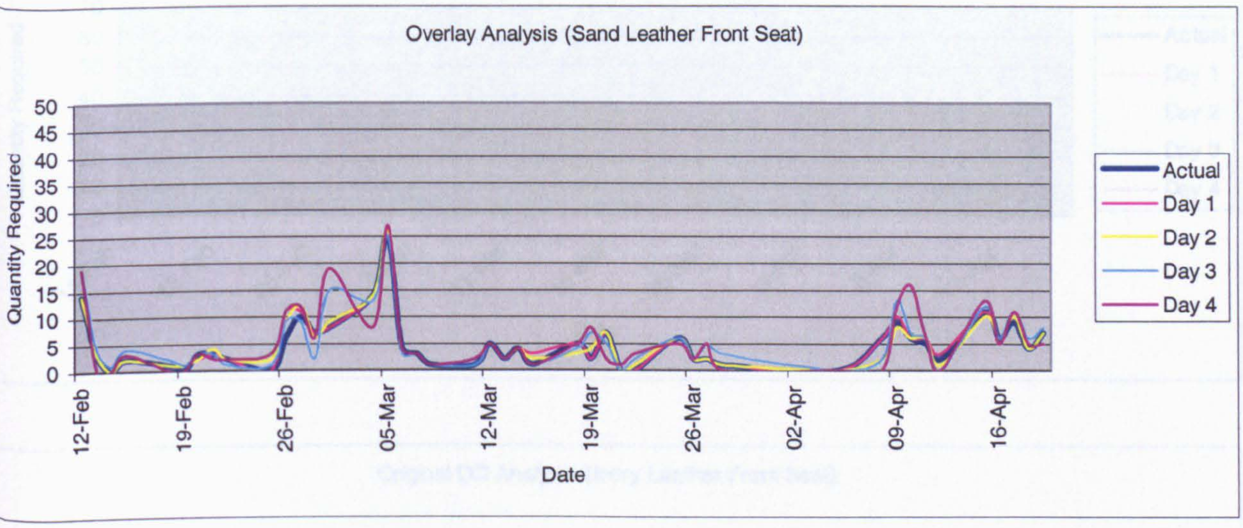
```
CMMSAAIA                  SUPPLIER RELEASE - 1              05/04/02 11:58:56
==> _________ _________________________________________________ PLT 02641 JH__
PART:    1X43-   600B01-CH0ADX______        SUPP: BPVKA     830/862 (P/S):  S
PROG START DATE: 01/04/02 PROG NO. 663-35_  Send (F,R): _   Process Status: S
Date    TW % Adj  Quantity         Cum Pend Amnd:   Amnd Type:     Strik Prot:
------ -  - -   --------- --------- Ship Freq: 11               Final Rlse:
PRIOR                            2 Part Desc: REAR SEAT KIT
050402                 0         2 Supplier:  LEAR CORP UK LTD
060402                 0         2 Issue Dte: 05/04/02  Thcknss:       0.0000
070402                 0         2 Pct Bus:   100       Width:          0.000
080402                 0         2 Part Stat: C         Length:          0.00
090402                 0         2 R/F/G:  RF7 K03      T&G:
100402                 0         2 Ship/Del:  S         Stl Comm:
110402                 0         2 Trn Dy/Sr:  1.3      Thck Dsc:
120402                 0         2 862 Code:  D         S/B:
130402                 0         2 Last No:   032802     PO. No.: HW9118
140402                 0         2 Last Date: 29/03/02  Rel Type: A
150402                 0         2 Last Qty:           1   Buyer Name/Phone #
160402                 0         2 Cum Rec+IT          2  N J GASSOR
170402                 1         3                         +44-2476-202805
180402                 0         3 Ship To:             Bill To:  02641
```

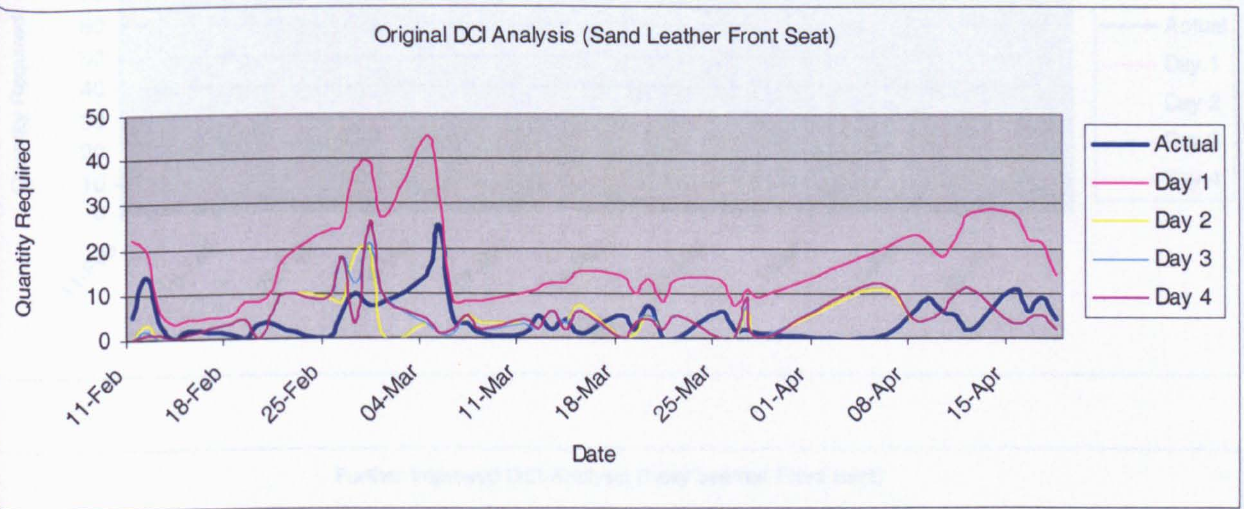
```
CMMSAAIA                 SUPPLIER RELEASE - 1                  05/04/02 11:59:10
==> _______ ___________________________________________________ PLT 02641 JH__
PART:    1X43-    600B01-JH0ADX______          SUPP: BPVKA      830/862 (P/S):  S
PROG START DATE: 01/04/02 PROG NO. 663-35_  Send (F,R): _    Process Status: S
Date   TW % Adj   Quantity        Cum Pend Amnd:    Amnd Type:      Strik Prot:
------ -  -  -   --------- --------- Ship Freq: 11               Final Rlse:
PRIOR                             119 Part Desc: REAR SEAT KIT
050402                    15      124 Supplier:  LEAR CORP UK LTD
060402                     0      124 Issue Dte: 05/04/02  Thcknss:        0.0000
070402                     0      124 Pct Bus:   100       Width:           0.000
080402                     6      130 Part Stat: C         Length:           0.00
090402                     5      135 R/F/G:  RF7 K03      T&G:
100402                     6      141 Ship/Del:  S         Stl Comm:
110402                     7      148 Trn Dy/Sr:  1.3      Thck Dsc:
120402                     6      154 862 Code:  D         S/B:
130402                     0      154 Last No:   032802    PO. No.: HW9163
140402                     0      154 Last Date: 29/03/02  Rel Type: A
150402                     7      161 Last Qty:          43  Buyer Name/Phone #
160402                     6      167 Cum Rec+IT        109 N J GASSOR
170402                     2      169                        +44-2476-202805
180402                     9      178 Ship To:             Bill To:  02641
```

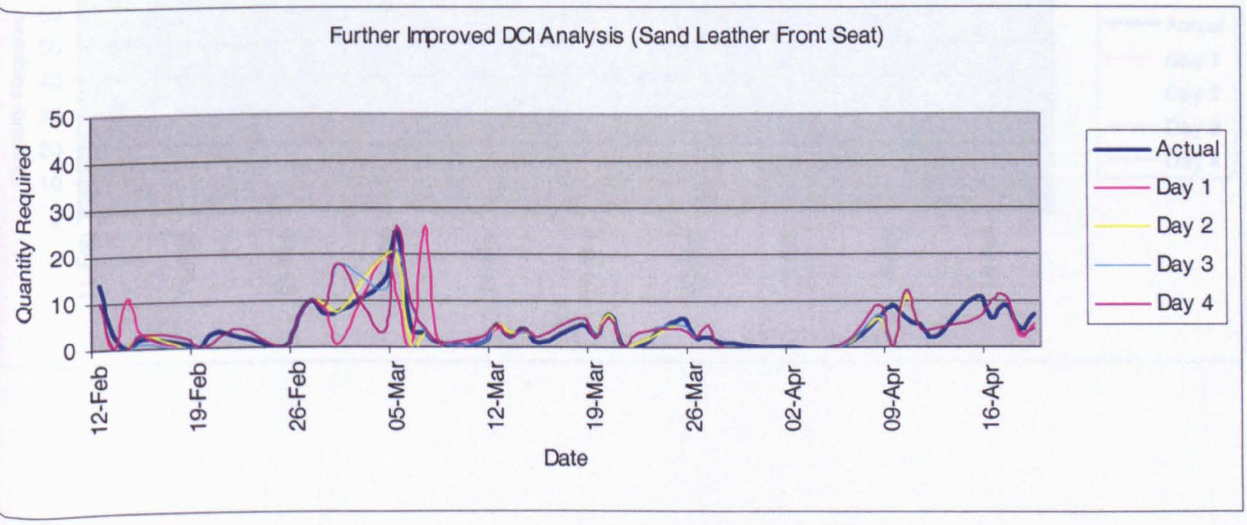
```
CMMSAAIA                 SUPPLIER RELEASE - 1                  05/04/02 11:59:28
==> _______ ___________________________________________________ PLT 02641 JH__
PART:    1X43-    600B01-KH0ADX______          SUPP: BPVKA      830/862 (P/S):  S
PROG START DATE: 01/04/02 PROG NO. 663-35_  Send (F,R): _    Process Status: S
Date   TW % Adj   Quantity        Cum Pend Amnd:    Amnd Type:      Strik Prot:
------ -  -  -   --------- --------- Ship Freq: 11               Final Rlse:
PRIOR                               3 Part Desc: REAR SEAT KIT
050402                     1        3 Supplier:  LEAR CORP UK LTD
060402                     0        3 Issue Dte: 05/04/02  Thcknss:        0.0000
070402                     0        3 Pct Bus:   100       Width:           0.000
080402                     0        3 Part Stat: C         Length:           0.00
090402                     0        3 R/F/G:  RF7 K03      T&G:
100402                     0        3 Ship/Del:  S         Stl Comm:
110402                     0        3 Trn Dy/Sr:  1.3      Thck Dsc:
120402                     0        3 862 Code:  D         S/B:
130402                     0        3 Last No:   032702    PO. No.: HW9170
140402                     0        3 Last Date: 28/03/02  Rel Type: A
150402                     0        3 Last Qty:           1  Buyer Name/Phone #
160402                     1        4 Cum Rec+IT          2 N J GASSOR
170402                     0        4                        +44-2476-202805
180402                     1        5 Ship To:             Bill To:  02641
```

