AN EVALUATION OF MANAGING DIVERSITY IN THE SUPPLY CHAIN: A CASE STUDY OF AN ELECTRICAL WHOLESALE DISTRIBUTOR IN THE UK

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ABSTRACT

The method of understanding and managing diversity within a business is at the heart of the reasoning behind the concept of 'supply chain segmentation'. The overarching principle is to find economic segments within the diverse product and customer mix and to match differentiated strategies accordingly. The aim is to prioritise resource to the products and customers which contribute the highest proportion of sales and to reduce operational costs to those that contribute the lowest proportion of sales, whilst matching service level requirements. In essence this strategy balances supply chain costs for individual products against their value to the business. As a result overall costs are reduced and subsequently profits are increased.

This research study pulls together the extensive documentation which is available regarding many supply chain concepts and principles into a single approach. A critical evaluation of the current research is undertaken which concludes that the majority of supply chain segmentation is currently focused within the area of supply chain design and has parallels with the established lean and agile concepts. It is shown that supply chain segmentation can be considered a holistic supply chain strategy and by following a structured framework can be applied to all planning levels, strategic, tactical and operational.

The drive of the research was to consider which factors can be used to segment both products and customers. This was tested within an operational environment and it is shown how different strategies can be applied accordingly to each segment. It is proposed by Smith and Slater (2001) that products can be assigned inventory strategies depending on which one of six segments they fall within. The results of a variability index and volume calculations are the determining factors for the segmentation process. It is proposed within this study that an added dimension of lead time variability and a coefficient correlation calculation to determine the level of variability will produce a more accurate inventory model.

A segmentation strategy, which combines different supply chain and research methodologies, was applied to a company called Newey and Eyre, which operates within the electrical industry. This is presented within the case study chapter. The practical research programme was designed as three separate research projects and these represent the different planning levels of the business. The first and second research project was carried out within the South West region of the business, where changes were made to the design of the supply chain and to the design and layout of a regional distribution centre (RDC) based at Avonmouth respectively. The third research project is based upon analysis which was undertaken of the company's purchasing and inventory system. A discrete event simulation (DES) model of this system was created and this provided the platform to test a number of segmentation strategies against the current system of operation.

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LIST OF FIGURES

GLOSSARY

ABC	**Activity based costing**
BFG	**Branch gained benefit**
BOH	**Balance on hand**
CDC	**Central distribution centre**
CO	**Customer order**
CRP	**Continuous replenishment program**
DO	**Distribution order**
DPP	**Direct product profitability**
DRP	**Distribution Resource Planning**
ECR	**Efficient consumer response**
EDI	**Electronic data interchange**
EOQ	**Economic order quantity**
EPOS	**Electronic point of sale**
ERP	**Enterprise Resource Planning (ERP)**
FMS	**Flexible manufacturing systems**
GDP	**Gross national product**
HP	**Hewlett Packard**
JIT	**Just-in-time**
KPI	**Key performance indicator**
LOB	**Lines of billing**
MAD	**Mean absolute deviation**
MRP	**Materials Requirements Planning**
MRP II	**Manufacturing Resource Planning II**
P&I	**Purchasing and inventory**
PO	**Purchase order**
PVD	**Product value density**
QR	**Quick response**
RDC	**Regional distribution centre**
ROCE	**Return on capital employed**
ROP	**Reorder point**
ROI	**Return on investment**

SCC	**Supply chain council**
SCM	**Supply chain management**
SCOR	**Supply chain operations reference**
SD	**Standard deviation**
SKU	**Stock keeping unit**
TNC	**Trans-national company**
VMI	**Vendor managed inventory**

CONTENTS

Chapter 3: An evaluation of mathematical modelling and inventory management literature

Chapter 4: Corporate context

Chapter 5: Research design and research methodology

Chapter 6: A case study of the application of a supply chain segmentation strategy

Chapter 7: Conclusion

CHAPTER 1

1 INTRODUCTION

1.1 Strategic alignment

Businesses are complex dynamic systems, operating within non-linear environments. The term 'business' is defined by Ansoff (1987, p.21) as an "economically or money motivated social organisation". Businesses are driven by strategic plans which are conceived and implemented within the tactical and operational levels of the organisation, executed through a myriad of processes and decision-making, by a combination of technological and human-resource. They operate within markets which are diverse, and where the needs and service expectations vary drastically, as does the perceived values customers have of a company. There is an implicit relationship between the diversity of the market and the diversity within the organisation. This external and internal diversity is a key driver in the formulation of strategies which ultimately determine how a business functions operationally and performs in the market.

Strategies are formulated within different levels of an organisation (Hines, 2004). At the top level of organisations, business strategies are concerned with "the purpose and direction of the enterprise and hence its fundamental goals, activities, and the polices it selects in order to attain its objectives" (Bennett, 1999, p.3). Designed in conjunction with the business strategy, supply chain strategies set out the framework whereby the overall objectives are met operationally. This can also be seen as the direction in which the "supply chain should operate in order to compete" (United Parcel Service of America, 2005, p.1). A supply chain incorporates all of the activities involved in the supplying of a product or service from its creation through to the customer.

A definition is provided by Hines (2004, p.5):

> "The supply chain encompasses all activities associated with the flow and transformation of goods (products and services) from initial design stage through the early raw material stage, and on to the end user."

In the context of this research study a supply chain strategy is defined in the broader sense. It is concerned with the long term direction and goals of the business and how the supply chain should operate in order to compete. The approach is consistent with that of Harrison and van Hoek (2005, p.24) who have identified five important characteristics of strategy:

- time horizon: this is long-term rather than short-term;
- pattern of decisions: decisions are consistent with each other over time;
- impact: changes are significant rather than small-scale;
- concentration of effort: the focus is on selected, defined capabilities rather than 'broad brush';
- comprehensiveness: all processes in the supply chain are coordinated.

The term "supply chain management" (SCM), which frequently appears throughout this thesis, is sometimes mistakenly used by others interchangeably with the term "supply chain strategy"[1]. The management of the supply chain has a short to medium planning horizon where the main aims focus on reducing costs and satisfying customer requirements. Levi *et al* (2004, p.2) place this into context:

[1] A detailed explanation of these definitions and the link between strategy and competitiveness are provided within the context of the literature review in Chapter 2.

> "Supply chain management is a set of approaches used to efficiently integrate suppliers, manufacturers, warehouses, and stores so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time in order to minimize system wide costs while satisfying service-level requirements".

The design principle of a supply chain strategy is to support the plans laid out within an organisation's business strategy. Gattorna *et al* (2003, p.25) surmise that "the advantage of aligning the supply chain strategy to the business strategy is that it can increase revenue, reduce costs and improve competitive advantage". The importance of aligning strategies and simple methods of strategy development are proposed in 'The importance of aligning strategies' produced by The United Parcel Service of America (2005). The premise of the paper showed the importance that should be placed on the development of a supply chain strategy as a requisite and as a separate entity to the business strategy. It is put that the supply chain strategy is "not simply a linear derivative of business strategy" but can at best be "the enabler of the business strategy" (United Parcel Service of America, 2005, p.1).

To achieve strategic alignment the supply chain strategy has to be fully implemented throughout the business. This means that the operation should function to satisfy the requirements of the market to fully maximise profit. Chopra and Meindl (2007, p.25) highlight a number of key points that are involved in successfully achieving strategic alignment:

1. the competitive strategy and all functional strategies must fit together to form a coordinated overall strategy. Each functional strategy must support other functional strategies and help a firm reach its competitive strategy goal;

2. the different functions in a company must appropriately structure their processes and resources to be able to execute these strategies successfully;

3. the design of the overall supply chain and the role of each stage must be aligned to supply chain strategy.

1.2 Managing diversity using supply chain segmentation

The aim of a business is to maximise profits, the difference between sales and operational costs. In the context of the supply chain the objective is to "maximise the overall value generated" (Chopra and Meindl, 2007). This is not easily achieved because the measures of cost and customer service trade-off against each another. The cost of supplying a customer increases exponentially as the level of servicing all customers reaches the maximum level (Christopher, 1998). This is further complicated because businesses are diverse; they supply many different types of products and services to many different customers who have many different needs. The financial value to the business and the costs which are incurred vary amongst different products and customers.

The method of understanding and managing the diversity within a business is at the heart of the reasoning behind the concept of 'supply chain segmentation'. The overarching principle is to find economic segments within the diverse product and customer mix and to match differentiated strategies accordingly. In essence, the strategy balances supply-chain costs for individual products against their value to the business. The strategies are selected depending on the properties of each segment. The aim is to prioritise resources to the products and customers which contribute the highest proportion of sales and to reduce operational costs to those that contribute the lowest proportion of sales, whilst matching service level requirements. As a result overall costs are reduced and subsequently profits are increased.

The outcome is that the supply chain is correctly aligned to the market and competitiveness increased. Chopra and Meindl (2007, p. 23) show that a competitive strategy "targets one or more customer segments and aims to provide products and services that satisfy these customers' needs". This research study investigates how this supply chain strategy can be applied practically to a business and to assess the benefits that this can achieve.

Fuller *et al* (1993) laid out the foundations for a concept of segmentation within the supply chain. The notion of this paper is that where an averaging of logistics functions exists, a 'diseconomy' is created when uniform standards and policies are applied (Fuller *et al*., 1993, p.90) – 'a one size fits all approach'. They argued that it is suboptimal to treat each product and customer as equal when in fact there is much diversity. The supposition is that "customers who needed specialized products quickly but unpredictably tended to be underserved, while customers for more commodity-like products were overcharged" when a single approach is applied.

Supply chain segmentation strategy in recent years has been adopted as a method for supply chain design (Christopher and Towill, 2002; Fisher, 1997; Lee, 2002; Mason-Jones *et al*., 2000; Naylor *et al*., 1999: Payne and Peters, 2004). Lovell *et al* (2005) build upon the methodology laid out by Fuller *et al* (1993) and embrace segmentation as a strategy. Lovell *et al* (2005) go further than Fuller *et al* (1993) by using many more characteristics in the segmentation process and increase its application to different aspects of the supply chain.

1.3 Motivation for research

Since the 1990's supply chain management (SCM) has grown in importance and has become one of the main sources of competitive advantage for companies. Developed through a formal strategic planning process supply chain segmentation provides a smart way for companies to operate at all levels of the business. The importance of segmentation has been stressed for some time (Fuller *et al*, 1993; Fisher, 1997; Lee, 2002; Payne and Peters, 2004). There is a great opportunity for many businesses to use smarter ways of purchasing, storing and delivering their products.

In the current economic climate (2008-2010) it has become necessary for companies to stay in business by seeking to maximise their resources and focus their services in order to maximise profit rather than sales. By adapting segmentation strategies companies can reduce costs by ensuring their assets and operational resources are used efficiently and that the right products are delivered to the right customers at the right time. One management approach is to target product lines through rationalisation and resources may be concentrated on the products which add real value to the business.

Experience of supply chain operations has shown that it is quite common for companies to suffer from mismanaged inventory. This can result in stock excesses, obsolescence and stock-outs. The level of stock above that which the business needs to hold is known as excess stock. A product becomes obsolete when it is unlikely that it cannot be sold through the usual channels of distribution. A product stock-out occurs when a product that is required to be held is not available for a customer to purchase when ordered.

The pitfalls of failing to control stock were experienced by Marks and Spencer in 2005 when they wrote off £1.3 billion of obsolete products creating a fall in annual pre-tax profits of 19% (The Daily Telegraph, 25th May 2005). It is reported by Corsten and Gruen (2004, p.26) after examining the results of analysis taken from 71,000 consumers from 29 different countries, that there is a worldwide average of 8% stock-outs and of these 21% to 43% of customers would go elsewhere to make a further purchase. It is concluded that mismanaged inventory was at fault for 72% of` the stock-outs, indicating the importance of properly managed inventory (Corsten and Gruen, 2004, p.26). It is shown that “retailers should focus more on fixing the holes in high-loyalty inventories than on reducing stock-outs across the board” (Corsten and Gruen, 2004, p.26). This means that businesses should try to increase service level for inventories which add the greatest value. Using J. Sainsbury as an example it is shown that by concentrating on tracking their top 2,000 items, to ensure stock-outs do not occur, it led to a 2% increase in sales (Corsten and Gruen, 2004, p. 28).

In the past I have worked on a number of logistics projects where a segmentation approach was applied. These projects were carried out within different logistical areas of the business. At the time there was not a realisation that the principles applied could be formalised into a segmentation methodology. Research by Smith and Slater (2001) had highlighted that a segmentation approach could be formalised. It is proposed by Smith and Slater (2001) that stock segmentation analysis can be used to design supply chain routes. This is because products have different demand characteristics and should therefore be managed differently within the supply chain.

These factors gave me the motivation to want to add to the current literature on the subject by designing a comprehensive framework which could be applied as a holistic strategy. The aim is that this would be carried out throughout the supply chain and tested within a working environment. Smith and Slater (2001) propose that products can categorised into six sectors using the characteristics of sales volume and variability and then appropriate logistic strategies can be applied. The focus is to test the effectiveness of this strategy and to consider whether a number of different factors can be applied in the segmentation approach.

A further motivation is to show that the many problems faced in the management of supply chains can be solved or reduced significantly by implementing a segmentation strategy. There are not only fiscal benefits to be gained; the methodology can provide insights into the business, such as the value of individual products and customers and it can also highlight supply chain issues. Once implemented throughout the operation it can increase productivity, customer service levels and reduce levels of stock holding. When supply chain strategies fail to manage inventory correctly product margins are reduced, customer sales lost or products may have to be sold at reduced prices or written off when they become obsolete.

1.4 Supply chain segmentation: a practical approach

The instability of markets, the multifaceted layers of organisational structure, extensive resources and the many interactions between entities creates a high level of complexity for businesses to manage. This is supplemented by the many and often complex information systems and myriad of processes and procedures which are involved in the business operation. In contrast to this statement there are many strategic choices and management decisions which would respond to common sense, and which are often lacking in strategic thinking. In reality it has been noted that “common sense is quite rare” (Voltaire, 1838, p.866).

My experience of operations at companies such as Comet, Exel and Brakes Logistics has shown that many working methods are not designed using the most suitable and clearly evident approaches. This is a result of inadequate decision-making found at some, or all levels, of the business. At worst, businesses fold or, perhaps as is more likely, will lead to deficiencies within the operation, adding unnecessary costs and subsequently reducing potential profits. There are many reasons for this; a lack of foresight; skill shortages; risks associated with change; resistance of management arising from an embedded culture; or simply a lack of endeavour.

It is important that companies seek to apply optimum approaches at all levels of the business. It is particularly crucial that supply chain strategies are designed correctly. This is because strategic mistakes at higher business-levels create detrimental impacts which are felt increasingly downwards throughout the business hierarchy. The largest problems present themselves manifestly to the operation and to the ‘man on the ground’. For example the strategy at Keenpac Ltd, whilst working there during 2001, was to ensure that every customer-order was fulfilled in full and delivered when and how the customer wanted it. Pressure was put on the purchasing team which meant that products were ordered far in excess of customer demand. This created congestion in the warehouse, due to customer orders not being received in full or on time, and a consequent reduction in operation productivity. Bennett (1999) shows that decisions made at the strategic level set a precedent for the lower echelons. The effects cascade down through the business to affect functional, divisional and departmental operations (Bennett, 1999).

There are a number of established supply chain concepts which are fundamentally common sense approaches. In the 1980’s “lean production” was developed at Toyota. The company identified seven different types of wastes prevalent in their supply chain (Shingo, 1989). The aim was to remove these and reduce operational costs. The principle of what is known as just-in-time (JIT) emerged from this process. This is where “no activity should take place in a system until there is a need for it” (Christopher, 1998, p.179). It clearly makes logical sense that operational costs are at a minimum if this is achieved; it is one through which many businesses fail to achieve. This is also true for the concept of supply chain segmentation. The approach provides a practical solution to the way supply chains operate.

1.5 Research framework

1.5.1 Hypothesis

The concepts which were discussed in the previous sections have been put together to form the following hypothesis.

This research study tests the hypothesis that the stock management aspects of supply chain strategy, tactics and operation can be applied by stock and customer segmentation analysis to improve overall supply chain performance.

The majority of supply chain management literature that covers some aspects of segmentation, either intentionally or not, tends to be as part of a larger discipline, such as inventory management, supply chain and network design, warehouse design and management, transport and marketing. Whether through conscious efforts or through the application of a logical framework, organisations have always responded to market diversity by tailoring their products and approaches to meet the needs of their customers. An example of this can be found through investigation of the layout of a warehouse that is designed to maximise productivity by prioritising where particular products are located according to the number of sales that are generated. Further examples of this can are found within purchasing departments when different techniques are used to forecast sales for different types of products depending upon historical sales patterns.

It is uncommon for segmentation to be a key supply chain strategy which has undertaken a formal planning process and which is then carried out within the different planning levels of the business; strategic, tactical and operational. This is comparable to the decision phases in a supply chain strategy or design, planning and operation (Chopra and Meindl, 2007, p.9). Fuller *et al* (1993) shows the essence of what a supply chain segmentation strategy is and how it can benefit businesses and studies such as Lovell *et al* (2005) provide a working example.

The need for this research is to expand on these studies, providing further examples of this approach. It sets out to show that a segmentation strategy can be applied as a holistic strategy, which is implemented throughout the different levels of the business. This research study attempts to draw together studies such as those that apply a segmentation approach for supply chain design (Christopher and Towill, 2002; Lee, 2002; Mason-Jones *et al*., 2000; Naylor *et al*., 1999; Payne and Peters, 2004) and inventory management (Smith and Slater, 2001) into a sophisticated methodology.

1.5.2 Research aims

Supply chain segmentation is an underused method (Godsell, 2009; Lovell *et al*, 2005) but one which, as this research study shows, reduces costs significantly, increases customer service and which can subsequently lead to significant increases in competitiveness and profits. Companies tend to have a finite amount of assets and available resource so it is imperative that these are used in the most effective and economic way – this is fundamentally what segmentation based strategies try to achieve.

The research study seeks to drive forward the concept of supply chain segmentation as a comprehensive supply chain strategy. Articles such as by Fuller *et al* (1993) and Fisher (1997) promote the strategy but provide only anecdotal evidence and are lacking in methodological detail. This empirical study aims to add quantitative evidence, rigour and a clear methodology, to give further credence to the subject.

The foundations for this research study were primarily based upon the research developed by Smith and Slater (2001). It is proposed that supply chain routes can be designed using some key logistics characteristics. Furthermore, it is suggested that a logistics profile can be designed using six categories of products. The aim is to test this approach and to consider different factors and the possibility of using more segments. The intention is to wider this approach to include the segmentation of customers.

The main aims of this research study are as follows:

- to evaluate the principles of supply chain management and strategy and review the current literature which either indirectly or directly can be classed as a supply chain segmentation approach;

- to provide a methodological framework building on the research of Fuller *et al* (1993) which incorporates a supply chain segmentation approach bringing together established supply chain management techniques;

- to show that a segmentation strategy can be applied throughout the business at all planning levels;

- to test the Smith and Slater (2001) variability index which is used to categorise products into six segments and to determine if the variability of lead times is a significant factor.

- to investigate how customers can be included in the segmentation process;

- to investigate which factors can be used to create segments of products and how they relate to the different planning levels;

- to show the practical and financial benefits of the application of a supply chain segmentation strategy.

The findings of the study were disseminated in research papers which were presented at the European Logistics Association Doctoral Conference in July 2008 in Grainau, Germany and the Logistics Research Network (LRN) in

September 2008 and 2009. A research paper was accepted and presented at the 2010 LRN Conference which took place in September 2010. A paper has been submitted to the International Journal of Logistics: Research and Applications.

1.6 Case study: Newey and Eyre

An objective of this research study is to test, by gathering empirical evidence using a case study research strategy, that a single supply chain strategy is suboptimal in comparison to a segmented approach. This relates to the premise proposed in the hypothesis in section 1.5.1. Furthermore, the case study environment is the basis for carrying out the research aims and testing the methodology laid out in Chapter 5. The findings from the research programme are presented as a case study within Chapter 6.

The practical focus of the research study was to test whether supply chain performance can be improved when supply chain segmentation is applied to all levels of the business. A case study research methodology was applied to provide empirical evidence of the benefits that can be gained from the strategy. This investigation was based upon a practical research programme undertaken within an industrial company. An objective was to provide measurable operational benefits. These were tested by examining the effect on the performance of the supply chain by measuring the change against a number of key indicators. The scope of the case study was developed in an agreement with the requirements set out by the business. A time frame of two years was set for the completion of the research programme.

The case study was carried out within a company known as Newey and Eyre. They are a leading wholesale distributor of electrical materials and safety equipment, and parts and spares for maintenance, repair and operations (MRO). The company was previously part of the Hagemeyer Group until it was sold to the Rexel Group in 2008. Newey and Eyre is now part of Rexel (UK) Ltd which also owns other companies operating in the same market place including; Denmans, Senate, WF Electrical, Parker Merchanting and

Newey and Eyre Industrial Solutions. Newey and Eyre's customers range from large multinational blue chip companies to sole traders. Their main competitors, apart from other companies within the Rexel Group, are Edmundson Electrical, City Electrical Factors and the Wolsey Group.

The electrical wholesale industry is an intensively competitive market, with pressures from external forces, competing on price, product availability and delivery service. The business has developed a culture, reinforced through strategic policies, where the main aim has been a drive to increase sales. A single supply chain strategy is used to serve all customers with products regardless of their actual value to the business. This atomistic culture has resulted in reducing profits over the long term due to increased logistics costs such as the costs of carrying excess inventory. High volumes of stock obsolescence and logistics costs that exceed product margins have left many products and the accounts of some customers unprofitable. Specific supply chain issues highlighted are:

- high storage costs;
- low rate of productivity;
- high level of obsolescence;
- low stock liquidity;
- high rate of stock-outs.

The research programme which was undertaken within Newey and Eyre was carried out from September 2006 to December 2008. This investigation was split into three distinct research projects. They are presented within this thesis as a case study found in Chapter 6. A segmentation strategy was applied to reduce the supply chain issues which the business was experiencing.

The first of the research projects (September 2006 – September 2007) was a redesigning of the supply chain for the South West region and the regional distribution centre (RDC) based at Avonmouth. A pilot study approach was used to test and implement various solutions, which when proven to be successful could be implemented throughout the rest of the business, without exposing the entire company to the initial risk. A review was undertaken to gain an understanding of the design of the supply chain, operational methods and to uncover the reasons behind the under-performing operation. It was proposed that the supply chain should be redesigned so that the service levels of products and customers reflect their respective value to the business.

The first research project highlighted issues within the purchasing and inventory system. Analysis undertaken of a number of stock keeping units[2] (SKU's) showed that the behaviour and level of stock was erratic and in excess of what was deemed acceptable by the company. These issues were not solved by the solutions which were implemented. The second research project was a study (September 2007 – December 2008) of this system and the objective was to fill the gaps exposed by the first research project. This had a wider scope and covered the entire UK supply chain operation. The mechanics of the system were mapped out using a process mapping methodology and information gathering techniques. A simulation model was designed to fully replicate the system and to act as a vehicle to test a number of scenarios using a segmentation approach. The results generated were used to validate the final recommendations to the business and the findings of this research study.

The intention of the research objectives were to provide both insights into the business by reviewing various aspects of the supply chain operation; the policies, processes and methods, to highlight potential areas for improvement within the supply chain operation, and to develop new strategic and operational recommendations based upon these findings. These objectives are not exhaustive and it is possible that a different selection of objectives could lead to different conclusions and a successful outcome.

[2] A stock keeping unit (SKU) is used by the company to define a unique product.

The objectives of the case study are as follows:

- to measure the contribution to profit of products and customers and to comment upon their business significance;
- to conduct a review of Newey and Eyre's internal supply chain operation and external business market;
- to assess current supply chain practices that influence stock holding levels;
- to gain acceptability of solutions by management and implement changes to the operation which will improve working practices,
- to provide a comprehensive review of the purchasing and inventory system which includes the highlighting of areas for improvement.
- to measure the success of the implementation of the research programme.
- to provide differentiated strategic solutions to improve a number of chosen supply chain performance measures;
- to recommend strategic supply chain management solutions to Newey and Eyre that can be implemented within the business model;

1.7 Research methodology

1.7.1 Research strategy

Both the benefits and situations for when a research case strategy is applicable are laid out by Yin (2003). Yin (2003, p.13) defines the scope of a case study as:

- investigates a contemporary phenomenon within its real-life context, especially when
- the boundaries between phenomenon and context are not clearly evident.

A basic breakdown of the limitations of a number of different research strategies in respect to the scope of a case study approach is described by Yin (2003, p.13):

- experiment: deliberately divorces a phenomenon from its context, so that attention can be focused on only a few variables (typically, the context is "controlled" by the laboratory environment);

- history: deals with the entangled situation between phenomenon and context, but usually with *non*-contemporary events;

- survey: deal with phenomenon and context, but their ability to investigate the context is extremely limited.

Yin (2003, p.5) provides a table of different research strategies relative to a number of different situations (see Figure 1.1). It is suggested in the table that there are 'three conditions' which decide the appropriate research strategy.

A case study research approach is appropriate in this context due in part to the complexity of the problem but also because it is the most feasible way of testing the efficacy of the strategy employed. Furthermore, a working supply chain provides the platform to implement new solutions and provides a platform where observable results can be examined. It is not possible to form a supposition of the benefits of such as a strategy without carrying out a study of this kind. A case study research strategy is therefore the appropriate method to achieve these goals.

Figure 1.1: Relevant situation for different research strategies

Strategy	Form of Research Question	Requires Control of 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

As a strategy, a case study approach is a common method used in supply chain management studies (see Aramyan *et al*., 2007; Lambert *et al*., 1998; Mistry, 2005; Reddy and Vrat, 2007). It is an effective method for conducting research for studies of this type (McCutcheon and Meredith, 1993; Stuart *et al*, 2002; Seuring, 2008; Voss, 2002). According to Voss *et al* (2002, p.195) a case study research strategy has "consistently been one of the most powerful research methods in operations management". Typical research methods which use experiments, surveys and history are not applicable for this study because of their limited ability to deal with a large number of variables with a wide-reaching focus. The research questions which are shown in section 5.5 are explanatory and a case study approach is an appropriate method. This corresponds with Yin's (2003) interpretation of when a case study is a suitable research strategy.

1.7.2 Data gathering process

The key design and methodological principles used throughout the research process were either adapted or inspired by Yin (2003) or Coghlan and Brannick (2001). The empirical investigation is fundamentally a study with emphasis placed on evidence-based solutions, comprising of both qualitative and quantitative collections of data and information. To achieve a consensus of opinion a convergence of evidence is sought by triangulation from multiple sources of information. This is further enhanced by conducting analysis of a number of independent entities to show similarity, thus validating the findings.

The proposals and conclusions formed as part of the case study are based upon the analysis of a large amount of evidence. The analysis of the collected data is to fulfil the research aims and objectives. Various statistical techniques and mathematical models were used to perform the data analysis. These are outlined in Chapters 5. The results of the analysis are used to identify areas of concern and to support the proposed recommendations and conclusions. The analysis is fully interpreted in the form of graphs and statistics within the two case studies.

The data-gathering is a formal process and crucial to the outcome of this research study. The process of gathering data involves making a number of decisions such as how much and what type of data to collect. It is important to collect enough data to make sure there is a sufficient amount of evidence from which to be able to draw relevant conclusions. A balance has to be struck because to gather too much data would be too time-consuming. The data also had to be relevant and without bias so that the research aims could be fully satisfied. A list of relevant questions to ask before collecting the data is provided by Curwin and Slater (1996 p.44):

1. What is the relevant population?

2. What are the sources of data?

3. How many people were asked and how were they selected?

4. How was the information collected from these respondents?

5. Who did not respond?

6. What type of data was collected?

Real time data is collected by Newey and Eyre as customer and purchase orders are processed. A large quantity of historical data is stored on a central database. The majority of the data gathered is primary data because it is required specifically for this research study. The remaining information collected was in the form of interviews, direct observation and documents. Interviews are conducted on a one to one basis and are used to create an understanding of working methods and processes used within the business. The documents and direct observations were used in conjunction with the other methods to fill in any of the missing gaps.

1.7.3 Unit of analysis and research variables

The unit of analysis for this research study is the quantity of stock which is held[3] within an RDC or branch for each stock keeping unit (SKU). The unit of analysis is "the major entity" of the study (Social Research Methods, 2009). This can be described as "those things that we examine in order to create summary descriptions of all such units and to explain differences among them" (Babbie, 2009, p.99). Yin (2003) states that the unit of analysis should be linked to the research aims. The ability to show a reduction in the overall level of stock holding is a major objective because it gives some validity to the conclusions formed from the findings of the research programme.

A large number of variables were used within the research programme. A variable is one that is "able to vary or have different values" and can be independent, dependent or extraneous (Gliner and Morgan, 2000, p.48). The purchasing and inventory model which was developed requires a large number of variables. Independent variables were manipulated by the model when it was running and were used to calculate the performance measures, which are dependent variables, when the model had completed running.

[3] The quantity of stock held is the sum of the products held at an individual location or at multiple locations.

1.8 Structure of the thesis

This thesis is structured using common conventions (Mauch and Park, 2003). It is broken down into seven chapters which cover the main areas of; introduction, literature review, methodology, case study and conclusions. The different chapters are outlined including a brief description in Figure 1.2. The chapters in which the specific aims relate to are shown in Figure 1.3.

Figure 1.2: Chapter structure

Title	**Chapter**	**Description**
Introduction	1	Introduction to the thesis which includes a brief outline of supply chain segmentation, the hypothesis, the research aims and objectives of the study, an outline of the research methods and the motivation for the project.
An evaluation of supply chain segmentation literature	2	Evaluation of supply chain management concepts and techniques, including supply chain modelling. A comprehensive review of the current supply chain segmentation related literature.
An evaluation of mathematical modelling and inventory management literature	3	Evaluation of mathematical modelling and inventory management methods,
Corporate context – Newey and Eyre	4	Review of Newey and Eyre's business market and supply chain.
Research design and research methodology	5	Research strategy, data collection and methods used within the case study. A segmentation concept and framework is laid out. The methodology is linked to the research aims.
A case study of the application of a supply chain segmentation strategy	6	The findings from three projects are illustrated and detailed. Results from a simulation model of the inventory system are included.
Conclusion	7	Recommendations and conclusions. Review of the research aims and evaluation of the hypothesis. Contributions to academic theory and to practice. The limitations of the research study and opportunities for further work.

Figure 1.3: Specific aims in relation to chapters

Aims	**Chapter**	**Area of Investigation**
Evaluate the principles of supply chain management and strategy and review the current literature which either indirectly or directly can be classed as a supply chain segmentation approach.	2/3	Literature review
Provide a methodological framework building on the research of Fuller *et al* (1993) which incorporates a supply chain segmentation approach bringing together established supply chain management techniques.	5	Methodology
Show that a segmentation strategy can be applied throughout the business at all planning levels	6	Case study
to investigate which factors can be used to create segments of products and how they relate to the different planning levels;	6	Case study
Test the Smith and Slater (2001) variability index which is used to categorise products into six segments and to determine if the variability of lead times is a significant factor.	6	Case study Study of Inventory system
Investigate how customers can be included in the segmentation process.	6	Case study Supply chain design
Show the practical and financial benefits of the application of a supply chain segmentation strategy.	7	Conclusion

CHAPTER 2

2 AN EVALUATION OF SUPPLY CHAIN SEGMENTATION LITERATURE

2.1 Chapter introduction

This literature review is designed to gain an understanding of any relevant studies within the subject area of supply chain segmentation. This is stated within the scope of the research aims. Primarily this is to provide a thorough understanding of the subject area but also to show possible areas which can be evaluated and developed. The methodology laid out in Chapter 5 is designed in accordance with this and tested within the context of the case study environment.

The literature review process evolved out of an initial study by Smith and Slater (2001). It is proposed that different logistics strategies can be applied depending on how products fit into a structure of six segments. This helped to develop the initial thought process and the idea that a strategy could be developed so that it could be applied in a wider context throughout the hierarchy of a business. Furthermore, the factors used by Smith and Slater (2001) could be analysed to test their relevance. In addition a number of different factors could be analysed to test their relevance to the segmentation process. This chapter reviews and evaluates not only the studies which were found to be directly related to a supply chain segmentation approach but broader studies which were in some way found to be related.

This chapter covers the more general aspects of supply chain management (SCM) and strategy. It provides a historical context with definitions to review current supply chain segmentation literature. A number of methods which were directly relevant to this research study, such as simulation modelling and inventory management, which were applied to major aspects of the research programme, are reviewed in detail within Chapter 3 of the literature review.

2.2 Supply chains

2.2.1 Origin of supply chains

The trading and movement of goods and services along what would have been described as supply trade routes or lines has been common throughout human history. There is historical evidence which shows that great feats of engineering in ancient times were accomplished primarily because they were supported by supply lines. An example of this is the construction of The Great Pyramid in Giza during the fourth Dynasty reign of King Khufu (c.2589 – c.2566 BC). This project took between 20 and 25 years to build and involved the transportation of over two million blocks of stone, some of which were transported hundreds of miles and supported by a 30,000 man workforce (Baluch, 2005). This required many lines of supply which were as long and as complex to manage as many in use in large modern construction projects; all were completed without the use of modern mechanics and transport. Herodotus, the Greek historian, writing on his travels to Egypt in the fifth-century BC, describes the movement of limestone along a supply line:

> "Some were forced to bring blocks of stone from the quarries in the Arabian hills to the Nile, where they were ferried across by others who hauled them to the Libyan hills. The work went on in three-monthly shifts, a hundred-thousand men in a shift. It took ten years of this oppressive slave-labour to build the track along which the blocks were hauled - a work, in my opinion, of hardly less magnitude then the pyramid itself" (Herodotus, Book two of the histories, 440 BC, p.124).

The silk routes are further early examples where goods were exported from East to West over thousands of miles across many countries. Furthermore, it has been acknowledged that traders along the silk routes were "engaged in market led supply chains strategies" (Hines, 2004, p.7). Throughout history the success of nations to maintain the supply of their troops with arms and food has played a significant role in many wars. In World War I, for example, the U.S had to manage supply lines to reach 2 million troops, the largest up to that time. In World War II the management of supply lines was a significant factor in the outcome of the war for the allies (Malone, 2007).

It has become universal practice (see Christopher, 1998; Harrison and van Hoek, 2005; Hines, 2004) to traditionally refer to terms of supply routes or supply lines as "supply chains". According to Kent and Flint (1997, p.17) the first text to contain the term "supply chain" in the title was '*The integrated supply-chain process*' by Bowersox and Closs in 1996. There are earlier accounts that have 'supply chain' in the title such as an article written by Arnold Kransdorff in the Financial Times in 1982 (Heckmann et al, 2001). The definition of a supply chain and how it has evolved out of the concept of value chains (Porter, 1985) is discussed later in this chapter. It is believed that supply chains gained world prominence after the commencement of capitalism and colonialism (Wang *et al*, 2006). This is described below:

> "The idea of international division of labour was systematically applied to obtain raw materials from the colonies to feed the factories of the colonial masters and to export manufactured goods to the colonies" (Wang *et al*., 2006, p.vi).

In recent history supply chains have become synonymous with modern business practice. In the 1980's supply chains were seen as a source of competitive advance after the impacts of deregulation, advances in technology, globalisation, customisation and increases in competition (Ballou *et al*, 2000). In the last three decades there have been developments in the way supply chains are both used and understood in response to environmental changes and also as a result of advances in theoretical understanding, driven forward by new concepts.

A history of the changes with regards to a number of selected attributes is shown in Figure 2.1 (Emmett and Crocker, 2006, pp.11-12). The table shows that the types of supply chains through the years have changed from functional, responsive to adaptive. Businesses have sought to increase the ability to supply their consumers more quickly. A major driver in the ability to do this is through increases in technology that allow the development of new methods for the way information is handled and used. Strategies have moved from short to long term and an insular focus has taken on a collaborative approach involving all parties in the supply chain.

Figure 2.1: Supply chain history

Attribute	Functional supply chains To the 1980s	Responsive supply chains The 1990s	Adaptive supply chains The 2000s
Integration focus	Over the wall Reactive/quick fixes Monopoly suppliers	Transactional Responsive Competitive in suppliers	Collaboration Decision/proactive Joined-up networks of enterprises
Customer focus	Customer can wait 'You will get it when we can send it'	Customers wants it soon ' 'You will have it when you want it'	Customer wants it now 'You will get it'
Organisation focus	Departmental and ring fencing	Intra-enterprise 'Internal' involvement	Extended enterprise involvement
Product positioning	Make to stock Decentralised stock holding Store then deliver	Assemble to order Centralised stock holding Collect and cross dock (transit handling with only 'hours' of storage)	Make to order Minimal stock holding Whatever is needed
Management approach	Hierarchical	Command and control	Collaborative
Technology focus	Point solution	ERP	Web connected
Time focus for the business	Weeks to months	Days to weeks	Real time
Performance focus	Cost	Cost and service	Revenue and profit
Collaboration	Low	Medium	High levels
Response times	Static	Medium	Dynamic

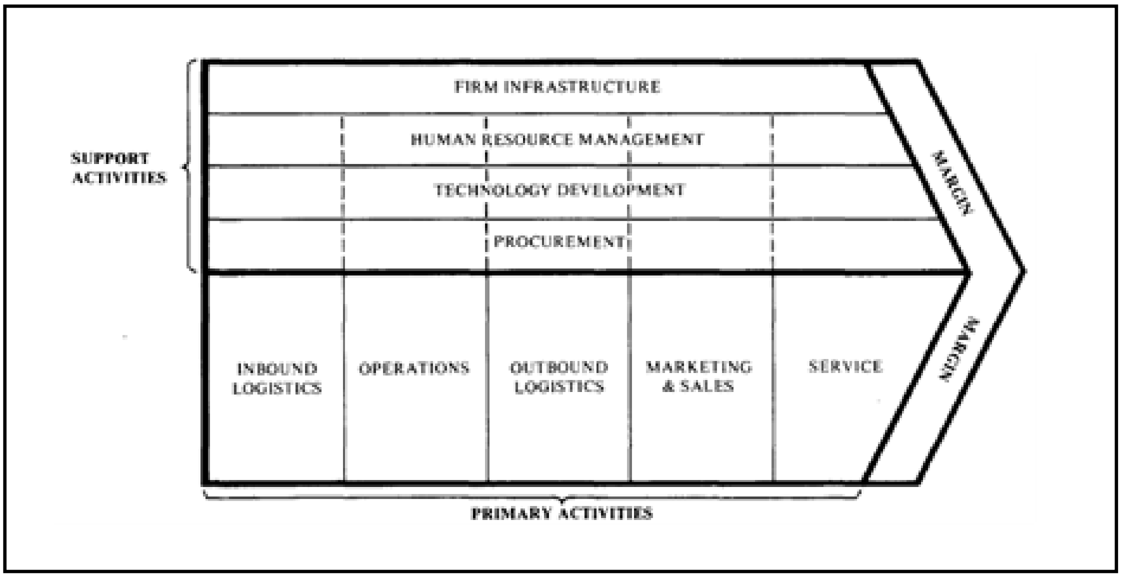
2.2.2 Value chains

Michael. E. Porter, the Bishop William Lawrence University Professor, at Harvard Business School and an expert on competitive strategy introduced the concept of the value chain, in Chapter 2 of his seminal book 'Competitive advantage'. The value chain is the precursor to the paradigm principles of the supply chain. The principal functions of all companies - designing, production.

marketing, delivering and supporting of products, are composed of a collection of activities, and illustrated as the value chain (Porter, 1985, p.36). This is shown in Figure 2.2. These activities can be disaggregated into discrete, or ‘strategically relevant activities’, which independently add cost and create differentiation (Porter, 1985, p.33).

The value chain is subdivided into primary and support activities. Primary activities consist of logistical functions, such as transportation and storage and customer driven services such as marketing and sales. These primary activities are supported by the activities - firm infrastructure, human resource management, technology and procurement. The dotted lines indicate which support activities are directly associated with primary activities. The margin is a representation of the difference between the cost and the sales value of the product. A company’s ability to reduce costs and create differentiation within these activities ultimately leads to the increase of margins and market competitiveness. Differentiation is created by increasing the performance of activities through efficiency gains or their uniqueness in the market (Christopher, 2005).

Figure 2.2: The generic value chain



Porter's perception that a company is a breakdown of a disaggregated series of activities is a useful tool for understanding the individual value contributions to the overall value. The outcome of such a study could show which activities management resource might be best focused on. Porter (1985) stipulates that the constituent parts should not just be evaluated independently of another part. This is because changes to individual activities could directly impact upon other activities. It is fundamental that an holistic approach is applied to understand the overall impacts of any perceived changes, a practice which is often neglected by companies. This prevents any advantages gained in one activity being offset by a disadvantage in another (Minzberg *et al*., 1998, p.106). This insight is a key principle involved in the modern management of supply chains.

The concept of supply chain segmentation is related to Porters (1985) value chain. The principle that margins can be increased by reducing the costs of the primary activities for products and customers which add less value to the supply chain is at the core of both principles. The value chain is a generic concept and does not indicate that different products and customers add different levels of value. For some products the costs of activities would be increased because it is necessary to improve service levels. These may reduce margins but it would be expected that an increase in sales would offset this in the long term.

2.2.3 Definition of a supply chain

The term supply chain is now commonly used in literature (Christopher, 1998; Harrison and van Hoek, 2005; Hines, 2004). It is an extension to Porter's concept of the value chain. The value chain illustrated the capacity for cost reductions and the differentiation of discrete activities to act as a source of gaining competitive advantage for individual companies. The supply chain alternatively encompasses a much wider scope whereby many companies within the entire chain are considered collectively. This involves all of the activities that are involved from the extraction of raw materials through to consumption. Furthermore, Porter (1985) showed that cost, quality, focus and speed are sources of differentiation but it can be argued that these are now merely commodities and are simply the price of market entry, leaving customer value as the one main differentiator in modern supply chains (Sridharan *et al*., 2005, p.313).

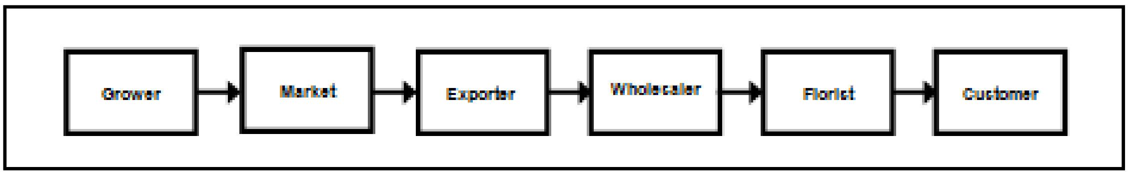
The distinction between a value chain and a supply chain is expressed by the following statement. A value chain is a "management of a chain of value as though it is a single entity" and a supply chain is a "group of disparate functions" (Feller *et al*, 2006, p.3). Many authors and organisations have provided definitions of what activities they consider to be the activities that make up the supply chain. A number of chosen definitions are shown below. All of these definitions are holistic in their meaning, emphasising that all activities constitute to the makeup of a supply chain.

> "A supply chain encompasses every effort involved in producing and delivering a final product or service, from the supplier's supplier to the customer's customer" (Supply Chain Council, Feb 2008).
>
> "All the activities involved in delivering a product from raw material through to the customer including sourcing raw material and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, delivery to the customer, and the information systems necessary to monitor all of these activities" (Lummus and Vokurka, 1999, p.11).
>
> "A supply chain is a group of partners who collectively convert a basic commodity (upstream) into a finished product (downstream) that is valued by end-customers, and who manage returns at each stage" (Harrison and van Hoek, 2005, p.7).
>
> "The supply chain is a network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer" (Christopher, 1998, p.15).

Modern supply chains are global; they span many thousands of miles, concerning many companies and a multitude of different activities. All of these activities add value as goods travel and services are received between organisations from the point of origin to their final destination. Within these systems, many different modes of modern transport are used. An example of a typical modern global supply chain is shown in Figure 2.3. It illustrates the various links in the supply chain. The flower industry which had a sales turnover of €3.6 billion in 2007 (The Dutch Flower Auctions Association, 2008) exports flowers from growers thousands of miles around the world. The flowers are transported using different modes from the growers through to the customer.

The majority of the world's cut flowers are grown in Kenya, Ethiopia, Israel and South America (Flora Holland, 2008). When the flowers are ready for distribution they are exported by air to buyers around the world. The majority of the worlds cut flowers (60%) are sold through auctions in Dutch markets (The Dutch Flower Auctions Association, 2008). The largest example is in Aalsmeer, Amsterdam, which handles 19 million flowers and 55,000 transactions a day (The Dutch Flower Auctions Association, 2008). These flowers are sold to wholesalers and exporters which export the flowers on the same day (85%) by truck and/or ship to wholesalers and retailers in countries outside of the Netherlands (Bloemenveiling Aalsmeer, 2008). The wholesalers then sell and distribute the flowers to florists where they are finally selected and purchased by customers.

Figure 2.3: A typical design of a flower supply chain



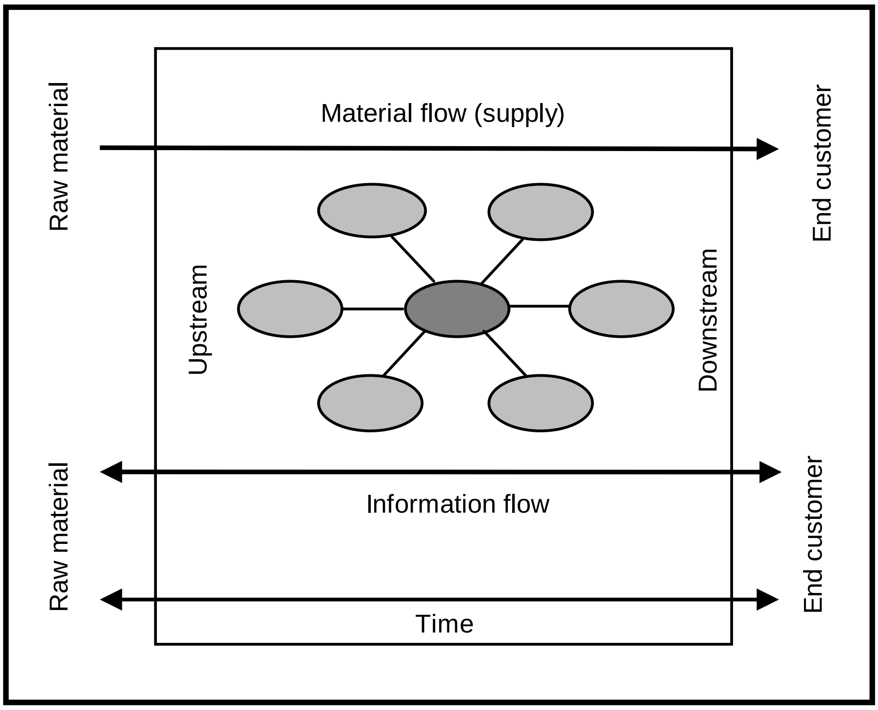
This simple example depicts the movement of only one particular product through a chain of individual companies. In reality industries are more complex than this. Many companies are served by several suppliers, selling many products and supported with information, which flows in both directions. It is also possible for parts within a supply chain to come together to form new products. The assembly of computers operates in this way. Many parts which are supplied from many different suppliers converge at one point within the supply chain to create a computer.