Appendix P

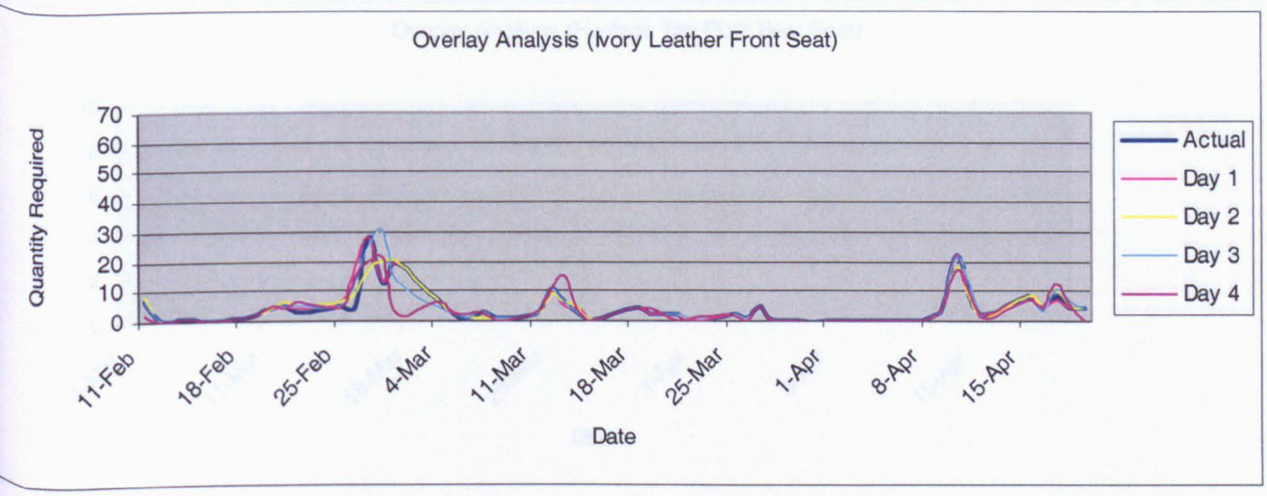
Sand Leather Front Seat:

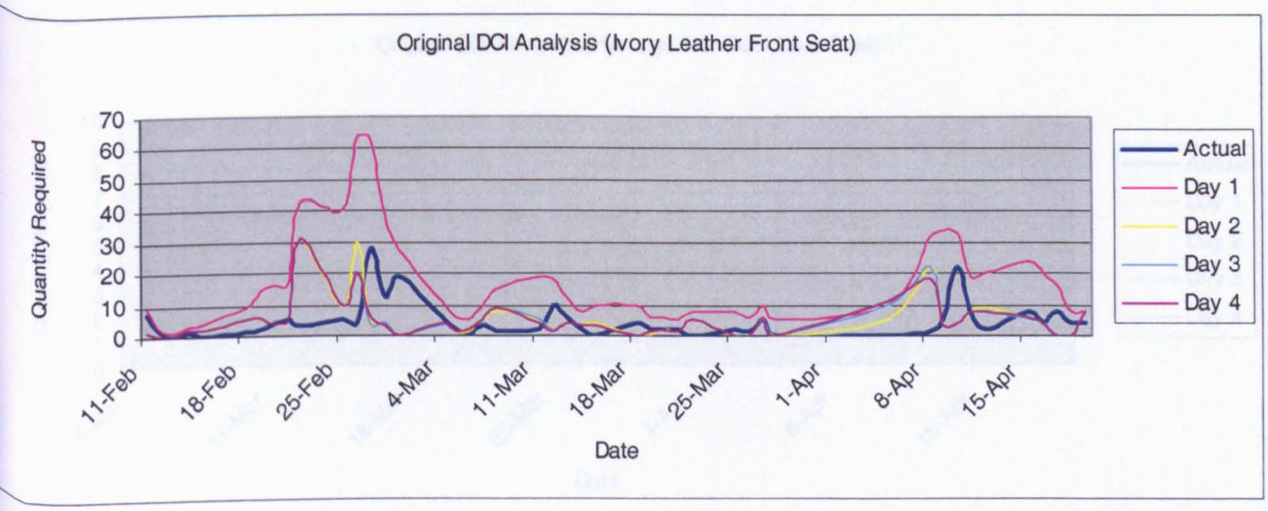


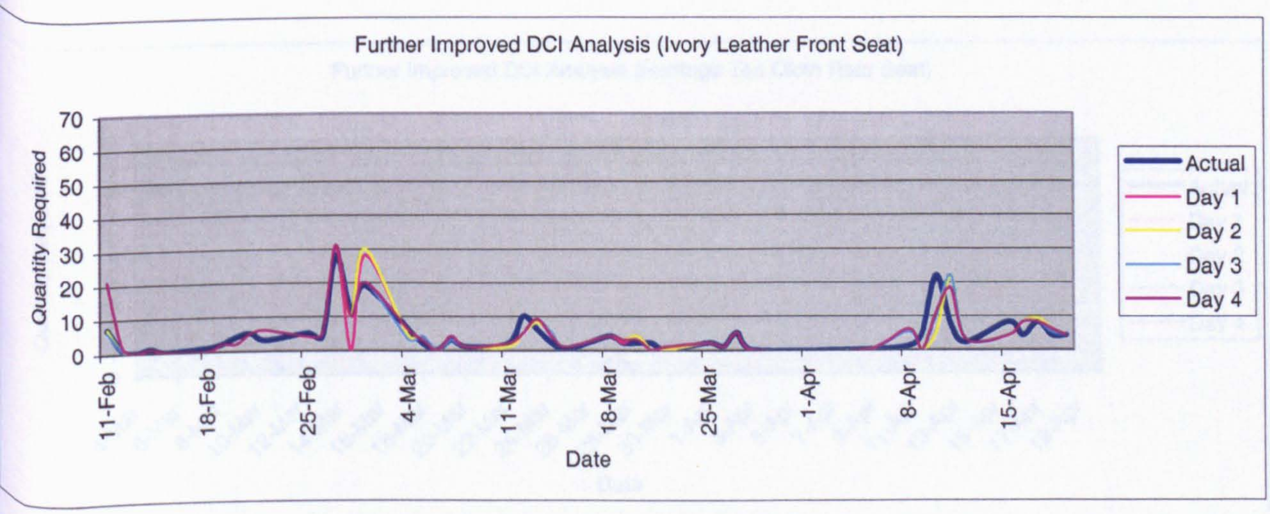




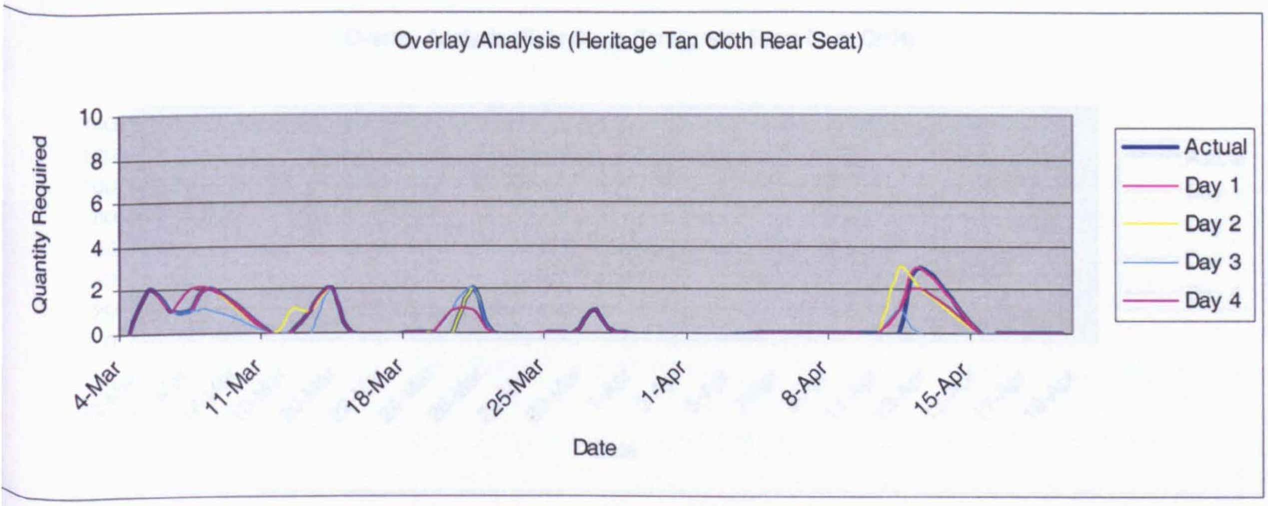
Ivory Leather Front Seat:

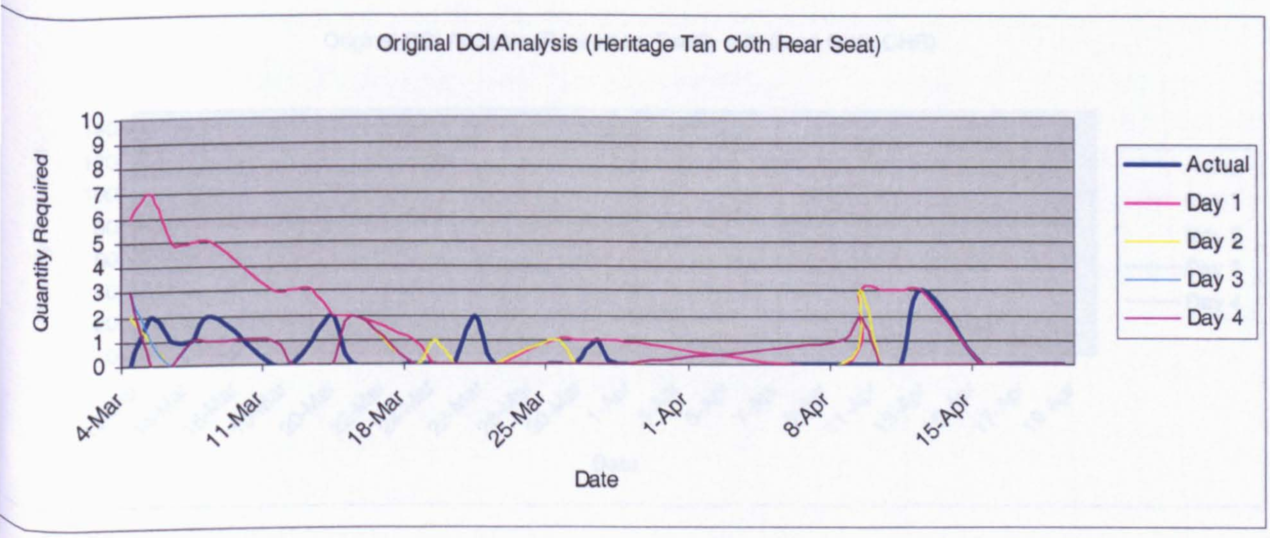


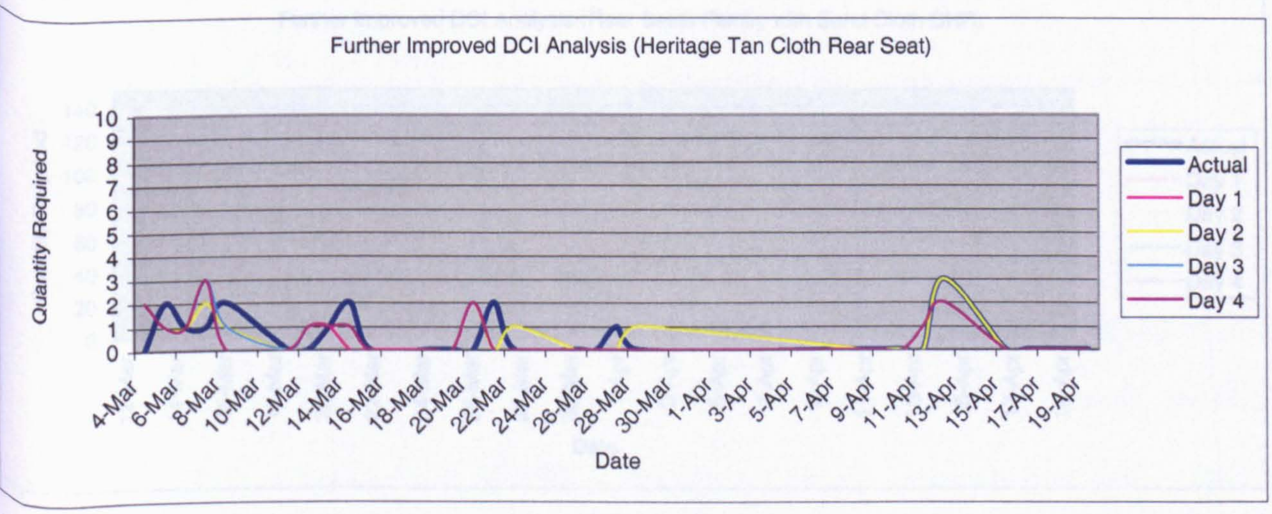




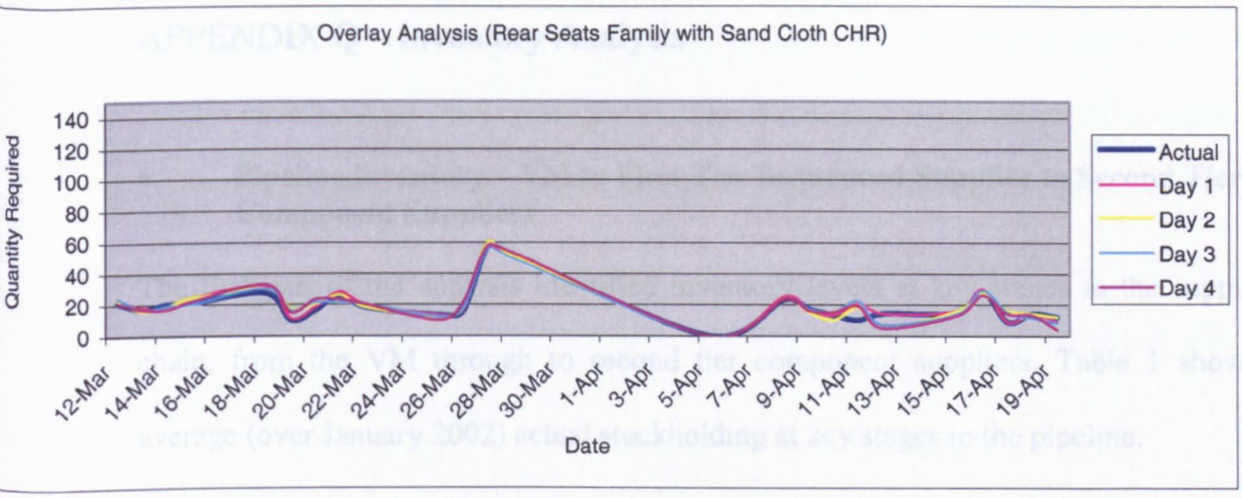
Heritage Tan Cloth Rear Seat:

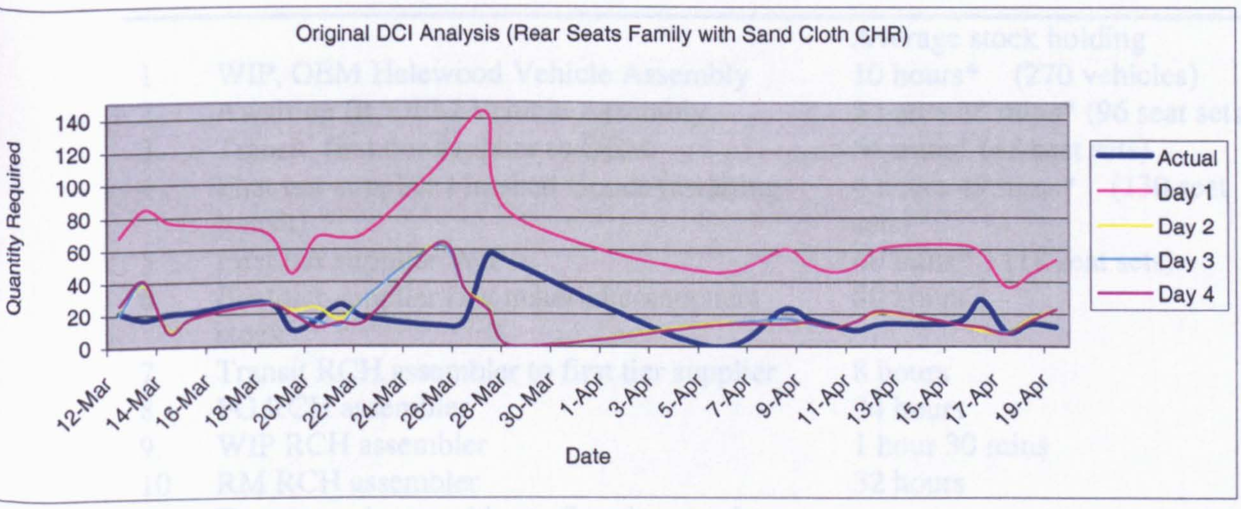


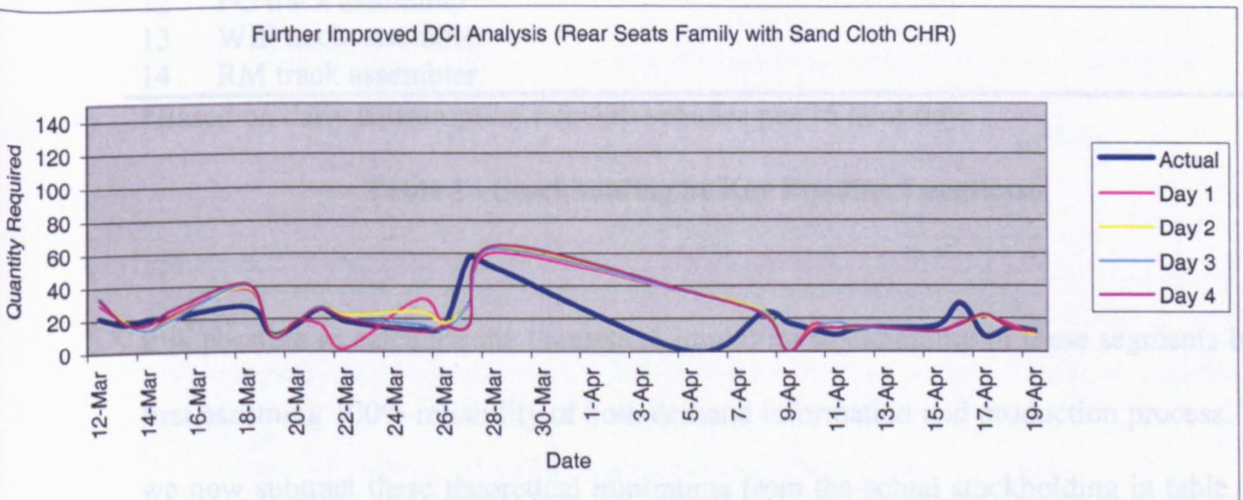




Rear Seats Family with Sand Cloth Centre Headrest:







APPENDIX Q – Inventory Analysis

- **Pipeline inventory – VM to First Tier Sequenced Supplier to Second Tier Component Suppliers**

The first part of the analysis identified inventory levels at key stages in the supply chain, from the VM through to second tier component suppliers. Table 1 shows average (over January 2002) actual stockholding at key stages in the pipeline.

		Average stock holding
1	WIP, OEM Halewood Vehicle Assembly	10 hours* (270 vehicles)
2	Awaiting fit, OEM Vehicle Assembly	3 hours 38 mins* (96 seat sets)
3	Transit, first tier supplier to OEM	54 mins* (48 seat sets)
4	First tier supplier Finished Goods (awaiting transit)	4 hours 49 mins* (130 seat sets)
5	First tier supplier WIP	40 mins* (18 seat sets)
6	First tier supplier raw material/component stock	80 hours
7	Transit RCH assembler to first tier supplier	8 hours
8	FG RCH assembler	24 hours
9	WIP RCH assembler	1 hour 30 mins
10	RM RCH assembler	32 hours
11	Transit track assembler to first tier supplier	
12	FG track assembler	
13	WIP track assembler	
14	RM track assembler	

*Based on daily consumption rate 430 vehicles per 16 hour day

Table 1 - Stockholding at Key Pipeline Locations

It is possible to calculate the theoretical minimum stockholding in these segments by first assuming 100% reliability of both demand information and production process. If we now subtract these theoretical minimums from the actual stockholding in table 1, an estimate can be made of the safety stock held to buffer against uncertainty. This analysis is presented in table 2

This highlights those points in the supply chain branch with the highest levels of 'non-lean' safety stock, and those with the greatest potential for improvement. The analysis in table 2 shows that vehicle assembly through to first tier component/module assembly is comparatively lean. However, up-stream of this, from first tier component stock, through to second tier, stock holding is excessive when compared to calculated minimum 'lean' levels.

		a) Actual stock	b)Theoretical Optimum stock[1]	Non lean stock	Non lean (£000)	Ratio (b/a)
1	WIP, OEM Vehicle Assembly	10 hours	10 hours	0	0	1
2	Awaiting fit, OEM Vehicle Assembly	[2]3 hours 38 mins	40[3] mins	2 hours 58 mins	[4]58.5	0.18
3	Transit, first tier supplier to OEM	[5]54 mins	54 mins	0	0	1
4	First tier supplier finished Goods (awaiting transit)	4 hours 49 mins	1 hour 12mins[6]	3 hours 37 mins		0.25
5	First tier supplier WIP	40 mins	40 mins	0	0	1
6	First tier supplier raw material/component stock	80 hours	18[7] hours	62 hours	[8]308	0.22
7	Transit RCH assembler to first tier supplier	16 hours	16 hours	0	0	1
8	FG RCH assembler	24 hours	8[9] hours	16 hours	4	0.33
9	WIP RCH assembler	1 hour 30 mins	1 hour 30 mins	0	0	1
10	RM RCH assembler	32 hours	18[10] hours	14 hours	3	0.56
11	Transit track supplier to first tier supplier	8 hours	8 hours	0		1
12	FG track supplier					
13	WIP track supplier					
14	RM track supplier					

Table 2 - Lean VS Non Lean stock at key pipeline locations

[1] At this stage an assumption is made that delivery frequencies (**daily** deliveries from 2nd tier to 1st and **multi-daily (avg. 10 per day)** deliveries from 1st to Jaguar) have been optimised considering holding and ordering costs. Theoretical minimum stock is therefore comprised of cycle inventory (to cover any batch rules in the production process; and pipeline inventory (to cover production between deliveries)

[2] 96 seat sets

[3] transit time – unloading to point of fit. Equivalent to 40/16*60 seat sets = 18 seat sets

[4] 96-18= 78 seat sets @ £750 per seat set

[5] 48 seat sets per delivery, i.e. 1 hour 48 mins worth at average production rates. This is max. stock – average divide by 2.

[6] Cycle stock to cover time to accumulate 48 seat sets (1 wagon load) at 3 minutes per seat set, divided by 2 to represent average stock level.

[7] Cycle stock to cover interval between deliveries (16 hours), plus pipeline stock to cover transit time (2 hours)

[8] First tier supplier consume approx. £79,400 stock per day, therefore 62 hours (or 3.88 days) = £308k

[9] Cycle stock to accumulate one wagon load (16 hours), divided by 2 to represent average stock level.

[10] Assuming daily deliveries + transit time.

Total Non Lean = approx. 350 hours (including assumed value for the first tier suppliers other suppliers). Total Actual = approx. 480 hours (including assumed value for the first tier suppliers other suppliers).

From Table T.2 it can be seen that the highest impact of the current information/ operations system redesign is likely to be in the raw material/component stock at the first tier supplier and Finished Goods/Raw materials at second tier suppliers. Adding the 'non-lean' stock from table 2, and extrapolating (based on known stock values) for the remaining 25 first tier suppliers' suppliers gives a total of some 350 hours. Using sample stock value data, an estimated of the value of this non-lean stock can be made as £729K. This figure comprises £354 from table 2 then an assumption has had to be made as to the average stockholding at other first tier suppliers' suppliers. Based on known consumption rates, a figure of £15k per supplier has been used here. Figure 1 shows the total value of the first tier supplier stock during January 2002, which fluctuates from £800K and £425K, with a target of £500K. At average usage rates this target equates to approximately to 4 days of stock.

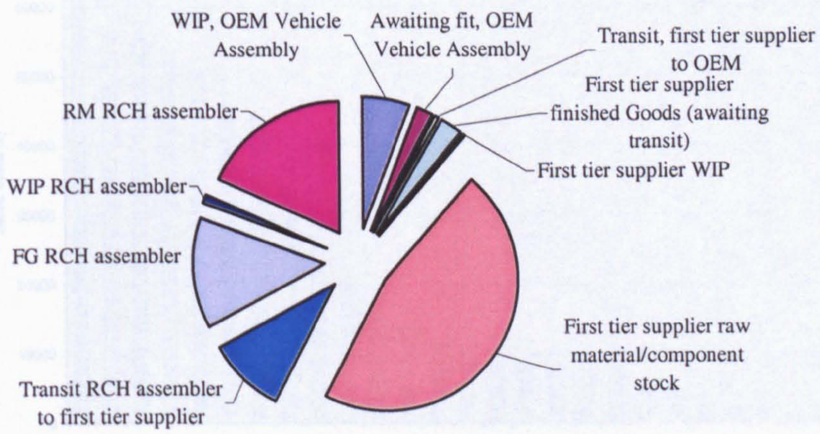


Figure 1 - Average Actual Stock (hours)

It can be seen from figures 2-9, that the components with greater potential for inventory reduction are those with lower and more sporadic usage. For example, Rear Centre Headrest, Heritage Tan Cloth has an average usage rate per day of less than two, and yet stock levels of up to ninety. It is hence these 'stranger' items where more accurate or timelier data is likely to impact the most.