The term ‘supply network’ is sometimes used to explain the complex nature of some supply chains (Harrison and van Hoek, 2005). In this context the nodes represent the complex structure of many organisations. This is illustrated (see Figure 2.4) by Harrison and van Hoek (2005, p.11). The diagram is centred on the focal firm. Externally, material and information flow upstream from the raw material stage, downstream to the end customer. A supply chain segmentation strategy manages the material flow from the raw material stage to the end customer. Different strategies and methods are selected for different products and customers by using the information as it flows up the supply chain.

Schwaninger and Vrhovec (2006, p.377) use the term ‘supply system’ to try to better represent the more realistic nature of the complex relationships and information feedbacks that exist. The interactions between competing chains and networks are incorporated. Despite a chain not representing the complex interconnecting of links of some systems, for the sake of clarity, the term ‘supply chain’ will be used throughout this thesis.

Since the advent of the Internet a new type of supply chain has emerged: the digital supply chain. Digital supply chains allow for music and/or videos to be purchased and downloaded by customers directly to their data storage device. iTunes^{TM} launched by Apple on January 9th 2001 (Apple Press Release, 2001) provides customers with a library of songs which can be downloaded to their computer in an MP3 format. These supply chains do not have physical attributes and have zero inventories and lead times. This gives companies such as Apple an advantage to operate with low fixed costs providing an immediate service without delays to customers. This has proved to be a great competitive advantage for Apple and in 2007 the company was voted in top place in a poll conducted by AMR Research of best supply chains (AMR Research, Feb 2008). In 2008 Apple had become the top US music retailer moving above Wal-Mart for the first time (Apple, June 19th, 2008).

Figure 2.4: The network in context



2.2.4 Supply chain strategy

The term strategy is used in many different contexts and there are many different types and levels (Bennett, 1999; Mintzberg and Quinn, 1995). Strategy was initially a military concern and actually originates from the Greek word ‘strategia’, meaning ‘generalship’ (Compact Oxford English Dictionary, 2008). The Compact Oxford English Dictionary (2008) defines strategy as:

1. a plan designed to achieve a particular long-term aim;

2. the art of planning and directing military activity in a war or battle.

Henderson (1989) shows that the origins of strategy were first exhibited in biological systems, as a result of a competition to survive, as expressed by Darwin. Henderson (1989, p.139), referring to Gause’s principle of competitive exclusion, where “no two species can coexist that make their living in the identical way”, shows that this is also applicable for businesses. This is because differentiation between competing businesses is required in order to survive. Differentiation can be achieved by a process of evolution through conceived strategies, allowing businesses to continue to survive and grow until they either "displace their competitors or outgrow their resources" (Henderson, 1989, p.140).

A business strategy can be defined as "a deliberate search for a plan of action that will develop a business's competitive advantage and compound it" (Henderson, 1989, p.141). It is therefore concerned with obtaining an advantage over its competitors in order to achieve long term survival and growth (Henderson, 1989). Another possible definition is provided below:

> "The totality of management decisions that determine the purpose and direction of the enterprise and hence its fundamental goals, activities, and the policies it selects in order to attain its objectives" (Bennett, 1999, p.3).

The renowned writers Igor Ansoff, Michael Porter and Henry Mintzberg, among others, have all published works describing their own particular visions of strategic planning (Ansoff, 1965; Mintzberg, 1991; Porter, 1980). Differences in opinion invariably contend with one another and in the past have spilled out into the public domain as heated exchanges (Mintzberg, 1990, 1991; Ansoff 1991). Mintzberg *et al* (1998) outlines what are termed the three fallacies of strategic planning - criticising planning from analysis and methods of prediction, to a preferred intuitive approach.

Mintzberg *et al* (1998) believes that complex systems such as economic markets are too chaotic to be forecasted accurately. The unpredictability of complex business systems is examined by Forrester (1961). A supply chain segmentation strategy relies heavily on planning at all levels of the business. Although as Mintzberg *et al* (1998) suggest, predictions are difficult to make, but with the correct use of information, informed judgements can be made. This is crucial in allowing management to plan and make effective use of the available resources. Within the case study it is shown that by analysing the variability of customer demand, different levels of forecasting parameters can be set to improve the ability to manage forecasts.

Mintzberg *et al* (1998) equates strategy formation to a blind man describing parts of an elephant where the whole is missed:

> "We are the blind people and strategy formation is our elephant. Since no one has had the vision to see the entire beast, everyone has grabbed hold of some part or other and "railed on in utter ignorance" about the rest" (Mintzberg *et al*., 1998, p.3).

According to Mintzberg *et al* (1998, p.5) the different planning approaches can be categorised as ten different schools.

- The Design School: strategy formation as a process of *conception;*
- The Planning School: strategy formation as a *formal* process;
- The Positioning School: strategy formation as an *analytical* process;
- The Entrepreneurial School: strategy formation as a *visionary* process;
- The Cognitive School: strategy formation as a *mental* process;
- The Learning School: strategy formation as an *emergent* process;
- The Power School: strategy formation as a process of *negotiation;*
- The Cultural School: strategy formation as a *collective* process;
- The Environmental School: strategy formation as a *reactive* process;
- The Configuration School: strategy formation as a process of *transformation.*

Strategies are conceived at different levels of the business. According to Bennett (1999, p.4) strategies can be devised at either a corporate, division/subsidiary or functional levels of a business. Corporate strategies are concerned with the 'nature' of the business, the "overall allocation of physical, human and financial resources" and "long-term goals" (Bennett, 1999, p.4). Division/subsidiary strategies are created where there are areas of the business that are distinctly different, sometimes referred to as strategic business units (Bennett, 1999).

Functional strategies are concerned with distinct operational areas (Bennett, 1999). A supply chain strategy is a functional strategy, whilst a business strategy is concerned with the overall direction of a business. A supply chain strategy is concerned with the operation of the business (United Parcel Service, 2005). Lowson (2002, p.284) provides some elements of a supply chain strategy:

- coordination and integration of all supply chain activities into a seamless process within and external to the organization;
- planning and collaboration across a distributed supply chain;
- optimally delivering the right product to the right place at the right time.

The importance of aligning the supply chain strategy with the business strategy has been noted (Chopra and Meindl, 2007; Cohen and Roussel, 2005; Hines, 2004; Lummus and Vokurka, 1999; Gattorna *et al*, 2003; United Parcel Service, 2005). Cohen and Roussel (2005, p.22) show how a supply chain strategy can contribute to the primary business strategy (see Figure 2.5). The table is broken down into four key primary strategies of innovation, cost, service and quality. It is shown that competitive advantage can be gained if the supply chain strategy is aligned to match the respective primary strategy using the appropriate methods.

Figure 2.5: Supply chain contribution to business strategy

Primary strategy	Source of advantage	Basis of competition	Key supply chain contributor
Innovation	Brand and unique technology	Desirable and innovative products	Time to market and time to volume
Cost	Cost-efficient operations	Lowest prices in the product-category	Efficient, low-cost infrastructure
Service	Superb service	Tailored to meet customer specific needs	Designed "from the customer in"
Quality	Safest, most reliable products	Product you can count on	Supply chain excellence and quality control

Hines (2004) using a similar method has identified six key market variables which determine the attributes to a supply chain structure. These are volume, time, variety, service level, price, rate of change – innovation and new product development. If for example the primary business strategy is for the company to focus on innovation the supply chain strategy is the enabler for this. A supply chain strategy which is responsive is able to increase the speed by which it can bring new products to the market. The competitive advantage gained is a measure of its success. Hines (2004, p.61) breaks this down into a number of measurable abilities:

- respond to volume changes in demand;
- compress lead times (quick response or QR);
- deal with variety of products;
- build and deliver innovative new products quickly;
- achieve a high service level.

When strategies are not aligned it creates an operational dysfunctionality. A number of risks have been identified by The United Parcel Service (2005, p.5):

1. developing a supply chain strategy without a true understanding of the business case and value propositions – the costs and benefits are not know;

2. utilizing different or new resources in the operational model development that weren't exposed to the original business strategy thinking, thereby diluting and weakening the supply chain strategy;

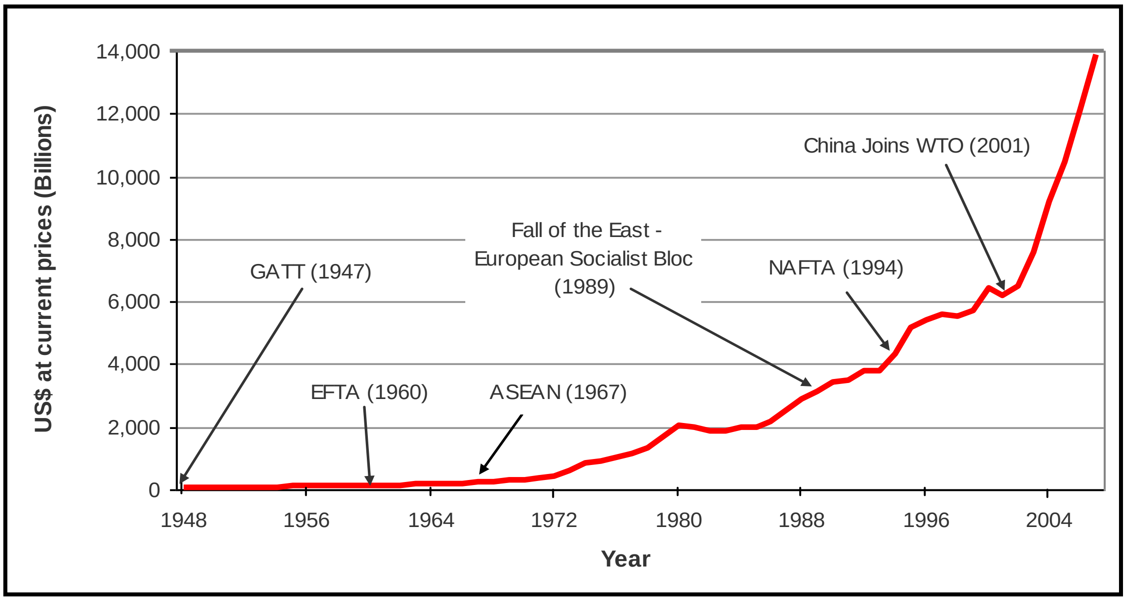
3. confusing or conflicting communications to the organization where objectives mat be contradictory.

2.2.5 Globalisation of supply chains

There is no precise starting date or clear event that triggered the start of global trading. As early as c.140-87 BC merchants exported commodities through the continents of Europe, Africa and Asia, known as the silk routes[4] (Saccomano, 2002). A culmination of factors throughout history, including wars, technology, cultural advances and political affairs has changed the ability of trade to move freely between nations. Since the conclusion of the Second World War in 1945, globalisation in the modern sense has seen a revolution in global trade as trade barriers have declined coupled with some major advances in technology. Data taken from the World Trade Organisation (2008) shows the extent at which trade has increased since 1947 to 2007, including some key events that have freed the movement of trade (see Figure 2.6).

[4] The travels of Marco Polo the Venetian, edited by Wright (1854) offers an interesting insight of commodity trading along the silk routes between 1271 and 1298.

Figure 2.6: Total world merchandise export trade (1948 – 2007)



KEY

GATT - General Agreement on Tariffs & Trade
EFTA - European Free Trade Association
ASEAN - Association of Southeast Asian Nations
NAFTA - North American Free Trade Association
WTO - World Trade Organisation

The end of the Cold War in 1989 changed the dynamics of global trading allowing the lowering of barriers and the opening up of cultures, creating new trading markets:

> "The fall of the Berlin Wall on 11/9/89 … tipped the balance of power across the world toward those advocating democratic, consensual, free-market-oriented governance, and away from those advocating authoritarian rule with centrally planned economies" Friedman (2005, p. 49).

Supply chains are expanding in size and complexity as trade barriers continue to be broken down and companies seek to reduce margins through economic gains in production and logistics costs. The advancement of technology has played a crucial role in the progression of global supply chains. The ability to gather and share information with relative ease has meant communication between markets and business has improved significantly in the last 50 years.

Bill Gates of Microsoft Corporation (cited in Kerkhoff, 2006, p.13) expresses that:

> "This is a very exciting time in the world of information. It's not just that the personal computer has come along as a great tool. The whole pace of business is moving faster. Globalization is forcing companies to do things in new ways".

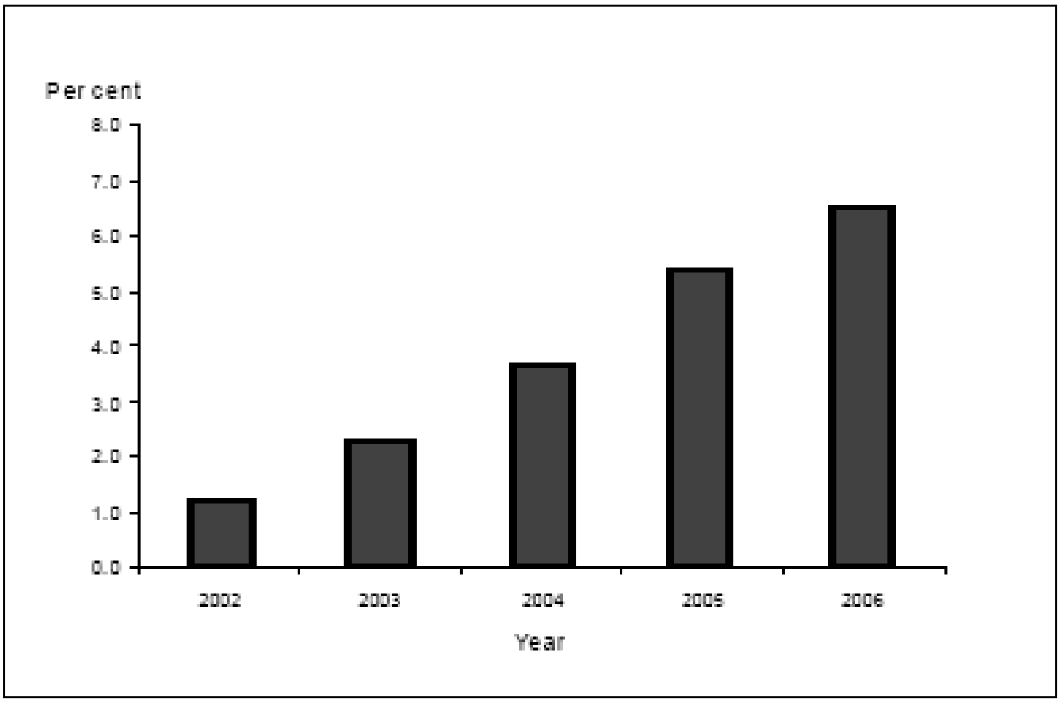
The Internet, first developed by military research in the 1960's in the US (Cailliau and Gillies, 2000), led to the development of Electronic Data Interchange[5] (EDI). This gave businesses the opportunity to send electronic transactions quickly and efficiently and is a major step in the advancement of globalisation.

At a time close to the end of the Cold War a technological revolution was taking place, with the invention of the World Wide Web (WWW). The World Wide Web, referred to as 'The Web', was developed by Englishmen, Sir Tim Berners-Lee, whilst working at the European Organization for Nuclear Research (CERN) in Geneva, Switzerland (Cailliau and Gillies, 2000). The Web created the platform for electronic commerce, known as E-Commerce[6], which has significantly increased global trade. E-Commerce allows business access to new markets and creates economic efficiency gains. Data taken from UK Government Statistics (2006) shows that the UK is indicative of this trend. The growth in the share of total internet sales has risen from 1.1% to 6.5%, in 2002 to 2006 respectively (see Figure 2.7).

[5] 5 "The Tradacoms standards for the exchange of data between organizations became available in 1982 from the Article Number Association (ANA)" (Bamfield, 1994).

[6] The Organisation for Economic Co-Operation and Development (OECD) provides the following broad definition for E-Commerce: "An electronic transaction is the sale or purchase of goods or services, whether between businesses, households, individuals, governments, and other public or private organisations, conducted over computer mediated networks" (The OECD, 2008).

Figure 2.7: UK Internet sales as a proportion of all sales (2002 to 2006)



All of these factors have played significant roles in the advancement of global supply chains. The next stage of globalisation in the twenty-first century has been witness to an increasing number of companies doing business in many different countries and the continued growth of China. Thomas Friedman, a New York columnist and prominent writer on globalisation and author of the well known books, 'The Lexus and the Olive Tree' and 'The World is Flat', describes this next phase since 2000 of Globalisation. Globalisation 3.0 as he describes it is "shrinking the world from a size small to a size tiny and flattening the playing field at the same time" (Friedman, 2005, p.10). Freidman (2005, p.7) describes how this has affected a supply chain for a company in India:

> Nilekani said, they ''created a platform where intellectual work, intellectual capital, could be delivered from anywhere. It could be disaggregated, delivered, distributed, produced and put back together again - and this gave a whole new degree of freedom to the way we do work, especially work of an intellectual nature. And what you are seeing in Bangalore today is really the culmination of all these things coming together' (Freidman (2005, p. 7).

As globalisation continues to increase more and more trans-national companies[7] (TNC's) are created. This inevitably means that more businesses have supply chains which are global. The first TNC, British East India was created on the last day of 1600, when they were given an English Royal Charter by the Queen and granted trade privileges in the East Indies (Robins, Dec 13th 2004). TNC's have since grown in number to an estimated 79,000 and represent over $31 trillion of global sales in 2007 (World Investment Report, 2008, p.36). Production measured as value-added activities accounted for 11% of Global GDP[8] in 2007 (World Investment Report, 2008, p. 36). To put this in context a press release in 2002 by the UNCTAD reported that twenty-nine of the world's 100 largest economies are TNC's, with Exxon Mobil ranked higher than the country Pakistan (UNCTAD, Press Release 2002).

2.3 Supply chain management (SCM)

2.3.1 Origins of SCM

The management of supply chains, although a relatively recent paradigm, and appearing increasingly in literature throughout the last 25 years, is not a modern phenomenon, nor is it confined to the science of business management. SCM is a prerequisite of logistics management and physical distribution, which started to become prominent in business in the 1950's and early 1960's, emerging from the disciplines of marketing (Ballou *et al*., 2000; Gripsrud *et al*., 2006). According to Kent and Flint (1997) physical distribution management first appeared in literature in 1901.

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[7] "Transnational corporations (TNCs) are incorporated or unincorporated enterprises comprising parent enterprises and their foreign affiliates. A parent enterprise is defined as an enterprise that controls assets of other entities in countries other than its home country, usually by owning a certain equity capital stake" (United Nations Conference on Trade and Development (UNCTAD).

[8] GDP is defined as "The total market value of all final goods and services produced in a country in a given year, equal to total consumer, investment and government spending, plus the value of exports, minus the value of imports" (Investorwords.com, May 2009).

Long before logistics management became a business science, logistical methods existed with roots firmly linked to military history. The term logistics[9] originates in military history, referring to the "movement and supply of troops and equipment" (Compact Oxford English Dictionary, 2009). An early example of the successful management of supply chains was the conquests of the Persian Empire by Alexander the Great, the Commander of the Macedonian Army (336 - 323 BC) (Van Miegham, 1998, p.42). Alexandra was able to move quickly over great distances because he was able to supply his troops adequately with food and arms provisions, with supply chains that stretched across countries, importing over both land and sea. This was a complex task in ancient times and was achieved by making crucial strategic and tactical management decisions, not dissimilar to those common in modern businesses today such as strategic alliances, purchasing, time scheduling and route planning to name a few[10].

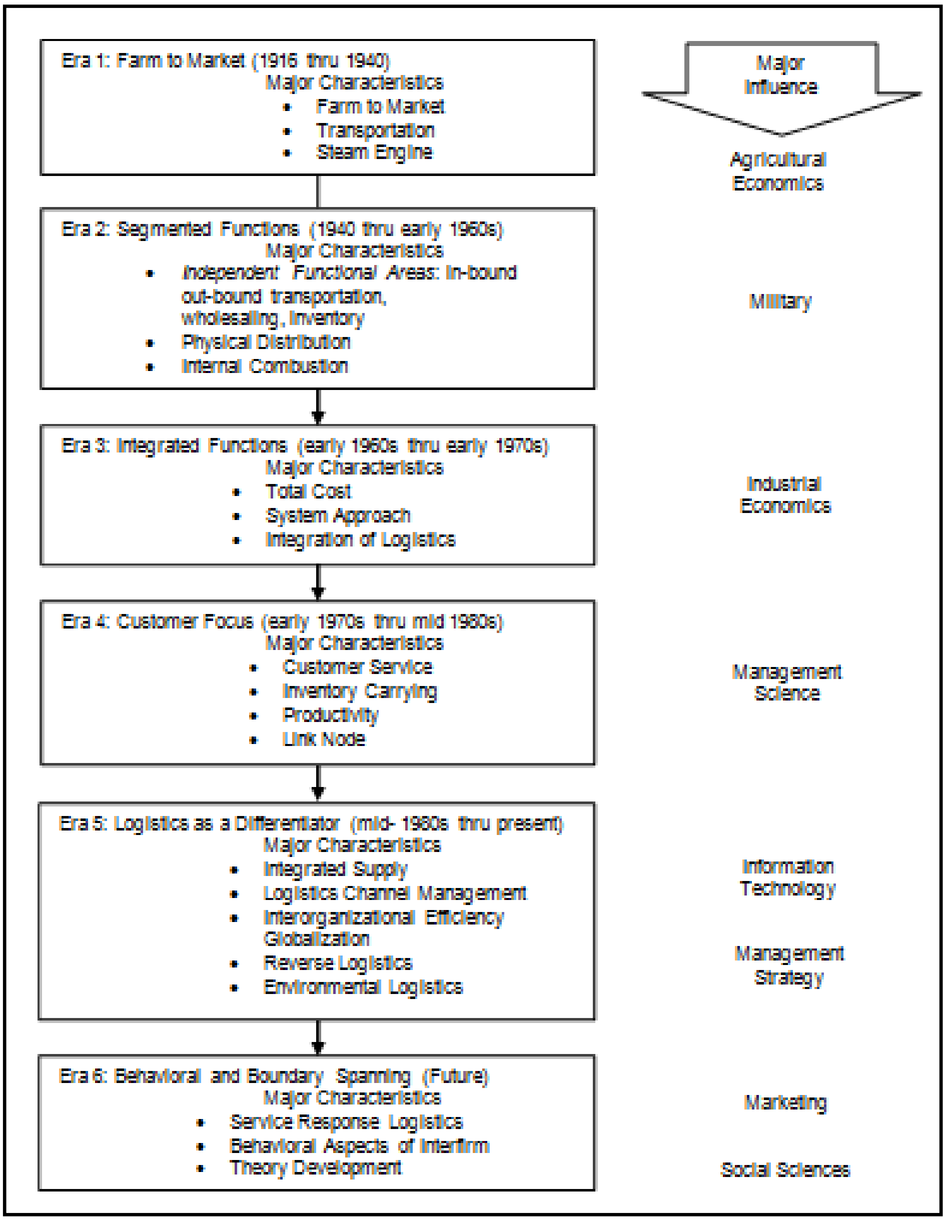
Before the concept of SCM emerged, logistics management was the dominant business science. Gripsrud *et al* (2006, p.650) believe that SCM "bridges the gap between logistics and marketing channels research". Figure 2.8 shows the different eras of logistics management since 1916. It shows that logistics has moved from primarily being used in agriculture to an added value activity for business. This is summed up below:

> "Thought about logistics has evolved from a transportation focus based primarily on agricultural economics to the view that it is a diverse and key component of business strategy, differentiation, and link to customers" (Kent and Flint, 1997, p.15).

9 The term logistics originates from the French word 'logistiques'. "French soldiers used the work loger to mean lodge" and "in or around the year 1861 the process of moving of supplies in and out of the barracks became known as logistiques" (Malone, 2007. p.88).

10 The book Alexander the Great and the Logistics of the Macedonian Army by Engels (1980) provides a comprehensive study of the logistics issues faced by Alexandra the Great and the techniques used to overcome these using models and data analysis.

Figure 2.8: Chronological model of the evolution of logistics thought



Gripsrud *et al* (2006) describes three transformations that took place within business logistics management since the 1950's. The first transformation was for logistics to become recognised as a separate function within organisations. The second transformation was the stage in which logistics was considered to be a management discipline where more complex ideas such as cost and service trade-offs became a focal point. The focus on processes then became the last transformation using concepts such as lean production. A comprehensive literature analysis of the key events in the evolution of logistics (Kent and Flint, 1997, p.22) is shown in CD Appendix A.

The term SCM, first appeared in the public domain in an article in the Financial Times, entitled “Booz Allen’s rather grandly titled supply chain management concept” written by Arnold Kransdorff in 1982 (Heckmann. *et al*., 2001). The term is supposed to be coined out of a meeting where Keith Oliver, a consultant for Booz Allen, was describing what he meant by integrated inventory management:

> “We’re talking about the management of a chain of supply as though it were a single entity, not a group of disparate functions” (Laseter and Oliver, 2003, p. 2).

Many of the concepts which were previously associated with logistics management are now directly associated with those of SCM. This can lead to confusion between the two if the differences are not properly understood (Emmett and Crocker, 2006; Lambert and Cooper, 2000). SCM in contrast to logistics management is a holistic strategy. SCM is where decisions are made to benefit the whole chain rather than smaller entities. This is achieved by information sharing and co ordination between parties in the supply chain. Drawing on Drucker (1998) and Christopher (1998), Lambert and Cooper (2000, p.65) show that there has been a definite management paradigm shift:

> “One of the most significant paradigm shifts of modern business management is that individual businesses no longer compete as solely autonomous entities, but rather as supply chains”.

Ballou *et al* (2000, p.10) provides a conceptual framework for SCM based upon logistics management:

1. intrafunctional coordination (administration of the activities and processes within the logistics function of a firm);

2. coordination of interfunctional activities, such as between logistics and finance, logistics and production, and logistics and marketing, as they take place among the functional areas of the firm;

3. coordination of interorganizational supply chain activities that take place between legally separate firms within the product-flow channel, such as between a firm and its suppliers. A distinguishing factor between each of these dimensions is the degree of control with which a product-flow manager has to achieve the coordination.

2.3.2 Definition of supply chain management

The supply chain is defined to include all aspects involved in the sourcing of raw materials through to the delivery of the final product to the consumer. SCM, therefore, is the management of all the activities involved in this process. The Supply Chain Council offer the following definition,

> "Supply-chain management includes managing supply and demand, sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, and delivery to the customer" (Supply Chain Council, 2008).

SCM covers all aspects of the supply chain and traditionally areas such as commerce, production, purchasing, marketing and logistics-functions for example are treated as separate operational entities but are now increasingly amalgamated under the same umbrella of SCM. Furthermore, SCM is considered with decisions at the strategic level. It is understood that individual activity changes made within a company can lead to effects that are detrimental within other activities and an overall weakening of the entire supply chain. SCM promotes a holistic approach to strategy formation and management to improve the entire supply chain as a result.

Supply chain collaboration is an example of an holistic strategy which is shown to be a successful approach for increased competitiveness for all companies within a supply chain. Supply chain collaboration promotes a sharing of information and a removal of conflicts between parties within the supply chain. A study of 20 executives showed that supply chain collaboration can lead to overall improvements such as reduced inventory, improved customer service, reduced cycle times and competitive advantage over other supply chains (Mentzer *et al*., 2000, p.57). Although this study shows some anecdotal evidence of the benefits of supply chain collaboration, the study represents a small sample size. Further research is required to fully show the benefits of this type of strategy.

Managing the supply chain as one single entity can be beneficial for all companies within the supply chain and creates a competitive advantage for all parties. Laseter and Oliver (2003, p.3) show that the following are the main strategic principles of SCM:

- set supply chain policies strategically;
- analyze trade-offs holistically;
- employ cross-functional support systems.

SCM literature started to appear in the mid 1980’s (Cooper et al, 1997) and has been developing since then. There is now a vast and growing amount of literature spanning a wide range of areas that are covered by SCM. There have been many books written over the past 25 years that pull together all of the many SCM concepts (Christopher, 1998; Chopra and Meindl, 2007; Cohen and Roussel, 2005; Cooper *et al*., 1997, Coyle *et al*., 1996; Gattorna, 1998; Harrison and van Hoek, 2002; Hines, 2004; Levi *et al*, 2004). Prominent SCM writers Christopher (2005), Chopra and Meindl (2007) and Harrison and van Hoek (2007), among others, provide some of the notable research within the industry and have an expansive body of work. Chapters can be found on the many SCM principles and practices and industrial case studies are used to show operational examples of success. These works provide generic frameworks for the key concepts and principles that fall within the field of SCM.

Otto and Kotzab (2003, p.309) have divided SCM into what they describe as the six main perspectives: system dynamics, operational research, logistics, marketing, organisation and strategy (see Figure 2.9). They describe the purpose of the perspectives within the context of SCM and what areas are improved. This table is useful in showing some of the different subject areas of SCM. In reality it is much harder to define boundaries as many of the areas of improvements shown interrelate and should not be thought of as separate areas of management. A supply chain segmentation strategy for instance is wide ranging and is concerned with managing many of the perspectives and areas of improvements listed in the table.

Figure 2.9: Perspectives to derive the goals of SCM

Perspective	Purpose of SCM	Focal area of improvement
System Dynamics	Managing the trade-offs along the complete supply chain	Order management
Operations Research	Calculating optimal solutions within a given set of degrees of freedom	Network configuration and flow
Logistics	Integrating generic processes sequentially, vertically and horizontally	Integration of processes
Marketing	Segmenting products and markets and combine both using the right distribution channel	Fit between product, channel and customer
Organisation	Determining and mastering the need to coordinate and manage relationship	Intra-enterprise segmentation
Strategy	Merging competencies and re-locating into the deepest segments of the profit pool	Ability to partner; positioning in the chain

2.3.3 Changing global markets

In 1908 Henry Ford rolled out the Model ‘T’ from a plant in Detroit marking the start of mass production (Hounshell, 1985). This manufacturing revolution helped shape the perception that stability created prosperity and that industrial economics could be controlled like a machine. It is a supply driven approach to the mass production of products and by creating economies of scale leads to a reduction in average costs. This is a short lived revolution and the Ford company saw its market share drop from 55% in 1921 to 30% in 1926. Production of the Model ‘T’ came to an end in 1927 (Hounshell, 1985). This decline came about because markets and the economy are less predictable and controllable than envisaged (Stewart, 2002) and as a result of increased consumer purchasing power (Hounshell, 1985).

Markets moved to mass customisation, which is less predictable and unstable than mass production (Saise and Wilding, 1997). The concept of lean manufacturing, from Japan first realised by Toyota in the late 1980's is developed as a consequence (Womack *et al*., 1990). This approach is market and people driven and involved businesses seeking flexibility and innovative working practises.

Technological advances at the beginning of the twenty-first century have had a profound effect on the way business is conducted. Integrated communication systems and global markets, created by the spread of the Internet, have quickly made Globalisation a reality for businesses. Complex financial and business systems have become inexplicitly linked and supply chains stretch across the globe. Higher competitive environments have been created and the focus has turned from competing on price to competing on customer service which is the main differentiator and driver for companies (Sridharan *et al*., 2005, p.313).

An increase in competitiveness in markets and consumer spending power has led businesses to seek strategies such as to increase product diversity and create greater choices for the consumer. In the US this is prevalent in the food retail market where the average supermarket has experienced growth in product lines from approximately 6,000 lines in the 1980's to approximately 45,000 in 2000 (Boatwright and Nunes, 2001, p.50 and Food Marketing Institute, 2007).

The current business outlook for forecast for the next few years at least would appear to be that many countries will continue in a period of recession and any recovery will be slow (IMF, April 2009). For many businesses this will mean a downturn in sales, as consumer demand decreases. If this is the case businesses will seek to reduce costs and find ways to increase performance within their supply chain operation. A greater awareness of the environment and ethical attitudes will push for reductions in waste and overproduction. The ability to adapt to changing market conditions and reduce costs can be an enabler for companies to compete in changing and weakening global markets. The implementation of SCM projects has been shown to be a successful method (Chopra and Meindl, 2007; Hammel *et al*., 2002; Sridharan et al., 2005).

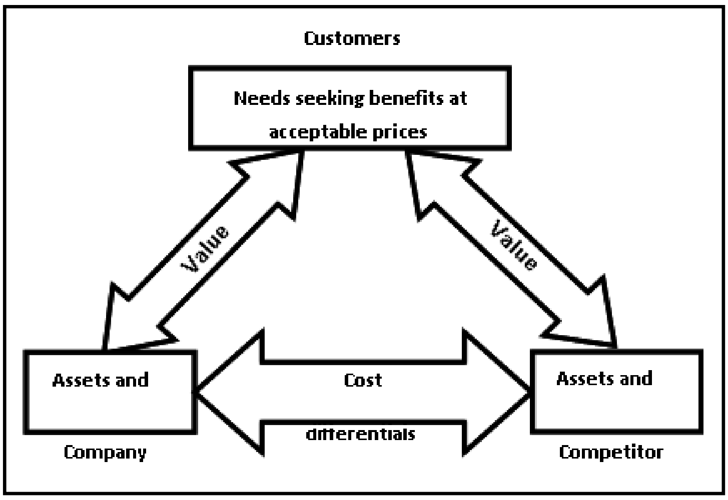
2.3.4 Achieving competitive advantage through SCM

In every industry and sector SCM is becoming increasingly important (Christopher, 2005, p. ix). This has been apparent in the increase of the profile of SCM jobs, borne out in the well paid salaries, expansive skills required and plentiful vacancies, as seen advertised in many journals such as Logistics Focus and Logistics Manager and on recruitment websites. The importance of SCM can be seen by the increasing presence of Supply Chain Directors appearing at Board Level. This is true of many of the largest retailers in the UK such as Tesco, J. Sainsbury's and John Lewis, all of which have had long standing distribution or logistics directors. Large retailers that previously didn't have such roles are beginning to create new positions. Jessops, the largest photographic retailer, and HMV, the largest music retailer, both created Supply Chain Director roles in 2007. There is still a need to further increase awareness of the importance of SCM (Christopher, 2005).

Unless a situation exists where there is a pure monopoly, the majority of companies operate within competitive markets. In many cases markets are highly competitive. The automotive, fashion and commodities markets are examples of highly competitive markets where formulating competitive strategies becomes paramount. Competitiveness is gained through the ability of a company to achieve cost leadership and/or differentiation of its products and services (Porter, 1985, p.3). The capability to deliver strategies is therefore the difference between a successful company generating profits and an unsuccessful company struggling for survival. A successful company is one which is able to not only attract new customers in the short term but is able to attract customers back for repeat business over the long term.

The ability to manage a supply chain effectively is a key differentiator in the success of a business and a source of competitive advantage. A company's competitiveness can be described as "the appropriateness of a firm's activities that can contribute to its performance, such as innovations, a cohesive culture or good implementation" (Porter, 1985, p.1). SCM is a strategic tool for businesses to reduce costs, add value to activities and it can create differentiation from its competitors and hence increase profits. It has been shown that meeting the needs of the customer is key to business survival (Christopher, 2005). A simple model produced by Christopher (2005, p.6) shows how competitive advantage is gained and the relationship between companies, customers and competitors (see Figure 2.10). The model shows that competitive advantage is driven by the relationship between a company, its customers and its competitors. Competitive advantage is gained by a company differentiating itself from its competitors and utilising its assets in excess of its competitors.

Figure 2.10: Competitive advantage and the 'Three Cs'



The customer service explosion, globalisation of industry and organisation integration are challenges that have to be met by a strategic approach to SCM

(Christopher, 1998). The awareness of the importance of SCM by businesses has grown since its initiation in the early 1990's. This is especially evident in recent years for UK manufacturers and particularly for textiles and apparel companies, because a global slowdown in revenue and increasing competition from China. Laszkiewicz (2003, p.30) states that:

> "Increased globalization, greater competition, price pressures, and erosion of margins are placing enormous pressure on manufacturers to re-evaluate how they produce products and generate profits."

Data which was taken from the UK National Statistics (2004, 2009) and illustrated in the two graphs, Figures 2.11 and 2.12 respectively, show the extent to which UK manufacturing has declined since the early 1990's. There has been a steady decline since 1996 in total gross value added as a percentage of the total value, falling from approximately 21% in 1996 to 14% in 2004. This has been compounded since the global slowdown in 2008. The UK's manufacturing output measured as Gross Value Added (GVA) has decreased rapidly over the last year by just under 15% (June 2008 – June 2009).

Figure 2.11: The percentage of UK manufacturing of total gross value added at basic prices (1992 – 2004)

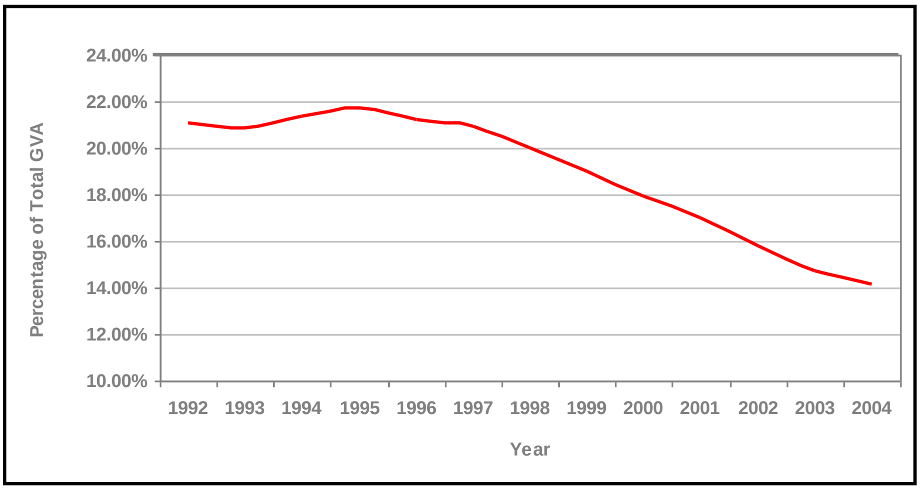
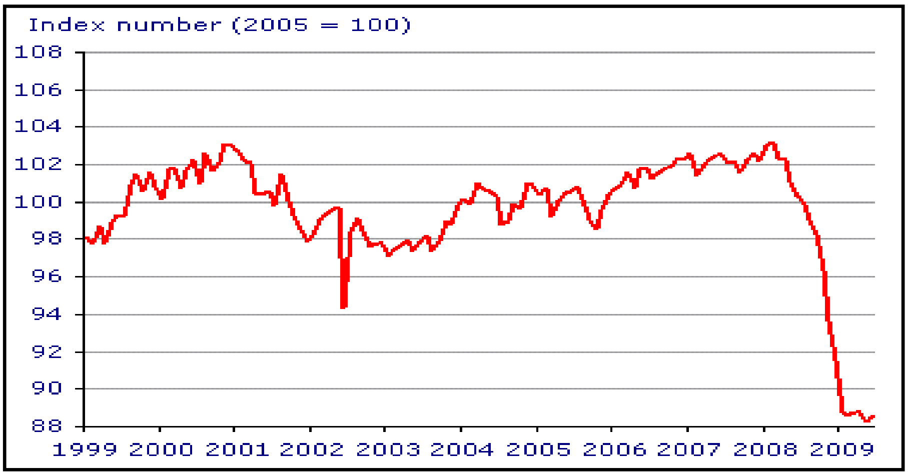


Figure 2.12: Index of UK production (1999 – 2009)



The low labour costs and raw material prices in the Far-East and India have led to the importation of many products into the UK. This has resulted in the closure of many manufacturing businesses. SCM is becoming an increasingly important and effective method for manufacturers to increase their competitive advantage (Laszkiewicz, 2003). Pricewaterhouse Coopers, one of the leading business consultants in the UK, states the effective use of SCM to manufacturing:

> "Effective supply chain management is crucial to manufacturing companies. By working with customers and suppliers to plan supply and demand, identify and qualify improvement opportunities and implement process and technological improvements, organisations can significantly reduce costs and improve reliability of materials supply, stock holding and distribution, while improving customer service and cash flow" (Pricewaterhouse Coopers, 2008).

Emmett and Crocker (2006, p.13) show how SCM methods can be applied to benefit either cost leadership or service differentiation (see Figure 2.13). It depends on the market as to whether a reduction in cost or an increase in service will create a competitive advantage.

Figure 2.13: Benefits of SCM

Cost leadership	**Service differentiation**
Standard products produced cheaply	Customer designed products
Production push	Market pull
Flow and mass volume production, with high mechanism	Job shop production with low mechanism
Low inventory	Flexible and varied inventory
Focus on productivity	Focus on creativity
Stable planning	Flexible planning
Centralisation	Decentralisation
Standardisation	Bespoke and one-offs

2.3.5 Successes and failures of SCM

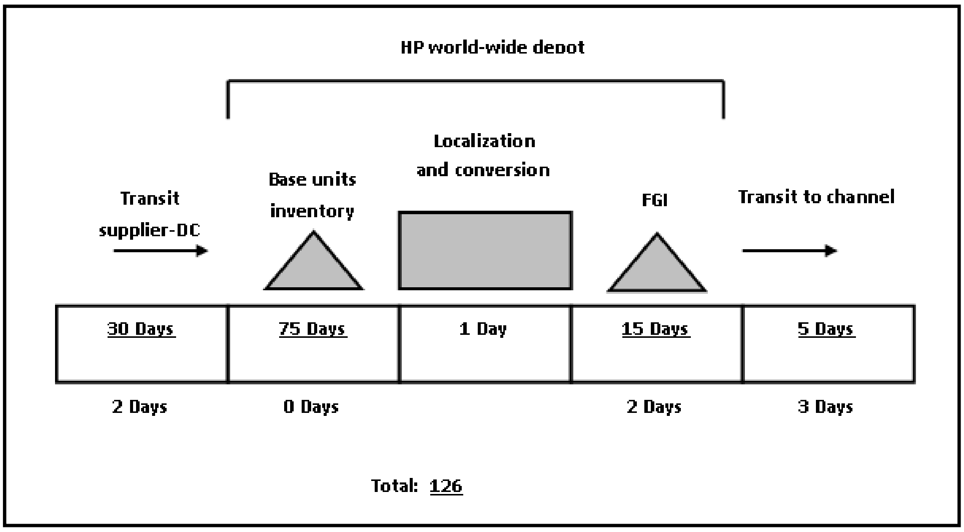
There has been mixed fortunes for businesses that have implemented SCM projects (Tummala *et al*., 2006). There have been some well documented high profile successes and failures. Effective SCM projects have shown that companies have been able to gain a significant competitive advantage over their rivals. Tummala *et al* (2006, p.179) suggests that an "effective and efficient supply chain can become a core or even a distinctive competency". The SCM successes at Dell Inc (Chopra and Meindl, 2007; Christopher, 2005; David, 2007; Holzner, 2006; Sridharan *et al*., 2005), Hewlett-Packard (Lavel *et al*., 2005; Lee and Billington, 1995; Hammel *et al*., 2002; Tummala *et al*., 2006), Zara (Chopra and Meindl, 2007; Christopher, 2005) and Wal-Mart (Chandran, 2003; Stalk *et al*., 1992) are well documented and held as the benchmarks for best practice.

Wal-Mart is seen to have an effective supply chain (Christopher, 1998; Hines, 2004; Levi *et al*., 2004). Throughout the 1980's Wal-Mart was able to transform their business from a relatively small company in the US to the largest retailer in the world. The company successfully applied SCM to create an efficient and quick replenishment inventory system. They did this by implementing a cross-docking and responsive transport system which was made possible because of their ability to incorporate and utilise information within their supply chain (Stalk, 1992, p.58). This approach has been described as "capabilities based competition" Stalk (1992, p.57). From 2001 to 2002 Wal-Mart was ranked first in the Global Fortune 500 as a result of their efficient supply chain (Chandran, 2003). Wal-Mart's best practice stems from a proactive use of information technology, which has meant they have been able to reduce operational costs. Collaboration with their suppliers through the sharing of point-of-sale (POS) information has been instrumental in their success (Comm and Mathaisel, 2008).

Zara, the fashion retailer, used SCM to reduce lead times far lower than their competitors. They created a responsive supply chain which reduced design to sales cycle times from a traditional industry 6 months down to 5-6 weeks (Chopra and Meindl, 2007, p.17). Hewlett-Packard, prior to the implementation of a SCM project, were suffering from excessive inventory and decreasing customer service levels. To remove these issues they implemented supply chain scenario based modelling techniques to aid in strategic decision making (Tummala *et al*., 2006).

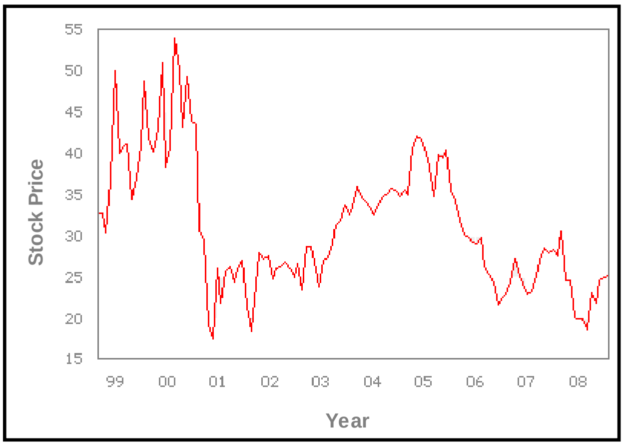
A case example is the company's CD-RW product which in 1998 was uncompetitive on price because its supply chain was too "slow, expensive and unresponsive" (Hammel *et al*., 2002). A supply chain modelling technique was used to test eight scenarios. The results were used in the designing process of a new SCM solution. A supply chain re-engineering project was implemented and a central distribution centre (CDC) in Asia which utilised air transport was created. Hammel *et al* (2002, p.116) showed that this reduced cycle times by 90% from 126 days down to 8 days as a result of the changes to the supply chain (see Figure 2.14). This saved the business an annual $50 million (Hammel *et al*., 2002, p.117).

Figure 2.14: Hewlett Packard before and after cycle time



Dell Inc was very successful at using SCM effectively to gain competitive advantage over its rivals. In 2001 the company had propelled itself to the market leader overtaking its rival IBM. Dell's approach is to reduce inventories and customer lead times by selling directly to their customers. The direct effect of this strategy can be seen in the rise of stock prices from 1999 to 2001 (see Figure 2.15).