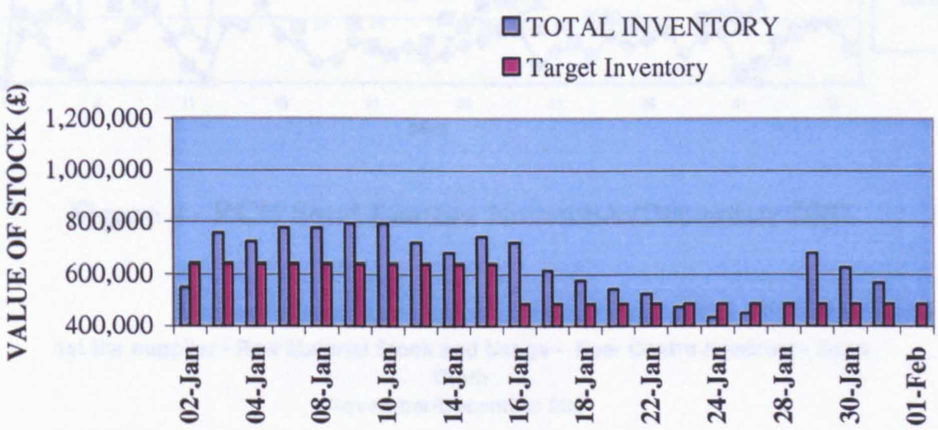


Figure 2 - 1st Tier Supplier Component Stock Jan 2002

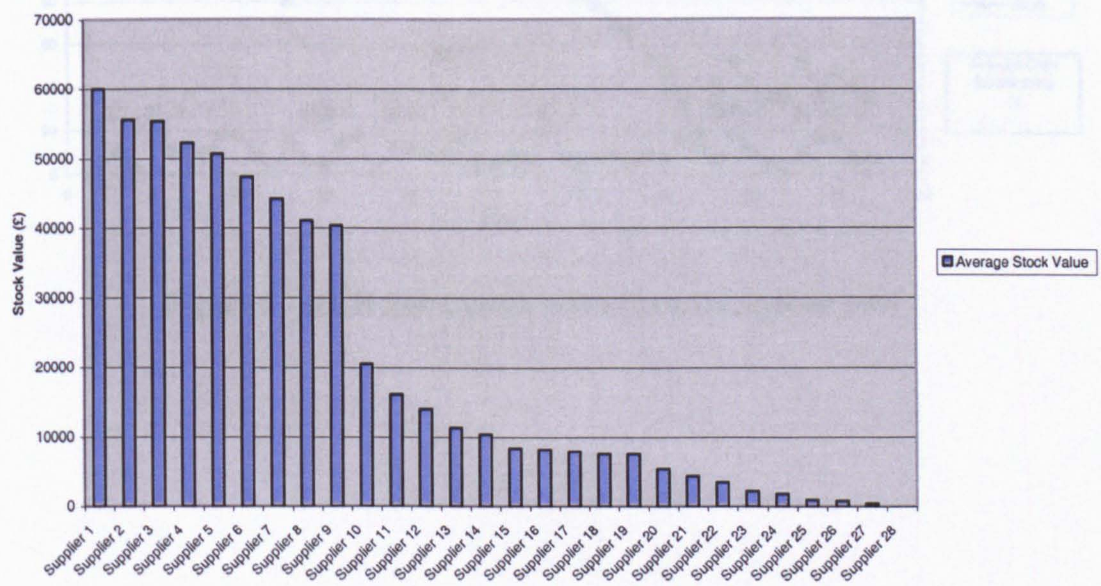


Figure 3 - 1st Tier Supplier Average Component Stock by Supplier (Jan 2002)

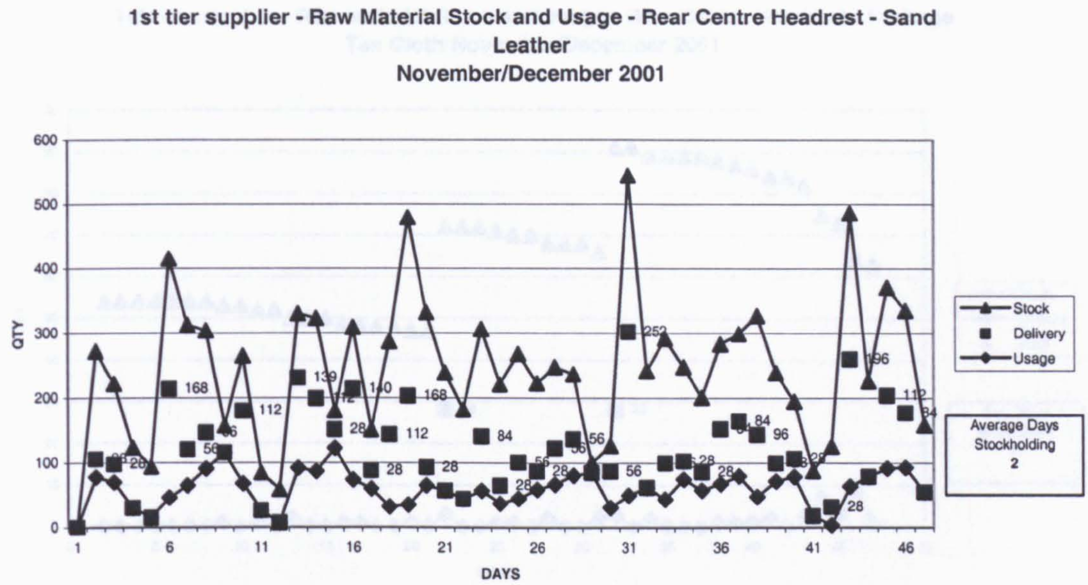


Figure 4 - RCH Sand Leather November/December 2001

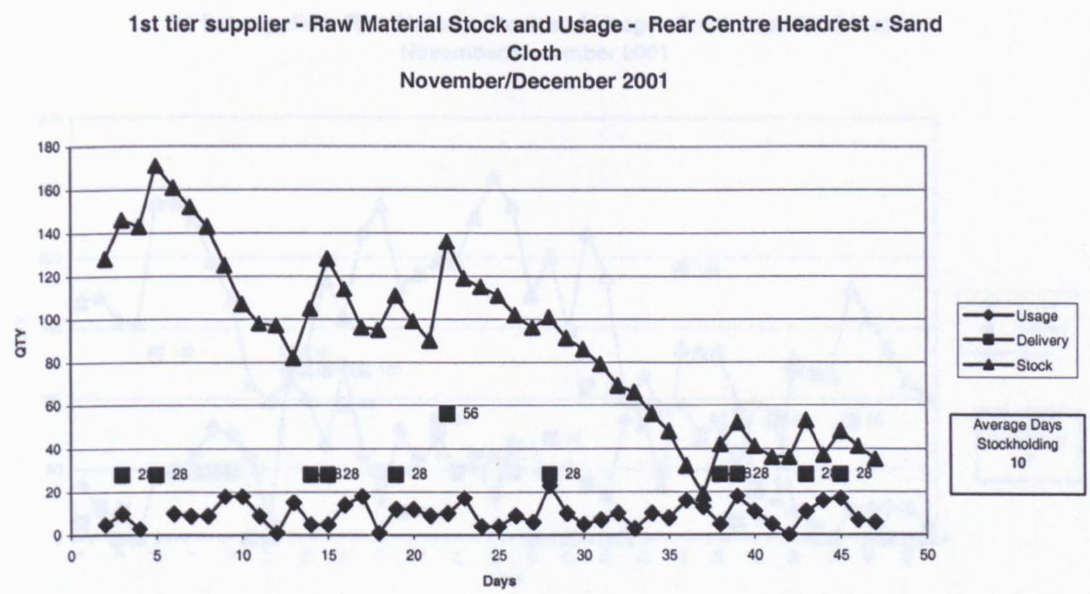


Figure 5 - RCH Sand cloth November/December 2001

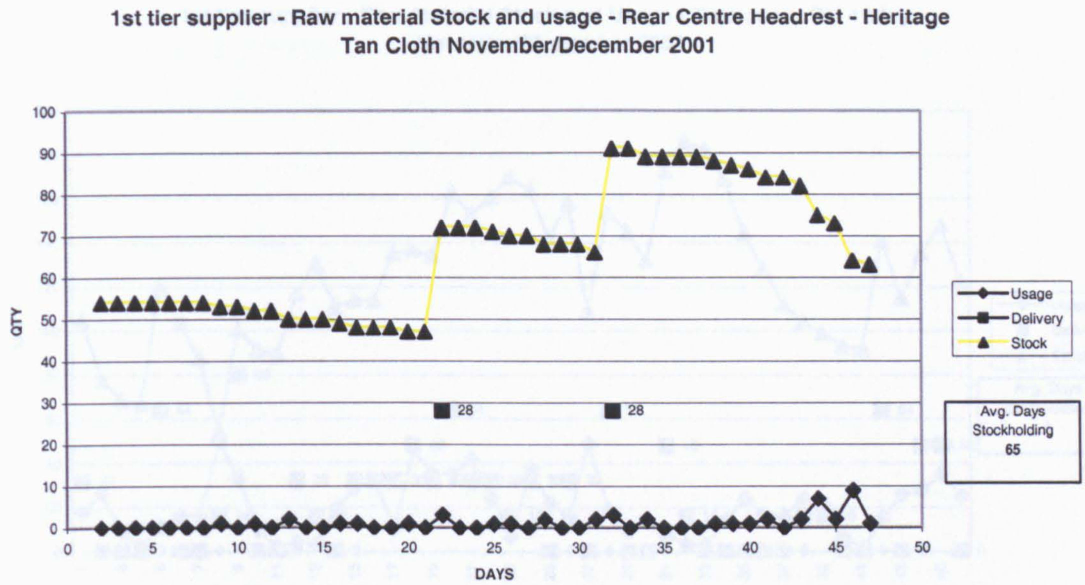


Figure 6 - RCH Sand leather November/December 2001

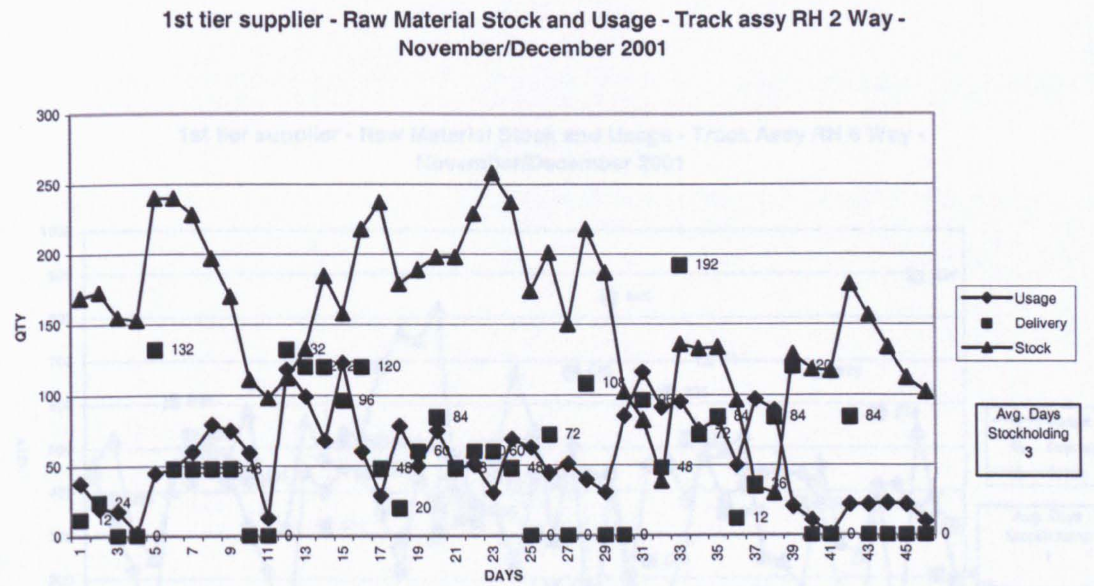


Figure 7 -Track Assembly RH 2Way November/December 2001

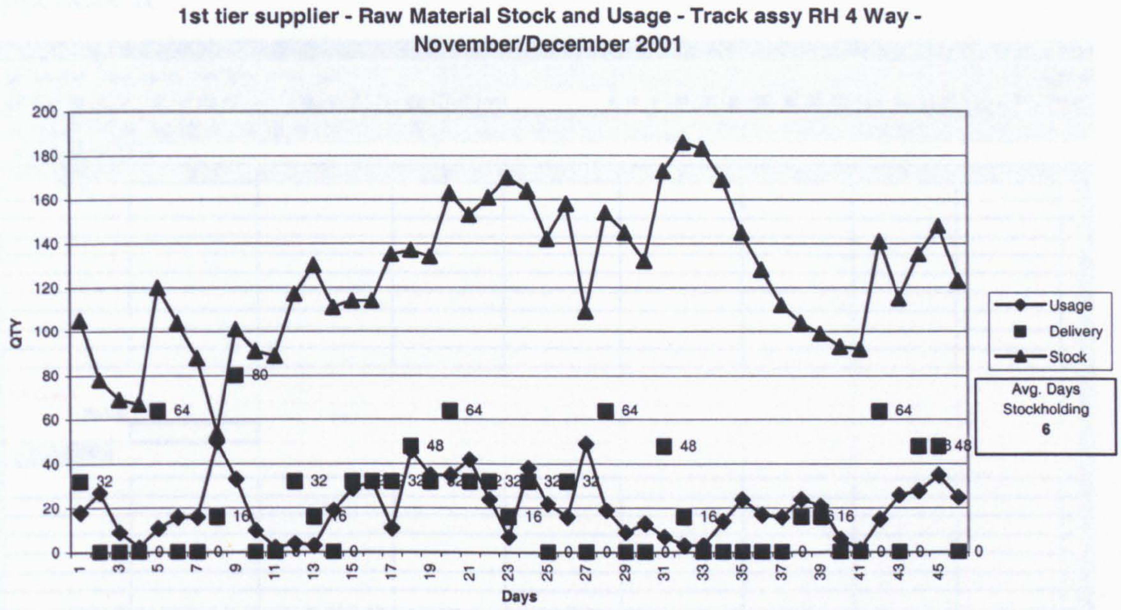


Figure 8 - Track Assembly RH 4 Way November/December 2001

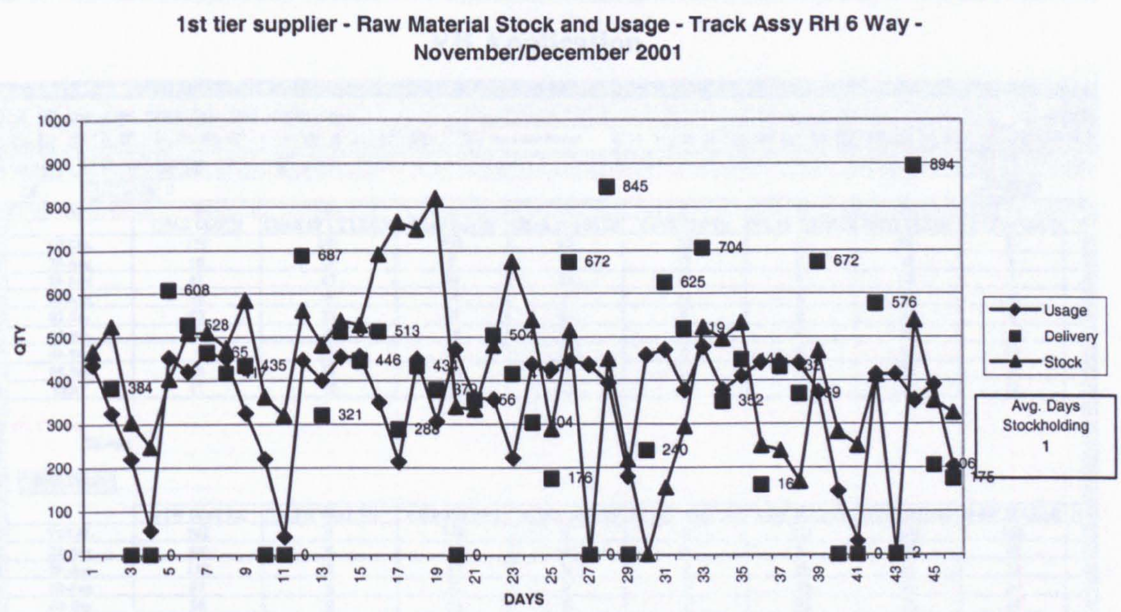
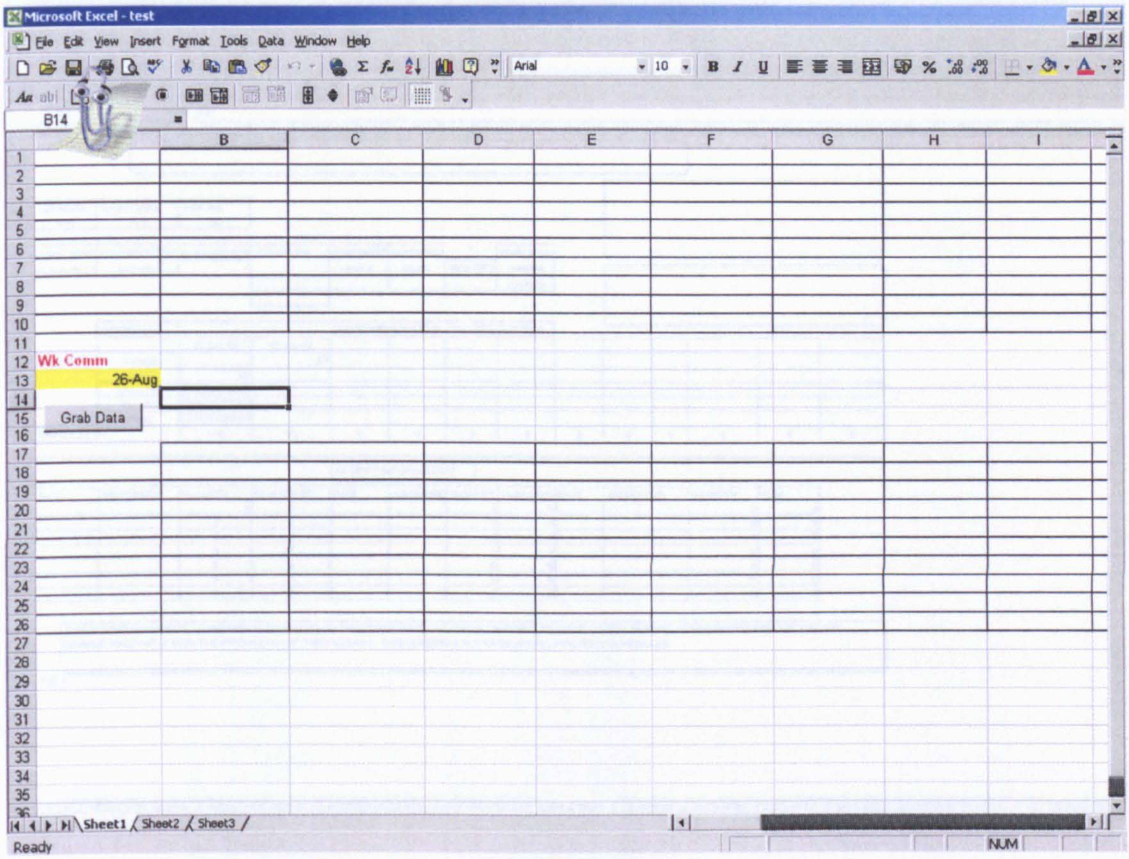
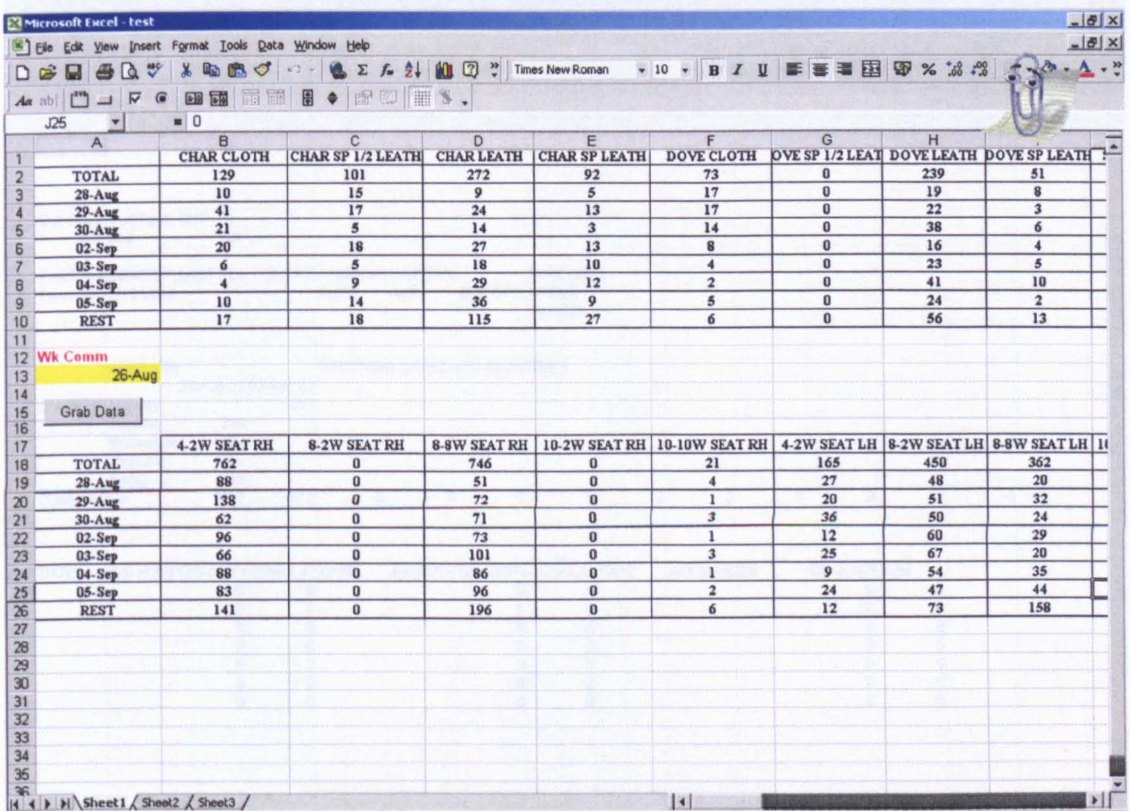