Figure 2.15: Dell Inc stock prices (1999-2008)



Source: Dell Inc (www.dell.com/stockquote, Feb, 2008).

Michael Dell and Keith Rollins in an interview for Fortune Magazine describe their SCM strategy:

> **Michael Dell, Chairman, Dell Inc:**
>
> "It's free flow of information, no intermediaries, no boundaries, fast reaction times" (Kirkpatrick, April 19th, 2004).
>
> **Keith Rollins, CEO, Dell Inc:**
>
> "Our strategy is the direct business model: bringing great value to customers through a unique and world-class supply chain, customer intimacy, and great support" (Kirkpatrick, April 19th, 2004).

A detrimental effect occurs when a supply chain is mismanaged. There have many cases throughout history where this has been the case. A notable example from history occurred after the French invasion of Russia in 1812 led by the French imperial army of Napoleon Bonaparte. The French failure to effectively manage their food supply chain led to devastating consequences. A shortfall in provisions led to starvation and the 450,000 strong army of June 1812 was reduced to half as a consequence in the succeeding six months (Bell, 2007, p.258).

Although it is widely accepted that SCM can be a source of competitive advantage, many supply chain projects prove to be unsuccessful. The impression that SCM hasn't lived up to its potential is held by many senior executives worldwide (Heckmann *et al*., 2003, p.2). Booz Allen Hamilton conducted a worldwide survey of 196 respondents. It concluded that:

> "SCM continues to fall short of its substantial promise." and "suggesting that top management needs to take a broader view of supply chain management, deepen its own involvement in the design and ongoing guidance of the function, and take a more realistic view of what technology can – and cannot do" (Heckmann *et al*., 2003, p.2).

The survey showed that the majority of companies were implementing IT solutions in an attempt to reduce inventories. The main choice of investment is Enterprise Resource Planning (ERP)[11] at 71%. A large number of the respondents (45%) said expectations prior to the project hadn't been met. A number of high profile documented ERP implementation failures in the past have included FoxMeyer, Boeing, Dow Chemical, Mobil Europe, Applied Materials, Hershey, and Kellogg's (Chen, 2001).

This is significant because it shows that badly managed SCM projects can fail to deliver what is expected. This could be because the expectations were not clearly explained, there was not the involvement from the required level of management or there was a failure to plan sufficiently and execute. The failure of ERP implementations could be because sales people ramp up the expectations to sell the product in the first instance. It is important within the context of this research study that the expectations should be clearly laid. It is also crucial that the appropriate levels of management are involved at each throughout. If there is sufficient commitment then it is more likely the required operational changes are followed through and accepted.

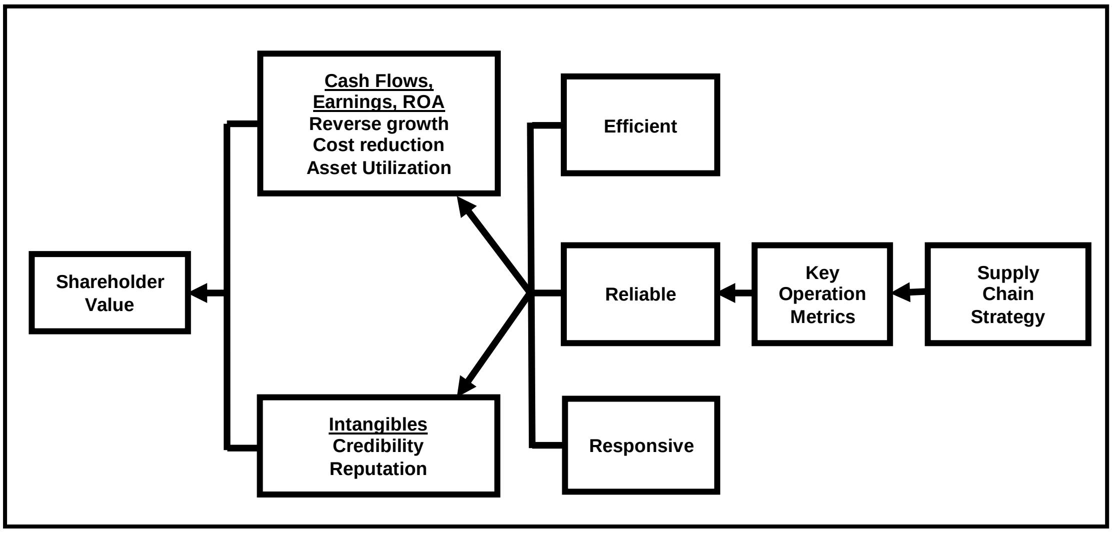
According to the SCM literature (Christopher, 1998; Chopra and Meindl, 2007; Harrison and van Hoek, 2002; Levi *et al*, 2004) companies which fail to manage their supply chain effectively increase the risk of rising costs, damaging customer service levels and a decline in competitiveness. Moreover, this can then lead to a loss of market share and a decrease in share values.

Hendricks and Singhal (2003) investigated the link between what they describe as 'supply chain glitches' and a decrease in shareholder value. This is illustrated in Figure 2.16 (Hendricks and Singhal (2003, p.503). It is shown that a supply chain can be measured by its ability to be efficient, reliable and responsive. A failure in any of these areas ultimately leads to decreases in shareholder value. The results of the study indicated that 'supply chain glitches' resulted on average in decreases of 10.82% in shareholder value (Hendricks and Singhal, 2003, p.520). This shows the importance of SCM

[11] ERP systems "links all areas of a company including order management, manufacturing, human resources, financial systems, and distribution with external suppliers and customers into a tightly integrated system with shared data and visibility" (Chen, 2001, p.374).

because the potential impact of mismanagement can be severe for businesses. It is shown in Chapter 5 how this model of supply chain performance relates to the model of segmentation.

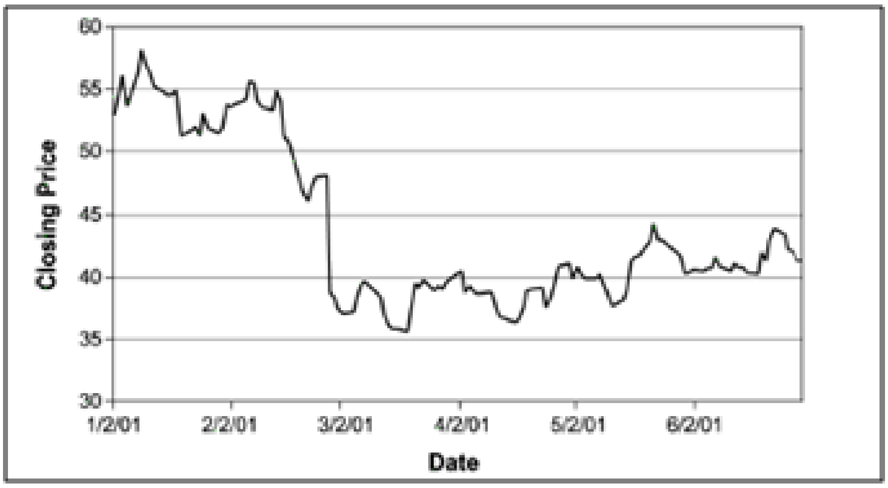
Figure 2.16: Linking supply chain performance to shareholder value



Dell Inc, who in previous examples were shown to have gained a significant competitive advantage from SCM, have also been responsible for mismanagement. It is reported by Forbes that "Dell lost sight of those basics and lost touch with its customers" (Lappin, February, 2007). In October 2007 Dell Inc were facing problems supplying the Inspiron Notebook XS M1330 product. It was taking 6-8 weeks for the product to reach their customers, well above their normal time of 3-5 days (Allison, 2007). This ineffective management of their supply chain had meant that their stock price had fallen significantly as a result (see Figure 2.15). From 2005 to 2008 they lost a significant market share to Hewlett Packard.

There are further examples of SCM failure. The food company Hershey implemented a management system which cost $112 million. The system failed to work as planned and resulted in $150 million in lost sales in 2001 (Sridharan *et al*., 2005, p.315). In 2001, Cisco had to write off $2.25 billion of inventory because the company failed to align a slowdown in demand with their manufacturers (Lee, 2004, p.110). The implementation of supply and demand planning software by vendor company I2 Technologies at Nike did not meet the expected requirements (Sridharan, 2005). The forecasting software created stock-outs and overstocking of shoes, costing the company $15 million in profits in the third quarter of 2001 (Konicki, 2001). The fall in Nike's stock price in 2001 is shown in Figure 2.17 (Sridharan *et al* (2005, p.316). Phillip Knight, CEO of Nike reportedly said "is this what I get for $400 million, huh?" (Konicki, 2001).

Figure 2.17: Nike stock price (January 2001 – June 2001)



2.4 Lean, agile and leagile supply chains

2.4.1 Lean supply chain

After the Second World War the Japanese had to redevelop their country and industry. They did this very successfully and by the late 1980's had created industry that was second to none (Burnes, 2004). New management practices were formed in the restructuring process. These were in contrast to the mass production techniques pioneered by Henry Ford I and the Model 'T'; where high volume and low cost priced cars had opened up the mass market (Saunders, 1997).

The Institute of Technology at Massachusetts set up a research program called the International Motor Vehicle Program (IMVP) to study these techniques. They released their findings in a book called ‘The machine that changed the World’ in 1990. The study was based on Toyota, the car manufacturers, which were using SCM techniques to reduce inactive inventory. The principle was to produce half of everything with double the output – with an aim towards ‘perfection’ (Womack *et al*., 1990). John Krafcik coined this approach ‘lean production’ (Harrison and van Hoek, 2005). The principle is described below:

> “It uses less of everything compared with mass production – half the human effort in the factory, half the manufacturing space, half the investment tools, half the manufacturing engineering hours to develop a new product in half the time. Also, it requires keeping far less than half the needed the inventory on site, results in fewer defects, and produces a greater and ever growing variety of products” (Womack *et al*., 1990, p.13).

The research was elaborated in a book entitled ‘Lean thinking’ and became the standard for manufacturing (Piciacchia, 2002). Lean thinking became the process of removing ‘waste’ or in Japanese ‘muda’ to improve efficiency and reduce costs (Womack and Jones, 1996). In the business context waste is classified as “not adding value to a process or service” (Naylor *et al*, 1999, p.110). Naylor *et al* (1999) shows that a supply chain would be totally lean if there were zero inventories. Hines and Rich (1997) identify seven possible areas of wastes, which can be removed from the system:

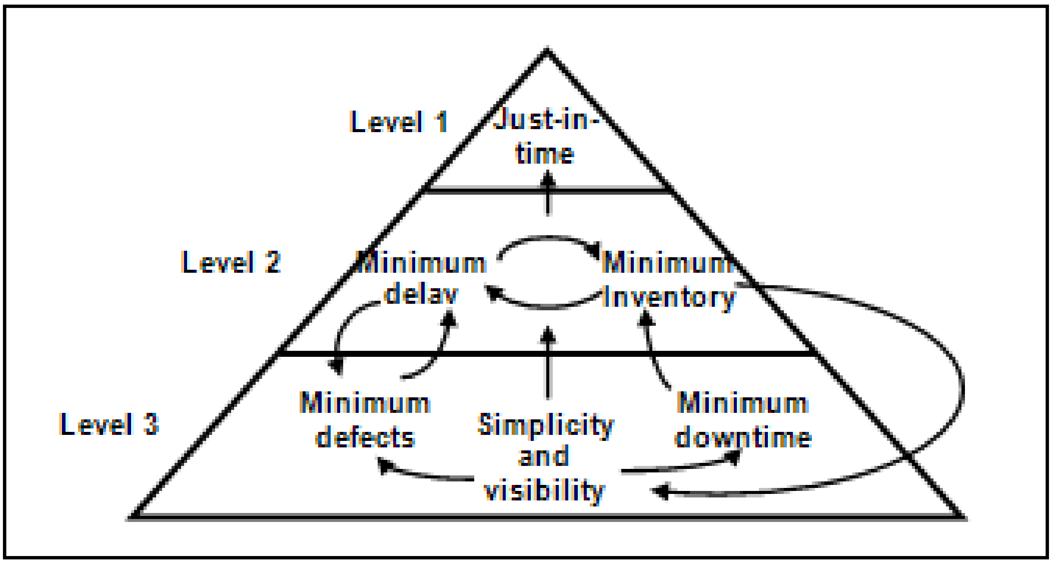
1. Overproduction.
2. Waiting.
3. Transport.
4. Inappropriate processing.
5. Unnecessary inventory.
6. Unnecessary motion.
7. Defects.

Hines and Rich (1997) identify overproduction as the most serious waste. To identify and remove waste from the system Hines and Rich (1997) have use a process of what they term 'process activity mapping':

1. The study of the flow processes.
2. The identification of waste.
3. A consideration of whether the process can be rearranged in a more efficient sequence.
4. A consequence of a better flow pattern, involving different flow layout or transport routeing.
5. A consideration of whether everything that is being done at each stage is really necessary and what would happen if superfluous tasks were removed.

A concept known as 'Just in Time' (JIT) is a technique that has arisen out of lean manufacturing. The approach does what the name suggests - stock should arrive at the time it is required, "neither too early, nor too late" (Harrison and van Hoek, 2005, p.155). A pull system is used rather than the traditional push system to replenish stock. In a push system stock is ordered when a signal is triggered, usually the reorder point (ROP) when the level reaches a predetermined point. In a pull system demand at the end of the supply chain triggers signals further down the supply chain, so stock is ordered when it is required. In the process lead times are reduced, deliveries increased and the level of stock is reduced. Harrison and van Hoek (2005, p.158) show that a number of factors have to be achieved to reach a JIT capability (see Figure 2.18).

Figure 2.18: The pyramid of key factors that underpin JIT



An approach which is similar to the concept of JIT to reduce lead times is 'quick response' (QR). It is argued that QR is an extension of JIT aided by advances in technology (Sullivan and Kang, 1999). Harrison and van Hoek, (2005) divorce the two concepts, showing that QR is applied to the distribution management between the retailer and the supplier and that JIT is applied to materials management. QR essentially enables business to quickly respond to changes in customer demand patterns (Office of Technology Assessment, US Congress, 1987). Harrison and van Hoek (2005, p.180) describe this as supplying "the right quantity, variety and quality at the right time to the right place at the right price".

It was first developed in the 1980's within the textile and apparel industry in the US (Emmett and Crocker, 2006). This was a reaction to the threat from low priced overseas supplier competition (Office of Technology Assessment, US Congress, 1987). This is evident in the ten years previous to 1987 when US imports had risen from 25% to 50% of the total market share (Office of Technology Assessment, US Congress, 1987). The principle is to increase efficiencies within the entire supply chain to compete with the low labour costs which are underpinning the prices of overseas suppliers. The Crafted with Pride in U.S.A. Council Inc commissioned Kurt Salmon Associates to carry out a study of QR within a number of companies (Office of Technology

Assessment, US Congress, 1987). The results of their report showed that the benefits of QR are:

- stock-outs were avoided or detected early;
- reorder cycle time was reduced by 33 percent;
- cut authorization-to-finished goods availability reduced by 30 percent;
- colour assortment-to-shipment time was reduced by 50 percent.

A research study by Sullivan and Kang (1999) into the benefits of QR concluded that a significant competitive advantage and an increased market share can be gained by an implementation of QR. Fundamentally, QR is made possible by advances in information technology, such as EDI and uniform product codes in bar coding (Harrison and van Hoek, 2005). Electronic point of sale (EPOS) information is sent directly from the retailer to the supplier and allows for a reduction in lead times and as a result, there are reductions in inventory. This principle of sharing information between supply chain partners to create a pull inventory system is referred to as a continuous replenishment program (CRP). An extension of this principle is vendor managed inventory (VMI). In this approach the retailer controls all decisions relating to inventory within the supply chain. This can lead to increases in profits for the entire supply chain (Chopra and Meindl, 2007).

The concept of QR was later developed and applied within the grocery industry and termed efficient consumer response (ECR). There is added emphasis on collaboration between supply chain partners (Christopher, 1998) and is broadened to include the added business areas of “new product introductions, items assortments and promotions” (Food Marketing Institute, 2009). A report by Kurt Salmon Associates (1993) which examined ECR within the grocery industry showed that total industry costs were cut by 10 percent or $30 billion by its application (Food Marketing Institute, 2009). The two principles of category management and continuous replenishment are the key aspects of ECR. Category management uses demand information to be shared between supply chain parties. It enables product volume and variety to be balanced at the retailer (Harrison and van Hoek, 2005). The FMI (April, 2009) show that the main components of ECR are as follows:

- efficient store assortment (category management);
- efficient replenishment (continuous replenishment);
- efficient promotion;
- efficient new product introduction.

2.4.2 Agile supply chain

It is unclear where the paradigm 'agility' actually came from (Stratton and Warburton, 2003). It has been said that it was a result of the economic threat posed by Japanese manufacturers (Burgess, 1994) or developed from flexible manufacturing systems (FMS) (Harrison and van Hoek, 2002). A definition of agility is shown below:

> "The ability of an organisation to thrive in a continuously changing, unpredictable business environment. Simply put, an agile firm has designed its organization, processes and products such that it can respond to changes in a useful time frame" (Prater, 2001, p.823).

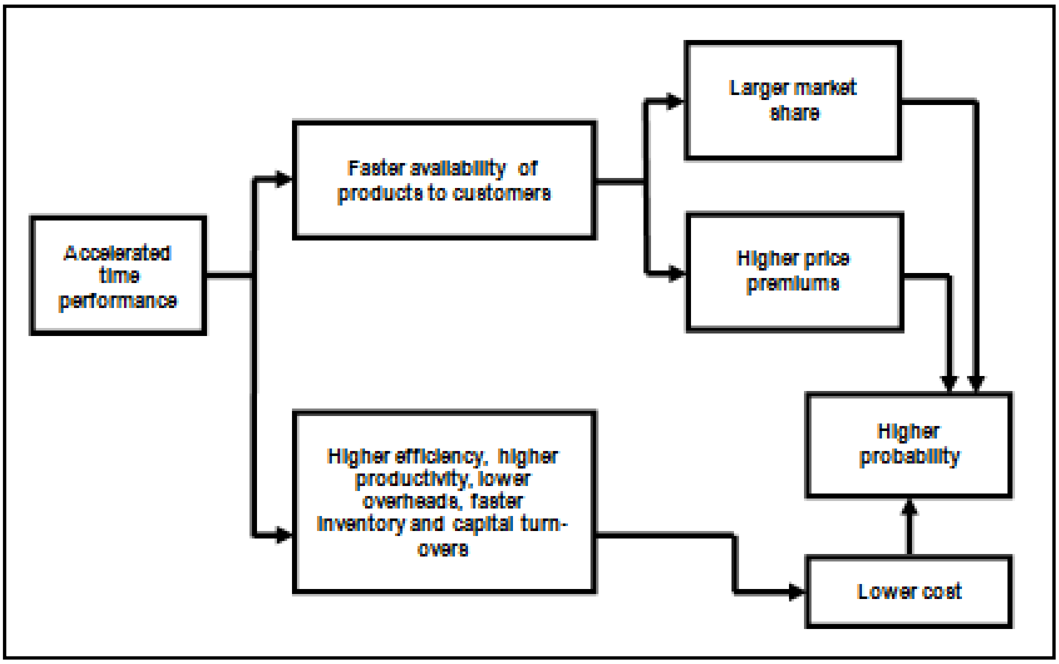
The main premise of agility is the ability of a business to be flexible in a way that it is can respond quickly to changes in demand. It is argued that flexibility is required to respond to changes in customers, technology and competitors (Zhang *et al*., 2003). Agility within businesses is required in instances where demand is volatile and variety of products is high (Christopher and Towill 2001). To hedge against demand uncertainty extra inventory is required (Naylor, 1999). This is in contrast to a lean supply chain which aims to minimise inventory levels. There is an explicit link between the level of flexibility required to be agile and the uncertainty of demand. If uncertainty increases it is harder for a company to be flexible and more resources are required.

Underpinning the notion of agility is a requirement to do things quickly. Kumar and Motwani (1995, p.37) describe this as time-based competitive advantage (see Figure 2.19). It is achieved by reducing delivery times and improving information flows. Responsive demand planning relies on fast information flows. Towill and Christopher (2007, p.406) describe agility in the context of demand planning:

> "Underpinning the idea of agile manufacturing is the search for the capability to respond to actual demand rather than planning ahead and making the forecast".

Responsive demand planning is made possible by using techniques such as efficient consumer response (ECR) and supply chain collaboration (Harrison and van Hoek, 2002). These have been made possible by advances in technology such as the retrieval of electronic point of sales (EPOS) data. The fashion company Zara is cited as a successful example of the application of agile principles to gain competitive advantage (Christopher 2000).

Figure 2.19: Time-based competitive advantage



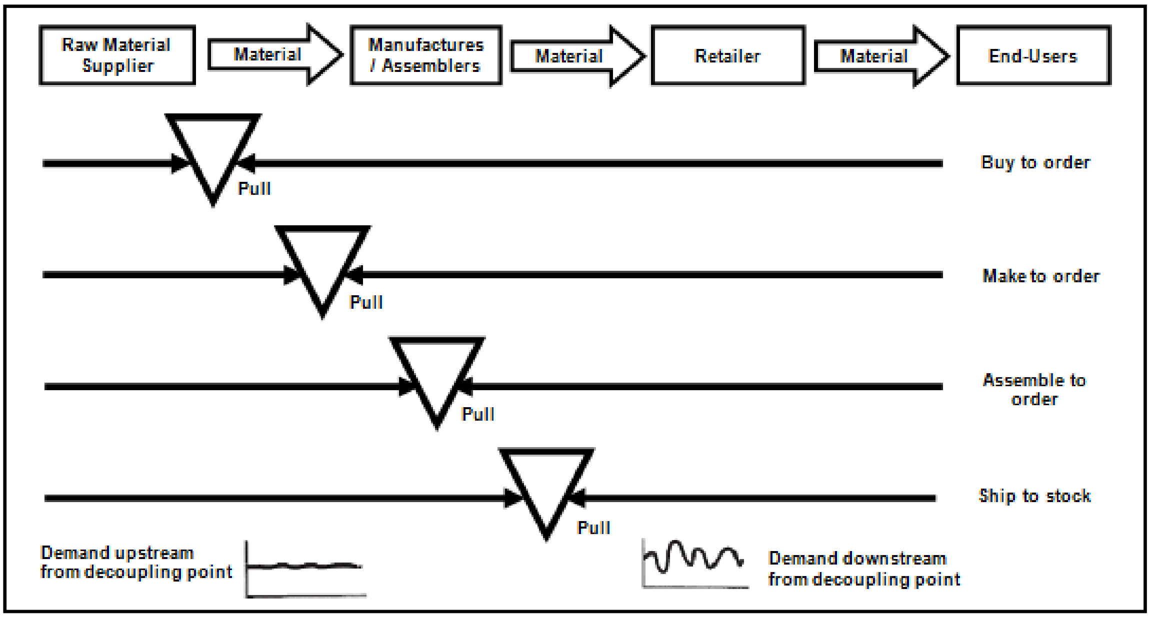
2.4.3 Leagile supply chain

The concept of adapting both lean and agile supply chains is known as "leagility" (Naylor *et al*, 1999). The principles have been discussed by a number of authors (Mason-Jones *et al*, 2000 a, 2000 b; Naylor *et al*, 1999; Prince and Kay, 2003; Towill and Christopher, 2007). It is shown that lean and agile do not need to be applied in isolation (Naylor *et al*, 1999; Towill and Christopher, 2007). Leagility was first used to describe the positioning of the decoupling point (Naylor *et al*, 1999). The decoupling point is defined as:

> "The decoupling point separates the part of the organisation [supply chain] orientated towards customer orders from the part of the organisation [supply chain] based on planning" (Naylor *et al*, 1999, p.108).

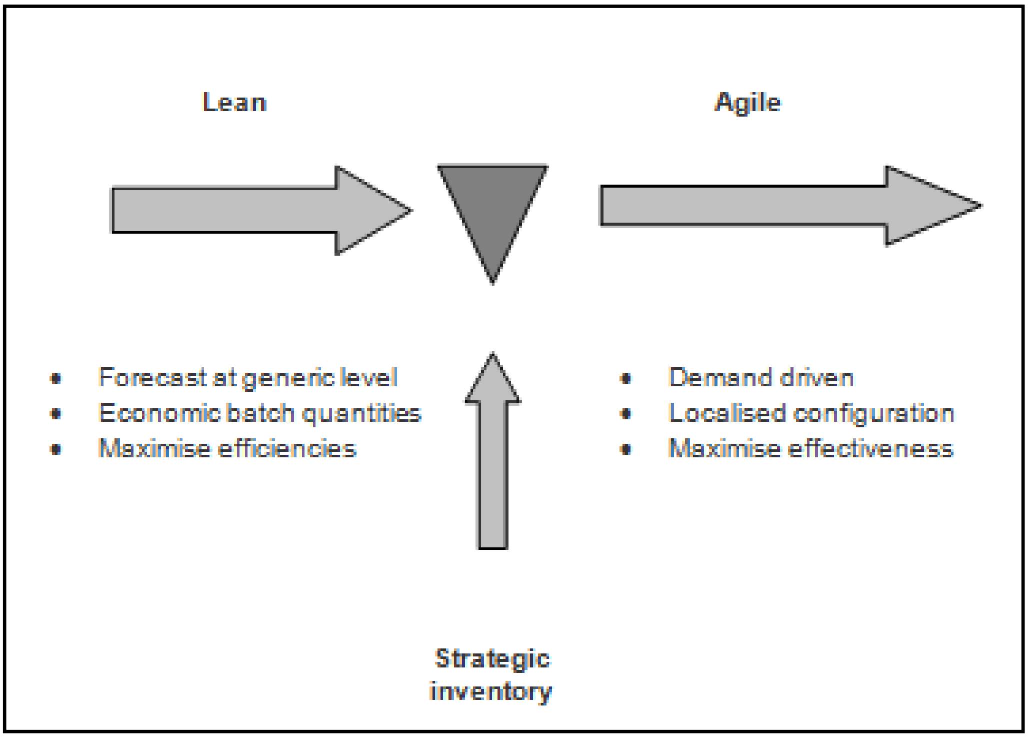
This can be described as the place in a supply chain where the system changes from a push to a pull system (Christopher and Towill, 2007). Mason-Jones *et al* (2000 b) shows this is also the point where strategic inventory is held. Strategic inventory is extra stock held to buffer against unexpected changes in demand. An example of the decoupling point positioned at various points of the supply chain is shown in Figure 2.20 (Hoekstra and Romme (1992, Cited in Mason-Jones et al, 2000, p.57). The difference in variation in demand is shown from upstream to downstream. The decoupling point can be moved with the supply chain. The nearer it is placed towards the customer, known as postponement, the risk of being out of stock at the retailer reduces (Naylor *et al*, 1999).

Figure 2.20: Supply chain structures and the decoupling point



This approach has been extended to incorporate agile concepts upstream and lean concepts downstream of the decoupling point (see Figure 2.21, Christopher, 2005, p.121). This is referred to as a leagile approach. Different techniques are used either side of the decoupling point. Naylor *et al* (1999) uses the example of Hewlett Packard (HP) printers to show a successful example of where a leagile approach was applied to overcome variability in demand. HP postponed the decoupling point when supplying generic printers up to that point in the supply chain and then customised the product as late as possible. The company then applied a lean strategy before the decoupling point and an agile strategy afterwards.

Figure 2.21: The decoupling point



Leagility has also been used to describe the matching of a particular type of product with a type of supply chain, lean or agile. Commodities and fashion product types are often cited as examples of where lean and agile approaches can respectively be best matched (Mason-Jones *et al*, 2000 a). This is because demand is more stable for commodities and more unpredictable for fashion products. Naylor *et al* (1999, p.108) makes the following distinctions between agility and leanness:

Agility:

"Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place."

Leanness:

"Leanness means developing a value stream to eliminate waste, including tie, and to ensure a level schedule."

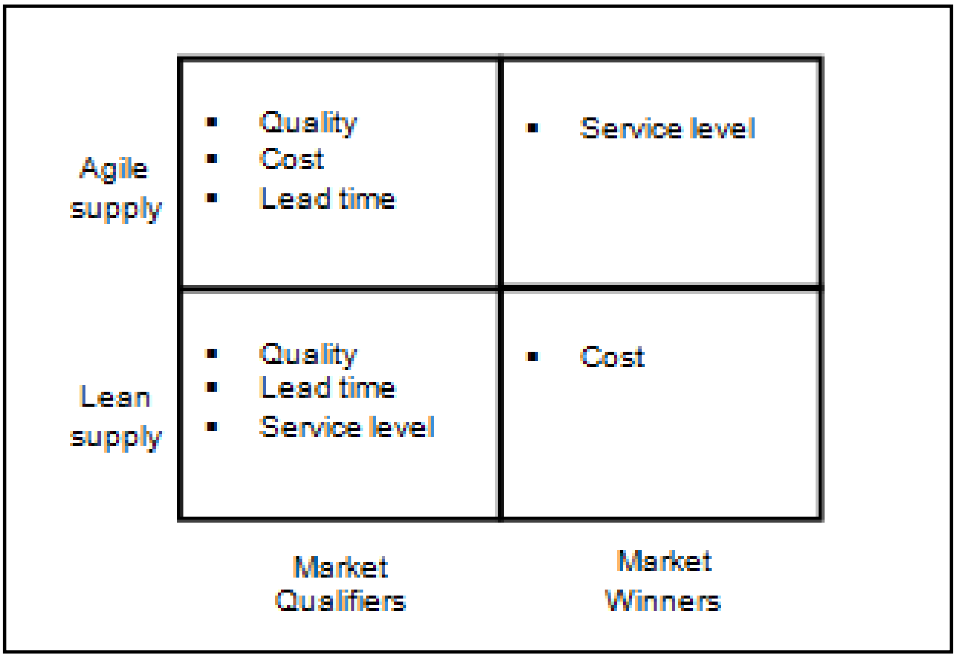
If a company uses a hybrid strategy that combines both lean and agile concepts a decision has to be made on which type of supply chain best matches which type of product. Mason-Jones *et al* (2000 b, p.56) have developed a table of distinguishing attributes to categorise products into either lean or agile supply (see Figure 2.22). The key attribute of lean supply is a predictable demand pattern and a low cost supply chain for commodity type products. The key attributes of an agile supply is volatile demand, and a high cost supply chain for fashionable products.

Figure 2.22: Comparison of lean supply with agile supply: the distinguishing attributes

Distinguishing attributes	Lean supply	Agile supply
Typical products	Commodities	Fashion goods
Marketplace demand	Predictable	Volatile
Product variety	Low	High
Product life cycle	Long	Short
Customer drivers	Cost	Availability
Profit margin	Low	High
Dominant costs	Physical costs	Marketability Costs
Stockout penalties	Long-term contractual	Immediate and volatile
Purchasing policy	Buy materials	Assign capacity
Information enrichment	Highly desirable	Obligatory
Forecasting mechanism	Algorithmic	Consultative

A matrix has been developed by Mason-Jones *et al* (2000 b, p.55) to show how the leagile approach links to competitive advantage (see Figure 2.23). This is developed from Hill (1993) who showed that there are five performance indicators, four of these are market qualifiers and one is a market winner. Mason-Jones *et al* (2000) uses these indicators to show that an agile supply chain primarily competes on service and a lean supply chain primarily competes on costs. Hill (1993) makes the point that market winners can become market qualifiers as the market changes. Ford for example which had adopted the lean model approach for the manufacturing of its 'Model T' had gained great success when competing on cost. When consumer power and tastes changed in the US the market winner switched to service levels and as a result the model 'T' became obsolete (Hounshell, 1985).

Figure 2.23: Market winners and market qualifiers for agile versus lean supply



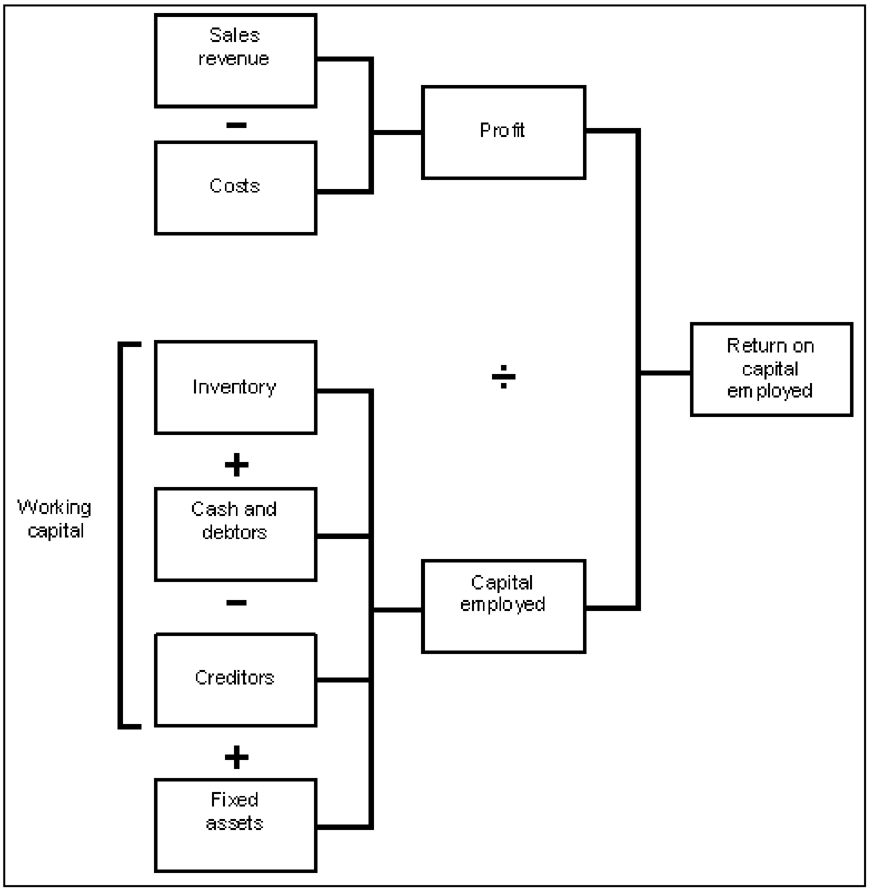
2.5 Supply chain performance

2.5.1 Definition

Most businesses measure and collect information to monitor performance using a number of chosen indicators. These are "the criteria with which the performance of products, services and production processes can be evaluated" (Aramyan *et al*, 2007). There are many different methods and a large quantity of measures. A business has to collect data and information in order to calculate the different supply chain measurements. Gunasekaran *et al* (2004) argue that many companies fail to maximise the performance of a supply chain because they fail to develop the necessary performance measures.

Financial performances are the most significant measures with shareholder value being the primary objective (Harrison and van Hoek, 2005). The return on capital employed (ROCE) is usually used to assess shareholder value (Harrison and van Hoek, 2005). The breakdown of this is depicted in Figure 2.24 (Harrison and Christopher, 2005, p.61). It is shown that the key drivers of ROCE are asset utilisation and sales revenue.

Figure 2.24: The make-up of return on capital employed (investment)



Financial performance measures gauge the extent to which a business is successful from a financial context but do not indicate operational competencies (Kaplan and Norton, 1992; Maskell, 1991). The success of a business is underpinned by the performance of the supply chain operation. An approach that evaluates both financial and operational performance is the most beneficial for business (Maskell, 1991). There are a number of trade-offs that exist between the company's assets and the sales revenue it can generate. For example liquid assets such as inventory create sales revenue and buffer against uncertainty in demand but also incur a cost of storage and tie up cash. SCM is critical in resolving trade-offs and increasing supply chain performance to gain competitive advantage. The Supply Chain Council[12] (https://www.scorlabs.org) show that supply chain performance is a measurement of:

- reliability - achievement of customer demand fulfilment on-time, complete, without damage etc;

- responsiveness - the time it takes to react to and fulfil customer demand;

- agility - the ability of supply chain to increase/decrease demand within a given planned period;

- cost - objective assessment of all components of supply chain cost;

- assets - the assessment of all resources used to fulfil customer demand.

Emmett and Crocker (2006, pp.61-62) have created a list of tools by which the entire supply chain performance can be measured (see Figure 2.25). These measures are calculated from historical business data or from internal company and customer surveys. The results show the performance level of the overall supply chain and the various areas within that. The business can then focus on the areas which require improvements and the total level of performance can be increased.

It is important to note that many of the performance measures shown in the table are interrelated. The focus to improve one performance measure can directly be detrimental to another. In reality managers have to consider the priorities of the business and attempt to manage this through in an effective and sustainable manner using appropriate supply chain measures. The principles of SCM, such as JIT management and supply chain segmentation can effectively manage these trades-offs by increasing the performance of the supply chain as a whole.

[12] According to The Supply Chain Council they are a global non-profit consortium. (http://supply-chain.org/about).

Figure 2.25: Supply chain performance measurements

Description	Measurement tool	Definition	Units
Customer order fulfilment	On-time/in-full rate (OTIF) Lead time	Orders OTIF Receipt of orders to despatched/delivered	% Hours/days
Customer satisfaction	Customer survey	A sampling survey to ask for customers experiences for example: - support available - product availability - flexibility - reliability - consistency - comparison to the competition	% satisfied
Supply management	OTIF Supplier survey Effectiveness Lead time	As above As above customer survey Year-above customer survey Time placed order to time available for use	% % satisfied % Hours/days
Inventory (measure for each holding place of raw materials, work in progress and finished goods)	Forecast accuracy Availability On hand	Actual/forecast sales per SKU Ordered/delivered per SKU Value on hand/daily delivered value	% % Days
Cash flow	Cash to cash	Time from paying suppliers to time paid by customers	Days
Quality	Quality	Non conformances, as appropriate	Per 100 or 1000 or million
Operations	Utilisations Productivity Costs Lead times	Used/available Actual/standard Actual/standard Time start/time completed per operation	Units Hours Costs Hours/days
People relationships	Internal Internal External	Absence rates Staff turnover rates Opinion surveys, for example: - support given - development - morale - work conditions - communication, etc.	% % % satisfied
Costs	Total supply chain or per operation cost	Cost per time period/units	£ per unit

2.5.2 Key performance indicators (KPI's)

Gunasekaran *et al* (2004) show that there are different measurement levels within a business; strategic, tactical and operational planning and control. Strategic level measurements for example are received by directors and would influence decisions such as business policies and strategic goals. The lower levels of the business require more detailed measurements. There are a number of supply chain measurement frameworks which have been developed (Aramyan *et al*, 2007; Gunasekaran *et al*., 2001, 2004; Kaplan and Norton, 1992). A framework developed by Gunasekaran *et al* (2001, p.83) is shown in Figure 2.26. The table shows a number of different financial and non-financial measures.

A number of decisions have to be made regarding which methods to use, which measures to calculate and which managers will carry out the process and receive the results. There are many different performance measures which a business can choose to monitor. Each of the measures has to be evaluated so a decision can be made whether the resource which is required to gather the information and perform the calculations is beneficial. This process can be undertaken by "brainstorming sessions, ranking scales, research and analysis" (Wang *et al* (2006, p.344). There are relatively few measures which contribute significantly to the competitive advantage of a business (Christopher, 1998). These are called key performance indicators (KPI's). Measures such as lead times have been shown to be a source of competitive advantage (Christopher, 1998, Stalk 1988). The availability of stock has a direct impact on the level of revenue and affects customer satisfaction.

Figure 2.26: Performance measures and metrics

Level	Performance metrics	Financial	Non-financial
Strategic	Total supply chain cycle time		▪
	Total cash flow time	▪	▪
	Customer query time	▪	▪
	Level of customer perceived value of product		▪
	Net profit vs. productivity ratio	▪	
	Rate of return on investment	▪	
	Range of product and services		▪
	Variations against budget	▪	
	Order lead time		▪
	Flexibility of service systems to meet particular customer needs		▪
	Buyer-supplier partnership level	▪	▪
	Supplier lead time against industry norm		▪
	Level of supplier's defect free deliveries		▪
	Delivery lead time		▪
	Delivery performance	▪	▪
Tactical	Accuracy of forecasting techniques		▪
	Product development cycle time		▪
	Order entry methods		▪
	Effectiveness of delivery invoice methods		▪
	Purchase order cycle time		▪
	Planned process cycle time		▪
	Effectiveness of master production schedule		▪
	Supplier assistance in solving technical problems		▪
	Supplier ability to respond to quality problems		▪
	Supplier cost saving initiatives	▪	
	Supplier's booking in procedures		▪
	Delivery reliability	▪	▪
	Responsiveness to urgent deliveries		▪
	Effectiveness of distribution planning schedule		▪
Operational	Cost per operation hour	▪	
	Information carrying cost	▪	▪
	Capacity utilisation		▪
	Total inventory as:	▪	
	- Incoming stock level		
	- Work-in-progress		
	- Scrap level		

2.5.3 Activity based costing (ABC)

Activity based costing (ABC) is a method which allocates costs to products according to the resources they consume (Christopher, 1998). It replaces the traditional accounting methods which allocated costs to products on an arbitrary basis (Christopher, 1998; Hines, 2004). Cooper and Kaplan (1988) argue that poor information from traditional costing models had led to bad corporate strategies. The approach breaks down a business into a number of processes, such as storage and distribution, and then breaks down the processes into a number of activities, such as picking and put away (Harrison and van Hoek, 2005). A cost driver is then identified and a cost per activity can be calculated. The benefit of this approach is that managers can make decisions based upon accurate information (Christopher, 1998). Harrison and van Hoek (2005) show that there are a number of limitations to the method due to its complexities such as identifying the discrete processes and single cost drivers.

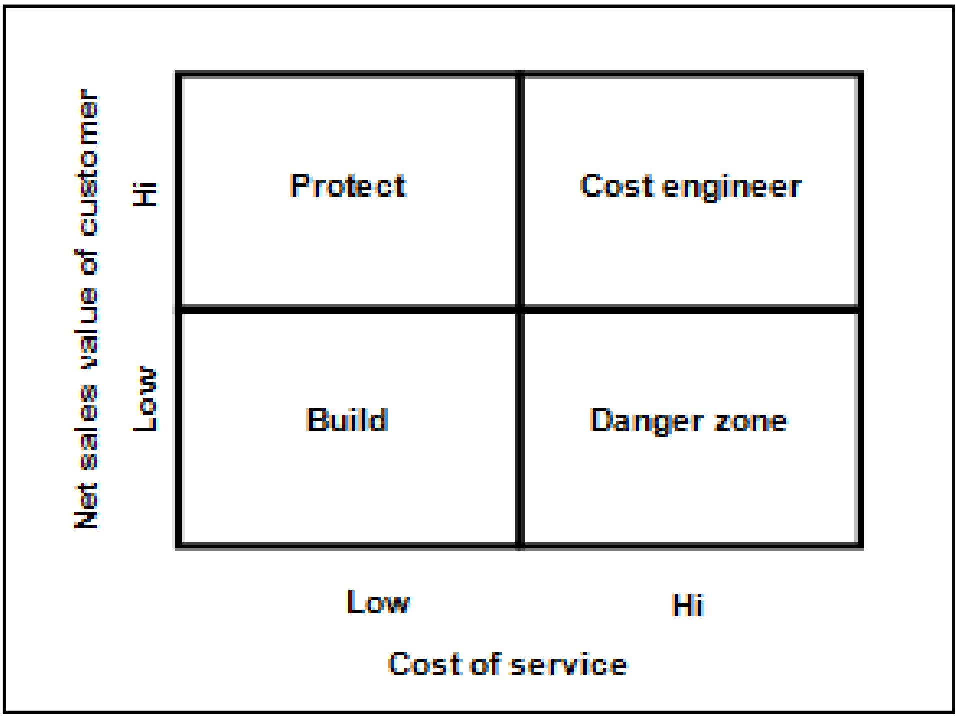
2.5.4 Direct product profitability (DPP)

Direct product profitability (DPP) is a method of calculating the actual profitability of individual SKU's. The true costs of a SKU are calculated so that not only is the buying cost deducted from the selling price but all the other costs, which are not so easily identifiable, are removed (Hines, 2004). These costs include the logistics costs of storing, handling and transportation. This removes an average cost being allocated for all products and gives a true reflection of individual product values. This shows which products have a negative profitability and can be targeted for further analysis. Emmett and Crocker (2006, p.65) show the calculation for DPP is as follows:

DPP	=	Sales, less the cost of goods sold
	=	Gross margin, plus allowances/discounts
	=	Adjusted gross margin
		less warehouse costs
		less transport costs
		less retailing costs

The approach that was used for DPP can be used to calculate the profitability of particular customers. This will show which customers are the most profitable and which if any have a negative profitability. This process can then guide the sales and marketing teams in their strategic decisions. Christopher (1998, p.91) has developed a matrix which places customers into four different quadrants depending on their costs and sales (see Figure 2.27). Customers which fall into the build quadrant should be targeted to increase profitability. Customers which fall within the protect quadrant add the greatest value to the business and should be targeted to prevent against a decrease in service. Customers which fall within the cost engineer and danger zone have a high cost of service. These sectors can be targeted to reduce operation costs where possible. Customers which fall within the danger zone add little value to the business and the operational costs are high. This sector should be prioritised and a reduction in customers here would be desirable.

Figure 2.27: Customer profitability matrix



2.5.5 Benchmarking

Benchmarking was first used as a competitive strategy by Xerox in 1976 (Hines, 2004). It is a method of measuring performance against other business typically within the same industry. In February 2002 the NHS Logistics Authority formed a benchmarking club for the logistics industry (NHS Logistics Authority Logmark, Jan 2004). This is now part of the Chartered Institute of Logistics and Transport (CILT) (UK) and according to them is the only logistics benchmarking club (CILT (UK) Logmark, April 2009). The club consists of members representing different businesses and from a number of industries all of which are involved in logistics. Each member fills out a questionnaire consisting of the following areas:

- inventory measures;
- operational measures;
- transport measures;
- HR measures.

In 2004 a benchmarking club was attended on behalf of Brakes Logistics. An example of a questionnaire, taken from a benchmarking exercise carried out in 2004, is shown in CD Appendix B and the results of the exercise are shown in CD Appendix C. The CILT (UK) Logmark (April, 2009) lists the following as the processes involved in benchmarking:

- regularly comparing agreed key performance indicators;
- identifying and understanding differences in performance;
- sharing best practice to develop new ideas and solutions;
- reviewing progress and ensuring continual improvement.

The principle of a benchmarking exercise is to identify the strengths and weaknesses of a business and best practice. This can then be used as a driver for change. The CILT (UK) Logmark (April, 2009) lists the following benefits:

- improvements in performance, quality and productivity; and
- improvements in performance measurement.

A model has been designed which is used to measure the performance of supply chains. The Supply Chain Council (SCC) (https://www.scorlabs.org/) has developed a framework which evaluates and compares the performance of activities within a supply chain. This framework is known as the Supply Chain Operations (SCOR) model. The model identifies five processes that are present within supply chains; plan, source, make, deliver and return. These processes include all the activities which are involved from "identifying customer demand through to delivering the product and collecting the cash" (Christopher, 1998, p.106).

The Supply Chain Council (https://www.scorlabs.org/) lists the following benefits of supply chain performance by adopting their framework:

- determining what processes to improve first and how much to improve them;
- to guide the consolidation of internal supply chains (which results in significant cost reductions from eliminating duplicative assets);
- create standard processes and common information systems across business units (which generates major cost savings, cycle-time and quality improvements);
- create a common SCORcard by which customers can measure their performance and by which SCC members can measure suppliers' performance (which can lead to major cross-organizational process improvements).

2.6 Supply chain trade-offs

The trade-offs which exist in the supply chain are at the heart of management decisions which are faced by generations of strategists and operational managers. Levi et al (2004) pp.36-39) lists a number of supply chain trade-offs:

1. The cost-customer service trade-off.
2. The lot size-inventory trade-off.
3. The inventory-transportation cost trade-off.
4. The lead-time-transportation cost trade-off.
5. The product variety-inventory trade-off.

The cost-customer service trade-off is the most commonly known and has the greatest impact on profit. It is crucial for businesses to both retain and win new customers. In an ideal world businesses would best direct their strategies towards total customer satisfaction. If customers are not satisfied with the service they receive it is likely that they will move their business elsewhere. To satisfy all customers across the entire business (100% service level) however would require an unprecedented level of invested cost (Woo and Fock, 2004). Levi et al (2004, p.35) shows that to satisfy customers a business should aim to provide the following:

- short order lead times;
- efficient and accurate delivery;
- in stock items;
- enormous variety;
- low prices.

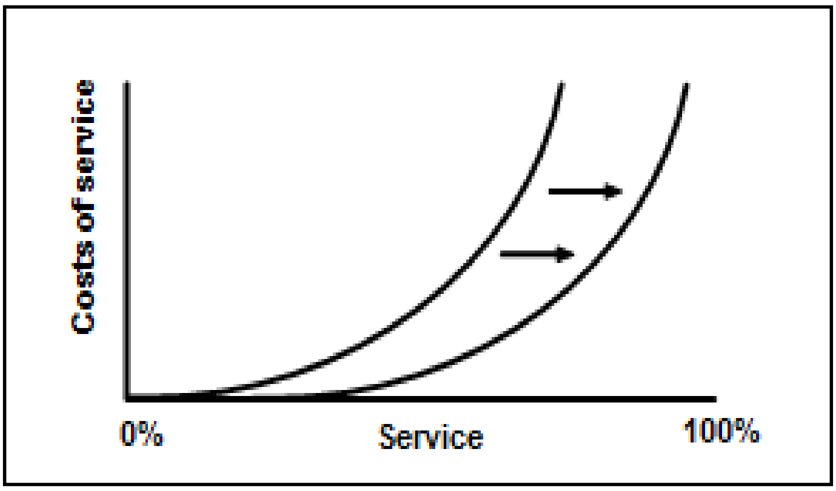
Due to the operational costs that would be involved in trying to achieve this a strategy that results in leaving some customers with some level of dissatisfaction, is not to be construed as a strategic failure on every occasion. This is the view of A.T Kearney (Sept 2008):

> "Providing customers with the right products and services all of the time can be a complex, asset-heavy process, fraught with inefficiencies, waste and duplicate efforts".

It is naturally advisable for companies to compete for business by delivering requirements demanded upon it by its customer base because fundamentally, it is the customers who provide the income to keep a company solvent. According to Porter (1985) a company has to ensure that it has a vision which accentuates a sustainable approach in the way it operates, striking a balance between cost and service to obtain long term profits, as it is uneconomical for companies to attempt to satisfy all its customers. Within SCM a number of trade-offs have therefore to be negotiated.

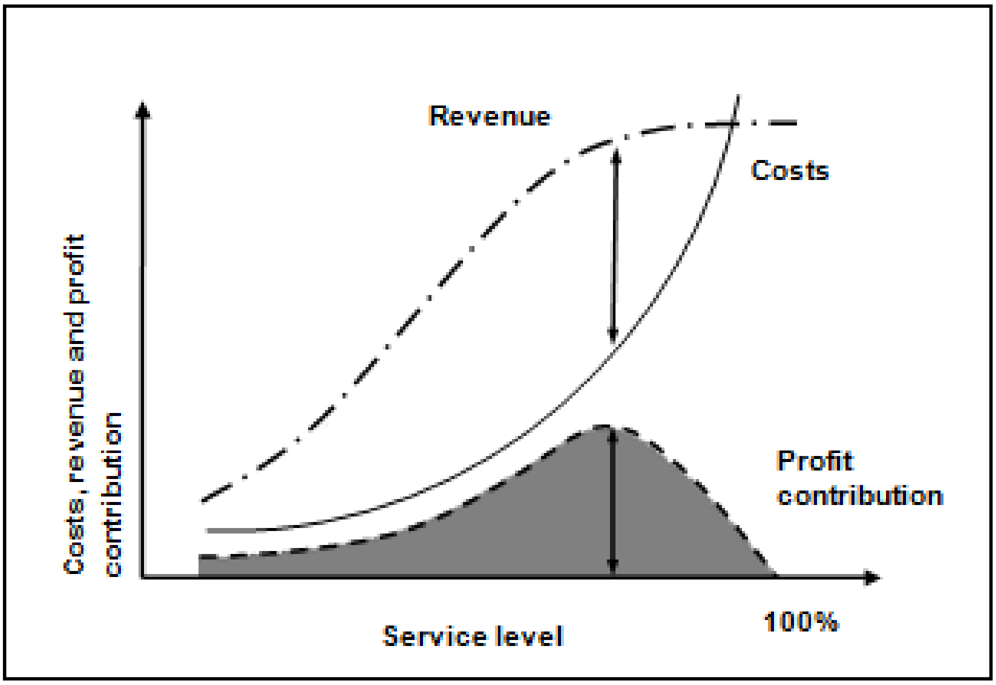
According to Christopher (1998, p.54) as customer service levels approach 100% the elasticity of cost increases exponentially. At this point many products and services become unprofitable as operational costs begin to outweigh market prices (see Figure 2.28, Christopher, 1998, p.55). There is a possibility to move the curve to the right as depicted in the diagram. This is achieved by improving the operation or finding new strategies without reducing the level of service.

Figure 2.28: The cost of service



The trade-off gives rise to a number of questions which businesses have to endeavour to answer, such as, what level of customer service should be achieved? should different customers and products have different levels of service? and how should these decisions be made? A point is reached where an optimum service level cost is reached. The cost of service starts to outweigh the benefit of revenue returns and profits are maximised. A pictorial representation of this premise is shown in Figure 2.29 (Christopher, 1998, p.56).

Figure 2.29: The cost/benefit of service



There is no simple method for accurately calculating this trade-off and finding an optimum profit level. The many unpredictable factors such as the chaotic nature of markets mean that the choices for businesses are complex. It is only possible to estimate to a certain degree of accuracy the expected revenue a company can make and the loss of lost sales in respect to service levels. It is also very difficult to calculate operational supply chain costs at an individual product level. A business therefore has to make decisions based on a number of assumptions to a reasonable degree of accuracy.

It was argued by Forrester (1961) that managers often fail to make choices that are beneficial for the long term. Intuitive decisions made by managers can be detrimental because they aren't able to understand the structure and behaviour of a system. This can manifest itself when businesses focus too heavily on customer satisfaction in an attempt to maximise revenue and as a result place less emphasis on operational costs. It is necessary that managers understand the trade-offs so that a logical approach is used with the aim of maximising profits in the long term.

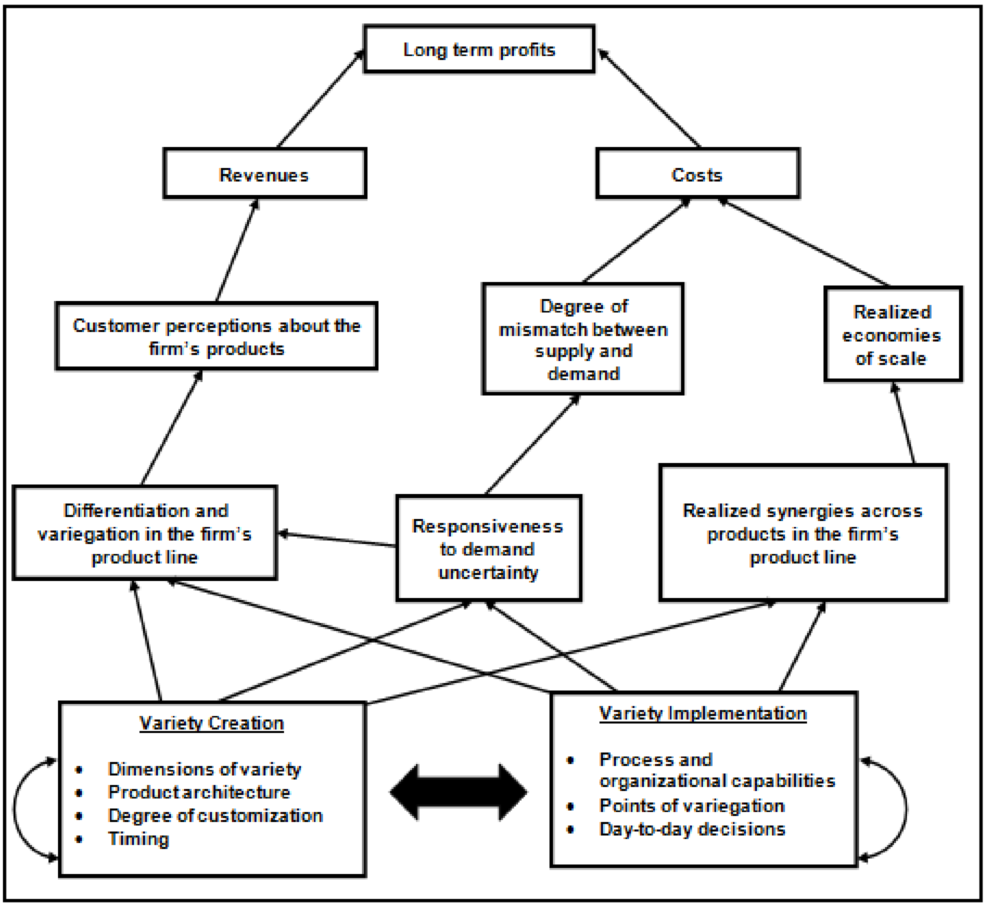
2.7 Business diversity

There is much diversity within supply chains because businesses sell a wide range of products to many different customers. It is desirable to serve customers with a mix of products to satisfy varying needs. Increasing global competition, new technologies and changing customer habits have led to greater customisation and product variety; have changed the dynamics of markets (Fisher *et al*., 1994; Ramdas and Speckman, 2000; Ramdas, 2003). This has led to business strategies which increasingly compete on service, putting pressure on the operation and leading to increases in inventory carrying costs, markdowns and write-offs and reductions in profit margins (Fisher *et al.*, 1997).

It is believed that mass customisation is the new business frontier for manufacturing and service industries (Pine and Davis, 1999). This is different to mass production markets which serve the "average customer". Mass customisation aims to offer "the most suitable product to each one of their customers" (Saisse and Wilding, 1997, p.200). This adds to the diversity in supply chains as product choices are increased and life cycles are shortened. This has been particularly true in markets such as personal computers, consumer electronics, cars and chemicals which have seen increases in new product introductions and product variety (Saisse and Wilding, 1997, Ramdas, 2003). Ramdas (2003) remarks that a diversity strategy doesn't always result in increased profits for a business.

A framework developed by Ramdas (2003, p.81) shows how a company's variety of products can impact on sales and costs (see Figure 2.30). These are impacted by a number of interrelated criteria, such as differentiation, realised synergies and responsiveness to demand uncertainty. The framework shows that to maximise profit a balance has to be struck between the level of variety and the cost. Furthermore, it is suggested that by increasing responsiveness to demand, costs can be reduced by "better matching supply with demand" (Ramdas, 2003, p.21). An important assumption is made that higher variety increases demand variability. This then increases "forecast errors, increasing excess inventories and shortage, buffer capacity and workforce fluctuation" resulting in "market mismatch costs" (Ramdas, 2003, p.83).

Figure 2.30: Framework for a firm's variety-related decisions



The characteristics of products determine the level of resource that is required to serve the customer. In an instance where resources are uniformly allocated to products, a disproportionate level of supply chain costs are incurred. For products which incur excess operational costs their margins are eroded, sometimes to an extent which can result in a negative profit for those items. Furthermore high value products can become neglected if operational resources are not directed effectively. Products which are deemed high priority by customers can fall below service expectations. This means that all products and customers should not have the same level of service (Sabath and Whipple, 2004).

2.8 Supply chain segmentation

Organisations, whether or not this is recognised or carried out logically, have always applied a level of segmentation to the design of their strategies. This idea was first formalised by Smith (1956) to market segmentation. He suggested market strategies could be segmented by using consumer demand. This concept is now widely understood and is a core principle of marketing literature (Kotler and Armstrong, 2010; Lamb *et al*., 2008; Lilien *et al., 2007)* and commonly applied to the way companies design their market strategies. This has been developed into all markets and has been shown to work for businesses operating on the Internet (Ren *et al.,* 2010*).* Botha *et al* (2004, p.61) define market segmentation as:

> "The process of dividing a total market into market segments or target market of consumers with common needs or characteristics and selecting one or more segments to target with a distinct marketing mix".

Companies such as Marks and Spencers have successfully used market segmentation. In 2002 they increased their market share of womens clothing after introducing a new brand called Per Una to attract younger women (Lilien *et al*, 2007). This was based upon a segmentation study (Lilien *et al*, 2007). There are other uses of segmentation which been suggested such as the framework proposed by Erevelles *et al* (2001) to segment a company's supplier base.

Supply chain segmentation follows the same basic concept of market segmentation to the management of the supply chain operation. It is a method which manages business diversity throughout the supply chain. This is achieved by segmenting products and customers by targeting individual characteristics and then to assign category specific strategies.

> "The key to supply success lies in dynamic management – matching the right strategies with the right situation" (A.T. Kearney, Feb 2008).

It can reduce overall supply chain costs and increase overall service levels by finding solutions to the various supply chain trade-offs. This point is summed up below:

> "In an increasingly competitive environment the need for supply chain segmentation is critical to develop winning supply chain strategies that successfully balance the cost of inventory and the cost of service" (http://www.supplychainsegmentation.com/index, Jan 2009).

This approach can be applied throughout the supply chain and more specifically in the following areas:

- manufacturing;
- storage;
- handling;
- transportation;
- purchasing;
- marketing.

An article in the Harvard Business Review in 1993, entitled 'Tailored logistics: The next advantage' showed that companies should have distinct channels of distribution which serve different customer segments, describing them as 'logistically distinct businesses' (Fuller *et al*., 1993, p.87). The article has been described as the first to address this within the context of a supply chain (Lovell *et al*, 2005). The central point of the article was to show that an 'averaging' across logistics functions exists, where "things flowed through consolidated channels at an average speed and were charged at an average cost", a 'diseconomy of scale' is created by logistics managers who apply uniform standards and polices (Fuller *et al*., 1993, p. 90) – 'a one size fits all approach'. This creates an unbalanced level of customer service and resource priorities are given to the wrong types of products, leading to congestion within the supply chain and an increased level of operational costs.

Fuller *et al* (1993, p.90) argued that it is suboptimal to treat each product and customer as equal when in fact there is much diversity, leading to the notion that "customers who needed specialized products quickly but unpredictably tended to be underserved, whilst customers for more commodity-like products were overcharged". This is to say that segments of customers and products can be served through distinct logistical pipelines, through a predetermined process which uses individual product and customer characteristics.

It is proposed in the article that by tailoring logistics to distinct customer segments companies can substantially reduce their operational costs. Coco-Cola is cited as a successful case where an average of $80 million to $90 million a year for ten years was saved by tailoring their logistical activities (Fuller *et al*., 1993, p.88). The article provides an outline of a simple methodology (Fuller *et al*, 1993, p.92), which is described as 'logistically distinct business methods' (LDB methods):

1. Segmenting customers exactingly by means of, in some cases, highly original buyer purchase criteria related to logistics.

2. Establishing appropriate, hence differential, standards of service for different customer segments.

3. Tailoring, that is disaggregating and reconfiguring, logistics pipelines to support newly mandated standards of each segment.

4. Exploiting economies of scale among different logistics pipelines, but only where these permit competitiveness in chosen customer segments.

5. Sustaining multifunctional cooperation in the creation of an integrated reporting system so that the flow through each pipeline is balanced.

Fuller *et al* (1993, pp.93-98) sets out a number of questions that are required to be answered as part of the methodology. These are as follows:

1. What do customers want?
2. What will make customers defect?
3. What business are we in?
4. How can we get products to customers?
5. New economies of scale? Opportunities to share logistics assets?

The first step is to segment customers by their needs and to define service criteria based upon this. Chopra and Meindl (2007, pp.26-27) provides a list of customer attributes. The attributes can be used to segment customers.

- the quantity of the product needed in each lot;
- the response time that customers are willing to tolerate;
- the variety of products needed;
- the service level required;
- the price of the product;
- the desired rate of innovation in the product.

Fuller *et al* (1993, pp.93-94) lists a number of questions, which are listed below, relating to stock keeping units (SKU's). These questions can be answered as part of the process of segmentation.

1. Is the SKU a high margin or a low margin item?

2. Do we sell many of these during a year?

3. Does the SKU need to arrive with others?

4. Must the people delivering the product perform a service?

5. Does the customer need rapid response for the delivery?

6. Does the customer typically buy the SKU in small or large amounts?

7. What are the handling and storage characteristics of the SKU?

8. Is the product substitutable by another product?

The next stage is to segment products with similar customer requirements. Logistics strategies are then designed to serve these segments. Chopra and Meindl (2007, p.23) state that a:

> "Competitive strategy targets one or more customer segments and aims to provide products and services that satisfy these customers' needs" (Chopra and Meindl, 2007, p.23).

The strategies are based around the costs of process capabilities - inbound and outbound transportation rates, variable handling costs, fixed costs and facility capacity. There are trade-off decisions between these costs and the customer requirements of the segments. The last step is to find which assets from the various logistic strategies can be shared to create economies of scale.

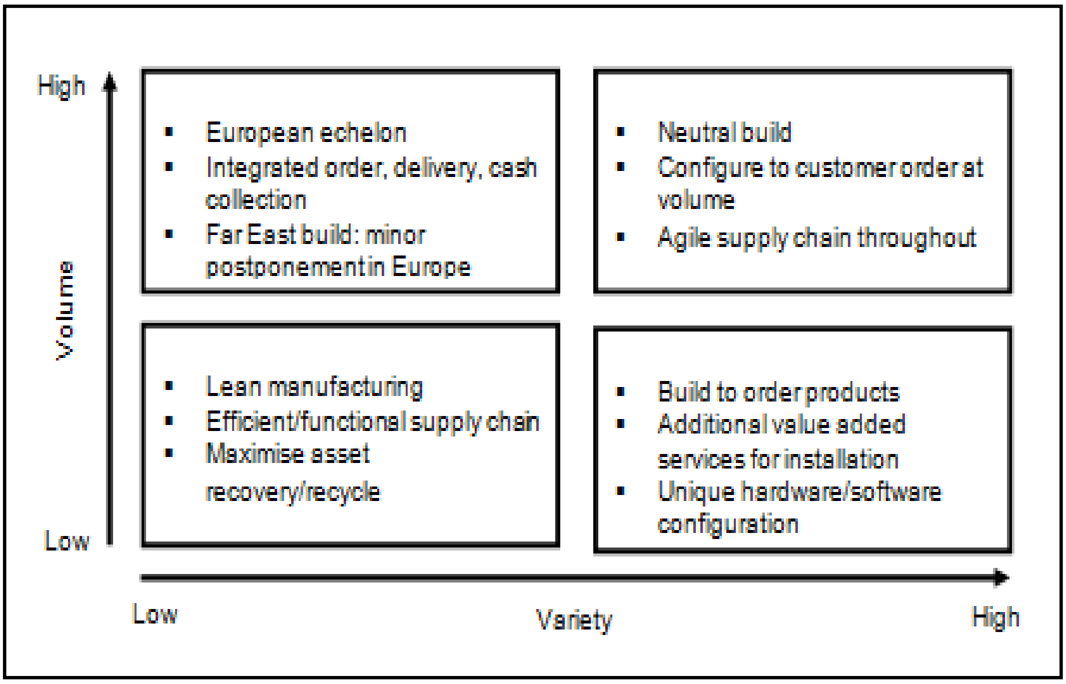
In addition to Fuller *et al* (1993) it has been argued that different product types require different supply chains (Fisher, 1997; Haung *et al.*, 2002; Selldin and Olhager, 2007; Payne and Peters, 2004). Fisher (1997) uses an approach not too dissimilar to Fuller *et al* (1993). It is unclear to what extent the article was influenced by Fuller *et al* (1993) but there are parallels to be drawn. Fisher's article however has less detail and doesn't ask some of the more precise questions that were posed by Fuller *et al* (1993).

It is suggested by Fisher (1997, p.106) that 'before devising a supply chain, consider the nature of the demand for your products'. Fisher (1997) suggests that a supply chain strategy of efficiency or responsiveness can be adopted depending on whether the type of product is either functional or innovative. A functional product is described as a staple product and an innovative product as a fashion product. A particular product is segmented as either a functional or innovative product by the characteristics it exhibits (see Figure 2.31, Fisher, 1997, p.107). Harrison and van Hoek (2005, p.194) use the characteristics of volume and demand variability and product variety to segment the supply chain into four distinct categories (see Figure 2.32). The approach was used at Xerox and it successfully reduced overall supply chain costs.

Figure 2.31: Characteristics of functional and innovative products

Aspects of demand	Functional (Predictable Demand)	Innovative (Unpredictable Demand)
Product life cycle	More than 2 years	3 months to 1 year
Contribution margin	5% to 20%	20% to 60%
Product variety	Low (10 to 20 variants per category)	High (often millions of variants per category)
Average margin of error in the forecast at the time production is committed	10%	40% to 100%
Average stockout rate	1% to 2%	10% to 40%
Average forced end-of-season markdown as percentage of full price	0%	10% to 25%
Lead time required for made-to-order products	6 months to 1 year	1 day to 2 weeks

Figure 2.32: Segmenting the market



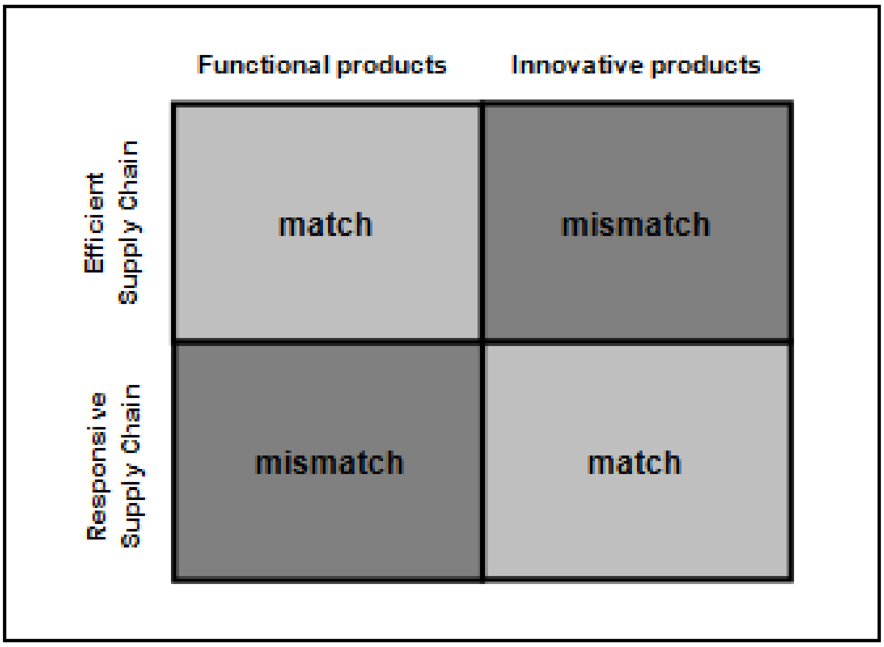
Christopher and Towill (2002) propose that three variables can be used to define supply chain strategy - products (either standard or special), demand (either stable or volatile), and lead time (either short or long). A matrix, often referred to as Fisher's Matrix (see Figure 2.33, Fisher, 1997, p.109) is used to depict this principle. Campbell Soup and Sport Obermeyer are cited as examples where the strategy had successful outcomes. It is shown that in one instance a two week inventory cost saving was produced which increased company profits by 50% (Fisher, 1997, p.113).

Using Fisher's matrix, Harrison and van Hoek (2005) compare a high-volume dishwashing product with a fashion ski jacket to show how differentiating strategies can be applied to different types of products. It is suggested that the high volume product is best suited to a supply chain that is focused on "low-cost, reliable supply" and the fashion product is best suited to a supply chain that is focused on "flexibility and responsiveness" (Harrison and van Hoek, 2005, p.27). A survey conducted by Selldin and Olhager (2007) of 128 companies showed that more companies which had used Fisher's model out performed companies which did not.

Recent academic articles have tended to cite Fisher's matrix as the foundation for discussion on supply chain segmentation and it has been mostly used as a method in supply chain design (Christopher and Towill, 2002; Lee, 2002; Lovell *et al* (2005); Mason-Jones *et al*., 2000; Naylor *et al*., 1999; Payne and Peters, 2004). Since the 1980's the two paradigms of lean and agile were developing exclusively of each other. In the late 1990's these two paradigms were drawn together to form a new paradigm called leagile (see section 2.4.3). The methods shown in Fisher's segmentation matrix and leagile methods, which combined lean and agile principles, were aligned (Childerhouse and Towill, 2000, p.340; van Hoek *et al*., 2001, p.131).

Leagile methods are superimposed onto Fisher's matrix, where the functional supply chain represents lean practice and the innovative supply chain represents agile practice. It is unclear if Fisher's matrix developed this new approach or it was done as an afterthought. Ramdas and Spekman (2000) evaluate how functional and innovative supply chains relate to supply chain performance.

Figure 2.33: Matching supply chain with products



Haung *et al* (2002) build upon this matrix adding a third product type of hybrid. A hybrid product is one that has both functional and innovative characteristics. These articles were formed from a marketing perspective and many of the examples are taken from the textile and apparel industry (Bruce *et al*., 2004; Bruce and Daly, 2006). This is because a leagile approach has its advantages in fashion supply chains where there are two distinct supply chains for staple and fashion products (Bruce and Daly, 2006).

For some companies the level of investment required to operate two supply chains which are physically distinct could possibly outweigh the benefits. This would apply to businesses with small revenues that operate a local supply chain and have a small number of suppliers or products. The process which segments products by their characteristics (see Figure 2.33) into either functional or innovative is vague and doesn't focus on the use of business data. The research concentrates on the different types of products and how they should move within the supply chain. There is no consideration of how this relates to different types of customers and does not attempt to solve supply chain trade-offs and there therefore a profitability approach is not used.

Sabath and Whipple (2004, p.11) have taken an approach which draws together different types of product and customer types into what is described as a customer/product action matrix (see Figure 2.34). Their approach segments products and customers by their business value. Products and customers can be one of the four different segments - extremely profitable, highly profitable, marginally profitable and unprofitable. An activity based costing (ABC) system is used to calculate their respective contribution to profit. This acts as a guide for managers to then adopt a particular strategy for each segment. Sabath and Whipple (2004) show that the model was successfully implemented to reduce inventories and increase customer service.

Figure 2.34: Customer/product action matrix

Customer Category	Product Category			
	1	2	3	4
A	Perfection / Never Miss	Regular / Priority Schedule	Reserve Capacity / Inventory	Tough It Out / Outsource
B	As Promised	Regular Schedule	Schedule Capacity / Inventory	Redirect / Outsource
C	If Available / If Scheduled	If Available	Only if Capacity or Inventory are Available	Only if Transaction is Profitable
D	Respond to Transaction	If no Conflict	Only if Inventory is Available / Cull Candidate	Cull

In reality grouping products into two distinct categories using a small number of factors isn't always the best solution to adopt, an observation made by Lovell *et al* (2005, p.143). Supply chains for many companies are too complex because of their diverse product range and large supply base to make that simple distinction. A study of segmentation by Lovell *et al* (2005) builds on the work of Fuller *et al* (1993). It is the most in-depth study of this nature and embraces segmentation as a strategy and methodology in its own right.

Lovell *et al* (2005) argue that the optimum segmentation strategy lies somewhere between the two distinct supply chains used in Fisher's (1997) model and a supply chain for every individual product. Lovell *et al* (2005, p.143) provide a table of possible factors that can influence supply chain segmentation of products and customers (see Figure 2.35). This is not exhaustive but does allow for an understanding of the different factors that can be considered.

There are different types of strategies discussed but there is little detail on an operational methodology. For instance it is argued that products with a short life cycle would lend themselves best to networks that hold low levels of inventory and use fast transport modes without going into any detail. An emphasis is put on value density as a measure to determine the choice of supply chain and it is argued that centralised inventory is well suited for higher product value densities.

Lovell *et al* (2005, p.149) show a link between the factors that make up supply chain design and the supply chain trade-offs (see Figure 2.36). This is an important distinction because it means that segmentation strategies are based upon profitability. Lovell *et al* (2005) show that these should be considered in the process of segmentation by examining the link between the factors and the trade-offs.

Lovell *et al* (2005) present a case study based at Sony BPE, part of the Sony Corporation to illustrate the benefits of a segmentation approach. The key drivers for segmentation are throughput, demand variability and Product Value Density (PVD). The PVD considers both the weight and value of a product. The outcome of the study is to implement a consolidation of products which exhibit a slow throughput and a high value density. The research study is primarily strategically based and focuses mainly on the design of a supply chain and the locations of products. These strategies can work well for large businesses operating global supply chains. For smaller companies the investment cost might be too high to strategically operate a number of facilities. There are different options, which require a localised depot solution, available for companies that do not source globally. In a case study which was carried out at British America Tobacco (BAT), Godsell (2009) use volume and variability as their primary driver in the segmentation process.

Figure 2.35: Factors that influence supply chain segmentation

Group	Factor
Product	Life cycle Variety within product group Product type: functional or innovative Handling characteristics Shelf life Physical size and weight Value Product value density (PVD)
Market	Demand location/dispersion Demand level (throughput) Demand variability Service expectations
Source	Limitations on raw materials Economies of scale Production flexibility Lead-time
Geographic and commercial environment	Existing infra-structure Transport mode availability Customs/duties/trade areas Legislation

Figure 2.36: Principal cost drivers in the supply chain

Fundamental supply chain costs	Cost drivers
Manufacturing	Throughput level Raw material cost Labour cost Technology
Primary transport cost	Throughput level Product size and weight Location of manufacture
Facility cost	Throughput level Product source and weight Service (product availability)
Secondary transport cost	Throughput level Product size and weight Service (product availability)
Inventory cost	Throughput level Value Demand variability/service (product availability) factor

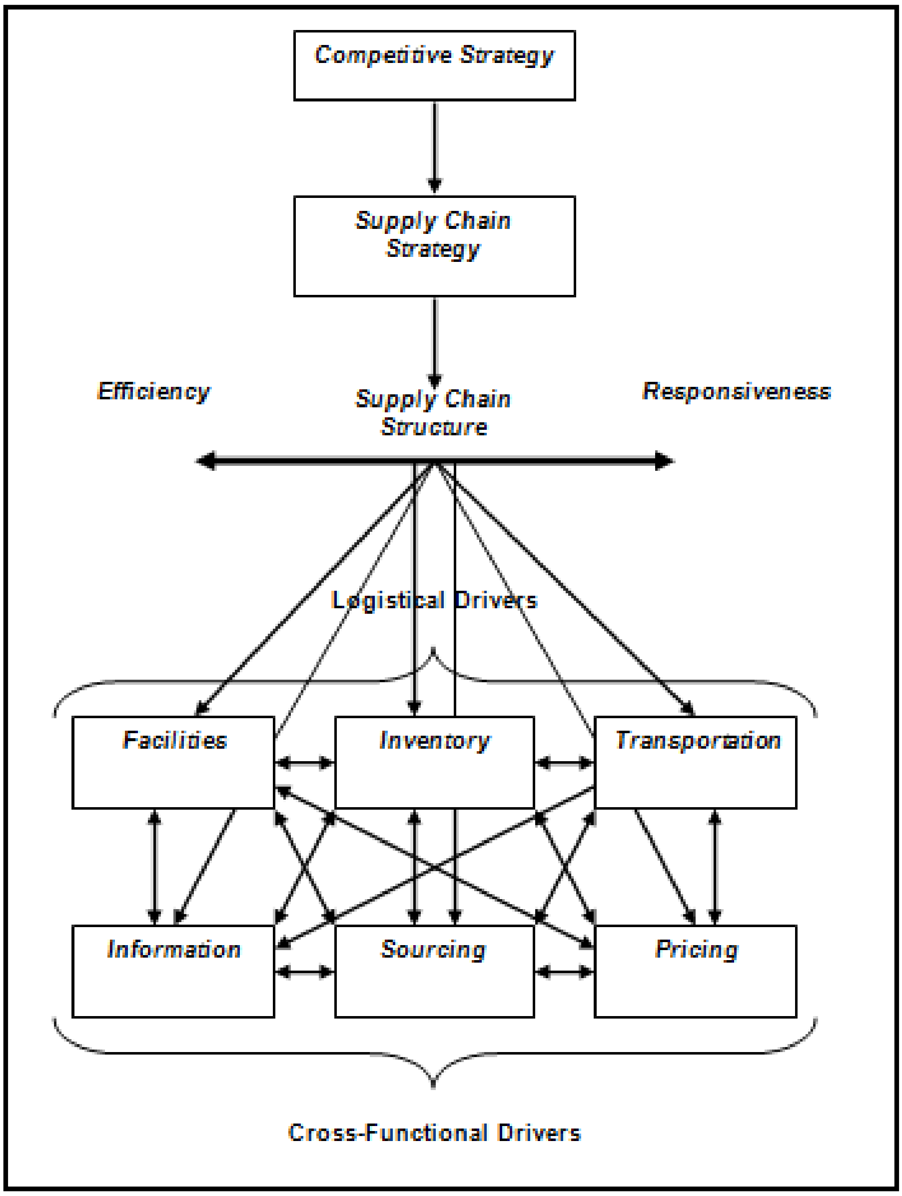
The segmentation process can provide practical solutions for operational decisions as well as strategic design. For instance solutions can be found to support storage, handling and purchasing decisions. The structures of inventory systems are well known. There are many textbooks which explain the different inventory techniques (Bernard, 1999; Tersine, 1994) and the various forecasting methods (Makridakis and Wheelwright, 1989). There is a lack of detail on what types of product are best suited to which type of technique and any method of categorisation. It is possible to use forecasting software to find the most optimum solutions for individual products but this is often impractical.

There are explanations that can be found which state that a product with a high variability of demand for instance would be best suited to a low smoothing coefficient in a exponential smoothing forecast. It is said that slow moving products are best suited to a Poisson distributed safety stock method. A methodology on how to combine these techniques using the appropriate parameters is lacking.

Cachon and Fisher (1997) show that inventory can be reduced if individual rules for average demand and demand variability are used. Smith and Slater (2001) propose that inventory decisions can be formulated by segmenting products into six categories by sales volume and sales variability. Different methods for forecasting and purchasing can be applied depending on the type of product. The calculations involved in inventory decision-making are dependent upon volume and variability. The variability of lead times is an important factor. The segmentation process can include an added dimension which includes the variability of lead times. Safety stocks can be increased to account for products which have high variable lead times.

Chopra and Meindl (2007, p.47) have designed a supply chain decision framework (see Figure 2.37). This brings together the supply chain in the context of a competitive strategy. A supply chain segmentation strategy uses the logistical drivers in its framework to create efficiency and responsiveness for different segments of products and customers.

Figure 2.37: Supply chain decision-making framework



2.9 Chapter summary

This chapter has set out the literature which is associated with the underpinning of this research study. The concept of supply chain segmentation was put into context and reviewed. The branches of supply chain segmentation, such as supply chain performance measures and supply chain trade-offs have been fully explained. It has been shown how this concept is part of the wider subject, supply chain management (SCM). It was shown how the methodological foundations set out by Fuller *et al* (1993) have been developed into methods for supply chain design (Fisher, 1997) and wider supply chain segmentation studies such as Lovell *et al* (2005).

It was shown that studies such as Lovell *et al* (2005) have attempted to show that a segmentation strategy can be a wide reaching business strategy. This can be expanded on to show how this can be applied throughout the business as a holistic strategy. The different segmentation approaches such as those used in supply chain design (Christopher and Towill, 2002; Lee, 2002; Lovell., *et a*l, 2005; Mason-Jones *et al*., 2000; Naylor *et al*., 1999; Payne and Peters, 2004) or the formulation of inventory decisions Smith and Slater (2001) can be drawn together to form a sophisticated methodology.

The next chapter sets out the literature related to inventory management and modelling.

CHAPTER 3

3 AN EVALUATION OF MATHEMATICAL MODELLING AND INVENTORY MANAGEMENT LITERATURE

3.1 Chapter introduction

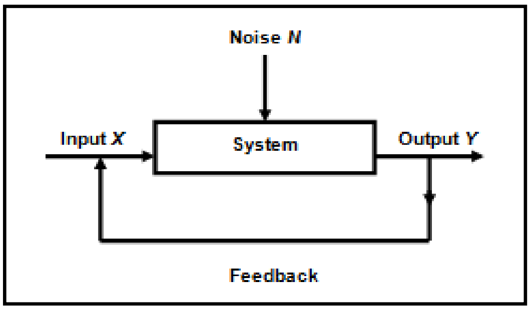
This chapter sets out to review the existing inventory management and modelling literature. The case study was built upon many of these techniques so it is important that these are fully explained. This chapter defines a model and gives explanation of the different types. This is developed to incorporate simulation modelling; putting it into context with the methods used in the case study of the purchasing and inventory system. The processes involved in designing and creating them are shown, including techniques such as process mapping which can be used to collect all of the necessary data.

The next part of this chapter details the methods of inventory management. It shows the different types of inventory systems and the many calculations on which these are based. The many forecasting techniques, which are a crucial element of inventory systems, and which are relevant to this research study are detailed.

3.2 Systems

A system can be defined as a "collection of interacting elements or components that act together to achieve a common goal" (Neelamkavil, 1987) and is not isolated but rather linked to adjacent systems (Boyd, 2001). A basic mathematical pictorial depiction of a system is shown in Figure 3.1 (Neelamkavil, 1987, p.19). An input (x) enters the system and is acted upon by external noise. These are factors within the external environment. This ultimately affects the behaviour of the system (Neelamkavil, 1987, p.25). The boundary of the system is an important element in the design of such models. An output (y) leaves the system and impacts upon the input (x). This relationship is known as feedback.

Figure 3.1: Multivariate system



A system is composed of entities, attributes (parameters and variables), interrelationships and activities (Neelamkavil, 1987). The value of these elements at a particular point in time defines the state of the system (Neelamkavil, 1987). The state of the system can change as a "result of the activities internal to the system (endogenous activities) or due to activities external to the system (exogenous activities)" (Neelamkavil, 1987, p.23).

A system can either be deterministic or stochastic and either dynamic or static. The behaviour of a system becomes an important factor in the decision of which type of modelling methodology approach to use. This is discussed in the next section. Examples of the different types of systems are shown in Figure 3.2-3.5 (Neelamkavil (1987, pp.23-24).

Figure 3.2: Deterministic systems

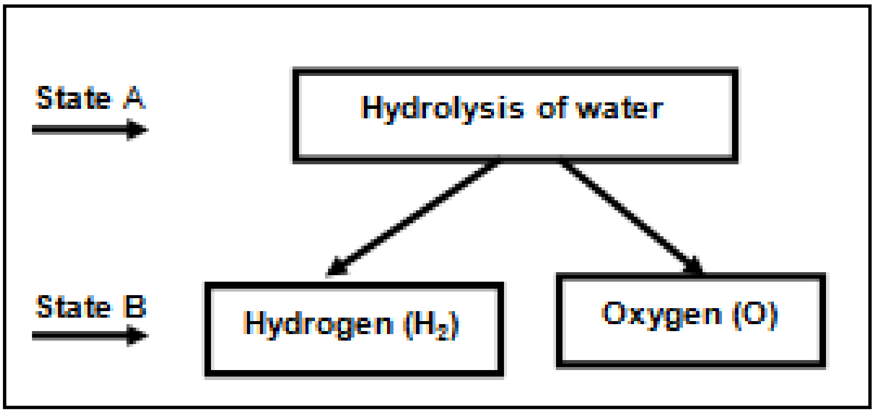


Figure 3.3: Stochastic systems

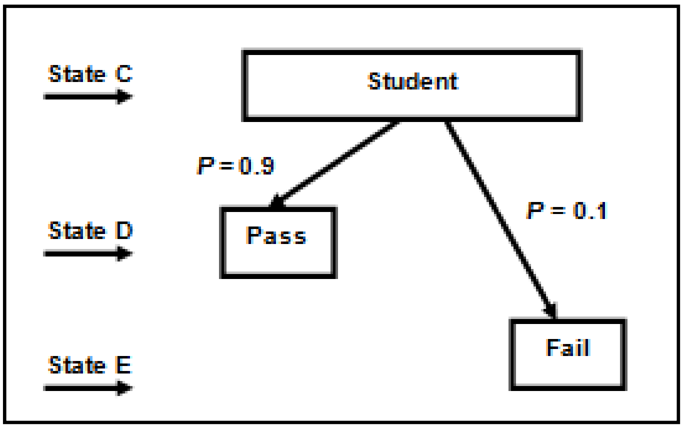


Figure 3.4: Static steady system

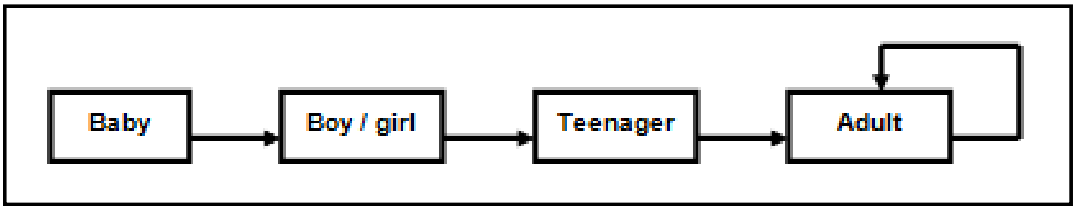
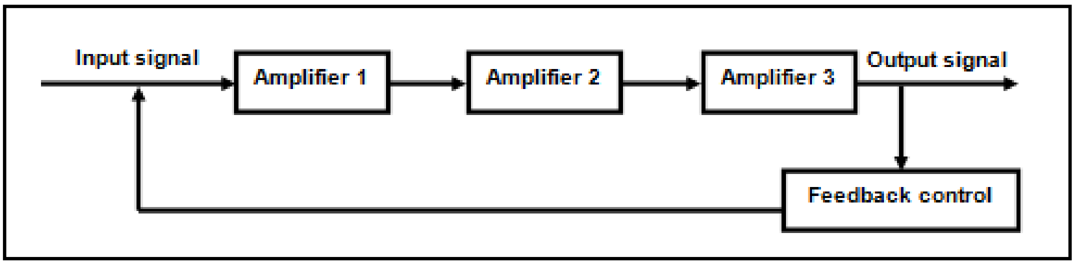


Figure 3.5: Dynamic steady state



3.3 Modelling

It is often desirable for systems to be replicated either physically or mathematically by creating a model. When a system cannot be understood by intuition alone a mathematical model can be used to find a solution or make predictions. This is so that models can simply be an object of art or a mathematical representation of some complex system. A model is defined in the Compact Oxford English Dictionary (2009) as being:

1. A three dimensional representation of a person or thing, typically on a smaller scale.
2. A Figure made in clay or wood, which is then reproduced in a more durable material.
3. Something used as an example.
4. A simplified mathematical description of a system or process, used to assist calculations and predictions.
5. An excellent example of a quality.
6. A person employed to display clothes by wearing them.
7. A person employed to pose for an artist.
8. A particular design or version of a product.

The replication of a system reduces the complexity to a level where it can be studied. In respect to this research study a model can be adequately defined as:

> "A model is a simplified representation of a system intended to enhance our ability to understand, predict and possibly control the behaviour of the system" (Neelamkavil, 1987, p.30).

A model can be expressed as a mathematical equation. Nash (1981, p.179) shows that a model can be represented as an algorithm for computing (see Equation 3.1).

Equation 3.1: A model as a mathematical equation

$$\mathrm{o} = \mathrm{M}(\mathrm{i})$$

Notation(s)

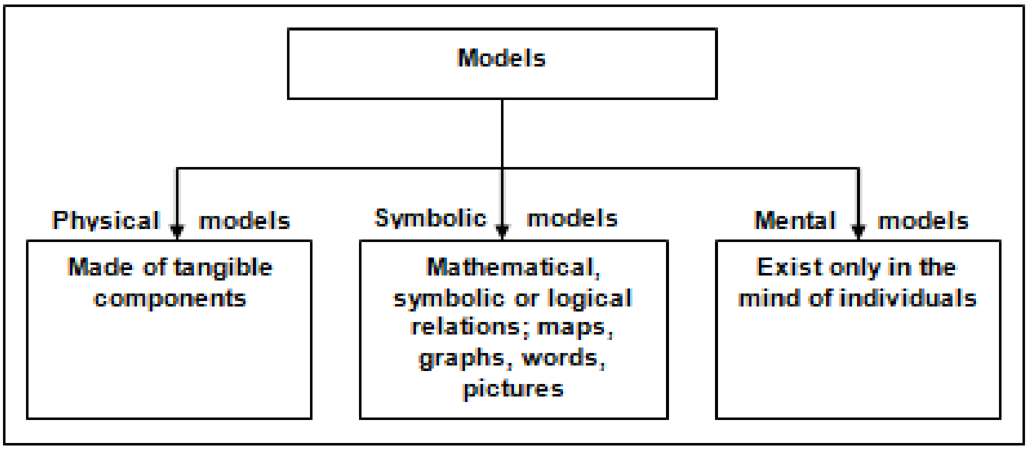
$\mathrm{i} = \mathrm{input}$

$\mathrm{o} = \mathrm{output}$

$\mathrm{M} = \mathrm{model}$

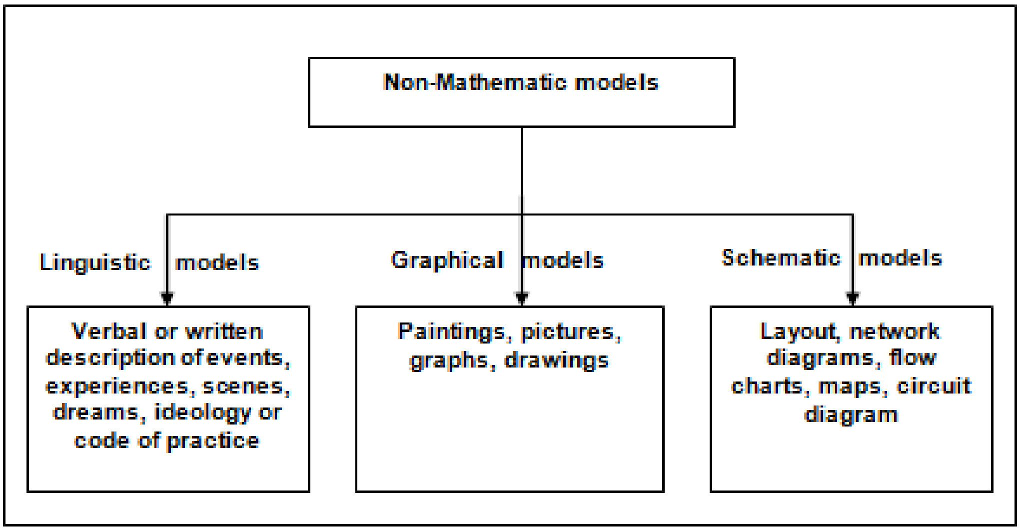
Models can be classified into different types (see Figure 3.6, Neelamkavil, p.32). According to this models can either be of a physical, symbolic or mental type. A physical model is a representation of a system that has tangible parts (Neelamkavil, 1987). These range from models of cars to models of a plumbing system in a house. They have variables, which are either constant or dynamic. A mental model is one that exists only in the mind (Neelamkavil, 1987) and is either heuristic or intuitive in nature. These models are not very accurate and are limited to the scope of the person.