Figure 9 - Track Assembly RH 6 Way November/December 2001

Appendix R



VB Application

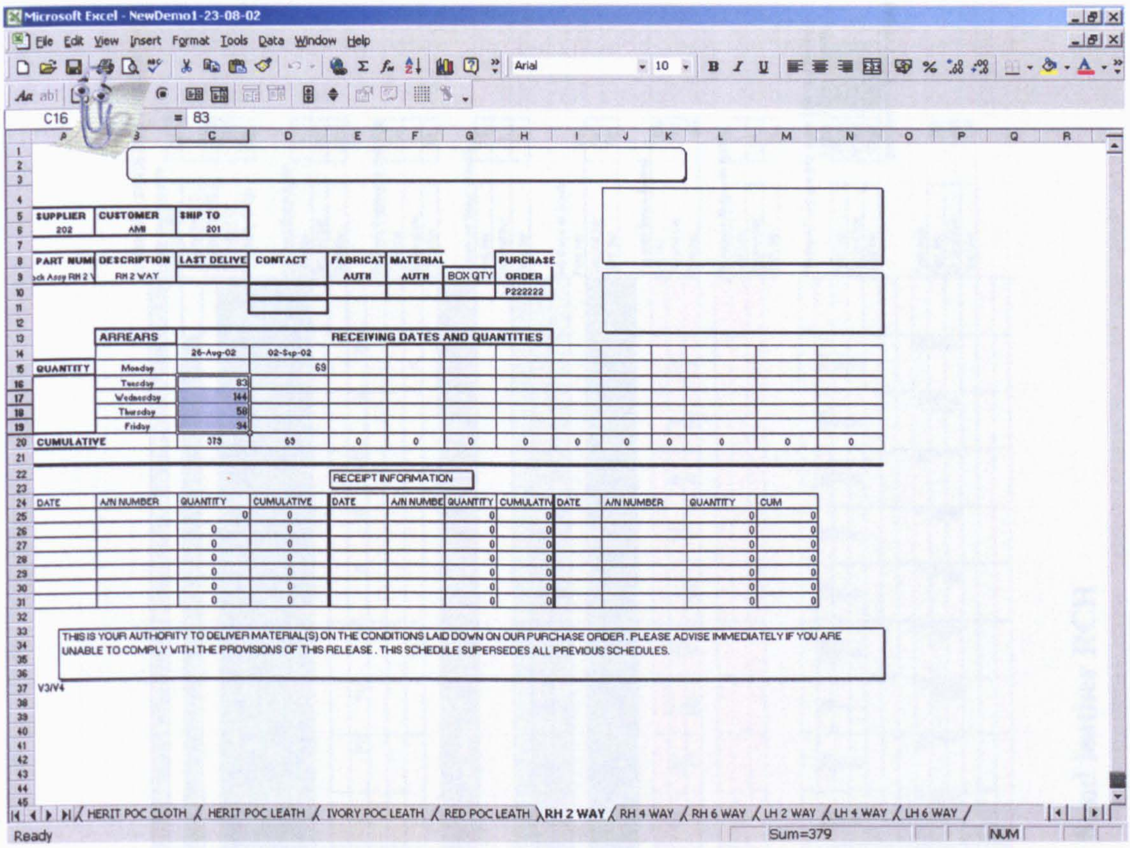


	CHAR CLOTH	CHAR SP 1/2 LEATH	CHAR LEATH	CHAR SP LEATH	DOVE CLOTH	OVE SP 1/2 LEAT	DOVE LEATH	DOVE SP LEATH
TOTAL	129	101	272	92	73	0	239	51
28-Aug	10	15	9	5	17	0	19	8
29-Aug	41	17	24	13	17	0	22	3
30-Aug	21	5	14	3	14	0	38	6
02-Sep	20	18	27	13	8	0	16	4
03-Sep	6	5	18	10	4	0	23	5
04-Sep	4	9	29	12	2	0	41	10
05-Sep	10	14	36	9	5	0	24	2
REST	17	18	115	27	6	0	56	13

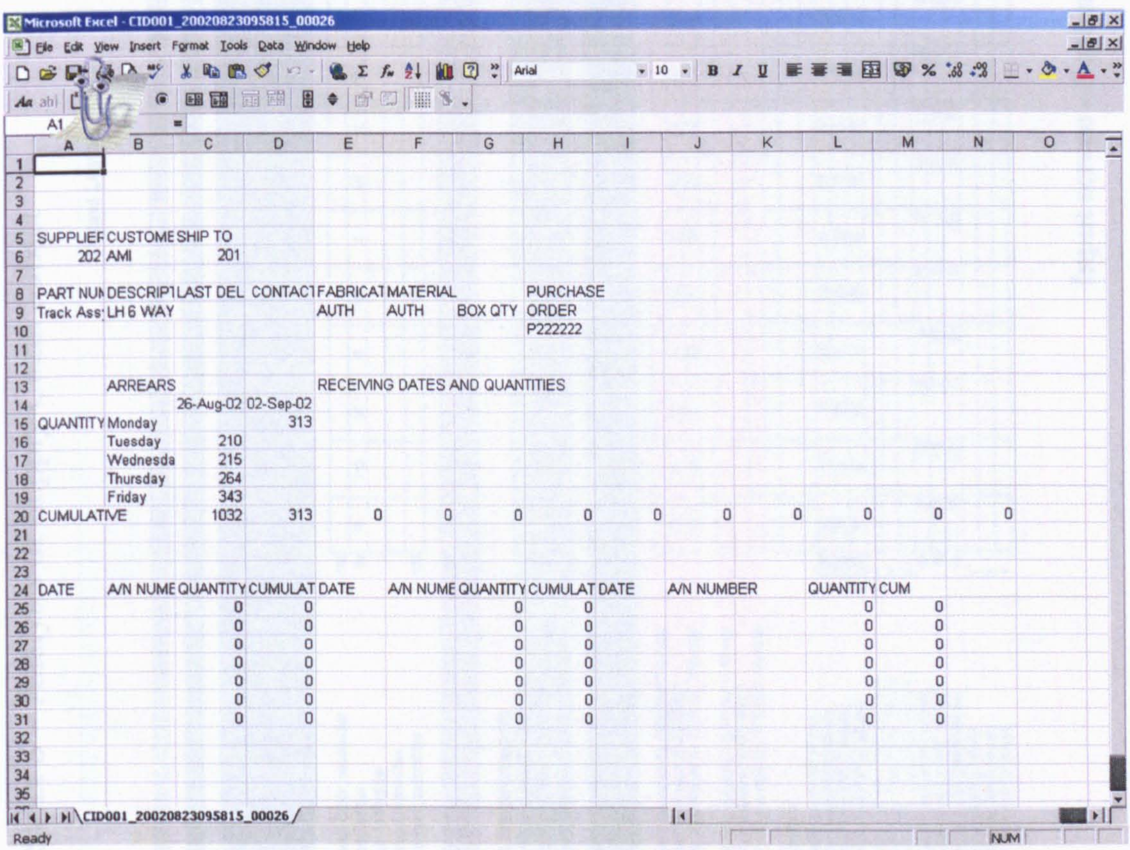
Wk Comm
26-Aug
Grab Data

	4-2W SEAT RH	8-2W SEAT RH	8-8W SEAT RH	10-2W SEAT RH	10-10W SEAT RH	4-2W SEAT LH	8-2W SEAT LH	8-8W SEAT LH
TOTAL	762	0	746	0	21	165	450	362
28-Aug	88	0	51	0	4	27	48	20
29-Aug	138	0	72	0	1	20	51	32
30-Aug	62	0	71	0	3	36	50	24
02-Sep	96	0	73	0	1	12	60	29
03-Sep	66	0	101	0	3	25	67	20
04-Sep	88	0	86	0	1	9	54	35
05-Sep	83	0	96	0	2	24	47	44
REST	141	0	196	0	6	12	73	158