Figure 3.6: Types of models



There are two types of symbolic model, mathematical and non-mathematical. There are three different types of non-mathematical models linguistic, graphical and schematic models (see Figure 3.7, Neelamkavil, p.34). Mathematical models are relevant to this research study and are looked at in more detail in the next section. There are different methods which can be used to classify models. Poole and Szymankiewicz (1997) for instance use an approach which classifies models by their process of decision-making into intuitive, analytical or numerical.

Figure 3.7: Non-Mathematical symbolic models



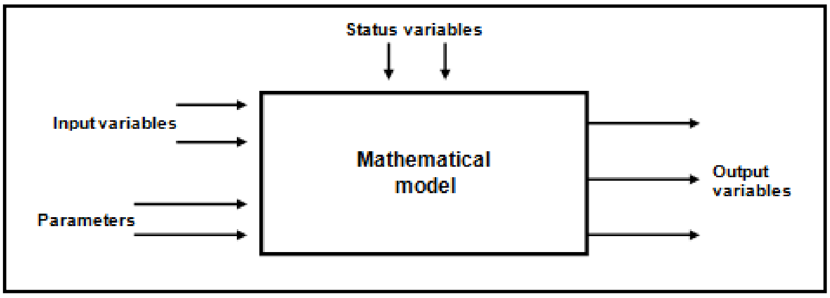
3.4 Mathematical modelling

Mathematical models are used to "describe some part of the real world in mathematical terms" (Meyer, 2004, p.1). It was put by Bacon (1267) that "the things of this world cannot be made known without a knowledge of mathematics". Mathematical models have been used to describe physical, biological and social systems (Meyer, 2004). Aris (1978) and Andrews and McLone (1976) were some of the early authors on the application of mathematical models. Any research prior to this was based on pure mathematical theory without real life application. A mathematical model represents a real system by using mathematical expressions. In this context Andrews and Mclone (1976, p.1) provide the following definition:

> "It is the representation of our so-called 'real world' in mathematical terms so that we may gain a more precise understanding of its significant properties, and which may hopefully allow some form of prediction of future events."

According to Curwin and Slater (1996, p.515) the construction of a mathematical model can be expressed arithmetically in terms of the relationships between its variables and parameters (see Figure 3.8). Input variables and parameters are exogenous to the model. Input variables are changeable and parameters are fixed. The status variables control the state of the model. The mathematical model contains all of the expressions which produce the results expressed in the output variables.

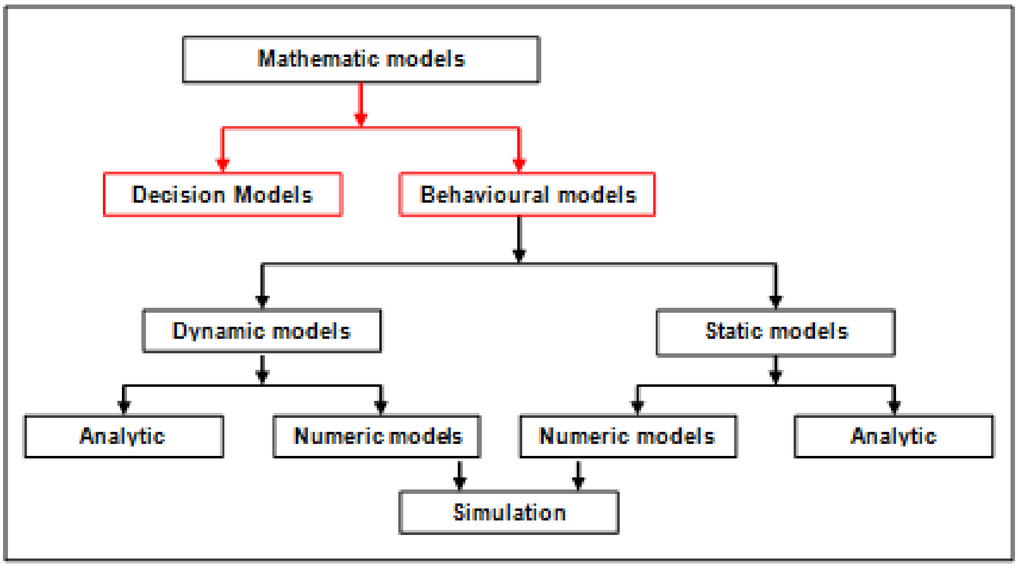
Figure 3.8: Representation of a mathematical model



According to Nash (1981) mathematical models can be either decision or behavioural. Neelamkavil (1987) breaks this down further showing that behavioural models can be of the dynamic or static type. This is illustrated in Figure 3.9 (Neelamkavil, 1987, p.34 and Nash, 1981). A model can be thus split into either dynamic or static. These distinctions are useful when deciding which technique is best suited to solve the problem. For instance static models can be solved by linear programming, spreadsheets and Monte Carlo simulation[13] and dynamic models by continuous and discrete event models (Greasely, 2004).

[13] Monte Carlo simulation bases it results on a method which involves ‘experimental sampling with random numbers’ (Greasley, 2004, p.12).

Figure 3.9: Types of mathematical models



It is useful to determine the type of mathematical model in respect of the characteristics and behaviour of the system. The choice of modelling methodology is based upon this. Neelamkavil (1987, p.36) lists some of various types of models:

1. Continuous.
2. Discrete.
3. Hybrid.
4. Linear.
5. Nonlinear.
6. Deterministic.
7. Stochastic.

The mathematical relationship between the input and output variables in each of the types of models are expressed in the diagrams and graphs in Figures (3.10 - 3.12, Neelamkavil, 1987, p.37).

Figure 3.10: Deterministic model

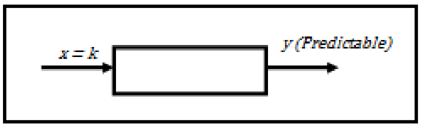


Figure 3.11: Stochastic model

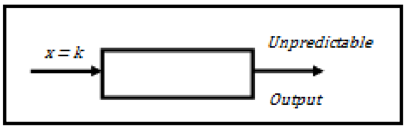
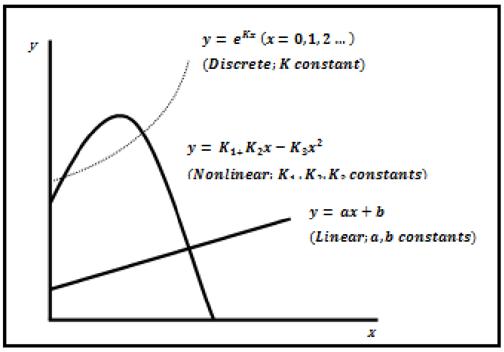


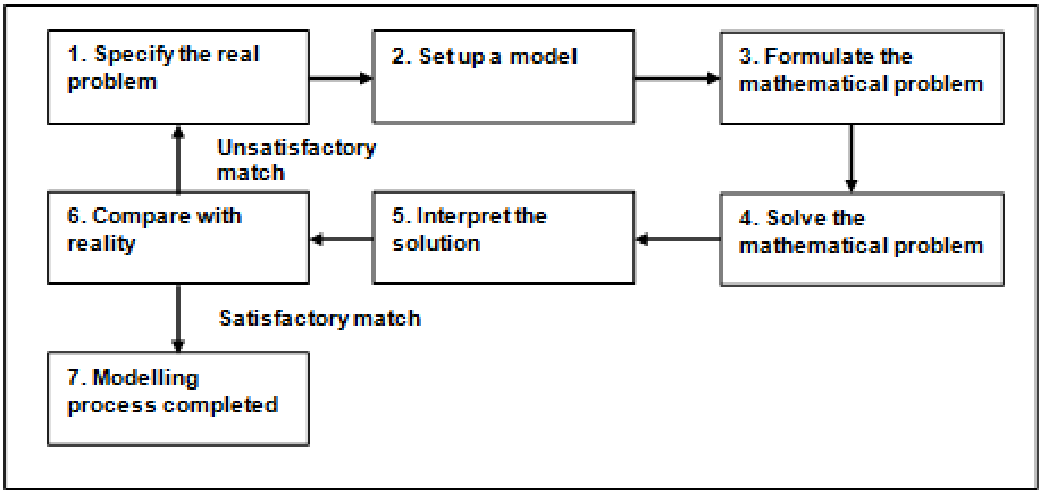
Figure 3.12: Linear, nonlinear, continuous and discrete models



The methodology of mathematical models has been discussed in great detail (Caldwell and Ram, 1999; Clements, 1989; Edwards and Hamson, 2001; James and McDonald, 1981; Kapur, 1988). A model can be produced which follows a process of key stages (Caldwell and Ram, 1999; Edwards and Hamson; 2001). An example of the processes is shown in the flowchart of Figure 3.13 (Caldwell and Ram, 1999, p.4). The process is iterative and if it fails at the validation stage (stage 6) then the model must be redesigned.

The process is limited to the design of the model and does not include implementation and testing. James and McDonald (1981) add the stages of implementation and monitoring of the system and model. These are critical stages and the model has to be re-evaluated once it is implemented against the original specification. Clements (1989) argues that all the processes are implicitly linked and a step-by-step process is not relevant.

Figure 3.13: Flowchart of the mathematical modelling process



3.5 Simulation modelling

3.5.1 Definition

Simulation modelling is an extension of mathematical modelling in that it uses the same basic principles with the added dimension of time. The modern term was coined by Von Neumann and Ulam in the late 1940's where they used what is known as "Monte Carlo Analysis"; a mathematical study of nuclear shielding (Naylor, 1968; Poole and Szymankiewicz; 1977; Pidd, 1989). Neelamkavil (1987) argues that simulation should only be used as a last resort when mathematical modelling techniques cannot provide the answer due to the complexities of the model. Neelamkavil (1987, p.12) provide a list of a number of reasons where the use of simulation modelling is applicable for solving a particular problem:

- the real system does not exist and it is expensive, time-consuming, hazardous, or impossible to build and experiment with prototypes;

- experiments with the real system is expensive, dangerous, or likely to cause serious disruptions;
- there is a need to study the past, present, or future behaviour of the system in real time, expanded time or compressed time;
- mathematical modelling of a system is impossible;
- mathematical models have no simple and practical analytical or numerical solutions;
- satisfactory validation of simulation models and results is possible;
- expected accuracy of simulation results is consistent with the requirements of the particular problem.

Complex systems are ones that have a large number of variables and often exhibit non-linear behaviour. Economic and weather systems are examples where the complexity is too great for satisfactory solutions to be found using mathematical techniques. Computers are required to construct and perform the calculations of simulation models, known as computer simulation modelling. A definition of simulation modelling is provided by Poole and Szymankiewicz (1977, p.4):

> "Simulation is a 'trial and error' approach which allows us to describe a problem and gain understanding of the factors involved, by asking questions and observing the answers."

A similar definition is provided by Neelamkavil (1987, p.6) with the added emphasis of time:

> "Simulation is the process of imitating (appearance, effect) important aspects of the behaviour of the system (plans or policies) in real time, compressed time, or expanded time by consuming and experimenting with the model of the system".

Simulation models are experimental in nature and can use a 'trial and error' or a logical 'what if' approach to find solutions. This is an importance point because it shows the distinction between analytical models which produce a single solution. Simulation models are run many times in order to test many different scenarios. The model variables and parameters are altered to change the outcome. Simulation models can be used as a method to search for better solutions or simply to gain a better understanding of the system. Greasley (2004, pp4-5) lists a number of advantages of using simulation:

- allows prediction;
- simulates creativity;
- avoids disruption;
- reduces risk;
- provides performance measures;
- acts as a communication tools;
- assists acceptance of change;
- encourages data collection;
- allows overview of whole process performance;
- acts as a training tool;
- acts as a design aid.

Within SCM there are a large number of possible uses for simulation. Analytical models aren't often able to deal with the complexity of many SCM problems (Thierry *et al.*, 2008). Thierry *et al* (2008) categorises SCM simulation into support supply chain decisions or evaluation of supply chain policies. Thierry *et al* (2008, p.6) provides a list of the possible uses of simulation modelling in SCM:

1. Supply chain decisions
    - localisation:
        - location of facilities,
        - supply and distribution channel configuration,
        - location of stocks;

- selection:
    - suppliers,
    - partner;
- size:
    - capacity booking,
    - stock level,
    - etc,

2. Evaluation of supply chain control policies

- control policies:
    - Inventory management, control policies,
    - Planning processes;
- collaboration policies:
    - Cooperation/collaboration/coordination, etc..,
    - Information sharing, etc.

It is suggested that simulation modelling should be used as a last resort in analytical techniques (Neelamkavil, 1987). This is because in the main it is much cheaper and simpler to build analytical models. There are many software applications, discussed later on in the chapter, which are now relatively easy to use and are likely in the future to reduce in price. There exists still a significant gap in the modelling expertise required to design simulation models and investment cost is also a determining factor. A number of further problems such as the difficultly in validation and the ability to convince both management and executives of the solutions they provide are relevant in simulation modelling. A number of limitations of simulation modelling have been identified by Neelamkavil (1987, pp.12-13):

- neither a science nor an art, but a combination of both;
- method of last resort;
- iterative, experimental problem-solving technique;
- expensive in terms of manpower and computer time;
- generally yields suboptimum solutions;
- validation is difficult;

- collection, analysis, and interpretation of results require a good knowledge of probability and statistics;
- results can be easily misinterpreted and difficult to trace sources of errors;
- difficult to convince others.

The uses and limitations of simulation modelling are to be considered when deciding the most appropriate approach to use. In some cases a simple spreadsheet approach is satisfactory. It is possible to evaluate different forecasting and inventory techniques in a spreadsheet for a small sample size for instance. When the complexity increases the methods need to be more sophisticated.

3.5.2 Types of system

According to Neelamkavil (1987, p.7) there are two different types of simulation systems; continuous and discrete:

1. continuous systems – variables (attributes of system elements or entities) undergo smooth changes;

2. discrete systems – changes in variables take place instantaneously in discrete steps.

These systems are defined in terms of their variables, which either undergo smooth or discrete changes. Furthermore, these two different types of systems can be modelled using a continuous approach (continuous simulation model) or using a discrete approach (discrete simulation model) for continuous and discrete systems respectively (Neelamkavil, 1987).

Traditionally discrete systems have been used to solve problems within the areas of industrial engineering, computer science and operations research. Continuous systems are used within the areas of electrical and mechanical engineering and physics. In reality many systems have both continuous and discrete variables. It is also possible to turn continuous variables into discrete variables and vice versa within a model.

It is clear both from literature and after visiting conferences that the field of simulation is divided into two distinct groups: system dynamics (SD) and discrete event simulation (DES). These groups use the modelling approaches of continuous and discrete simulation modelling, respectively. In the main the groups function in isolation of each other and there is little communication between the two fields (Banks, 1998; Sweetser, 2006). To some extent there is some rivalry and criticism of the opposing methods. Modellers have developed different ways of thinking and tackle problems from their own perspective, depending upon which of the two methods they are trained in. As a result the strengths, weaknesses and methodology of each field are not fully understood.

A decision has to be made as to which type of simulation model is most appropriate to model a particular system being studied. This is not always an obvious decision and it can be argued that both methods could be applied (Morecroft and Robinson, 2008). This was a theme explored at the UK system dynamics conference held at the South Bank University in London in February 2008. A well known fisheries problem was modelled by John Morecroft and Stewart Robinson, using an SD and DES approach respectively. They both presented different results, arguing from their own perspective their understanding of the characteristics and behaviour of the system. In this case it is unclear which of the models provides the most realistic representation. The key philosophical differences of the two methods are outlined in Figure 3.14 (Morecroft and Robinson, 2008):

Figure 3.14: Two Key Philosophical Differences

SD (Deterministic Complexity)	DES (Interconnected Randomness)
The future is partly and significantly pre-determined	The future is partly and significantly a matter of chance
Feedback structure creates puzzling dynamic behaviour	Interconnected random processes create puzzling dynamic behaviour

There are few papers which make a comparison between continuous and discrete simulation methods (Özgün and Barlas). Özgün and Barlas (2009) model a queuing system using both discrete and continuous simulation. The distinction is made that discrete event simulation is suitable for variables which change in discrete steps and continuous simulation is suitable for systems which change continuously. Furthermore, SD is useful in studying the dynamic behaviour within a system whilst DES can find precise statistical estimates (Özgün and Barlas. 2009). Sweetser (1999) models a manufacturing system using the two methods and draws the following conclusion:

> "System dynamics methodology is best suited to problems associated with continuous processes where feedback significantly affects the behaviour of a system, producing dynamic changes in system behaviour. DES models, in contrast, are better at providing a detailed analysis of systems involving linear processes and modeling discrete changes in system behaviour" (Sweetser, 1999, p.7).

In general SD models are well suited to aid in decision making at a strategic level, providing long term solutions which are often counter-intuitive in nature. There is an emphasis on non-linear behaviour where there is a lot of feedback and provide a good understanding of the structure of complex systems. In contrast, DES models are well suited for decision making at the tactical and operational business levels. A DES model can provide a detailed solution and can handle a large number of variables.

Banks (1998) argues that because most problems being studied are a combination of the two phenomena both methods should be used. In recent years a number of software companies have tried to combine the two disciplines. This is enhancing the types of model which can now be built (Banks, 1998). This is still at an early stage and the software tends to lean towards one discipline without truly combining the two.

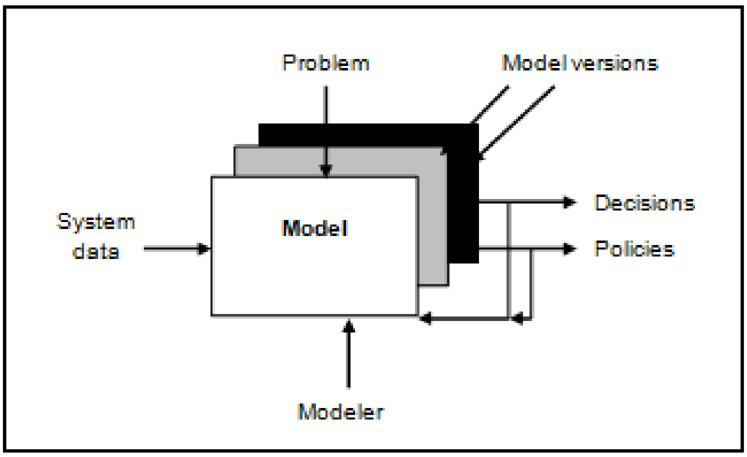
An understanding of both methods enables a modeller to make a rational decision. The objectives of the project and the characteristics of the system direct the modeller to the appropriate simulation method. The system has to be investigated and understood in sufficient depth before an informed decision can be made as to which method to use. Neelamkavil (1987, p.7) lists a number of factors that can aid in the decision process:

- accuracy;
- size;
- range;
- possible levels of aggregation of the variables involved;
- solution techniques;
- ease of solution;
- period of study.

3.5.3 Process

The simulation process is an extension of the mathematical modelling process. A simplified illustration of the model process provided by Banks (1998, p.34) is shown in Figure 3.15. The model is designed to solve a problem which defines the system being studied. The results of the model are used to evaluate various decisions and policies. This is an iterative process where there are many model versions which are improvements on the previous version.

Figure 3.15: Model-based problem-solving process



Poole and Szymakiewicz (1977, p.8) describe the modelling process as:

> “The building of an accurate, acceptable model is an evolutionary process for which good communication with line management, a simple method of producing flow diagrams and a systematic questioning procedure are essential. The flow diagram can be operated as a hand model to test the logic to gain understanding and to record the results of changing the parameters”.

There are a large number of publications that are dedicated to the subject of simulation. These range both in content and the principles on which they concentrate. The early books on simulation (Naylor, 1968; Neelamkavil, 1987; Pidd, 1989; Poole and Szymankiewicz, 1977) provide detailed knowledge that underpins the subject and generic methodologies used. These books are written by authorities in the area of modelling and their perspective gives clear and simple methodologies to follow for future modellers. Furthermore, they cover the important aspects of the subject such as probability and statistics, data collection and validation.

Zeigler *et al* (2000) among others use a systems perspective to outline the simulation process. These are heavy on theoretical mathematics and are well suited for system and control engineers because a high level of mathematical and technical experience is required. There are authors who provide specific methodologies for different types of models, continuous models (Morecroft, 2007; Sterman, 2000) and discrete models (Banks *et al*, 2000**;** Cassandras and Lafortune, 2008), whilst others are more software engineer specific such as Arena (Kelton *et al*, 2007).

The traditional simulation framework uses a process of key steps. Naylor (1968) sets out a nine-step approach of the key steps:

1. Formulation of the problem.
2. Collection and processing of the real world data.
3. Formulation of mathematical model.
4. Estimation of parameters of operating characteristics from real world data.

5. Evaluation of the model and parameter estimates.
6. Formulation of a computer program.
7. Validation.
8. Design of simulation experiments.
9. Analysis of simulation data.

There has been an attempt to combine the traditional approaches from a business perspective (Banks, 1998; Pidd, 2004). An approach by Banks (1998) simplifies the processes and incorporates the business activities of documentation and implementation:

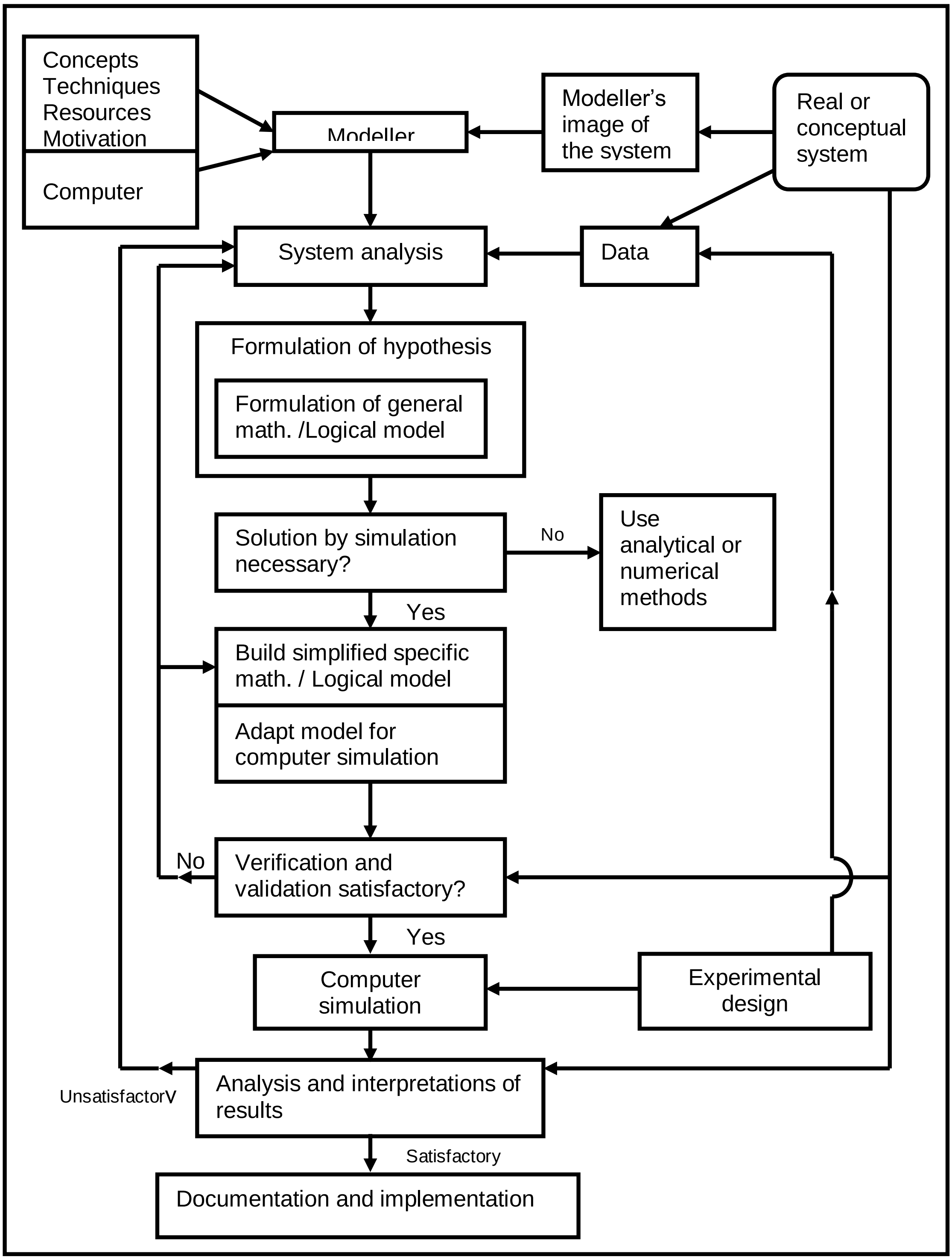
1. Problem formulation.
2. Setting of objectives and overall plan.
3. Model conceptualization.
4. Data collection.
5. Model translation.
6. Verification.
7. Validation.
8. Experimental design.
9. Production runs and analysis.
10. More runs.
11. Documentation and reporting.
12. Implementation.

Some authors have moved further away from a theoretical approach and focus primarily on the application of simulation within a business environment (Oakshott, 1997; Greasley, 1997). They use modern software packages such as Arena and a tutorial approach to learning, using a number of business case study examples. In these books the simulation process is discussed in terms of a simulation business project. A number of processes have been identified by Greasley (1997) which can supplement the approaches outlined previously:

- selecting sponsor;
- evaluation of potential benefits of simulation;
- estimation of resource requirements;
- selection of simulation software type;
- selection of simulation software package;
- identification of computer hardware requirements.
- identification of training needs.

The process of simulation is an iterative one that uses logic to perform loops until the final solution is found (Neelamkavil, 1968). A comprehensive simulation methodology is shown in Figure 3.16 (Neelamkavil, 1987, p.9). It draws together the main steps to form an iterative approach. It shows that at certain stages when the model is unsatisfactory the modeller returns to the analysis to make changes. This continues until the results are satisfactory. The final process involves the documentation and implementation.

Figure 3.16: Simulation modelling process



3.5.4 Data collection and model design

The analysis of the system requires the collection of a large quantity of relevant data. A number of different information sources are used. The system being studied has to be fully understood before it can be modelled. If it is not understood then crucial elements of the system could be missed rendering the model useless. The simulation input data is exported from the computer management system. The data which is used in the design of the simulation model is collected from the purchasing and inventory (P&I) offices at Newey & Eyre. A detailed definition and explanation of the functions within these offices can be found in section 4.3.4.

The collection of data from the management system uses the methodology outlined in Chapter 5. The inventory system is complex so a logical and in depth approach is required. This is because there are a large number of processes and variables which interact with one another. Relevant data of the system is collected from physical material and from interviews of employees conducted at each of the offices.

Chapter 9 of Hunt (1996) provides a methodology for the collection of data. The section on how to construct an interview is particularly useful. Hunt (1996, p.175) shows a number of stages in the collection of data:

- **Read background information**: The process map author gains familiarity with information about the subject matter area by collection and reading source information prior to interacting with the process experts to be interviewed.

- **Parallel interview:** The author would normally be interviewing other "process experts" concurrently who may provide information with respect to the process that will be focused on in the new interview effort. Maintaining separate data-gathering files will help eliminate the comingling of apparently similar process information.

- **Outside-the-box-thinking**: The process author should allow sufficient analysis time to see the big picture-to “ruminate.” Every once in a while you must merely stand back and let all of the process bits and pieces sink into place. This type of “outside-the-box” thinking time is the unstructured time that precedes actual process mapping.

- **Priority setting:** In this stage, the process map author examines the need for the preparation of key process maps to be created or analysed and establishes priorities as to the sequence of interviews that should be conducted.

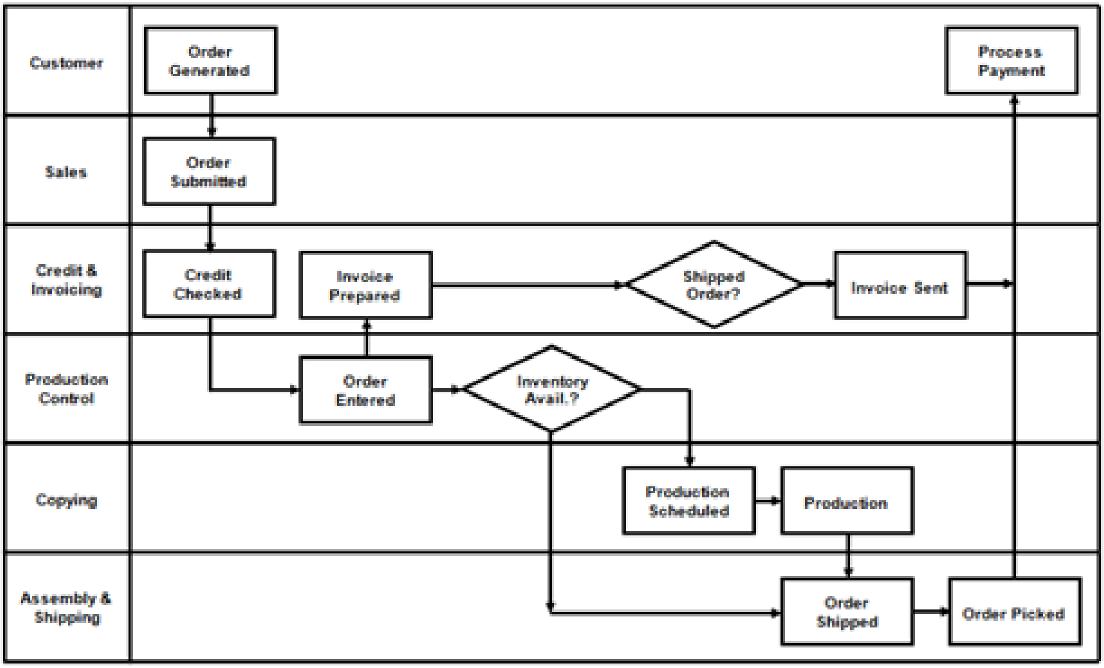
The model is conceptualised from the data that is collected. The structure of the model is designed using a process mapping approach which is outlined by Hunt (1996). A process map shows the interactions of all the processes of the model being studied. The approach is summarised as:

> “The process mapping concept “is used to describe, in workflow diagrams and supporting text, every vital step in your business processes” (Hunt, 1996, p.2).

An example of a process map is shown in Figure 3.17 (Hunt, 1996, p.11). The process map shows the typical processes in an inventory system and how they relate to the departments within a business. The methodology by Hunt (1996) provides all of the techniques and stages of process mapping which ranges from the assessment of the need for process mapping, through the construction stage to the application and business improvement.

The conceptualised model is translated into a final design which is used to build the simulation model. The boundary of the model is designed in accordance with the objectives of the model. The variables of the model are selected and the construction of the model is designed using programming flowcharts and pseudo code.

Figure 3.17: Example of a process map



3.5.5 Model testing

It is unlikely that no mistakes are made when first building a model. These mistakes therefore need to be located and rectified. The techniques of verification and validation are used. Verification is a vigorous process to ensure that a model is built correctly. According to Poole and Szymankiewicz (1977) a simulation model must be accurate and acceptable. Validation is a process that ensures that a model represents to an acceptable level the actual system. These processes are time consuming but are critical to the successful outcome of the project.

3.5.5.1 Verification

There are no standard methods for verification. The text books in the main provide a description of what verification is without providing a methodology. This is because both programmer and program are unique and different methods are adopted for each situation. It is the job of the programmer to make sure that the program at the end of the verifying stage is deemed sound. During the design of the simulation model the verification process is carried out as a number of steps. Each step has to be passed before the next can be tested. At the point that changes are made the process starts over again. This can involve the verification of the whole program or smaller sections depending on the size and impact of the change. The steps are as follows:

1. System syntax debugging.
2. Visual debugging.
3. Equation testing.
4. Extremity testing.
5. Individual product testing.
6. Aggregated output testing.

Simulation software has built in debuggers. These check the syntax of each for errors. The nature of the problem is shown in the event of an error. This is entirely based on the syntax and does not affect the logic of the program. The next stage is to visually check the program. Each line is checked to make sure that they are consistent with the design of the flowcharts and equations.

The rest of the verification process is the testing of the output which the simulation model produces. The approach taken is to systematically check the model from the basic building blocks to ever increasing complexity. The testing of equations is a simple process which is carried out in isolation. The answers which the model produces from each equation are tested against a comparative spreadsheet model.

The extremity testing involves examining the most extreme outputs. If there are mistakes within the model then it can produce unusual results. Statements are used to try and locate these. This method provides a quick way to find the most obvious mistakes. The next two stages are the most difficult and time consuming. Samples of outputs from randomly selected products are tested against spreadsheet comparisons. It takes a considerable amount of time to set up spreadsheets. The complexity of testing at this stage increases as outputs are deemed to be satisfactory. The final stage is to make sure the final results seem to be what would be expected. It is too difficult at this stage to draw comparisons against spreadsheets because of the complexity. A judgement is therefore required.

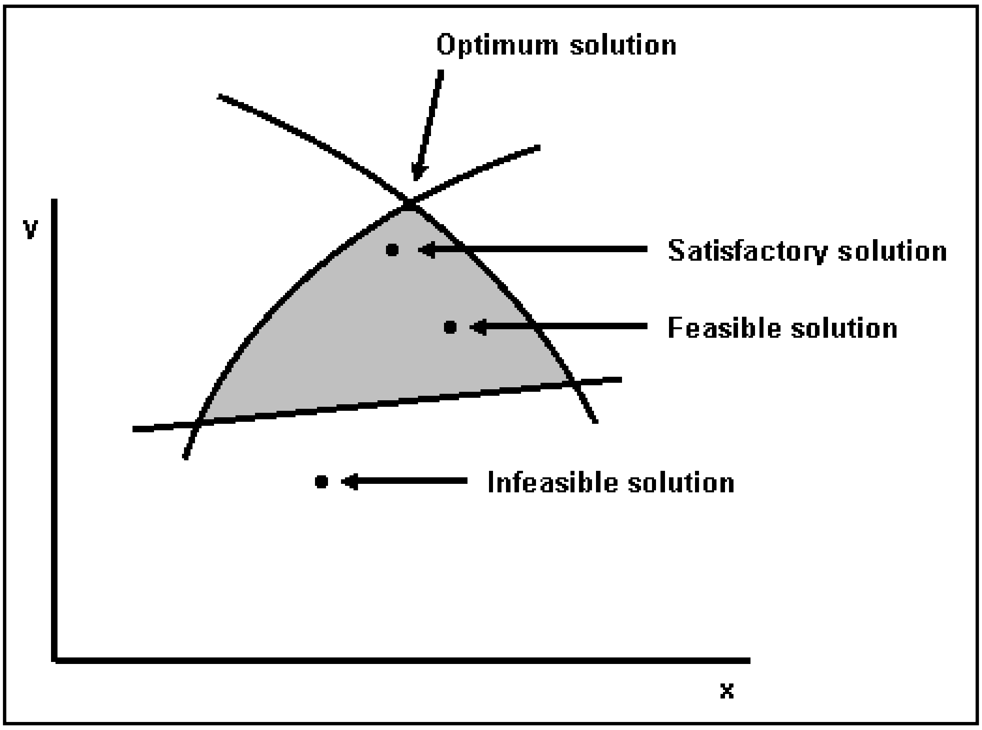
3.5.5.2 Validation

Neelamkavil (1987, p.2) shows that there are four types of solutions to a problem; infeasible, feasible, satisfactory and optimum (see Figure 3.18). A simulation model cannot produce an optimum solution because a 100% level of accuracy is not achievable. Furthermore, one particular solution cannot be assumed to provide the definitive answer. The results that are produced by the model are concerned with showing that the proposed solution is an improvement on the current system not an actual representation of the system.

The goal of the simulation model is to work towards an optimum solution and when it is completed should fall within the boundary of satisfaction. A decision is made as to what is deemed a reasonable level of resource that can be used to obtain a solution. The simulation process can provide as much understanding and insights into a system in terms of its structure and behaviour than is provided by the solution.

A validation method is used to provide evidence that the solution represents a reasonable level of accuracy. The assumption is that if the parameters are changed in the current system then the results of the simulation model should predict a similar pattern. The validity of the model is supported by the collection of evidence and by the view of experts. The experts are employees within the company who understand how the system works and can check the model to make sure it behaves in a way that is predicted.

Figure 3.18: Types of solutions to a problem



3.6 Computer modelling

The term computer first appeared within literature in 1646 by Sir Thomas Browne (Wurster, 2002). The word is derived from the Latin word 'computare', which means, someone who performs calculations. The computer revolution has been compared to the industrial revolution because of its impact upon the world (Akera and Nebeker, 2002). The application of mathematics using computers has improved the ability to solve complex problems. In 1971 the Intel 4004 microprocessor was designed (Wurster, 2002). The microprocessor has allowed computers to perform complex equations, which were previously not possible (Edwards, 2001). In the last 25 years computers have become more and more powerful and according to 'Moores Law' the processing speed will continue to double every 18 months (Moore, 1965).

The increase in processing power over time is enhancing the ability to study complex phenomena. Simulation modelling requires an extensive amount of computing power. This is due to the large number of variables and the complex interactions between processes which are being modelled. The widespread use of simulation modelling was previously restricted by the speed of microprocessors in the past and developed only on mainframe servers. This is summed up below:

> "The availability of cheap computer computing power, and colour graphics have eased the burden of programming simulation problems and hence the widespread usage of simulation for problem-solving in several disciplines" (Neelamkavil, 1987, p.11).

There is now sufficient processing power in modern personal computers to easily create simulation models. There are a large number of software packages which allow simulation models to be easily created with the right level of programmer expertise. The software available has changed significantly over the last 50 years. Simulation was first used in the 1950's in the defence industry (Greasley, 1997). The early simulation models were created using general purpose packages such as FORTRAN (Greasley, 1997). The modeller had to have experience in computer programming to develop models in these sorts of packages. The computer programming languages were not suited to easily deal with the dimension of time. The General Purpose Simulation System (GPSS) was designed in the late 1960's as a simulation language (Greasley, 1997).

Modern simulation packages now use an icon and pictorial approach with an embedded simulation language. These are called Visual Interactive modelling (VIM) systems (Greasley, 2004). This has opened up the use of simulation to a wider audience because less technical knowledge is required. A front end approach is available which can use animated images to illustrate the model. These are still quite basic but this technique can help persuade management of change and explain the behaviour of complex systems.

3.7 Inventory simulation modelling

The majority of simulation models are designed by experts and used as interactive tools by managers (Chang and Makatsoris, 2001). They can both provide an insight into how complex systems function and guide future management decision making. The decisions within a business are either taken at the strategic, tactical or operational levels. The framework (see Figure 2.26) developed by Gunasekaran *et al* (2001) shows a number of financial and non-financial performance metrics with fall within the different planning levels of the business. Supply chain models can be developed to improve performance of these metrics. Chang and Makatsoris (2001, p.26) shown that different supply chain management areas can be categorised as shown in Figure 3.19.

Figure 3.19: Modelling areas of SCM

Areas of supply chain	**Description**
Demand planning	Demand planning aims to reduce forecast error and to suggest buffers considering demand variability. In order to improve accuracy of forecasting, collaborative forecasting is essential.
Master planning	Provide multi-site planning. Master planning based on the material, capacity, transportation and other constraints, simultaneously.
Procurement	Constraints such as vendor capacities, costs and lead times can be modelled as part of supply chain resulting in superior plans.
Transportation	Consider dynamic transportation requirement and generate optimizing transportation plan.
Manufacturing	Plan considering material, capacity and other constraints which impact on manufacturing.

Thierry *et al* (2008, p.6) argue that simulation models in SCM can be used to "support supply chain decisions or evaluation of supply chain policies". The benefits of supply chain modelling quoted by Chang and Makatsoris (2001, p.27) are summed up below:

- it helps to understand the overall supply chain processes and characteristics by graphics/animation;

- are able to capture system dynamics: using probability distribution, user can model unexpected events in certain areas and understand the impact of these events on the supply chain;
- it could dramatically minimize the risk of changes in planning process: By what-if simulation, user can test various alternatives before changing plan.

The many different supply chain issues can be tackled using a diverse range of different simulation modelling methodologies and techniques. The modeller should follow a process of determining which method best matches the problem. This approach is not always followed and modellers often use the method which they are familiar with and trained to use. A valuable appraisal of the advantages and limitations of the different modelling types is provided by Riddalls *et al* (2007). They are categorised as being continuous time differential equations models, discrete time difference models, discrete event simulation models or classical operational research techniques.

Continuous time differential equations models are best matched to provide insights at the strategic and tactical levels of the structure and behaviour of the dynamics within non-linear systems. This field within the context of supply chain management is often referred to as system dynamics. These models are commonly used to solve supply chain issues and are therefore explained in detail in the next section.

Discrete time difference equation models are of a similar nature to continuous time models but use pure time delays (Riddalls *et al*., 2007); an important element in supply chains. A pure time delay incorporates any ‘dead time’ that exists. Discrete event simulations use events, activities and processes to model the situation (Thierry *et al*., 2008). These models are suited to solve problems at the tactical and operational levels of the business. They can model the detailed aspects of the supply chain, can be business specific and can deal with the stochastic nature of systems.

3.7.1 Industrial dynamics

The changes in the behaviour of stock are as a result of human and computer interactions and decisions. Inventory systems are complex and non-linear and can't be understood intuitively. Furthermore, the impact of suggested strategies could not be fore-known. There are many different approaches which use a variety of different techniques which attempt to recreate and understand inventory systems. A system dynamics methodology is often used to simulate these types of system. It can provide an insight into why systems behave as they do and in particularly what effect various feedback and delays have on the system.

The understanding of the behaviour of stock holding as a result of strategic polices and management decisions can be found through the application of system dynamics methodology. The roots of system dynamics lie within control system engineering which is an integral part of mechanical and electrical engineering. There is a substantial amount of literature dedicated to the study of physical dynamic systems (Karnopp *et al*, 2000; Ogata, 1998; Shearer *et al*, 1967). The design of mechatronic systems[14] requires a thorough understanding of the dynamics involved (Karnopp *et al*, 2000). The significant element of a dynamic system is by definition the change of systems over time. There are many definitions of system dynamics; all describe the relationship with time. A definition is proposed by Coyle (1996). It is relatively long-winded but provides a good description of the many facets involved in the discipline:

> "System dynamics deals with the time dependent behaviour of managed systems with the aim of describing the system and understanding, through qualitative and quantitative models, how information feedback governs its behaviour, and designing robust information feedback structures and control policies through simulation and optimization" Coyle (1996, p.10).

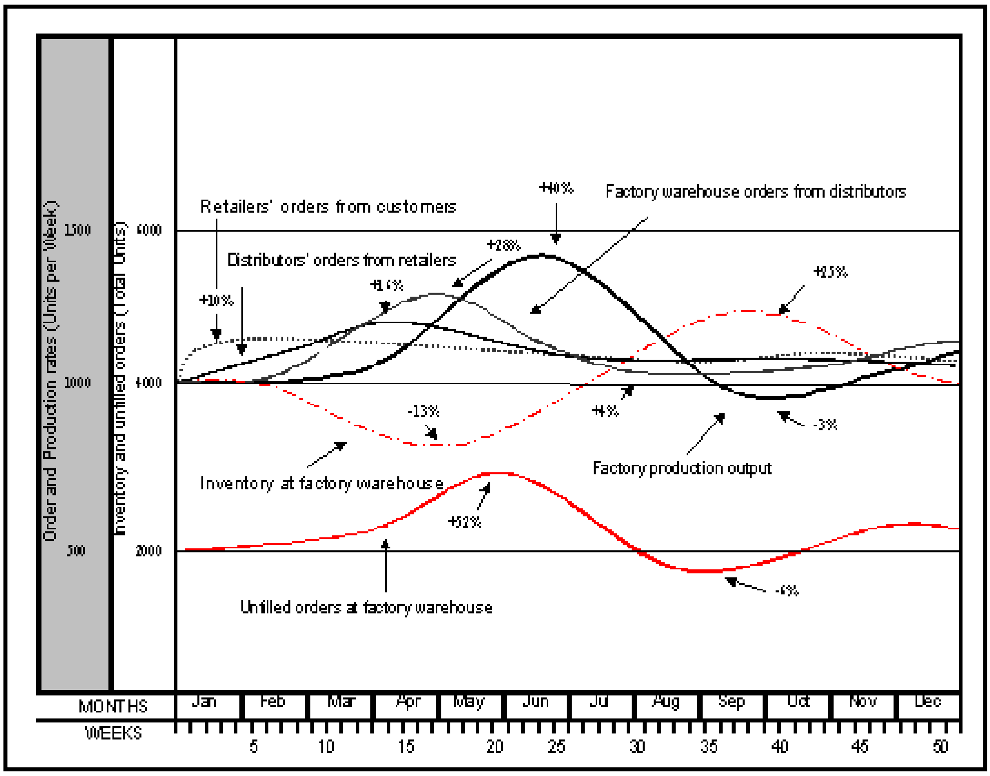
System dynamics within social science was first developed by Jay Forrester of the Massachusetts Institute of Technology (MIT) in 1956. His

[14] Mechatronic systems are fundamentally mechanical but involve electronic control (Karnopp, 2000).

understanding of servomechanisms, gained whilst an under-graduate at MIT, under the stewardship of Gordon. S. Brown and later developed through the planning and development of the Semi-Automatic Ground Environment (SAGE) system for the US Air Force, gave Forrester the experience required for the understanding of the dynamics involved in Industry.