Overlay Data



Populated ISP Spreadsheet



Sample CSV File

Appendix S – Analysis of Supply Chain Subset

Sand Leather (ADX)

		2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	9-Sep	10-Sep	11-Sep	12-Sep	13-Sep	16-Sep	17-Sep	18-Sep	19-Sep	20-Sep	23-Sep	24-Sep	25-Sep	26-Sep	30-Sep
INPUT																					
Analysis Days		2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	9-Sep	10-Sep	11-Sep	12-Sep	13-Sep	16-Sep	17-Sep	18-Sep	19-Sep	20-Sep	23-Sep	24-Sep	25-Sep	26-Sep	30-Sep
OEM																					
Jaguar demand		106	84	86	98	43	104	91	89	128	0	131	98	88	75	0	90	92	66	58	91
FIRST TIER																					
Input Demand from Jaguar schedules																					
Actual usage, First tier																					
MRP Schedule to Woodbridge		28	28	28	28	56	28	112	56	84	84	84	56	56	84	84	28	28	84	56	56
Daily Kanban call to Woodbridge	84	56	112	84	0	168	0	224	0	84	140	112	0	112	112	140	0	0	140	0	196
Raw material stock, Lear Halewood		137	165	163	65	190	86	219	130	88	228	209	111	107	116	256	166	74	148	89	194
SECOND TIER																					
Finished Goods Stock, second tier	140																				
Deliveries, second tier	84	56	112	84	0	168	0	224	0	84	140	112	0	112	112	140	0	0	140	0	196
MRP schedule to third tier																					
Daily Kanban call to third tier																					
Raw material stock, second tier	126					80					80					80					80
THIRD TIER																					
Finished Goods Stock, third tier	200																				
Deliveries, third tier		0	200	0	140	0	80	200	0	320	0	0	240	0	240	0	0	80	0	0	0
GLASS PIPELINE EXPERIMENTS																					
Glass Pipeline Experiment 1 (GPE1) First tier																					
Glass Pipeline Experiment 1 (GPE1) Woodbridge	92	115	83	104	1	118	95	95	122	122	114	103	100	85	0	80	71	83	73	0	63
Glass Pipeline Experiment 1 (GPE1) Remploy 92	115	83	104	1	118	95	95	122	122	114	103	100	85	0	80	71	83	73	0	63	
Glass Pipeline Experiment 2 (GPE2)* First tier																					
Glass Pipeline Experiment 2 (GPE2)* Woodbridge		84	84	112	0	196	112	0	112	84	140	0	112	84	0	140	28	84	84	0	112
Glass Pipeline Experiment 2 (GPE2)* Third tier		120	120	0	200	0	100	220	0	100	80	100	20	20	160	0	100	60	20	140	0
Glass Pipeline Experiment 3b (GPE3b)* First tier		84	84	112	0	196	0	112	112	84	140	0	112	84	0	140	0	112	84	0	112
Glass Pipeline Experiment 3b (GPE3b)*																					
Glass Pipeline Experiment 3b (GPE3b)* Third tier		120	120	0	200	0	180	20	120	100	80	140	0	0	160	0	140	0	40	140	0
Glass Pipeline Experiment 3a (GPE3a)* First tier																					
Glass Pipeline Experiment 3a (GPE3a)*																					
Glass Pipeline Experiment 3a (GPE3a)* Third tier																					
RESULTING STOCK																					
First tier raw material stock if MRP followed	102	111	110	128	31	106	97	101	134	128	242	214	216	213	138	218	199	190	197	139	111
First tier raw material stock if GPE1 followed	102	80	80	106	8	161	169	78	101	57	197	66	80	76	1	141	79	71	89	31	52
First tier raw material stock if GPE2 followed	102	80	80	106	8	161	57	78	101	57	197	66	80	76	1	141	51	71	89	31	52
First tier raw material stock if GPE3b followed	102																				
Second tier finished goods stock if GPE1 followed	x																				
Second tier Finished goods stock if GPE2 followed	x																				
Second tier Finished goods stock if GPE3b followed	x																				
Second tier raw material stock if GPE1 followed	41	9	30	-73	44	21	21	48	48	40	29	26	11	-74	6	-3	9	-1	-74	-11	-74
Second tier raw material stock if GPE2 followed	41	77	113	1	201	5	-7	213	101	117	57	157	65	1	161	21	93	69	5	145	33
Second tier raw material stock if GPE3 followed	41	77	113	1	201	5	185	93	101	117	57	197	85	1	161	21	161	49	5	145	33
Third tier finished goods if GPE1 followed	x																				
Third tier finished goods if GPE2 followed	x																				
Third tier finished goods if GPE3 followed	x																				

CURRENT STATE PARAMETERS

Safety stock targets	
First tier RM	56
Second tier FG	
Second tier RM	100
Third tier FG	200
Avg daily usage =	**80.9**
Delivery Batch sizes	
First tier	1
Second tier	28
Third tier	20
Delivery frequency (per day)	
First tier	10
Second tier	1
Third tier	0.5
Transport times (hours)	
First tier	0.3
Second tier	3
Third tier	3
FG Days of Stock	
First tier	0.4
Second tier	1.5
Third tier	2.8
Process times (hours)	
first tier	0.6
Second tier	1.5
Third tier	2.5
Transport distances (miles)	
First tier	1
Second tier	34
Third tier	15

Transport cost per trip (from RHA cost tables)

	3.5 ton	7.5 ton	13 tonne
First tier	109.41	133.6	150
Second tier	68.508	87.44	98.5
Third tier	60.68	75.74	85.1

(time costs = 109/day, mileage = 20.6p/m

Part cost

First tier	750
Second tier	20
Third tier	8

Input screen - September Sand leather RCH

Sand Leather Scorecard

Optimisation Parameters

SUPPLY CHAIN BEHAVIOUR MEASURES

	Current	GP1	GP 2	GP3
Synchronisation index - overall (%)	38.6	78.7	51.6	49.3
First tier	96.0	96.0	96.0	96.0
Second tier	13.4	70.0	43.0	39.5
Third tier	6.4	70.0	15.8	12.4
Bullwhip measure (OEM - Tier 3)	3.4	1.1	2.1	2.2
RESPONSIVENESS MEASURES				
**Forecast accuracy (%)				
First tier	35.7	27.5	30.8	44.0
Supply chain cycle times - overall (days)	9.2	5.7	6.6	6.2
First tier	2.3	2.3	1.5	1.4
Second tier	3.8	1.4	2.5	2.4
Third tier	3.1	2.0	2.6	2.3
Pipeline Inventory - overall (days of stock)	8.12	4.66	5.52	5.11
First tier RM	1.82	1.87	1.06	0.98
Second tier FG	1.5	0.9	1.2	1.1
Second tier RM	2.00	0.21	1.01	1.12
Third tier FG	2.8	1.7	2.2	2.0
Value adding\Non value adding (%)	13.3	23.2	19.6	21.2

RELIABILITY MEASURES

	Current	GP1	GP2	GP3
Stockout incidents - Overall	0	7	1	0
First tier RM days stockout	0	0	0	0
Second tier RM days stockout	0	7	1	0
Backorders - Overall	0	310	7	0
First tier RM Total backorders	0	0	0	0
Second tier RM Total backorders	0	310	7	0
COST MEASURES				
Transport	£4,372	£4,372	£4,372	£4,372
First tier	£2,855	£2,855	£2,855	£2,855
Second tier	£939	£939	£939	£939
Third tier	£579	£579	£579	£579
Inventory	£911	£613	£620	£567
Interest on capital cost	£49	£33	£34	£31
Storage	£85	£57	£58	£53
Obsolescence and depreciation	£706	£475	£481	£439
Opportunity cost	£71	£48	£48	£44
Yearly Inventory saving	x	£3,575	£3,491	£4,129
Average yearly cost/benefit	x	£3,575	£3,491	£4,129
Implementation cost	x	£6,356	£1,978	£1,978
Return on Investment	x	0.56	1.76	2.09
Payback period (years)	x	1.78	0.57	0.48

	Current	Optimisation Experiment
Safety Stock Targets		
First tier RM	56	74
Second tier FG	56	x
Second tier RM	150	87
Third tier FG	120	x
Batch sizes		
First tier	1	1
Second tier	28	28
Third tier	20	20
Starting stock		
First tier RM	137	102
Second tier FG	140	x
Second tier RM	126	41
Third tier FG	200	x
Delivery frequency (per day)		
First tier	10	10
Second tier	1	1
Third tier	0.5	0.5
Transport times (hours)		
First tier	0.3	0.3
Second tier	3	3
Third tier	3	3

Output Screen - September Sand leather RCH