In the July/August edition of the Harvard Business Review, Forrester (1958) published his findings in an article entitled ‘Industrial Dynamics’, later to be published in a book of the same name in 1961. Forrester showed that by understanding the nature of feedback loops in a complex system it is possible to gain an understanding of the systems behaviour. Forrester (1958) and later Burbidge (1961) showed that stock held at the manufacturer tier of the supply chain would exceed the level of consumer demand and stock levels amplify as sales pass downstream through the supply chain. Figure 3.20 (Forrester, 1958, p.43) is an example of this phenomenon, where a 10% increase in retail sales amplified production level stock further down the supply chain. This was a result of system delays and management decisions.

Figure 3.20: Response of production-distribution system to a sudden 10% increase in retail sales



Forrester (1961) showed that the separate parts of the business that were previously viewed as separate skills needed to be unified and studied as a whole system. The conclusions of the study showed:

- how small changes in retail sales can lead to large swings in factory production;
- how reducing clerical delays may fail to improve management decisions significantly;
- how a factory manager may find himself unable to fill orders although at all times able to produce more goods than are being sold to customers;
- how an advertising policy can have a magnifying effect on production variations.

Forrester branched into other areas of social science in the succeeding years by applying his knowledge of feedback systems to the understanding of more complex social problems, producing two more research projects: subsequently published 'Urban Dynamics (Forrester, 1969)' and 'World Dynamics' (Forrester, 1973). Forrester was able to demonstrate that the application of system dynamics can be applied to many disciplines and that this is necessary for the understanding of complex systems.

The Forrester effect, or bullwhip effect as it is more commonly known, has been the basis for the majority of research within supply chain dynamics. These applied studies aim to provide ways of understanding and reducing the issues of demand amplification or the bullwhip effect as it often referred. A diagram which shows a number of inputs into a supply chain, divided into those shown by Forrester (1958) and those by Burbridge (1961), which can create demand amplification is shown in Figure 3.21 (McCullen and Towill, 2002, p.166). There is a plethora of research studies covering this subject, varying in terms of degrees of value, substance, methodology and approach.

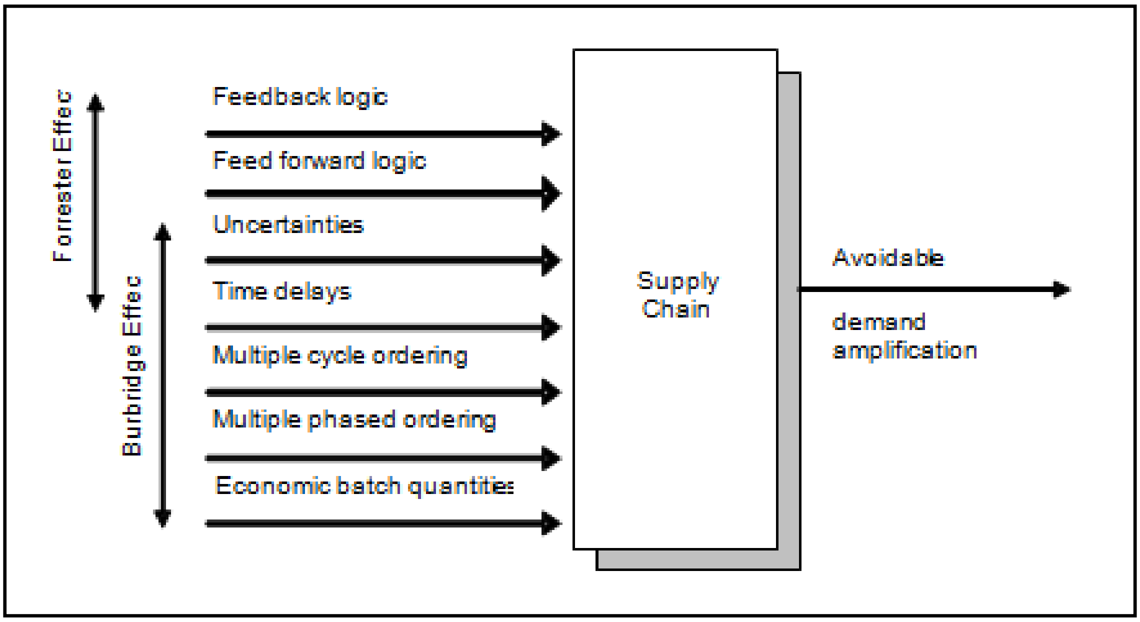
The majority of system dynamics research can be found in Operations Research and Management Science publications.

The Logistics System Dynamics Group at Cardiff University, founded in 2001, has expertise from both system dynamics and supply chain management and produces much of the notable research on demand amplification (Disney and Towill, 2003; Disney *et al*, 2006; Taylor, 2000; McCullen and Towill, 2002; Towill, 2005). Wikner et al (1991) show that these studies have resulted in showing that demand amplification can be reduced by:

- "fine tuning" the existing ordering policy parameters;
- reducing time-delays;
- removal of the distribution echelon;
- changing the individual echelon decision rules;
- better use of information flow throughout the supply chain.

Stock ordering policies as a result have been studied in some depth (Ouyang and Daganzo, 2006; Towill *et al*, 2005; Villegas and Smith, 2006; Wikner, 2006). Much of these studies concentrate on forecasting techniques, where it is shown that by smoothing the dynamics within the process, using optimal parameters, the demand amplification can be reduced and subsequently, stock levels. This is a desirable area of research because substantial gains can often be made at a small cost to the business. Technological advancements in computer systems have given rise to improved methods which have subsequently been used to reduce the amplification effect. This has led to solutions such as time compression and supply chain integration, which have become the focus of recent research (McCullen and Towill, 2002; Towill, 2005).

Figure 3.21: Input-output diagram showing Forrester and Burbidge sources of demand amplification



Supply chain integration has been shown to provide great reductions in the bullwhip effect. Enterprise resource planning (ERP) and Vendor Managed Inventory (VMI) systems, allow collaboration between supply chain partners and the sharing of information. Disney and Towill (2003) show how these systems can reduce the amplification effect from 144% to 69%. There are many studies of this nature and the solutions shown are readily accepted. The problem of excess inventory however after 50 years of system dynamics still exists in many supply chains. McCullen and Towill (2002, p.165) attempt to show the reasoning behind this management failure, described as the top ten-bullwhip clichés (see Figure 3.22).

Figure 3.22: Top ten bullwhip clichés

Common cliché	Description
1. The ignorance cliché	Bullwhip – Doesn't exist in the real world
2. The arrogance cliché	Bullwhip – Is just an academic invention
3. The negligence cliché	Bullwhip – Doesn't cost me any money
4. The indifference cliché	Bullwhip – So what? – the customer can wait
5. The transference cliché	Bullwhip - So what? – the supplier can cope. That's what service level agreements are for!
6. The acceptance cliché	Bullwhip – It's like tax – always with us
7. The despondence cliché	Bullwhip – It's a systems problem – nothing I can do about it
8. The decadence cliché	Bullwhip – It's old hat – surely it's been eradicated by now?
9. The intolerance cliché	Bullwhip – Japanese solutions don't work here
10. The avoidance cliché	Bullwhip – Those solutions are all very well – but not in my industry

The gap between academia and management understanding can be addressed through education. Much of the research details the issues and solutions but neglects to interpret this into understandable language that can be implemented in the business model by managers and is often left for consultants to implement.

Svensson (2002) and Svensson (2005) provide some early conceptual frameworks of non-traditional supply chains, but conclude that much research is still required within this area. There are certainly many other areas in which system dynamics can be applied within supply chain management, such as policy review and design. Network design (Li and Kumar, 2005) and competitive networks (Allwood and Lee, 2005) have been shown to be areas where system dynamics can be applied. The complexity, delays and feedback loops that exist in supply chains can be understood through studies applying system dynamic modelling and simulation to understand the behaviour of many phenomena.

3.8 Inventory management

Inventories are an essential part of wholesale and retail business. They are fundamentally an investment which is held by a business in the expectation a customer will purchase them in the future and which results in a financial transaction. In addition to supplying customer demand there are many functions of inventory. Seldon (2003, p.1) lists a number of reasons why a business has inventory:

- provide customer service;
- process and value to the stock;
- cater for non-forecast demand;
- counteract seasonal production cycles;
- protect against supply chain problems;
- be able to obtain (or offer) bulk discounts;
- enable the producer to utilise capacity;
- replace defective items;
- improve the company balance sheet.

These strategies employed are to be weighed against the cost of holding the stock. Strategic choice can be complex because of environmental uncertainties. This is evident for businesses that purchase inventory to hedge against future price increases. Products such as cable vary in price as the raw material price of copper fluctuates. Companies will build up their stock of cable to hedge against an expected future rise in the price of copper. Speculation of price is notoriously difficult and underlines the complex nature which underpins inventory management.

Inventories can be classified into different types. Dobler and Burt (1996, p.519) propose four different types of inventories:

1. Production inventories: Raw materials, parts, and components which enter the firm's product in the production process.
2. MRO inventories: Maintenance, repair, and operating supplies which are consumed in the production process but which do not become part of the product.
3. In-process inventories: Semi finished products found at various stages of the production operation.
4. Finished goods inventories: Completed products ready for shipment.

The management of inventory is an area that is widely covered in logistics and appears in all the core textbooks on the subject, such as those written by Gattorna (1990), Rushton *et al* (2000) and Coyle *et al* 1996). Tersine (1994) and Bernard (1999) provide a detailed account of the challenges of inventory management and the many possible methods available. Inventory management can be complex and can also be an area of contention across departments in a business such as warehousing, marketing, sales and purchasing.

Inventory costs represent a significant cost to the business. A report entitled "The state of logistics report" by the Council of Supply Chain Management Professionals (CSCMP) which tracks the costs of moving goods through the supply chain estimates that logistics costs are estimated to represent 9.9% of GDP in the US in 2006 (CSCMP, 2007). Inventory costs which includes, interest, taxes, obsolescence, deprecation, insurance and storage accounts for 34% of the total logistics costs in the US (CSCMP, 2007). It is crucial therefore that inventory is managed effectively to keep costs to a minimum. Reducing inventory levels is desirable as smaller buildings, operation resource for handling and administration are required Nilsson (2006).

Inventory costs can be classified into carrying costs and acquisition costs (Dobler and Burt, 1996, pp.524-526). The carrying costs are related to the investment of working capital, storage, handling and depreciation of products.

1. Opportunity cost of investment funds.
2. Insurance costs.
3. Property taxes.
4. Storage costs.
5. Obsolescence and deterioration.

The acquisition costs are related to the functions associated with purchasing new and replenishment products:

1. Wages and operating expenses.
2. Cost of supplies.
3. Cost of services.

A major component of inventory management is purchasing. This is sometimes referred to as procurement. Lysons and Farrington (2006, p.6) argues that procurement is a wider term which involves the ordering of goods by any method "including borrowing, leasing and even force or pillage". Purchasing is the process of sourcing new products and services. Lysons and Farrington (2006, pp.8-9) defines purchasing as:

> "The process undertaken by the organisational unit that, either as a function or as a part of an integrated supply chain, is responsible for procuring or assisting users to procure in the most efficient manner, required supplies at the right time, quality, quantity and price and the management of suppliers, thereby contributing to the competitive advantage of the enterprise and the achievement of its corporate strategy".

It is an important objective of the purchasing function to minimise on costs through efficient methods. The purchasing personnel should work towards achieving this principle by obtaining the right level of stock. The right level of stock can be defined as the minimum quantity of stock required to meet a desired level of availability. To find the right level of stock a number of key inventory decisions have to be answered

- How much to order?
- When to order?
- What to order?
- Where to order from?

3.8.1 Inventory systems

There are a number of inventory systems which businesses can employ to control the level of inventory. These systems are designed to support and provide the information necessary for managers to answer the key inventory decisions of how much to order and when to order. Businesses usually purchase specialist inventory software packages which have these system built in. For most companies it is not suitable to use a paper or spreadsheet based system because there is a large number of interactions and calculations. A judgment is made of which type of systems is best suited to the business. It is desirable for there to be an adequate level of experience in inventory management within the company so that the systems are designed effectively.

Dobler and Burt (1996, p.531) list a number of different general types of inventory replenishment systems:

- cyclical or fixed order interval (periodic review);
- just-in-time;
- materials requirements planning (MRP);
- order point or fixed order quantity (continuous review).

These general types can be classified as either pull or push systems. Push systems are based on the forecasting of customer demand and are generally used as a requirement of make to stock. Pull systems are based on actual customer demand and are generally used as a requirement to make to order. The continuous and periodic review systems are the most commonly used in industry (McKinnon, 1989). These are examined in detail in the next section.

The different systems have a number of advantages and disadvantages as a consequence of the equations which they are built upon. The definitions and descriptions which are provided by Dobler and Burt (1996) give a good foundation for understanding the intricacies of each system but there is a lack of practical advice on the selection process for companies. It is important that the appropriate system is used because the recommendations which will be produced have a direct influence on the number of orders placed and the quantity of stock requested on each order. These two factors control the distribution of operation costs and effect sales revenue as a result of the level of customer service achieved. There are also a number of possibilities to consider such as product and freight discounts and conditions which may be set by suppliers such as minimum invoice values and the length of lead times.

For smaller businesses it is often necessary to use a system which reduces the number of purchase orders placed and increase the total invoice value of each order. This is to seek reductions in distribution and administration costs and meet minimum invoice values set by supplier. A periodic review system which increases the period of time between orders can often be the appropriate choice in this instance. For larger companies where the quantity of products held is sufficient to create large purchase orders, continuous review systems can be a better choice to reduce the overall level of stock held. It addition to the size, the type of business should influence the decision. MRP systems for example are well suited to manufacturing and production environments. JIT systems can be well suited to business which has fast moving products and products with short life cycles such as those within the food industry.

Although Dobler and Burt (1996) have outlined the general inventory systems types it has to be noted that there are a number of specific systems within these categories. These are typically used to deal with specific planning issues within either manufacturing or retail environments. A number of these are listed below:

- materials requirements planning (MRP);
- manufacturing resource planning II (MRP II);
- distribution resource planning (DRP);
- enterprise resource planning (ERP);
- kanban;
- two bin;
- continuous replenishment program (CRP);
- vendor managed inventory (VMI).

Advances in technology and processing power have meant that there has been an increase in software which attempt to synchronise the different planning systems into one package. These are called Enterprise Resource Planning (ERP) systems. There is a module-based suite of software which pulls together different elements of planning, enterprise wide. An ERP system called SAP, which is the market leader in the UK for example, has the following modules:

- finance;
- sales;
- purchasing;
- banking;
- stock management;
- production;
- service;
- human resource;
- warehouse.

3.8.1.1 Periodic review system

The periodic review system is the oldest and simplest type of inventory control system (Dobler and Burt, 1996). At a scheduled point in time the level of inventory is reviewed and the stock is reordered up to a predetermined level. Stock which is ordered to replace products which have been sold is known as replenishment. Inventory managers are responsible for deciding the period of time which should elapse before a review is conducted. Products have different demand patterns which mean that the period of time varies between products. Dobler and Burt (1996) suggest that ‘A’ classified products should be reviewed weekly, ‘B’ classified products monthly and ‘C’ classified product quarterly. The equations used in a periodic review system are shown in Equations 3.2 (McKinnon, 1989, p.92). The reorder level (see Equation 3.2c) is calculated from the cycle stock (see Equation 3.2a) plus the safety stock (see Equation 3.2b). The period of time from placing an order to time it arrives is known as the lead time.

Equation 3.2: Periodic review system

Equation(s)

$CS = S(L + T)$ Equation (3.2a)

$B = k\sigma\sqrt{L+T}$ Equation (3.2b)

$RL = CS+B = S(L+T) + k\sigma\sqrt{L+T}$ Equation (3.2c)

Notation(s)

CS = Cycle stock

B = Safety stock

S = Average sales per day

RL = Reorder level

L = Demand during lead time

T = Demand between order

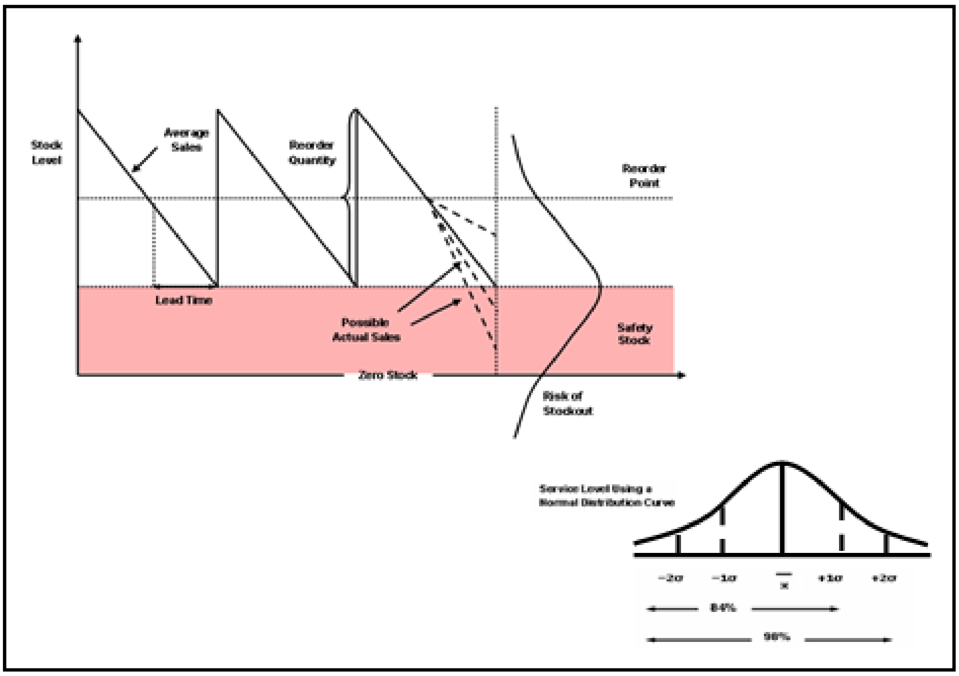
K = number of SD’s above the mean corresponding to the desired service level

σ = Standard deviation of the level of demand

3.8.1.2 Continuous review system

A continuous review or fixed reorder point system uses a predetermined point to determine the point when a particular stock is to be re-ordered. A model of the system illustrated by McKinnon (1989, p.87) is shown in Figure 3.23. The equations used in the continuous review system are shown in Equations 3.3 (McKinnon, 1989, p.88 and Tersine, 1994, p.213). The reorder point (see Equation 3.3d) is calculated from the expected level of sales demand, known as the cycle stock or lead time demand (see Equation 3.3a) and the safety stock (see Equation 3.3b and 3.3c).

Figure 3.23: Continuous review system



Equation 3.3: Continuous review system

Equation(s)

$CS = SL$ Equation (3.3a)

$B = k\sigma\sqrt{l}$ Equation (3.3b)

$B_2 = k\sqrt{m}\sqrt{l}$ Equation (3.3c)

$\text{ROP} = \text{CS}+\text{B} = \text{SL}+ \text{k}\sigma\sqrt{\text{l}}$ Equation (3.3d)

Notation(s)

ROP = Reorder point

CS = Cycle stock

m = Mean sales

B = Normal distribution safety stock

B_2 = Poisson distribution safety stock

S = Average sales per day

L = No of days to arrive

k = Number of SD's above the mean corresponding to the desired service level

σ = Standard deviation of the level of demand

Sales demand is stochastic so safety stock is used to buffer against any increases in the estimated average. The illustration in Figure 3.23 shows how possible sales can differ from the estimated average. An assumption is made that the possible sales fluctuate around a constant mean in accordance with the normal distribution curve. It is assumed that the lead time is known and constant. This assumption allows a business to calculate the probability of a stock-out occurring. The probability of a stock-out occurring is said to represent the level of customer service. For example a 5% stock-out probability represents a 95% customer service level. A standard deviation is used to calculate the level of safety stock for different levels of customer service.

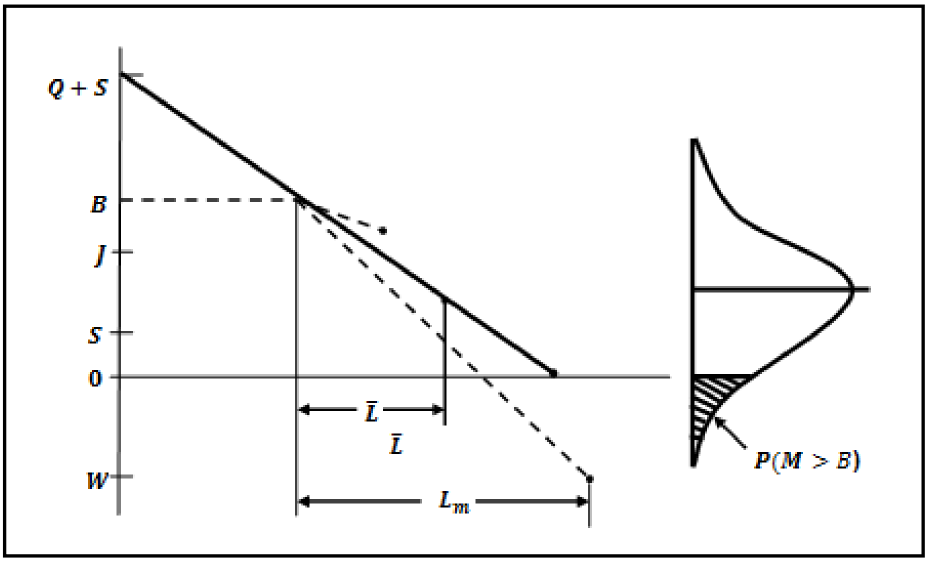
A list of the service levels and standard deviations are shown in Figure 3.24. A larger level of safety stock is required when there are higher fluctuations in sales demand. The equation for safety stock is calculated in Equation 3.3b. A Poisson distribution is sometimes used for slow moving products (Seldon, 2003 and Tersine, 1994). The calculation is shown in (see Equation 3.3c).

Figure 3.24: Safety stock service levels

Service level	Standard deviation
50	0.00
80	0.84
85	1.04
90	1.28
95	1.64
96	1.78
97	1.88
98	2.05
99	2.33

The continuous review systems which businesses apply usually assume that the lead times of their suppliers are constant and known. In reality this is not always the case and lead times can vary significantly. If in a particular month the demand and lead times are greater than expected then the company will run out of stock of that product. This is illustrated by Tersine (1994, p.228) in Figure 3.25. To buffer against this, extra stock can be held which accounts for that eventuality. The calculation is shown in Equation 3.4 (Tersine, 1994, p.231).

Figure 3.25: Variable demand and variable lead time



Equation 3.4: Continuous review system

Equation(s)

$$CS = S(k\sigma + l) \quad \text{Equation (3.4a)}$$

Notation(s)

$CS = \text{Cycle stock}$

$\sigma = \text{Standard deviation of lead time}$

$k = \text{Number of SD's above the mean corresponding to the desired service level}$

$L = \text{No of days to arrive}$

$S = \text{Average sales per day}$

3.8.2 Economic order quantity (EOQ)

The decision of how much to order is usually calculated using the economic order quantity (EOQ). The traditional approach uses what is referred to as the Wilson formula (see Equation 7.5). The EOQ model was first published in Factory Magazine by Ford Whitman Harris in 1913 and later appeared in Harvard Business review in 1934 by Wilson who became accredited with the model (Erlenkotter, 1990).

The EOQ is a method which attempts to find the most cost-effective purchase quantity. It does this by balancing intangible inventory carrying costs against tangible acquisitions costs. The carrying costs are concerned with the cost of holding inventory. Dobler and Burt (1996, p.524) estimate a breakdown of the carrying costs (see Figure 3.26). The acquisition costs consider the cost of “generating, processing and handling” inventory (Dobler and Burt, 1996, pp.525-526). The calculations for these are shown in Equations 3.5 and 3.6 respectively (Dobler and Burt, 1996, pp.525-529).

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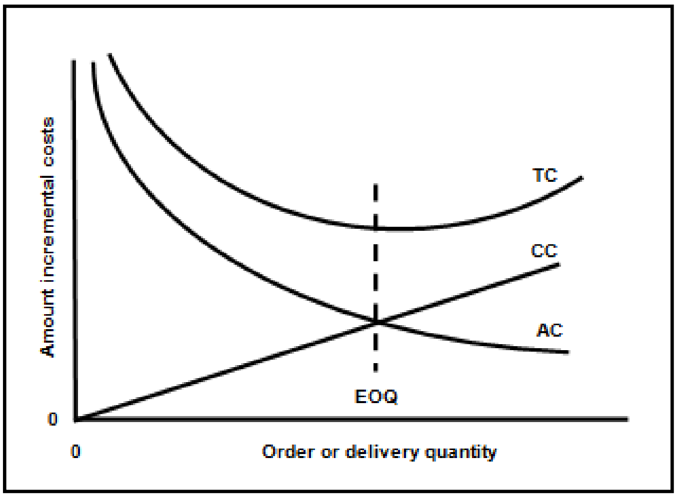
Figure 3.26: Inventory carrying costs

Costs	Percentage
Opportunity cost of invested funds	12 – 20
Insurance costs	2 – 4
Property costs	1 – 3
Storage costs	1 – 3
Obsolescence	4 – 10
Total	20 -40

The EOQ is found at the point where inventory carrying costs (see Equation 3.5) and acquisition costs (see Equation 3.6) converge (see Equation 3.7a). This is illustrated by Dobler and Burt (1996, p.528) in Figure 3.27. At this point the total cost is minimised and the most economic quantity is found based on this method. The point at which the two equations are equal can be solved using the calculation shown in Equation 3.7b.

The main difficulty with this model lies in the assumptions and the estimation of the holding and acquisition parameters. A study of the costs would reveal an indication of the costs but a high level of accuracy is difficult to achieve. The Wilson Formula is the traditional model which is used but there are different methods and variations on the model. It is sometimes preferable to simply calculate the ordering quantity to obtain a certain level of stock turnover. This gives a business some control on the level of inventory it holds. van Delft and Vial (1996) have adapted the Wilson equation to deal with products with a high obsolescence rate using discounted costs.

Figure 3.27: Economic order quantity



Notation(s)

AC = Incremental acquisition costs

CC = Incremental carrying costs

TC = Total incremental costs

Equation 3.5: Carrying costs

Equation(s)

$$CC = \frac{Q}{2} \text{ x C x I}$$

Notation(s)

CC = Carrying cost per year for the material in question

Q = Order or delivery quantity for the material, in units

C = Delivered unit cost of the material

I = Inventory carrying cost for the material, expressed as a percentage of inventory value

Equation 3.6: Acquisition cost

Acquisition cost per year = number of orders placed per year x acquisition cost per order

Equation(s)

$$AC = \frac{U}{Q} \text{ x } A$$

Notation(s)

AC = Acquisition cost per year for the material in question

U = Expected annual usage of the material, in units

Q = Order of delivery quantity for the material, in units

A = Acquisition cost per year or per delivery for the material

Equation 3.7: Economic order quantity (EOQ)

Equation(s)

$$\frac{Q}{2} \text{ x } C \text{ x } I = \frac{U}{Q} \text{ x } A \qquad \text{Equation (3.7a)}$$

$$EOQ = \sqrt{\frac{2UA}{CI}} \qquad \text{Equation (3.7b)}$$

Assumption(s)

1. Monthly demand for the item is known, deterministic and constant.
2. The lead-time is zero.
3. The receipt of the order occurs in a single instant and immediately after ordering it.
4. Quantity discounts are not calculated as part of the model.
5. The set-up cost is constant.

3.8.3 Forecasting

3.8.3.1 Business forecasting

A significant amount of decisions which are made are based upon a prediction of future events. The methods which are concerned with this process are formally referred to as forecasting. This technique can be defined as "the prediction, projection, or estimation of the occurrences of uncertain future events or levels of activity" (Tersine, 1994, p.35). It is prudent for businesses to design plans in the present which are based upon forecasts of the future. Referred to as business forecasting it allows a company to attempt to maximise their profit by optimising on their operational resource and potential sales revenue. Business forecasting is used at all levels of a business and within all departments. Strategic forecasts consider financial investments and help guide policy formulation whilst operational forecasts guide resource planning.

Historical information is a crucial element in the forecasting process and can be qualitative or quantitative or a combination of both. The information is used to indicate what is likely to happen in the future by making an assumption based on a trend. The success of a forecast is dependent on the quantity of information available and the unpredictability of the phenomenon being studied. This is measured relative to the actual event once it has occurred.

3.8.3.2 Demand forecasting

The forecasting of sales demand is a principle function for most businesses. Mintzberg (1994) believes that an overestimation of customer demand typically causes the most problems for an organisation. The ease and success of a forecast is increased if customer behaviour is predictable and the environment is stable (Mintzberg, 1994). The greater the time horizon the more difficult it becomes to forecast and it has been stated that it is actually not always possible (Mintzberg, 1994). The type of forecast can be categorised by its planning horizon (short, medium or long), business level (strategic, tactical or operational) and department of use. A long term forecast tends to be used at a strategic level, medium at a tactical level and short at an operational level. Smith and Slater (2001) provide a list of the possible applications of forecasts within supply chain management and how they relate to the planning horizons:

1. Short term

- Stock manufacturing capacity levels
- Manning levels
- Equipment levels
- Shift patterns
- Warehouse layouts
- Transport requirements
- Price promotions
- Shelf configuration
- Store opening hours

2. Medium term

- Stock manufacturing capacity levels
- Manning levels
- Equipment levels
- Shift patterns
- Warehouse layouts
- Transport requirements
- Price promotion
- Shelf configuration
- Store opening hours
- System requirements
- Budgeting
- Automated handling systems requirements
- Transport charges
- New product introductions

3. Long term

    - Fixed warehouse and manufacturing systems requirements
    - Budgeting
    - Automated handling systems requirements
    - Transport charges
    - New product introductions

Customer demand is stochastic so inventory systems rely on forecasting to predict future levels. If customer demand is stable then forecasting is not required. Forecasts are used in the calculation of reorder points and order quantities. Makridakis and Wheelwright (1989, pp. 61-62) have identified a number of different patterns that demand follows (see Figure 3.28 – 3.31). A forecasting technique is selected which best fits the pattern of demand.

Figure 3.28: Horizontal data pattern

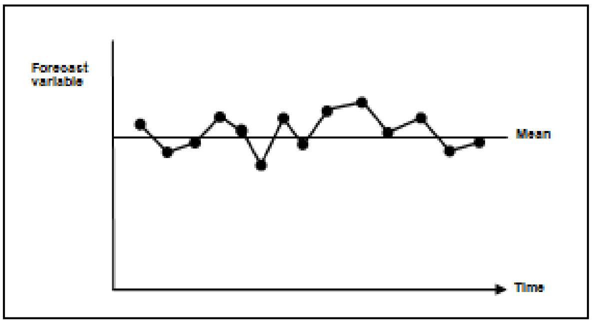


Figure 3.29: Seasonal data pattern

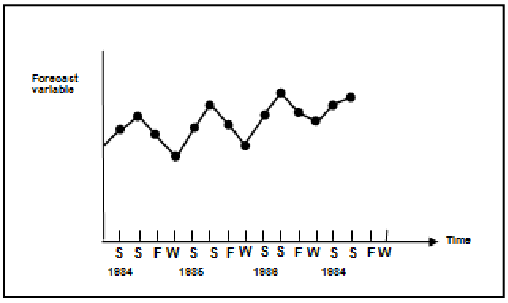


Figure 3.30: Cyclical data pattern

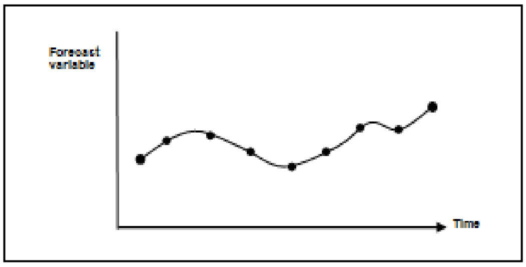
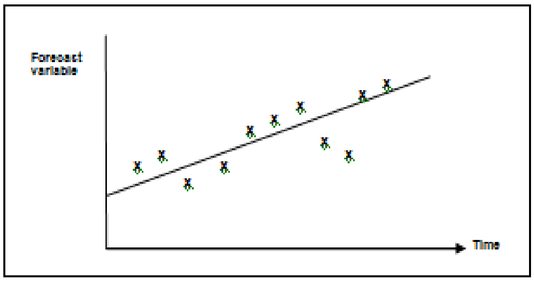


Figure 3.31: Trend data pattern



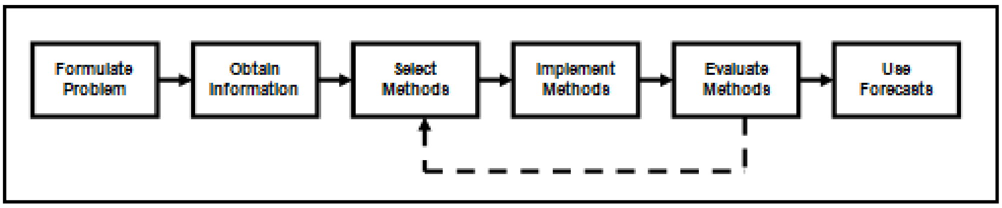
3.8.3.3 Forecasting process

Traditionally forecasts were formulated using common sense, intuition or basic analytical techniques. The degree of success would depend upon an individual's level of expertise and the availability and access of relevant information. The advancement of computer processing power has meant that forecasts can now be generated both quickly and with the use of sophisticated analytical methods. Forecasting software ranges in terms of its ease of use, time to calculate, range and complexity of techniques and price. This criterion forms the decision of which software is the most suitable. A spreadsheet-generated forecast for example is relatively cheap, quick to produce and requires a low level of knowledge but is limited in complexity, and is slow to reproduce in large scale quantities. Software packages such as Minitab and Forecast Pro can perform complex forecasts. Companies which use inventory management software usually have a forecasting function built in.

Armstrong (2001, p.8) shows that the forecasting process, although not an exact science, is an iterative formal approach as shown in Figure 3.32. The first two stages are relatively straightforward and involve formulating the problem and collecting the relevant information. The key stage is the selection of the most appropriate forecasting method. The different types of forecasting method are not often fully understood or are used inappropriately (Smith and Slater, 2001). The method used is a crucial element in the level of accuracy of forecast produced. If an incorrect type is used then a successful outcome is prohibited.

An appraisal is made to decide which method provides the best results at an acceptable cost to the business and ultimately which gives the largest payback. Although providing the best results, the most complex software driven forecasts may not always be the most feasible and economic to use. For example traditional methods might be adequate for simple problems, or where an analytical approach is not feasible or if the results generated in comparison to that of a computer based solution do not show a significant economic benefit to the business.

Figure 3.32: Stage of forecasting



An extensive range of forecasting methods is laid out by Makridakis and Wheelwright (1989) in their book titled 'Forecasting methods for management'. Since the release of the first edition in 1973 the authors have become well recognised within the field and have been described as a leading authority on forecasting by the renowned business strategist Henry Mintzberg (1994). Makridakis and Wheelwright (1989) categorise forecasting methods into three major categories; judgmental, quantitative and technological. The quantitative category and its sub category time-series methods are the subject of this study. According to Makridakis and Wheelwright (1989) the majority of literature is based within this area.

Jarrett (1991) shows that there are a wide range of techniques which are available and used by businesses:

- moving average;
- exponential smoothing;
- decomposition methods;
- regression analysis;
- econometric modelling;
- box-jenkins techniques;
- economic techniques;
- delphi method;
- forecast revision.

Practitioners have different reasons for selecting a forecasting technique. Yokum and Armstrong (1995, p.593) provide a survey conducted of members and non-members of The International Institute of Forecasting (IIF) (see Figure 3.33). The results showed that accuracy was the most important reason when selecting a forecasting technique. When there is a lack of expertise, criteria such as ease of use become the dominant factor. This is more likely to result in forecasts which are naive or simple. These forecasts might not provide the most accurate result or the greatest cost savings.

The forecasts which are commonly understood and used by inventory management systems to forecast demand are the moving average, single exponential smoothing, double exponential smoothing and seasonal exponential smoothing time series methods. The calculations for these are shown in Equations 3.8-3.11 (Wheelwright, 1989, pp.69-80). They use historical demand data to calculate the future forecast. The demand pattern and behaviour determines which method is the most suitable. The volume, variability and trend are characteristics of a product which form the pattern and behaviour.

Figure 3.33: Importance of criteria in selecting a forecasting technique

Question	Average
Accuracy	6.20
Timeliness in providing forecasts	5.89
Cost savings resulting from improved decisions	5.75
Ease of interpretation	5.69
Flexibility	5.58
Ease in using available data	5.54
Ease of use	5.54
Ease of implementation	5.41
Incorporating judgemental input	5.11
Reliability of confidence int.	4.90
Development cost (computer, human resources)	4.86
Maintenance cost (data storage, modifications)	4.73
Theoretical relevance	4.40
Scale – 1 “unimportant” to 7 “important”	

The moving average forecast uses an average which is taken over a long period of time (see Equation 3.8). This provides a smooth forecast but doesn’t react quickly to recent changes. The exponential smoothing method assumes that data is less relevant over time and places more value on recent data (see Equation 3.8). The equation uses a smoothing coefficient to give weight to historical data. A large coefficient gives weight to the most recent data and a small coefficient uses an average over a longer period of time. The double exponential smoothing uses a further coefficient to take into account any underlying trend (see Equation 3.10).

The season exponential smoothing adds a third coefficient to account for any seasonal trend (see Equation 3.11). A seasonal trend repeats over time. This is common in customer demand patterns because consumers tend to buy more or less depending on what month it is. This is particularly true at

Christmas where a large percentage of the yearly sales are achieved in one month.

Equation 3.8: Moving average

Equation(s)

$$F_{t+1} = \frac{X_t + X_{t-1} + \cdots X_{t-N+1}}{N}$$

Notation(s)

F_t = Forecast for time t

X_t = Actual value at time t

N = Number of values included in average

Equation 3.9: Single exponential smoothing

Equation(s)

$$F_t = \alpha X_t + (1 - \alpha)F_t$$

Notation(s)

F_t = Forecast for time t

X_t = Actual value at time t

α = Smoothing coefficient

Equation 3.10: Double exponential smoothing

$T_t = \beta(S_t - S_{t-1}) + (1 - \beta)T_{t-1}$ Equation (3.10a)

$S_t = \alpha X_t + (1 - \alpha)(S_{t-1} + T_{t-1})$ Equation (3.10b)

$F_{t+1} = S_t + T_t$ Equation (3.10c)

Notation(s)

F_t = Forecast for time t

X_t = Actual value at time t

T_t = Smoothed trend in data series

S_t = Equivalent of single exponential smoothed value

β = Smoothing coefficient, analogous to α

Equation 3.10: Seasonal exponential smoothing

Equation(s)

$$S_t = \alpha \frac{X_t}{I_{t-l}} + (1 - \alpha)(S_{t-1} + T_{t-1}) \quad \text{Equation (3.11a)}$$

$$T_t = \beta(S_t - S_{t-1}) + (1 - \beta)T_{t-1} \quad \text{Equation (3.11b)}$$

$$I_t = \gamma \frac{X_t}{S_t} + (1 - \gamma)I_{t-L} \quad \text{Equation (3.11c)}$$

$$F_{t+1} = (S_t + T_t)\, I_{t-l+1} \quad \text{Equation (3.11d)}$$

Notation(s)

F_t = Forecast for time t

X_t = Actual value at time t

S = Smoothed value of deseasonalised trend

T = Smoothed value of trend

I = Smoothed value of seasonal factor

L = Length of seasonality (number of months or quarters in a year)

β = Smoothing coefficient

γ = Smoothing coefficient

It is necessary to measure the accuracy of forecasts. This can be to test whether the forecast is performing as expected or to evaluate which methods best match a pattern of demand. Makridakis & Wheelwright (1989, pp.58-59) have identified a number of different methods (see Equations 3.12-3.18). The size of the result determines the success of the forecast. A small forecast error indicates that the forecast gave an accurate representation of what actually happened. It is not always practical to store forecasts for a long period of time. A smoothed forecast error is updated each period and does not require historical data to be stored for greater than one period. This is generated from the previous smoothed error and the error from the current period (see Equation 3.19) (Bernard, 1999, p.363).

Equation(s)

Equation 3.12: Mean error

$$\mathrm{ME} = \frac{\sum_{i=1}^{n} e_i}{n}$$

Equation 3.13: Mean absolute deviation

$$\mathrm{MAD} = \frac{\sum_{i=1}^{n} |e_i|}{n}$$

Equation 3.14: Mean squared error

$$\mathrm{MSE} = \frac{\sum_{i=1}^{n} e^2{}_i}{n}$$

Equation 3.15: Standard deviation of errors

$$\mathrm{SDE} = \sqrt{\frac{\sum_{i=1}^{n} e^2{}_i}{n-1}}$$

Equation 3.16: Percentage error

$$\mathrm{PE}_t = \frac{X_t - F_t}{X_t} 100$$

Equation 3.17: Mean percentage error

$$\mathrm{MPE} = \frac{\sum_{i=1}^{n} \mathrm{PE_t}}{n}$$

Equation 3.18: Mean absolute percentage error

$$\mathrm{MAPE} = \frac{\sum_{i=1}^{n} |\mathrm{PE_t}|}{n}$$

Notation(s)

$\mathrm{n} = \text{Number of observations}$

$\mathrm{e} = \text{Forecast error at period}$

$\mathrm{F_t} = \text{Forecast for time t}$

$\mathrm{X_t} = \text{Actual value at time t}$

Equation 3.19: Smoothed forecast error

$$\text{NEW MAD} = (\text{MAD})\alpha + \text{OLD MAD}(1 - \alpha)$$

Notation(s)

$\alpha = \text{Smoothing coefficient}$

$\text{MAD} = \text{Mean absolute deviation}$

3.8.4 Inventory performance measures

The inventory system should be measured to determine how successful it is controlling stock levels and maintaining customer service levels. The performance measures should reflect this objective. Any areas which are not achieving satisfactory levels should be highlighted and evaluated. A number of different measurements can be used to evaluate performance. Stock performance is measured using stock turnover calculations (see Equation 3.20) and service levels are measured using customer service calculations (see Equation 3.21-3.23) (Seldon, 2003, pp. 82 - 84).

The stock turnover calculation determines how long it takes for a product to be sold if the sales continue at the expected rate. A high stock turnover would indicate that there is excess stock being held. The customer service calculation is a percentage measure of how well a company has serviced its customers. The higher the percentage the better have the customers been serviced. The product and customer stock-outs are a measure of how well the stock is managed. If a product has a zero inventory it is said to be out of stock and therefore not available for the customer to purchase. A customer stock-out occurs if a customer wishes to purchase the product which is not available. If the level of stock-outs is high then this is a good indication that inventory is being managed ineffectively.

Equation(s)

Equation 3.20: Stock turnover

$$\text{Stock turnover} = \frac{\text{Current quantity in stock}}{\text{Expected future daily rate of sales of usaage of stock}}$$

Equation 3.21: Product stock-outs

$$\text{Stock out level} = \frac{\text{Numver of SKU'with zero stock in the last period}}{\text{Total SKUS}}$$

Equation 3.22: Customer service

$$\text{Customer service} = \frac{\text{Orders meeting customer service standards in the last period}}{\text{Total orders in the period}} \text{ x } 100$$

Equation 3.23: Customer stock-outs

$$\text{Customer stock out level} = \frac{\text{No of customer delivery failures due to zero stock last period}}{\text{Total customer order lines lst period}}$$

3.8.5 Inventory optimisation

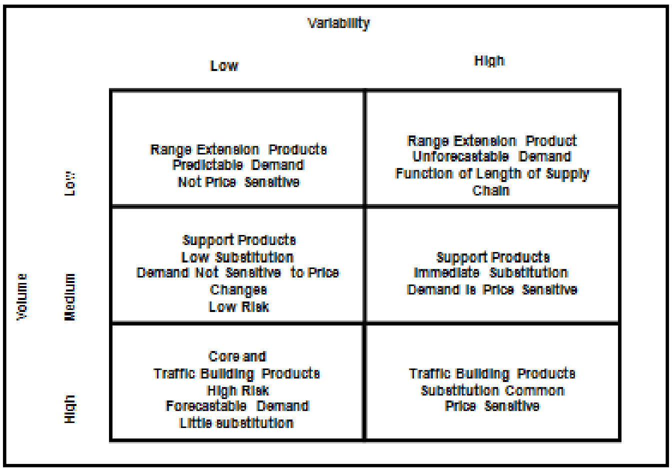
One of the essential objectives of a business should be to manage inventory efficiently. This is because the level of inventory held has a direct impact on the level of profit. Companies should seek to reduce stock holding to a minimum whilst meeting customer service requirements. This is sometimes referred to as inventory optimisation. It is not possible to fully optimise inventory because there are always different or better solutions not known or used. A number of advanced planning systems (APS) such as the Manugistics and Toolsgroup claim to have developed optimisation inventory software which achieves this.

The level of success is dependent upon the design of the inventory system; the information and communication systems; policies; and processes, and the decisions of personnel who interact with the system. The management of these dynamics can have either a positive or negative impact on inventory efficiency. Inventory optimisation can be defined as:

> "The ability to automatically determine the correct stock levels for multiple SKUs in multiple locations, in such a way that fulfills a global service level target and simultaneously optimizes a desired objective function" (Cornacchia, 2004, p. 3).

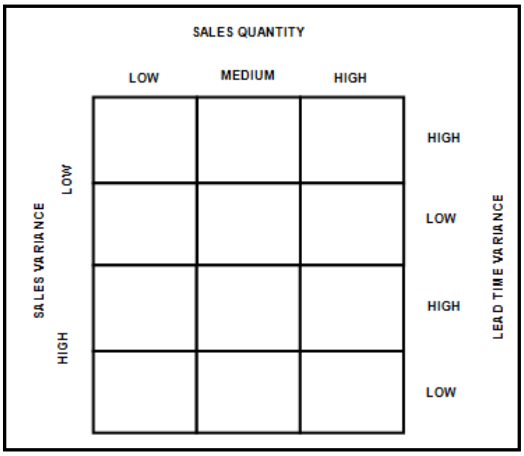
The inventory held by a business is made up of a large mix of different products. Products can be segmented by analysing their patterns of demand and variability (Smith and Slater, 2001, p.33). To minimise stock holding and meet required service level products can be segmented by volume and variability. Different techniques can then be attached to the different segments. A segmentation analysis is a process which is used to determine the category each product falls within. Smith and Slater (2001, p.39) propose six segments which are based upon sales volume and sales variability (see Figure 3.34). The types of products which relate to each segment are shown.

Figure 3.34: Segmentation sectors



For business where there is variance in product lead times an extra dimension can be added to the segmentation matrix to account for this. Products which have a high variability of lead times can have an increased level of safety stock to account for the variance. The segmentation matrix is shown in Figure 3.35.

Figure 3.35: Segmentation matrix



The segmentation analysis requires the volume and variability of products to be calculated. The percentage of volume is calculated by the total sales volume of an individual SKU divided by the total sales of all SKUs (se Equation 3.24). Smith and Slater (2001, p.7) propose a variability index which uses the difference between the maximum sales per week and the minimum sales per week (see Equation 3.25). A coefficient of variance can also be used which measures the ratio of dispersion of the mean using the standard deviation (see Equation 3.26) (Anderson *et al*, 2009, p.95). This approach was used by Godsell (2009). This can be calculated over the forecasting period such as a week or a month.

Equation 3.24: Volume percentage

$$\text{Volume percentage} = \frac{\text{Total SKU Sales}}{\text{Total Sales}} \text{ x } 100$$

Equation 3.25: Variability index

$$\text{Variability index} = \frac{\text{Maximum sales units/week} - \text{Minimum sales units/week}}{\text{Average sales units/week}}$$

Equation 3.26: Variability index – coefficient of variance

Equation(s)

$$C_v = \frac{\sigma}{\mu}$$

Notation(s)

$C_v = \text{Coefficient of variance}$

$\sigma = \text{Standard Deviation}$

$\mu = \text{Mean}$

The desired levels of service should be different for different types of products. It is not advantageous to opt for the highest level of customer service because of the operational costs involved. Smith and Slater (2001) give the following reasons why providing the best customer service levels may not lead to competitive advantage:

- the “best” customer service levels may not induce the customer to buy;
- If the cost of providing a service is too high, it will negate any new business and possibly generate a loss.

The customer service levels for each product type can be achieved by undertaking a cost benefit analysis (Smith and Slater, 2001). The difficulty of this is that it is hard to obtain actual costs at an individual SKU level. It is also difficult to establish customer requirements because customer are likely to say what they want but not what they actually need or are willing to accept. An estimated customer service level for each classification can be used if a cost/benefit analysis is not undertaken.

It is time consuming to set service levels for every product so they can be segmented using the volume of sales into such classifications as A, B and C. It is desirable for products with a higher volume of sales to have the highest service levels. The system can then be designed to match these segments. This allows the overall stock level to be reduced whilst maintaining service levels. The service level for each segment is maintained by the choice of forecasting and inventory methods used.

Initial parameter values have to be set for the equations used for each forecasting method. The parameters determine the level of accuracy of the method used. The choice of parameters values are based upon variability. For example a small smoothing coefficient is applicable for demand patterns with a high variability because it avoids severe fluctuations in demand (Smith and Slater, 2001). This is because more stock is required for products which exhibit higher degrees of variability

It is impractical to try and find optimum parameters for each individual product. To do this would require a large amount of processing power to test the extremely large amount of possible combinations. The complex and non-linear behaviour exhibited in inventory systems means that optimum parameter values cannot be confidently calculated on an individual basis to a high degree of accuracy.

3.9 Chapter summary

This chapter has shown how supply chain segmentation relates to inventory management. Mathematical modelling techniques were used for the analysis undertaken within the case study. The different techniques have been shown and the different processes involved in creating a model. A number of different methods which can be used to calculate sales variability have been shown. The next chapter is a description of the case study company and the market it operates within.

CHAPTER 4

4 CORPORATE CONTEXT

4.1 Context

The UK electrical wholesale industry is an intensively competitive market, with pressures from external forces, competing on price, product quality and availability and delivery service. The relative ease by which customers can switch to rival companies has created a climate of aggressive price competition. This places a significant pressure on product margins and on businesses to negotiate better terms and deals with manufacturers. This situation has been compounded by a declining economic climate in 2009. The value of the electrical wholesale market is expected to decline by 4% in 2009 (Mintel, January 2009).

Newey and Eyre, as part of the Hagemeyer Group, has evolved over time, reacting to changes in the external environment, this has manifested as an ongoing effort to reduce prices and increase sales. The business has developed a culture, reinforced through strategic policies, where the main aim is a drive to increase revenue by improving customer service levels. This was typified by the mission statement of the Hagemeyer Group in their Annual Report (2006):

> "Our mission is to exceed our customers' and suppliers' expectations in the value-added, business-to-business distribution of electrical parts and supplies, and electrical and non-electrical Maintenance, Repair and Operations (MRO) products in the Construction and Installation (C&I) market and in Industry."

This strategic goal is implemented through performance target motivations and bonus incentives. The decision making process of managers is influenced significantly as they attempt to meet the targets. They adapt and adjust their working methods to meet specific goals, blind to the wider impacts; an approach which is similar to Darwinian natural selection. The strategic aims have been met and the business has successfully been able to increase sales turnover year on year by increasing availability, diversity and serviceability of products.

The drive for increased sales has created an atomistic culture within the business. Lack of both a coherent supply chain strategy and holistic management decision-making has produced defective systems and a failure to maximise profits. The trade-off between customer service and operation costs is ignored in the drive to resolutely increase sales and this as a result has created a number of supply chain issues. An excess level of stock holding has resulted in high volumes of stock obsolescence where the demand had failed to meet sales expectations. The regional warehouses are congested with excess stock and as a result operational productivity levels are low.

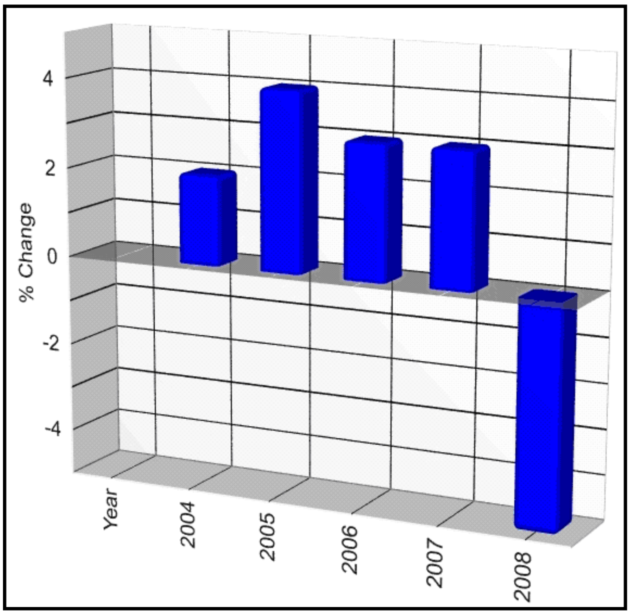
The overall impact of the business strategy is a reduction in product margins which has left many products and customers unprofitable and increased the number of 'write-offs'. The research programme is designed to undertake an investigation of the supply chain operation to determine the extent of the problems and find possible solutions. A supply chain strategy is developed with the aim of increasing the overall profitability of the business.

4.2 The UK electrical wholesale market

4.2.1 The market

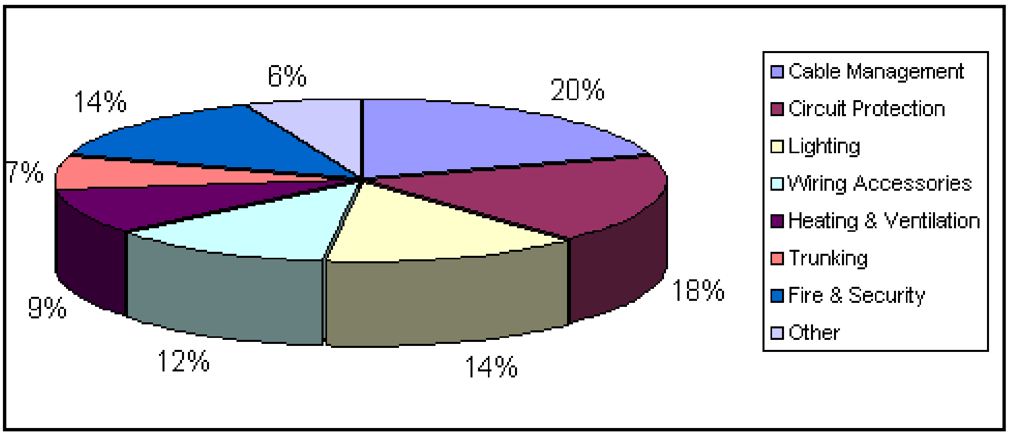
The UK electrical wholesale market is coming under pressure from a decline in the world economy and rises in raw material prices (AMR Research, May, 2009). The percentage change in outputs from 2004 to 2008 is shown in Figure 4.1 (Mintel, January 2009). There has been an average sustained growth of approximately 3% from 2004 to 2007. From 2007 to 2008 however there was a decline in the market of 4.7%. The peak of trade over the five year period was in 2007 with a sales value of £3,482 million.

Figure 4.1: The UK Electrical Wholesales Market (2004 – 2008)



The electrical wholesale market by sector in 2008 is shown in Figure 4.2 (Mintel, January 2009). The market is divided into 8 categories. Cable management is the largest sector at 20% with a sales value of £656.4 million. Sales of switchgears and circuit breakers have accounted for 18% of the total market with a sales value of £589.8 million (Mintel, January 2009). The worst performing sector is trunking due to the slowdown in the output in construction (Mintel, January 2009).

Figure 4.2: The UK Electrical Wholesalers Market, by Sector (2008)



The success of the electrical wholesale market is correlated to the output of the construction trade. In 2008 private housing construction declined by 15% due to the global financial crisis and a downturn in the housing market (Mintel, February 2009). This is in contrast to a growth of 19% between 2004 and 2007 (Mintel, February 2009). There has been a similar decline in private industrial construction which has fallen by 16% due to a reduced output of warehouses and distribution centres (Mintel, February 2009).

It is expected that the total construction output for 2009 will decline by 4% in real terms (Mintel, February 2009). The companies with a significant exposure to the residential sector are most at risk (AMR Research, May 2009). This is significant for Newey and Eyre because 43% of their sales come from this sector. The declines in construction output have put significant pressures on product margins.

Changes to Government legislation have had a direct impact on the industry. The Low Voltage Directive (2005) which meant that all electrical equipment must meet the CE standard led to increases in sales as accessories were required to reach the standard (Mintel, January 2009). In January 2007 the WEEE directive came into effect and it requires businesses to collect, treat and recycle certain electrical products. There are a number of building regulations that are already in effect and which are relevant for wholesalers:

- Part B - Fire Safety, (fire alarms and detection).
- Part F - Ventilation, (electrical ventilation products).
- Part L - Conservation of fuel and power, (lighting and controls).
- Part M - Access/use of buildings, (socket outlets and height of switches).
- Part P - Electrical Safety.

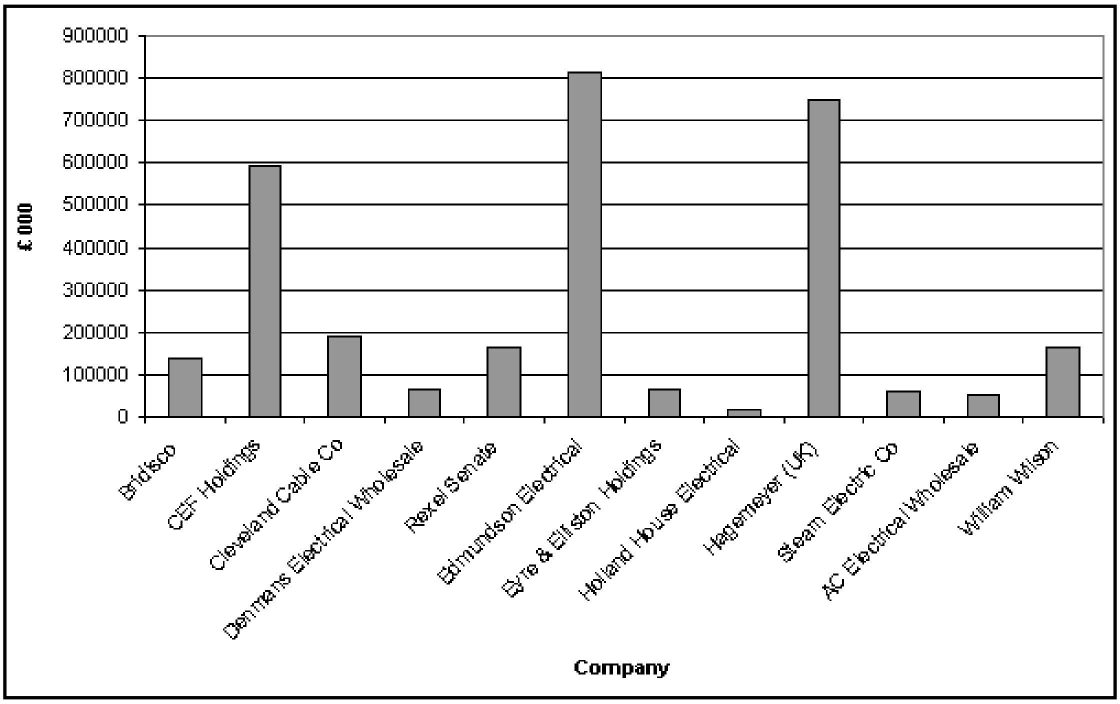
4.2.2 The competition

The wholesale industry acts an intermediary in the supply chain between UK manufactured and imported goods and the building trade (Mintel, January 2009). The main competitors to the wholesale industry are builders' merchants (Mintel, January 2009). The largest national house builders deal directly with electrical manufacturers and this represents some competition for the industry (Mintel, January 2009). The diverse range of products that electrical wholesalers sell put them in direct competition with industries such as DIY, plumbing merchants and electronic component distributors (Mintel, January 2009).

There is some competition between the wholesale and retail sectors. Companies such a B&Q which have added the warehouse and supercentre formats, and Screwfix are likely to take some business from smaller traders due to accessibility (Mintel, January 2009). In general commercial and domestic customers use wholesale and retail companies respectively. Screwfix have recently moved into the commercial sector by adding the companies Electricfix and Plumfix to their business in 2009.

There are many electrical wholesale companies and independents. Up to 2009 there has been a lot of consolidation and a small number of companies now have the majority market share. Wolsey has acquired AC Electrical, William Wilson and T&R Electrical Wholesalers and Rexel has acquired the Hagemeyer Group who had previously acquired WF Electrical. A selection of the largest companies is shown in Figure 4.3 (Mintel, January 2009). In 2007 the three largest wholesalers in respect to turnover were CEF Holdings, Edmundson Electrical and Hagemeyer (UK). These largest companies have a competitive advantage over the smaller companies because they can make use of economies of scale and an increased purchasing power which gives them discounts (Mintel, January 2009).

Figure 4.3: Electrical wholesale company turnover (2007)



4.2.3 The customers

The majority of customers for the electrical wholesale industry come from companies operating within the building trade. The customers range from a mix of large mechanical, building and electrical contractors to small independent electricians. A smaller proportion of the products sold are to retailers. There is a high degree of loyalty within the UK electrical wholesale market and this is based on delivery, product knowledge and credit payment facilities (Mintel, January 2009). The following have been identified by Mintel (January 2009) as the main factors of customer satisfaction:

- reliable delivery promises;
- quality of goods delivered;
- service and product advice;
- adaptability;

The cost of buying and the price of selling is an important dynamic in the wholesale market. The price of copper for example fluctuates significantly and this affects the price of many electrical products and especially the price of cable. There are standard prices within the industry, equivalent to the RRP price in retailing, for all products. These are subject to change if the wholesaler can negotiate a better price with the supplier when purchasing products. The difference between the industry price and the actual buying price is known as branch gained benefit (BGB). This allows the wholesaler to reduce the prices it can offer to its customer.

4.3 Case study company - Newey and Eyre

4.3.1 Company overview

Newey and Eyre is the UK's leading electrical wholesaler selling quality electrical supplies, safety equipment and other maintenance, repair and operations (MRO) products. Their customers range from large multinational blue chip companies to small independents. The business also provides a number of secondary services, available alongside the sale and distribution of electrical products:

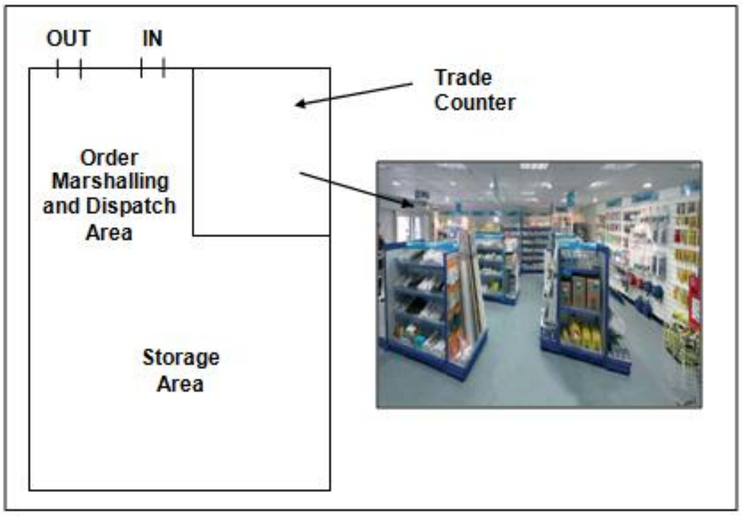
- Business solutions;
    - E–Business and Electronic Data Interchange.
    - Corporate Purchasing Cards.
    - Common Document Numbers.
    - Consolidated Invoices.
    - Customer Expediting Invoices.
    - Consignment Stock.
    - Project Management.
- Test instrument repair and calibration;
- Newlec heating design service;
- Crimping and cutting tool hire;

- Recycling services
    - WEEE[15] regulated Products and lamps.

Source: Newey & Eyre (May, 2009).

In January 2009 the company had 165 branches and a workforce of approximately 2,000 people located throughout the UK. A typical layout of branch is shown in Figure 4.4. The branch is divided into an area where products are stored and an area for customers to make purchases, known as the trade counter. The photograph in Figure 4.4 shows a typical trade counter section of a branch.

Figure 4.4: Typical branch layout

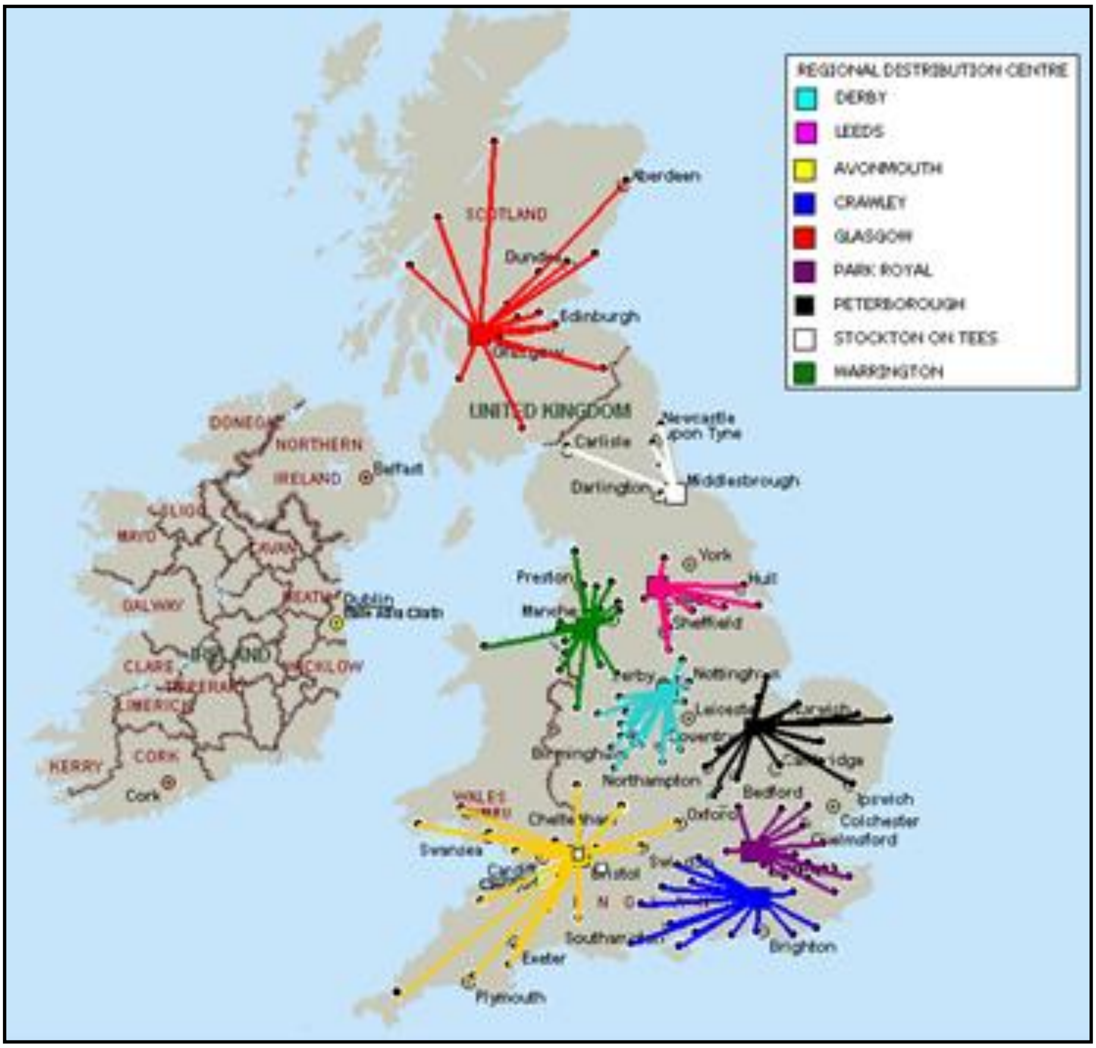


The branches are supported by 9 strategically located regional distribution centres (RDC's). The RDC's supply the branches with replenishment stock when levels fall to predetermined points. The replenishment process and the maintaining of stock are tasks which are undertaken within the purchasing and inventory offices. The Head office is based in Birmingham and contains administration, accounting, information and technology, marketing and

[15] The Waste Electrical and Electronic Equipment (WEEE) regulations came into force on 2nd January 2007 and implemented on 1st July 2007. The aim is to reduce the environmental impact by making producers responsible for the collection, treatment and recovery of end of life electrical and electronic waste (Newey and Eyre, http://www.neweysonline.co.uk).

product management departments. A map of the branches and the RDC's which support them is shown in Figure 4.5.

Figure 4.5: Regional distribution centres (RDC's)



4.3.2 Parent company – Rexel

Newey & Eyre was until March 2008 a division of Hagemeyer (UK) Ltd and part of the Hagemeyer Group and its parent company Hagemeyer N.V. Hagemeyer (UK) Ltd had three operating companies, Newey and Eyre, WF Electrical and Parker Merchanting. At the beginning of this research study (in September 2006) this was the shape of the business. The acquisition of WF Electrical in 2000 established Hagemeyer (UK) Ltd as the market leader. In

March 2008 the Hagemeyer group was acquired by the French based electrical distributor Rexel adding to their operating companies of Denman and Senate. Rexel is the leading worldwide distributor of electrical supplies, operating in 34 countries, with 33,000 employees and 2,600 branches (Rexel (UK) Limited, May 2009). In the last few months of the research study up to December 2008 this was the shape of the business. The Rexel Group (May 2009) list the following own branded products, sold by the separate companies within the Group:

- Newlec (Newey and Eyre);
- Alto (WF Electrical);
- Eski (Senate & Parker Merchanting);
- Defiance (Newey and Eyre, WF Electrical & Parker Merchanting);
- Sector (Senate);
- Basics (Denmans);
- Stratus Lighting (Senate);
- Designa (Denmans);
- Citadel (Senate);
- GigaMedia (Senate);
- New Classic (Denmans);
- Steeple (Denmans);

In June 2008 Rexel sold certain European Hagemeyer companies to Sonepar. Newey and Eyre is now currently an operating company of Rexel (UK) Limited, a division of Rexel. The companies Denmans, Senate, WF Electrical, Parker Merchanting and Newey and Eyre Industrial Solutions are also operating companies of Rexel (UK) Limited. The following descriptions of the various operating companies are provided by Rexel (UK) Limited (May, 2009):

Newey & Eyre is the UK's leading distributor of quality electrical products, providing off the shelf in-store purchasing of over 20,000 products.

Newey and Eyre Industrial Solutions has helped blue chip companies across the world to keep their businesses operating on target with a full range of maintenance, repair and operations products

Parker Merchanting is a leading UK distributor of construction consumables to the construction industry, with a product range covering the three key areas of Personal protective equipment, roadworks and site supplies.

WF Electrical is a leading distributor of electrical products with 76 branches throughout the UK. As a business, our stock answer is YES, and this means that we're committed to providing you with everything you need, whenever and wherever you need it.

Denmans offers a wide selection of own brand alternatives, across a diverse range of product groups at superb value for money. We are able to offer over 6000 stock lines direct to your door within 24 hours.

Senate distributes electrical products from leading manufacturers in all electrical areas including lighting, lamps, cables, wiring accessories, safety & security and ventilation.

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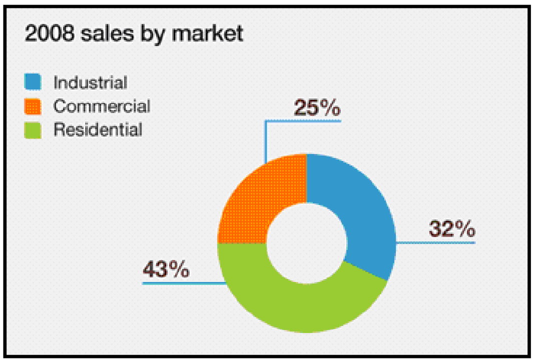
Rexel operate primarily in three key markets; industrial (32%), commercial (25%) and residential (43%) (see Figure 4.6) (Rexel Annual Report, 2008, p.3). These are located in over 34 countries and are supported by 2,400 branches and 33,000 employees. The majority of customer sales for Rexel (90%) are in Europe (58%) and North-America (32%). Asia Pacific and others make up the final 10% of sales. In 2008 Rexel had consolidated sales of

€13.735 billion and a gross profit of €3.262 billion (23.8% of sales) (Rexel Annual Report, 2008). A detailed income statement is shown in Appendix 1.

Figure 4.6: Rexel sales by market



The Rexel Group (May, 2009) provides the following descriptions of the markets they operate in:

The residential market: Comprises multi-unit and single-family homes which are being constantly improved to include better standards of comfort, security and automation. Customers are mostly electricians and SME contractors in charge of electrical installations and renovations in the residential sector.

The industrial market: Involves the integration, operation, and maintenance of electrical equipment in plants and other industrial sites. Customers are end-users, industrial companies, general and specialized contractors operating in the industrial sector.

The commercial market: Involves electrical parts and supplies required for the construction and renovation of stores, schools, offices, hotels, and public facilities. Customers in this sector are medium and large sized contractors.

4.3.3 The company's products

The products within the business are held within the regional distribution centres (RDC's) and branches. A branch has a trade counter from which customers can directly purchase stock. Some of the branches have a small warehouse attached which offer and hold a larger number of products. These are supplied by approximately 200 different manufacturers. There are a large and diverse range of over 20,000 different products which are held within the branch network and available over the counter to their customers.

A large range of different brands are available such as, MK Electric, Marshall Tufflex, Crabtree, Critchley, Osram, Smiths, Square D, Duracell, 3M, and Merlin Gerin. The company also have their own brands of Newlec and Defiance. This diversity requires different logistical methods to store, handle and distribute.

There are approximately 18,000 live products which are held at each RDC. A live product is a product which is continually reordered as and when stock levels reach a predetermined point. The remaining products are either to be sold down to zero or will become obsolete if they do not sell. Over 10,000 products from over 100 brands are available to purchase online from the company's website (http://www.neweysonline.co.uk). Online purchases can either be collected at the branch or delivered nationwide on a next day service if ordered by 8pm. The company has a catalogue which has over 3,500 own branded Newlec products. The extensive range of electrical products falls within the following categories:

- Luminaries;
- Lamps and lighting control gear;
- Cables and cable management;
- Wiring accessories;
- Industrial control and automation;
- Fuses;
- Circuit protection;
- Data networking;
- Fire and Security;

- Heating and ventilation;
- Hand tools and fixings;
- Power tools;
- Hazardous area;
- PPE and test equipment;

Any order which is placed by a customer at the branch and is available can be taken at the time of purchase. On occasions where a customer requires a product which is not held by the business a special order is placed. This is placed directly with the supplier and delivered at a later date to the branch for collection by the customer. It is also possible for customers to order a batch of products in advance, known as project orders. These products are grouped together and held in one storage location until such a time as they are required by the customer for delivery.

4.3.4 Purchasing and inventory

There are four of what are termed by the business as purchasing and inventory (P&I) offices in the UK (see Figure 4.7 and Figure 4.8). These are located in Leeds, Warrington, Avonmouth and Kirkcaldy. They control the purchasing and maintaining of inventory within 8 distinct regions. Their main responsibility is to replenish stock held at the RDC's and branches by placing orders with suppliers. The products are replenished at a point when the quantity held falls below a predetermined level, known as the reorder point (ROP). The workings of this system are explained in detail in Chapter 5. Purchase orders are raised by a number of different buyers who are responsible for different suppliers. There are occasions when products are out of stock at the branches and an order has to be raised with the supplier. These are known as customer back orders (CBO's). Purchase orders are placed with a supplier by either fax or by EDI.

Figure 4.7: Network map

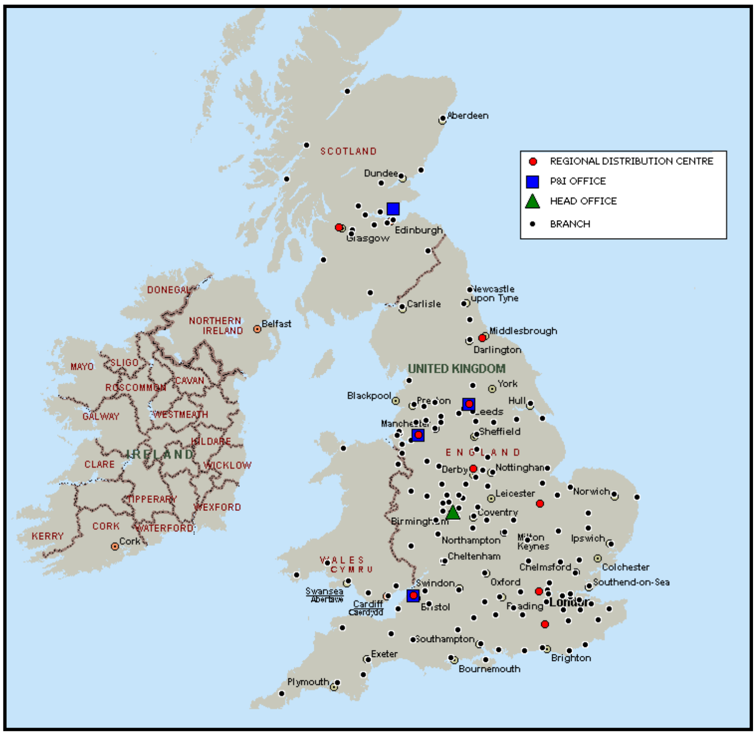


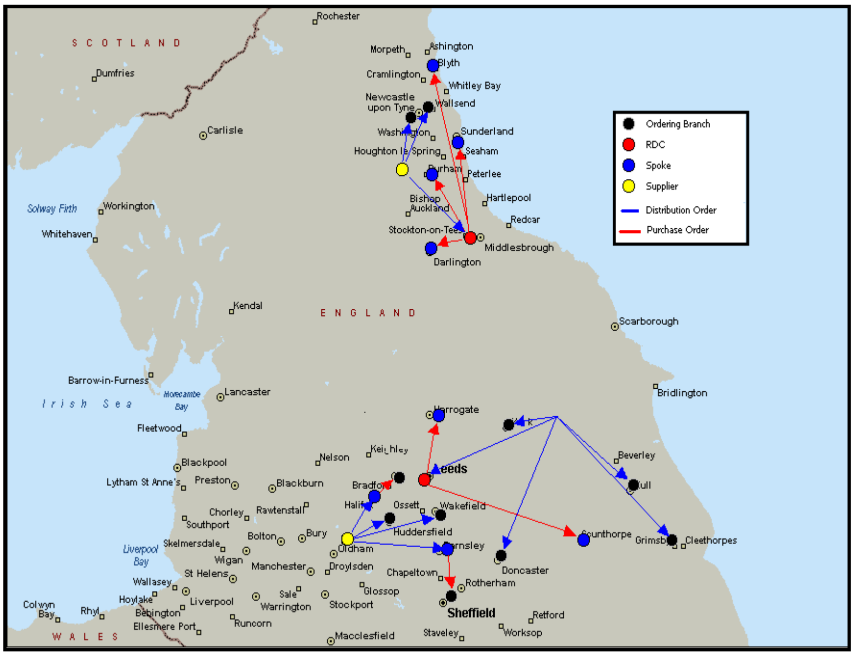
Figure 4.8: Purchasing and Inventory Offices

Purchasing and inventory office	Region	Supporting RDC
Kirkcaldy	Scotland	Glasgow
	Central London	Park Royal
Leeds	North East	Stockton / Leeds
	Midlands	Derby
	Anglia	Peterborough
Warrington	North West	Warrington
Avonmouth	South-West	Avonmouth
	South-East	Crawley

Replenishment stock is either supplied directly to the branch by the supplier or via an RDC. An example of supplier replenishment channels can be seen in Figure 4.9. The company defines two types of branch; an ordering and a spoke branch. An ordering branch orders the majority of its products directly from the supplier and conversely a spoke branch orders the majority of the products from the affiliated RDC. The spoke branches are supplied on a next day service from the RDC. Products which are ordered from suppliers have different delivery lead times. These can range from one day to a couple of months depending on the availability of the product at the supplier and the service they offer.

The inventory which is held is classified as either A, B or C by the business depending with it is fast, medium or slow moving stock respectively. The relationship between the suppliers, RDC's and branches, customer supply channels, inventory holding and service levels are shown in a representation of the supply chain in Figure 4.10. An ordering branch purchases the majority of their products directly from their suppliers. A spoke branch purchases the majority of their products directly from their allocated RDC.

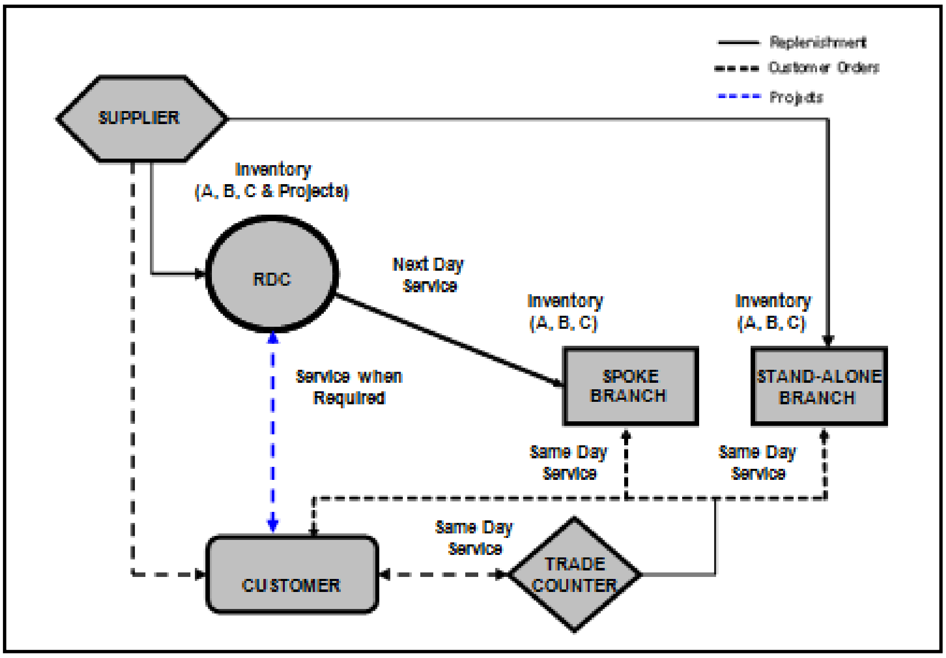
Figure 4.9: Supplier replenishment channels



Buying personnel within the offices are also responsible for purchasing new products and one-off customer orders that are not stocked within the network. These are referred to as special customer orders. The P&I managers at each office are responsible for the availability of products and the total costs held. To increase availability and reduce the costs they work to improve system based methods and processes within their offices. A number of reports are sent from head office on a daily basis which monitors the level of inventory held at the branches and RDC's. The offices are targeted and ranked on a monthly basis by a number of key performance indicators (KPI's):

1. A line availability (98%).
2. A line depth (92%).
3. ABC line availability (94%).
4. Stock Purchase orders (PO's) greater than 3 months.
5. Distribution orders (DOS's) greater than 10 Days.
6. Customer back orders (CBO's) greater than 10 Days.
7. Stock value (agreed % under current value).

Figure 4.10: Regional supply chain



4.3.5 Strategy

To increase market share both the Hagemeyer in 2000, and Rexel Group in 2008, have pursued a business strategy of acquisition and consolidation. The Rexel Group and its operating companies are now the largest distributors of electrical products worldwide. The company has grown organically after operational and commercial strategies had successfully produced an increased level of customer service. This was achieved by improving product availability, expanding brand selection and diversifying into new product markets. In the previous three years Rexel Group sales have more than doubled as a result (Rexel Group, May, 2009).

The key strategies in 2006 for the Hagemeyer Group (Hagemeyer Annual Report, 2006) are as follows:

- to accelerate our growth in the industrial segment;
- to increase the share of small and medium-sized accounts in our business;
- to increase value-added for customers and suppliers;
- to focus on strategic suppliers;
- to increase the penetration of our own brands.

The Rexel Group's philosophy is to create a business model which is "flexible and reactive" (Rexel Group, May, 2009) – a supply chain agility strategy. Rexel believe that the diversity of the market can be served by a supply chain that is "multi-channel, multi-banner and multi-service" (Rexel Group, May, 2009). They also seek to create partnerships with their top-tier manufacturers. There is a focus on both developing value within the supply chain and generated sustainable long term profits. This is signalled in their statement of their main business goal:

> "The goal is to improve operational profitability of data and product flows, propose the widest possible offer at the best value for money, and work with strategic manufacturers to seize new market segments, customers and projects"(Rexel Group, May, 2009).

More than ever, building on its recently enhanced market leadership, Rexel is committed to protecting its margins and continuing to generate strong operating cash flow. Management is confident that Rexel will emerge stronger from the current economic downturn.

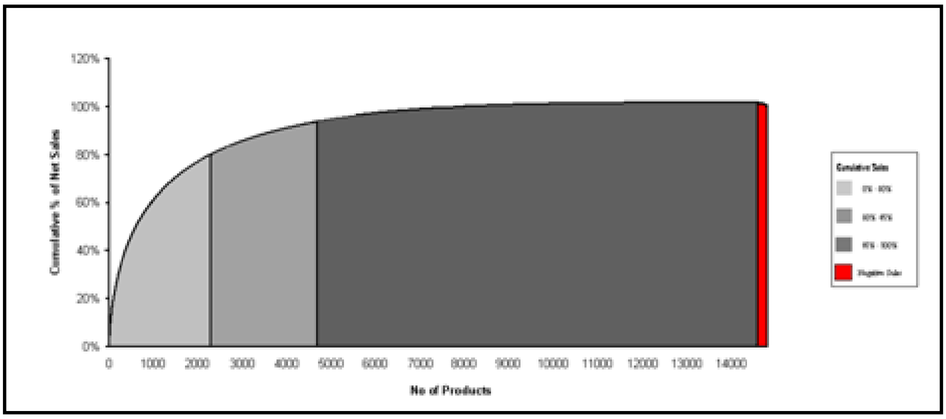
4.3.6 Business performance

An initial review was conducted to establish the reality of the state of business, provide some analytical validity to the general assumption that operational mismanagement has reduced the contribution of profit of products and customers and to highlight the issues. The initial analysis is not designed to be exhaustive but to provide general indications in a reasonable timeframe. A detailed analytical study is conducted after the direction of the research programme is formed. The analysis is formed from product and customer transactions at Warrington RDC from the period of June 2006 to September 2006. The RDC at Warrington stores 14,815 individual products at the end of September 2006. The analysis reviews the company's sales turnover and contribution of profit for each product and customer and the level of stock turnover. The methods used are explained in Chapter 5.

4.3.6.1 Product and customer sales turnover

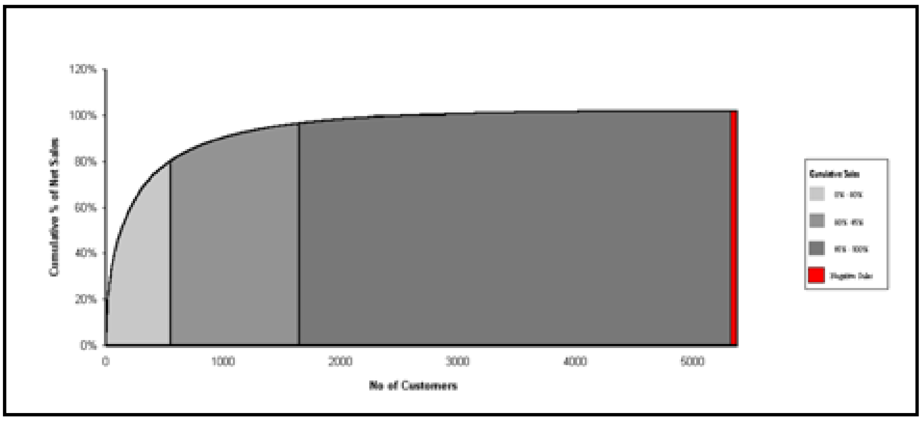
The total cumulative product sales value for the period is represented in Figure 4.11. A cumulative sales graph is normally expected to follow the Pareto principle, where 20% of products represent 80% of sales value. In this case less than 10% of products accounted for 80% of the total sales value. This gives the indication that the sales revenue for the business is being generated from a relatively small number of products. Conversely, small sales revenues are being generated from a large number of products. The results show that 8,256 of the products are generating only 10% of the sales revenue for RDC. Furthermore, 2,228 products in this period are recorded to have no sales. A small proportion of 339 products have negative sales because more products are returned than were sold to customers.

Figure 4.11: Total cumulative percentage of product sales



The total cumulative customer sales value for the period is represented in Figure 4.12. A total of 5,277 customers made a least one purchase in the period. A similar pattern to what was previously shown in Figure 4.11 is displayed in this graph. A small number of customers represent a large quantity of the sales revenue. The results showed that less than 10% of customers represent 80% of the total sales revenue. Moreover, as little as 29 customers represent 25% of the total sales revenue. In contrast over 4,000 customers contribute to as little as 10% of the total sales revenue. In summary a small number of customers purchase a large number of products and a large number of customers purchase a small number of products. The analysis has highlighted that a small number of customers are significant to the success of that particular RDC in terms of generating sales revenue.

Figure 4.12: Total cumulative percentage of customer sales



A summary of the total cumulative sales value for all products and customers by a number of selected percentiles is shown in Figure 4.13.

Figure 4.13: Sales profile by value

Sales Value	Number of Products	Number of Customers
10%	30	7
20%	100	20
30%	205	40
40%	370	75
50%	600	130
60%	950	215
70%	1,450	335
80%	2,250	550
90%	3,750	980
100%	15,000	5,375

4.3.6.2 Product and customer contribution to profit

The contribution to profit for each individual product and customer are calculated by removing the logistics costs of storage, handling and transport from their margins. The total cumulative profit of products is shown in Figure 4.14. The graph is split into two distinct shaded areas, profit and non-profit products. The results show that more products are making a loss (5,487 products) then are making a profit (9,328 products). This is a significant issue for the business. Furthermore, only 78 of the 14,815 products have contributed to 25% of the total profit value and approximately 1,500 products contributed to 80% of the total profit. It was clear on this evidence that there is a potential problem with the way products are being managed logistically or with the way products were being priced. The pricing structure for some of these unprofitable products was reviewed by personnel within the commercial department of the business. It was concluded that the prices for these products were set to the correct level and were representative of the market value.

The total cumulative contribution of profit of customers is shown in Figure 4.15. The analysis of customer profitability indicates a similar trend to that is shown in the analysis of product profitability. In this case more than 50% of the customers are shown to be profitable over the period. There are as few as 42 customers who have contributed to 25% of the total profit and approximately 1,000 customers have accounted for 80% of the total profit, roughly 20% of the total customers. This follows closely to what would be expected by the Pareto principle. The number of customers which are unprofitable, approximately 1,800, is a significant issue for the business. To serve these customers it is costing more in logistics costs than it is receiving in sales revenue.

There are a number of different methods which can be used to determine how to deal with unprofitable customers. There may well be a commercial decision that some of these customers should be served. It may also be possible to turn these into profitable customers. It is the view of Mittal *et al* (April, 2008) that a number of steps should be initially followed and as a final step, the customer should be terminated.

1. reassess the relationship;
2. educate the customers;
3. renegotiate the value proposition;
4. migrate the customers;
5. terminate the relationship.

It is also possible that by using supply chain management methods customers can be made profitable. This can be achieved through a combination of reducing logistics costs and increasing turnover. Supply channels which are serving particular markets need to be evaluated to determine where operational costs should be reduced and where responsive and service should be improved. This is one of the key elements of a supply chain segmentation strategy.

Figure 4.14: Total cumulative contribution to profit (£'s) of products

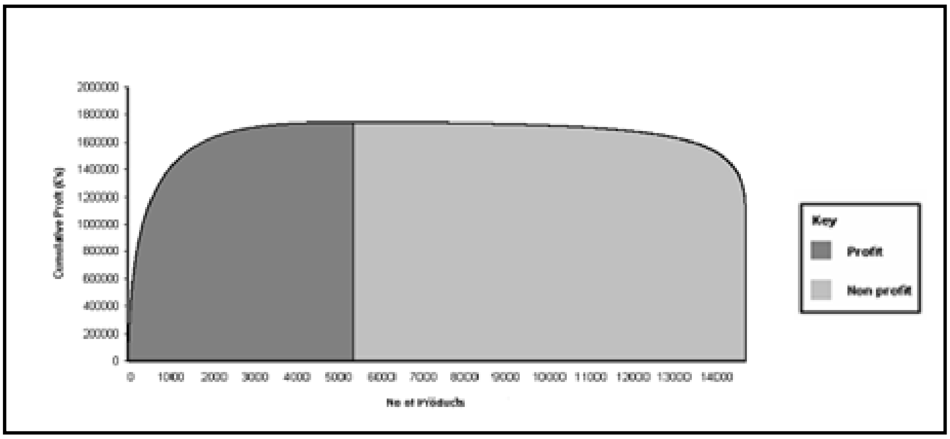
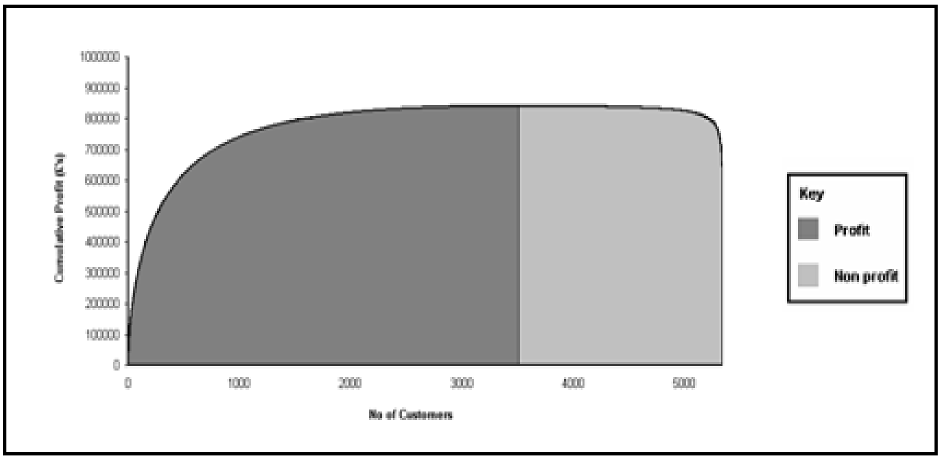


Figure 4.15: Total cumulative contribution to profit (£'s) of customers



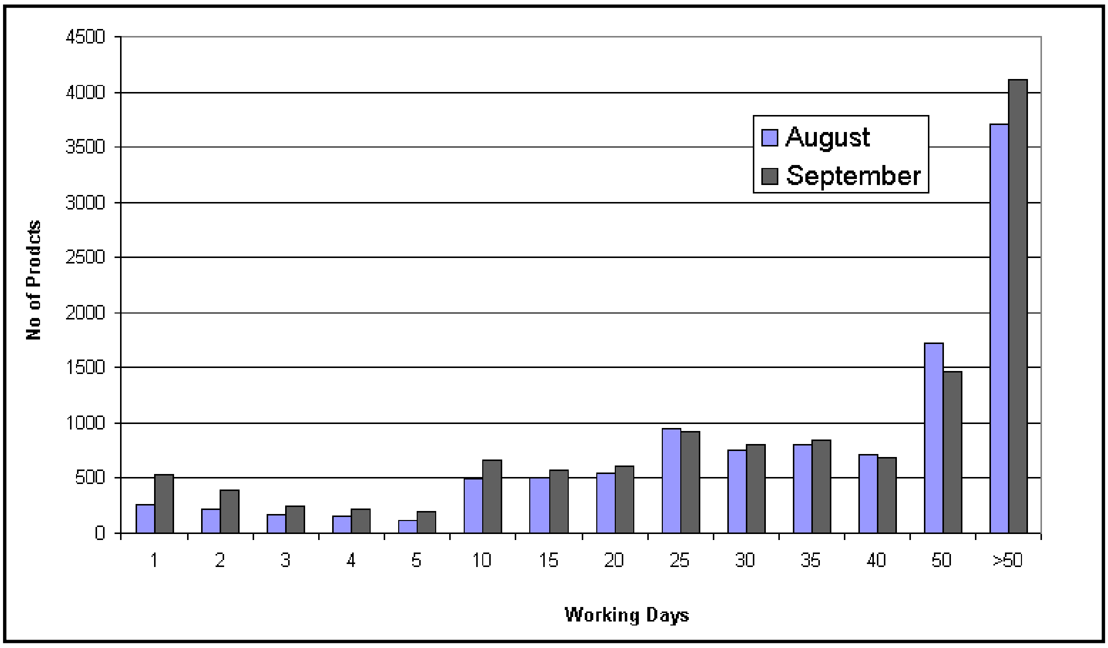
4.3.6.3 Stock turnover

Stock turnover is a measure of how well a company "converts stocks into revenues" (http://moneyterms.co.uk/stock_to/, August 2007). It shows how efficiently the company is turning its working capital into revenues. A high stock turnover period can be a consequence of lower than expected sales revenues or an inefficient management of inventory. Conversely low stock turnover periods are generally viewed as favourable but if they are not managed correctly can result in lost sales if products are unavailable. A company has to find a balance which maximises profits whilst keeping inventory as low as possible.

The stock turnover period for August and September at Warrington RDC is shown in Figure 4.16. The company aims for an average turnover period of between 14 and 21 days. The periods of turnover will be different for different types of products because they have different sales patterns. The products which have higher sales revenues are likely to have a lower stock turnover period to those that have lower sales revenues.

The analysis shows that there is an average turnover period of 6 weeks for all products. The majority, approximately 4,000 products in both months has a greater than 50 days turnover rates. There are also many products which have a high turnover rate of less than five days which suggest there is an issue with stock-outs. The conclusion of the analysis of stock turnover shows that the high average turnover and extremes of low and high indicate that the business is not managing the inventory effectively.

Figure 4.16: Stock turnover period



4.3.6.4 Summary of results

The analysis of the business has shown that:

- a large proportion of product sales value and profit were represented by a small proportion of products;

- a large proportion of customer sales value and profit were represented by a small proportion of customers;

- a large number of products and customers had a negative gross margin;

- a large number of products and customers were unprofitable;

- a large number of customers were receiving a small number of lines and a small monthly delivery frequency;

- a low level stock turnover period.

The business issues that are highlighted prior to the start of the project by managers, whose opinions were formed from operational experiences, observations and performance indicators, are substantiated according to the results of the analysis. The large number of unprofitable products and customers is a significant issue and is a challenge for the business to resolve.

The depth and range of categories and products is ever-expanding, by a combination of strategic choice; accessing of new markets; meeting the perceived needs of the customer; an attempt to exceed competitor service levels, and as a result of operational design and process. In part this expansion is borne out of a desire and need to grow and increase market share. It also comes about as a result of inadequate operational procedures and processes.

The business has grown unsustainably because priorities have been placed on customer service levels and have failed to balance this with an efficient and well maintained operation. This is indicated by the large proportion of products which have both low and high levels of stock turnover at Warrington RDC. This has created the following logistical issues:

- high storage costs;
- low rate of productivity;
- high level of obsolescence;
- low liquidity;
- high rate of stock-outs.

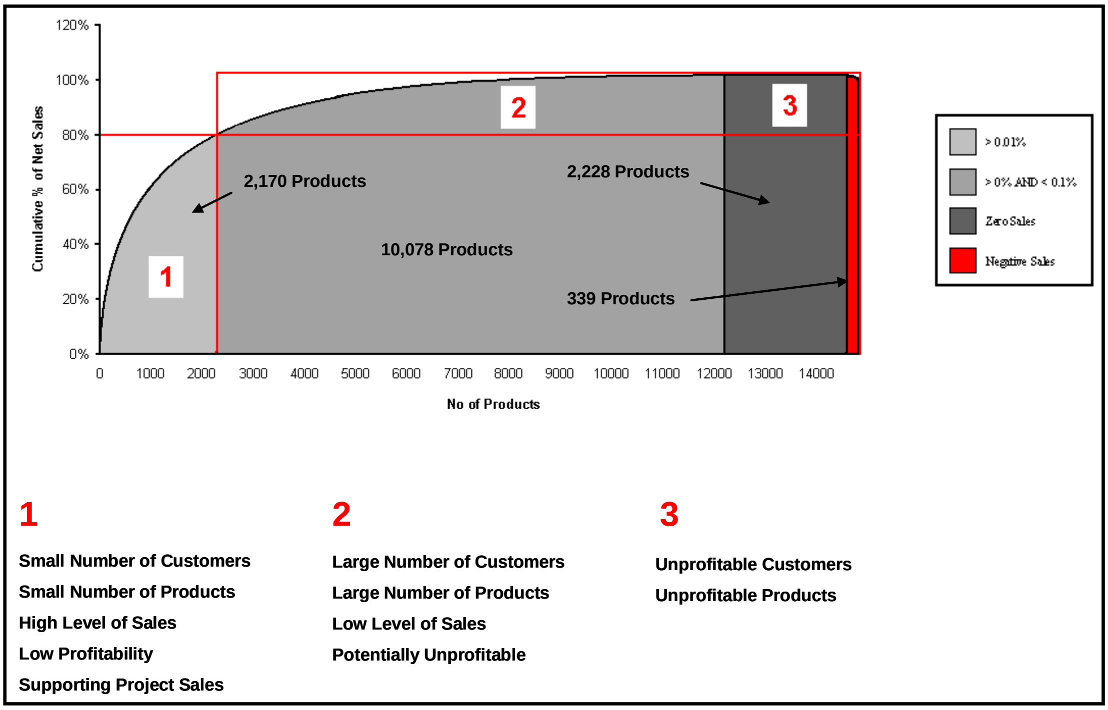
The slowdown in the world economy has changed the dynamics of the electrical market. It is anticipated that declines in volumes and reductions in the price of copper will result in a decrease of sales in 2009 (Rexel Annual Report, 2008). Issues in liquidity and product margins being pressurised have emerged as a result. In the pursuit to increase the market share and customer service levels the supply chain operation has been mismanaged and has lacked a strategic focus. The major decision makers have had to rethink their strategies in a reaction to the downturn. Mark Fiddy the Commercial Director of Newey and Eyre released the following statement in response:

> "Managing cash flow has always been a critical skill for any business. In the current economic climate, it is vital that any business has full control of its working capital. Reducing workloads, pressure on lending and customers often looking to delay payments can cripple cash flow and rattle nerves" (Mark Fiddy, Commercial Director,
> Newey & Eyre, June 2009).

4.4 Pilot project

The results of the data analysis were reported back to the directors of Newey and Eyre in a presentation in October 2007. The results showed that the businesses products could be categorised as one of three types (see Figure 4.17). The large number of slow moving products is a significant issue and is rendering many products unprofitable. The RDC's had become over congested with too many products and the stock turnover analysis indicated that the quantities of stock held were too high.

Figure 4.17: Distinct business segments



It was decided that a pilot project was to be undertaken within the South West region of the business. It was necessary to undertake a pilot project because of the business significance and operational disturbance a more detailed study would create. The success of the project could then be evaluated before it is to be implemented within the rest of the supply chain and hence reduce risk.

The aim of the research project was to reduce the supply chain issues which have been highlighted. The South West region of the supply chain was selected as an appropriate location. This is because the management personnel; who would be required to become significant stake holders in the context of the project, and the workforce on which the operational changes would impact upon, would be cooperative and open to change. This is contrast to the other regions where this is less likely to be so.

CHAPTER 5

5 RESEARCH DESIGN AND RESEARCH METHODOLOGY

5.1 Chapter introduction

This chapter shows all the research design and methodology which were applied within the case study. The type of research strategy used and the case study model is illustrated. The data qualitative and quantitative collection methods are shown. This includes an explanation of why such research methods were used such as the interviewing of employees and the processes involved. The methodology which includes the statistical approaches, theoretical equations and procedures and observations undertaken are explained. The assumptions and issues which were made are shown.

The concept of a supply chain segmentation strategy is laid out within this chapter and illustrated by a conceptual model. A generic methodological framework is shown. The validity of this framework is tested as part of the research programme and the findings are shown within the case study chapter. The research is undertaken to test the hypothesis and to complete the research aims, which are laid out in Chapter 1. The methodology which is shown within this chapter facilitates this. In this context the methodology is designed to test a number of the approaches of segmentation previously set out in within the literature chapters. Furthermore, it is designed to test new approaches of segmentation. It is shown in Figure 5.1 how the research aims, literature and case study are linked.

Figure 5.1: Structure of methodology

Research aim	**Key literature**	**Case study**
Provide a methodological framework building on the research of Fuller *et al* (1993) which incorporates a supply chain segmentation approach bringing together established supply chain management techniques;	▪ Fuller (1993) – Basic methodological outline.	▪ Research project 1-3: A framework is designed, laid out and tested out within each of the case study projects.
Show that a segmentation strategy can be applied throughout the business to all planning levels;	▪ Lovell *et al* (2005) – Discussed this as a principle but the emphasis of the case study was strategically based on the redesigning of the supply chain.	▪ Research projects 1-3: The three research projects represent the different tiers within the business hierarchy, strategic, tactical and operational.
Test Smith and Slater (2001) variability index which is used to categorise products into six segments and to determine if the variability of lead times is a significant factor.	▪ Smith and Slater (2001) – Propose that volume and variability of demand can be used to segment products into six categories.	▪ Research project 3 – Variability index, coefficient of variance, and correlation coefficient equations are tested to see if these measures of variability can be used to determine forecasting parameters. ▪ Research project 3 - Analysis is undertaken to test whether the volume and variability can be applied in practice to select appropriate inventory strategies which will reduce costs and increase customer service levels. A lead time variability factor is tested to see if it improves a selection of KPIs.

Research aim	Key literature	Case study
Test which characteristics products and customers can be segmented by and how these relate to different levels and size of a business.	▪ Fisher (1997) – Segmented products as being either functional or innovative using demand volume or variability and applied to the design of the supply chain. ▪ Lovell *et al* (2005) – Provide a list of possible factors to use in the segmentation process. The factors of throughput demand variability and product value density (PVD) are used to segment products and are used to redesign the supply chain. ▪ Christopher and Towill (2002); Lee (2002); Lovell *et al* (2005); Mason-Jones et al (2000), Naylor *et al* (1999); Payne and Peters (2004) – Application of segmentation/leagile designs to large global supply chain structures.	▪ Research project 1-3: A separate list of characteristics for products and customers are drawn up and applied in the segmentation process for each of the case study projects. ▪ Research project 1: To show how a segmentation strategy can be applied to a localised supply chain structure.
Investigate how customers can be included in the segmentation process.	▪ Sabath and Whipple (2004) – Segment both customers and products into what is described as an action matrix using activity based costing.	▪ Research project 1: Customers are segmented and supply chain routes and delivery service levels are assigned to each segment.
Investigate which factors can be used to create segments of products and how they relate to the different planning levels.	▪ Lovell *et al* (2005) – Lists a number of possible factors.	▪ Research project 1-3: Different factors are tested for each of the research projects.
Show the practical and financial benefits of the application of a supply chain segmentation strategy.	• Lovell *et al* (2005) – The benefits of a case study at Sony where a segmentation strategy is applied and the supply chain is redesigned.	• Research projects 1-3: The overall benefits from a segmentation strategy which is applied throughout the business planning levels. • Research project 1-2: Financial benefits from the implementation achieved from operational savings, stock reduction and increases in productivity. • Research project 3: A segmentation strategy is compared against the actual model to see the effect on a selection of KPIs

5.2 Research strategy

A case study design is relevant due in most part to the complexity of the situation. The vast number of variables and the dynamic nature of the situation mean the phenomenon cannot readily be quantified and an intuitive approach isn't viable. Eisenhardt (1989) defines a case study research strategy as one that "focuses on understanding the dynamics present within single settings". Prevailing factors in this case can only be surmised in the theoretical sense and are much better represented by the use of a real industry case. The unique strength of a case study is its ability to "deal with a full variety of evidence – documents, artefacts, interviews and observations" (Yin, 2003, p.8). The limitations of different methods are outlined in Chapter 1. An empirical case study as defined by Yin (2003, p.13) is therefore one that:

- investigates a contemporary phenomenon within its real-life context, especially when

- the boundaries between phenomenon and context are not clearly evident.

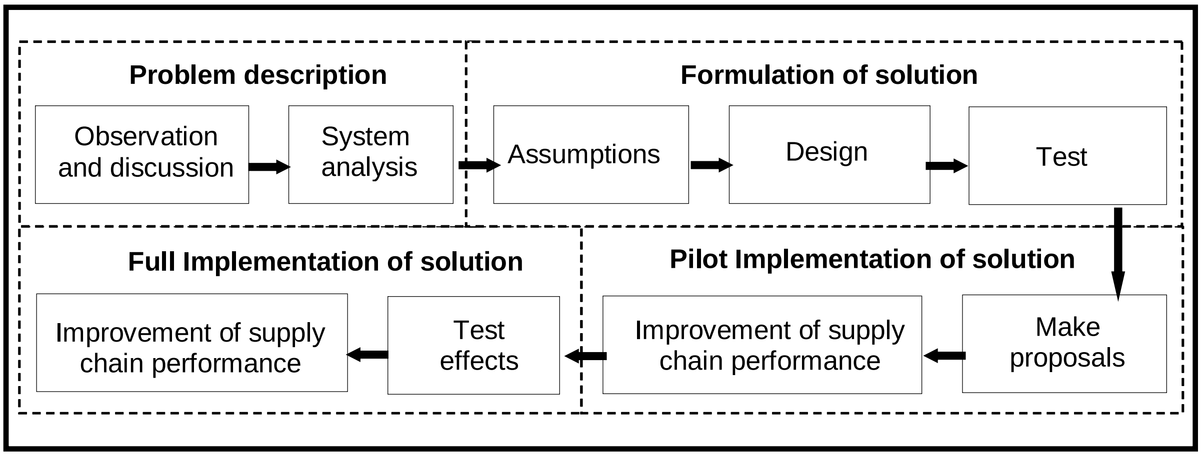
It is often shown that successful cases require the use of multiple cases (Yin, 2003). This can be a misconception as there are examples of successful single cases (Flyvberg, 2004). For this research study a number of research projects are carried out within the single case company.

5.3 Case study design

Every case study is different in its nature and there isn't a comprehensive method that can be applied in all cases. Robert K. Yin, who is well known for his series of books on case study research that are commonly adopted by researchers, does however provide what he describes as "a void in social science methodology". Chapters within Yin (2003) include design, data collection, preparation, collecting the evidence, analysing the evidence and reporting, all provide a useful framework.

The case study model (see Figure 5.2) was designed using the foundations laid out by Yin (2003). The structure follows a systematic approach which is organised into four main areas, the problem description, formulation of the solution, implementation of the pilot and the full implementation to the wider business. The process begins with observations and discussions which are translated into the description of the problem. The process follows through to the conclusion where it is expected there will be improvements in supply chain performance.

Figure 5.2: Case study model



Research design is critical to the success of any case study. The design process facilitates the aims, ensuring that relevant data is collected to draw conclusions based upon the study questions. Eisenhardt (1989) provides a summary of the process framework (see Appendix 2). Yin (2003, p.21) breaks the components of research design into five areas:

1. a study's questions;
2. its propositions, if any;
3. its units(s) of analysis;
4. the logic linking the data to the propositions; and
5. the criteria for interpreting the findings.

The research questions are designed to both focus and answer specific problems. These are either posed by the business or are formed after some analysis has taken place. They are developed to fulfil the propositions of the research study. The propositions are outlined in the research aims and more specifically the research objectives which are outlined in Chapter 1. The answers to the research questions can be found within the data analysis sections of this thesis.

1. Initial business review:

The initial review of the business is designed to show the current state of the business. This gives an indication of the issues and where are the potential solutions. The questions which were set are as follows:

(a) What products do we sell?

(b) Who do we sell these products to?

(c) What are the dynamics of each delivery?

(d) How profitable is each product?

(e) How profitable is each customer?

2. South West region case study:

The South West case study was designed in response to the issues which were highlighted in the initial business review. It was decided that design changes would be made to the supply chain and the RDC at Avonmouth. The questions which were posed reflect this and were set to determine further some of the issues highlighted, such as which products are obsolete. The questions which were set are as follows:

(a) How many distribution centres are required?

(b) Which products are obsolete?

(c) What storage media type is best fitted for each product?

(d) What is the preferred location for each product?

3. **Purchasing and inventory case study**

The purchasing and inventory case study was designed in response to the issues which were highlighted in the implementation of the first case study and could not be solved. It was found that there were many products which were obsolete and the quantities held were far in excess of what the company deemed a satisfactory level. The questions which were set are designed to find a better method for managing the purchasing and inventory system. The questions which were set are as follows:

(a) What customer service level is required for each product?

(b) What is the reorder point level for each product?

(c) Which forecasting method should be applied to each product?

The units of analysis are the sources of information used to fulfil the research questions. The level of stock holding for individual products is the major unit of analysis. The research study is focused around this measure and is key to proving the hypothesis. There are secondary units of analysis which include a number of selected variables and gathered documentation.

It is possible to substitute a measurement of profit for stock holding. This is not used because of the difficulty of surmising the effect on the level of contribution to profit for individual products. A sufficient level of detail is not available so many assumptions would have to be made. This would reduce the validity of the outcome. It can be inferred that a positive outcome based upon the measurements used will lead to an increase in contribution to profit.

The methodology which is outlined in this chapter and Chapter 5 are applied to link the data to the propositions. The models which are designed use data from different parts of the supply chain to show that the statistical results are repeated. These are compared to the actual statistics to test whether the results are credible. The findings of the case study are shown in Chapters 6. Yin (2003, p.34) shows that four tests can be applied to establish the quality of the findings:

- construct validity: establishing correct operational measures for the concepts being studied;

- internal validity: (for explanatory or causal studies only, and not for descriptive or exploratory studies): establishing a casual relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships;

- external validity: establishing the domain to which a study's findings can be generalized;

- reliability: demonstrating that the operations of a study – such as the data collection procedures - can be repeated, with the same results.

5.4 Ethics

An important element of the research study is the consideration of ethics. The information is sensitive and many employees are directly affected by the changes to the business. It is important to make sure that both the research methodology and the outcome of the investigation does not breach any ethical boundaries. This "involves not only deceiving or doing harm, but being true to the process" Coghlan and Brannick (2001). A list of ethical issues by Coghlan and Brannick (2001, p.73) that are considered throughout the process is:

- negotiating access with authorities and participants;
- promising and ensuring confidentiality of information, identity and data;
- ensuring participants the right not to participate in the research;
- keeping relevant others informed;
- getting permission to use documentation which was produced for other institutional purposes;
- maintaining your own intellectual property rights;
- keeping good faith by showing you are someone who can be trusted and always checking with others for any misunderstanding;
- negotiating with those concerned how you will publish descriptions of their work and points of view;

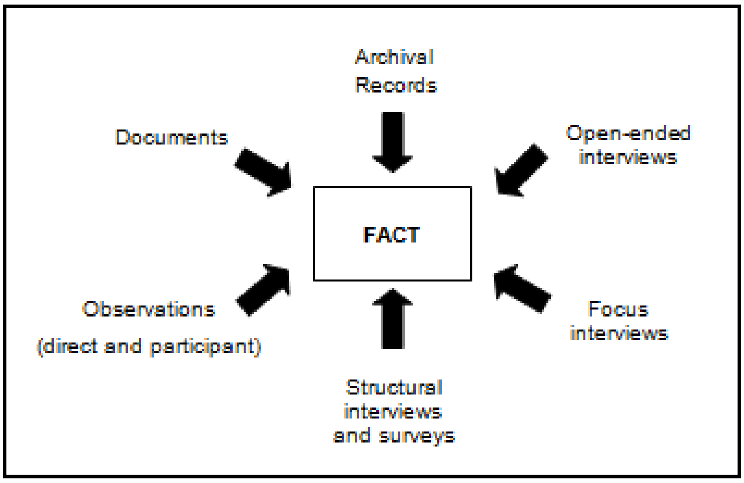
The scope of research programme covered aspects of a strategic nature. It is necessary therefore to ensure confidentiality and prohibit access only to a small number of critical stakeholders at the beginning of the research project to avoid employee anxiety and prevent leakage to competitors. As the research project evolved it was necessary to involve a larger number of employees and departments to avoid bias and to provide an in-depth knowledge of the business and resource for implementation. Permission was requested at each stage of the research project and the relevant employees were informed by their line managers of the project objectives.

5.5 Data collection

5.5.1 Data selection and retrieval

The triangulation of data is important to remove any bias (Yin, 2003). Multiple case studies and sources of evidence are a major strength of case studies. The convergence of data within a single study is an important stage in validating any conclusions. Yin (2003, p.100) categorises six major sources of evidence (see Figure 5.3).

Figure 5.3: Convergence of evidence (Single study)



The quantitative data which is used in the analysis sections of this thesis is taken from the business management software called Movex[16]. Movex is an application which is developed and sold by the company Intentia and is used by Newey and Eyre to manage their inventory and handle customer transactions. It has been in use within the company since 2002. The areas of analysis where the data was used and when it was downloaded are listed below:

1. Initial business review – September 2006.

[16] The structure of the data was constructed and downloaded from the management system by Tony Elkin. Tony Elkin is the company's project manager.

2. Detailed analysis South West region – February 2007.

3. Stock analysis – June 2008.

4. Simulation modelling – July 2008.

The database stores up-to-date and archival business information relating to products, customers and suppliers. Movex also performs a number of vital business functions such as sales order processing, purchasing, and forecasting and inventory management. It is designed to use multiple warehouse environments. The information which is stored can be accessed and exported as data text files. Movex is a relational database which means data can be grouped together using common attributes from the different data sets. Requests for information are sent to Movex specialists who design and run queries and retrieve the relevant data. The raw data is imported into either Microsoft Access or Excel where it is cleansed, manipulated and then analysed.

The initial analysis uses data taken from the Warrington RDC. Financial statistics and KPI's indicated that the Warrington RDC was the best performing of the RDC's. This was the best case scenario for the initial analysis and removed any concerns that the statistics represented a poor performing RDC and were not representative of the wider business. The first case study is based upon data taken from the South West region of the business. The final case study uses data taken from four different regions. The data selection and retrieval for this case study is outlined in Chapter 6.

The analysis which was undertaken at Warrington RDC and the South West region requires three data set files; historical sales transactions, costs and current product information. The structure of these files is shown in Figure 5.4. A period of data from June 2006 to September 2006 is used for Warrington RDC. Although this is not a sufficient time period to suggest any long term trends it is adequate to highlight some general issues and further areas for analysis. A period of data from January 2006 to December 2006 is used for the South West region.

Figure 5.4: Requested data file structure

File	Field	Type
Transactions	Product Number	String
	Product Name	String
	Customer Number	String
	Customer Name	String
	Cost Price	Number
	Selling Price	Number
	Delivery Code	Number
	Customer Sales	Number
	Customer Returns	Number
	Distribution In	Number
	Distribution Out	Number
Product information	Product Number	String
	Product Name	String
	Cube	Number
	Balance on Hand	Number
	Annual Demand	Number
Costs	Storage	Number
	Handling	Number
	Distribution	Number

5.5.2 Data assumptions and issues

When models are constructed it is necessary to make a number of data assumptions. Singer and Willet (2003) show that "assumptions allow you to move forward, estimate parameters, interpret results, and test hypotheses". The plausibility of the conclusions lies upon these assumptions. In some cases it is feasible to reduce the time taken to manipulate and analyse data by substituting averages for actual data in cases where a sufficient degree of accuracy can be obtained and wouldn't mitigate or skew the results. Data assumptions are also made in the place of missing, unattainable or inaccurate information. The assumptions which were made are listed below:

1. Number of working days = 260 per annum.

2. Unit selling price stored on Movex doesn't represent the actual selling price so an average was taken from actual customer invoices. The average is taken from all of transactions within the time period and scope which was used.

3. Unit cost price stored on Movex doesn't represent the actual buying price so an average was taken from actual purchasing invoices.

4. 50,000 out of 615,000 live products have volumetric data. Missing data were given an average = 125,000mm^3 per unit.

5. Unit of storage isn't always the unit of selling. Cable for example can be sold in multiples of 100 metre reels. Order multiples were multiplied to given a representative cube.

6. The size of an individual product determines the cost of storage.

7. The volume of lines sold determines the cost of throughput and transport.

8. A Working week consists of 5 days for the transport and throughput costs and 7 working days were used the storage cost.

9. Customer transport costs = 75%, Distribution transport costs = 25% (of total month transport costs attributed to Avonmouth RDC).

10. Interest charge = 7% per annum.

11. Storage interest costs are incrementally incurred on the length of time held in stock.

The issues which were discovered are listed below:

1. Volumetric data missing.

2. Unit of measure not defined.

3. No account of bulk goods buying (BGB) in cost price.

4. Returns not always processed as returns.

5. Can't differentiate project stock from consumer stock.

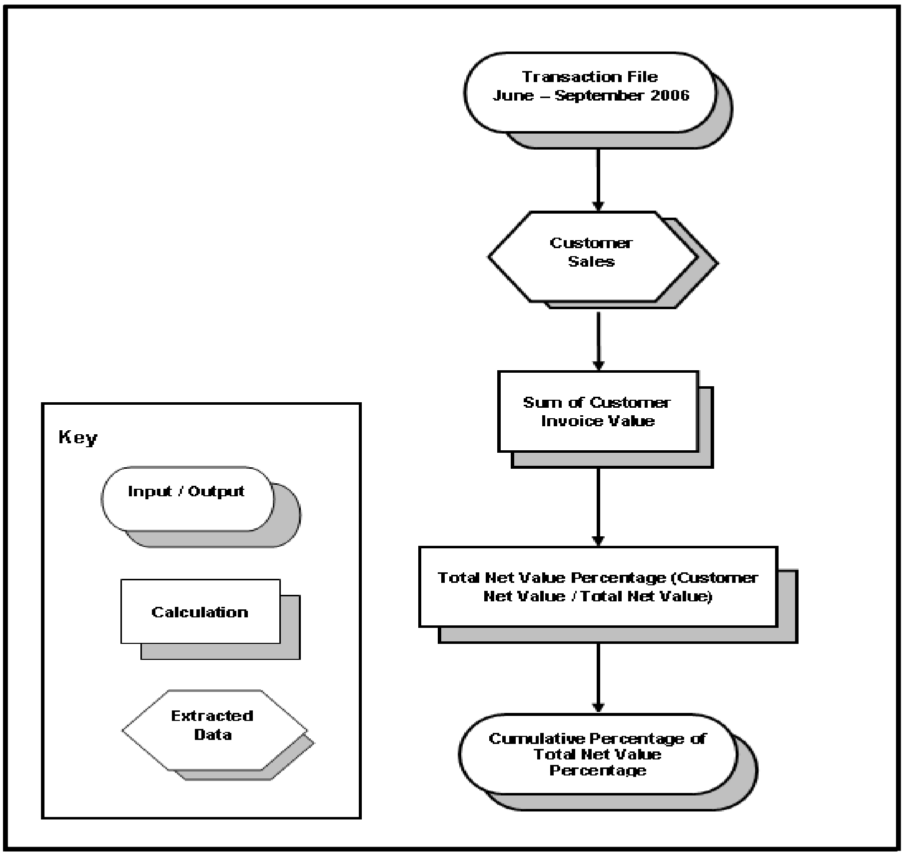
5.6 Data models and calculations

5.6.1 Product and customer sales cumulative sales

The data model structures for the calculations of total cumulative product and customer sales value are represented by the flow charts in Figure 5.5 and Figure 5.6. The unit selling cost stored on Movex isn't accurate so the actual customer sold price is used from customer invoices to act as an average selling price. The equation which represents the total sales value is shown in Equation 5.1.

Figure 5.5: Flow chart of total cumulative percentage of product sales

Figure 5.6: Flow chart of total cumulative percentage of customer sales



Equation 5.1: Total sales value

Equation(s)

Total sales value = (CO + DO – RT) x SP

Notation(s)

CO = Customer orders

DO = Distribution orders

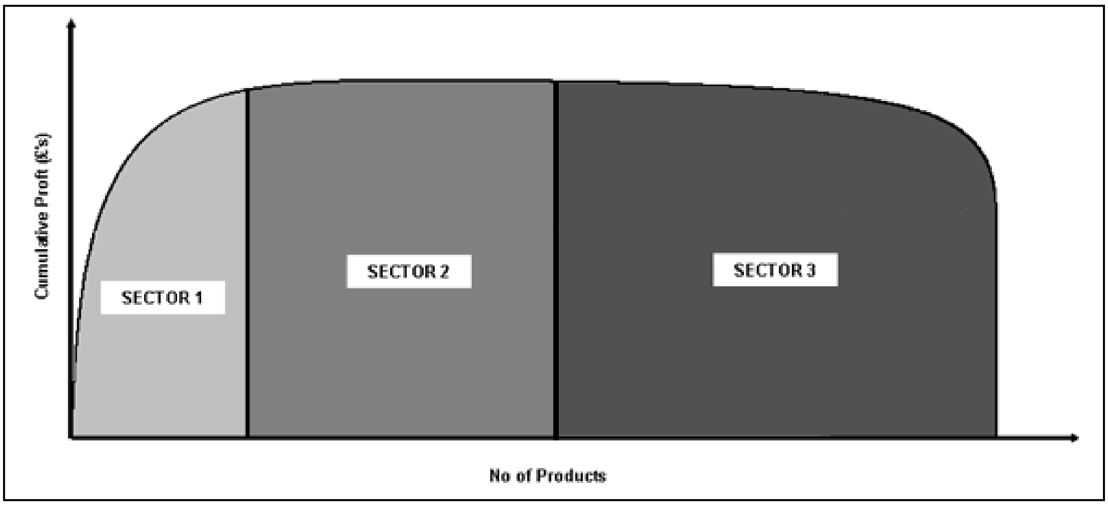
RT = Returns

SP = Selling Price

5.6.2 Product and customer contribution to profit

The data model structures for the calculations of total cumulative product and customer contribution to profit are represented by the flow charts in Figure 5.8 and Figure 5.9. The transaction data is exported from Movex. A Direct Product Profitability (DPP) method is used to allocate the costs (Smith and Slater, 2001). The resulting analysis is usually characterised by a 'Hook curve' (Slater and Smith, 2001). A typical representation of cumulative contribution to profit is shown in Figure 5.7. The graph is split into three sectors. The first sector contains the products which contribute the majority of overall profitability. Sector 2 contains a larger number of products; these contribute to a small amount of the overall profit. Sector 3 contains products which are unprofitable.

Figure 5.7: Cumulative contribution to profit



The unit selling cost stored on Movex isn't accurate so the actual customer sold price is used from customer invoices to act as an average selling price. The net costs for each product are an estimated average because the business isn't able to accurately record the actual costs on an individual product basis. The total costs per month per product are allocated depending on the size of the product for the storage costs, and the number of products sold for the handling and delivery costs. The delivery costs are allocated a weighting of 75% for customer deliveries and 25% for distribution deliveries. The total costs per month per customer are allocated depending on the size of the products sold to each customer for the storage costs, and the number of products sold to each customer for the handling and transport costs. An Interest charge is added to the storage cost to cover the period of time individual products have been held for. The equations for net contribution to profit are shown in Equation 5.2. The company adds discounts retrospectively to the buying costs after a purchase order has been placed. Within the data that was used these have been included in the values for unit cost.

Equation 5.2: Net contribution to profit

Equation(s)

$\text{Net margin} = \text{IV} - \text{C}$ Equation (5.2a)

$\text{Net costs} = \text{SC} + \text{HC} + \text{TC}$ Equation (5.2b)

$\text{Net contribution to profit} = \text{Net margin} - \text{Net costs}$ Equation (5.2c)

Notation(s)

$\text{C} = \text{Unit cost}$

$\text{IV} = \text{Invoice value}$

$\text{SC} = \text{Storage cost}$

$\text{HC} = \text{Handling cost}$

$\text{TC} = \text{Transport cost}$

Figure 5.8: Flow chart of total cumulative percentage of net contribution to profit

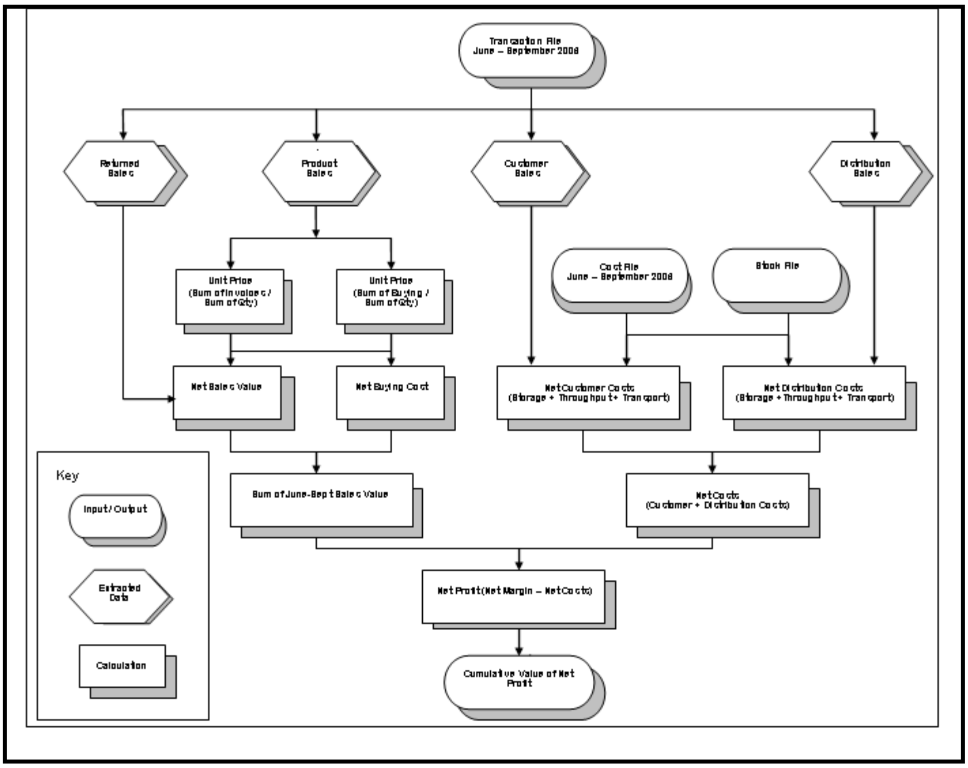
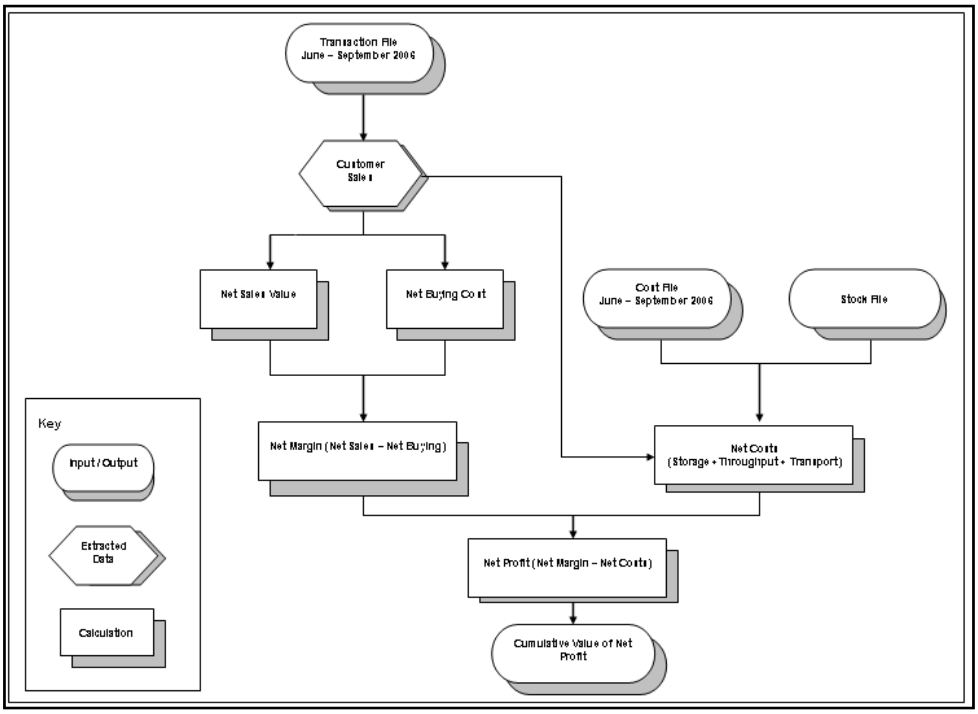


Figure 5.9: Flow chart of total customer cumulative percentage of net contribution to profit



5.6.3 Customer deliveries

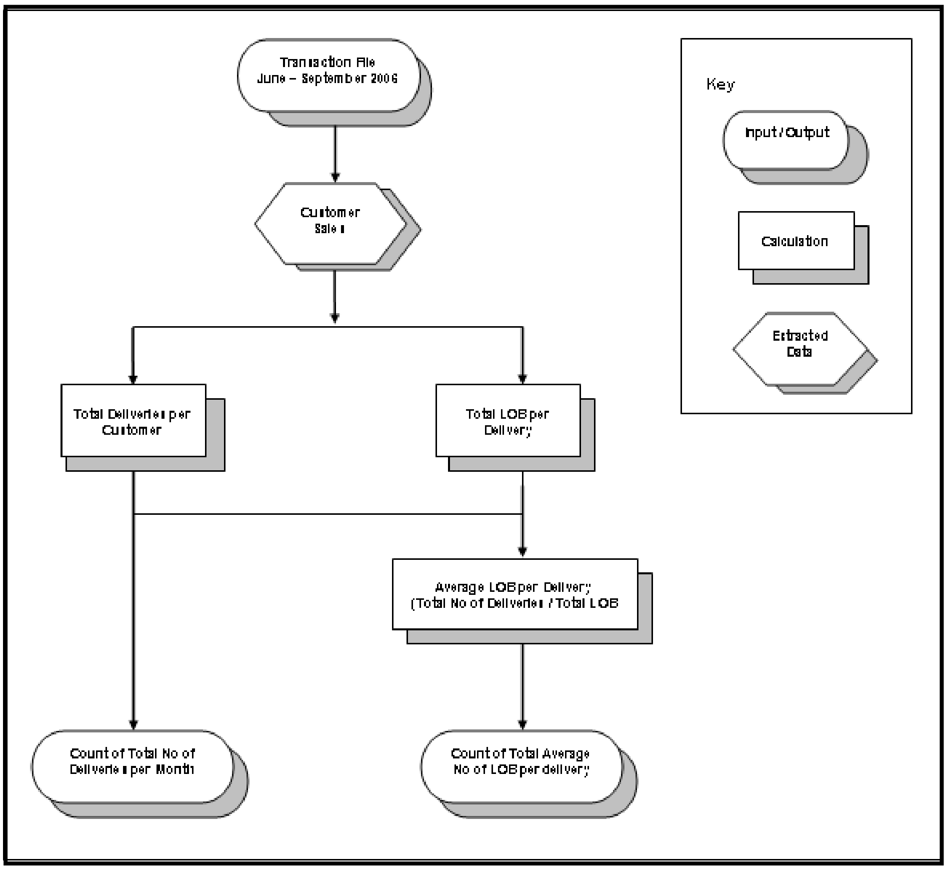
The data model structure for the calculation of average lines of billing (LOB) per customer delivery is represented by the flow charts in Figure 5.10. The average LOB per delivery is calculated from the total number of deliveries divide22d by the total LOB which were delivered (see Equation 5.3).

Equation 5.3: Average LOB per customer delivery

Equation(s)

$$\text{Averge LOB per customer delivery} = \frac{\text{Total no of customer deliveries}}{\text{Total LOB}}$$

Figure 5.10: Flow chart of average lines of billing per delivery



5.6.4 Stock turnover

The data model structure for the calculation of stock turnover is represented by the flow chart in Figure 5.11. The stock turnover for each product is calculated from the total balance of stock on hand divided by the average daily sales for the period (see Equation 5.4)

Equation 5.4: Stock turnover

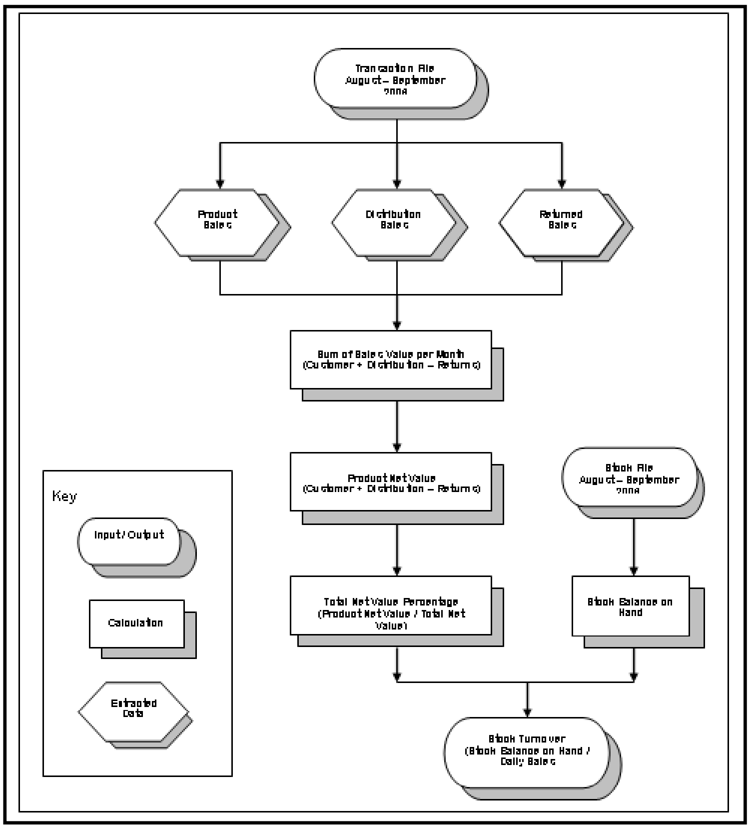
Equation(s)

$$\text{Total sales} = \text{CO} + \text{DO} - \text{RT} \qquad \text{Equation (5.4a)}$$

$$\text{Average daily sales} = \frac{\text{Total sales}}{\text{No of days in perdiod}} \qquad \text{Equation (5.4b)}$$

$$\text{Stock turnover} = \frac{\text{Stock balance}}{\text{Average daily sales}} \qquad \text{Equation (5.4c)}$$

Figure 5.11: Flow chart of stock turnover



5.7 Process mapping

A complete understanding of the inventory system was gained by using a process mapping approach. This uses an approach which is laid out by Hunt (1996) and was described in Chapter 3. A process map is a trace and visual representation of all of the activities, procedures and processes of the inventory system.

5.7.1 Interviews process

The qualitative part of the methodology was carried out using an interview research method. Descriptions of how to apply an interview research method is fully explained by (Kvale, 1996). The seven stages of an interview investigation' is a particularly useful method to follow when preparing and completing an interview. These are listed below:

1. Thematizing.
2. Designing.
3. Interviewing.
4. Transcribing.
5. Analysing.
6. Verifying.
7. Reporting.

The interview investigation is an important part of the methodology because it shows how the systems being studied behave in their natural environment. This behaviour can not always be understood by using quantitative research methods alone. A better understanding of how the intricacies of the system functions is achieved by talking directly to those who interact with it and are responsible for making decisions.

A series of interviews of employees were carried out to develop further the understanding of the inventory system. This was necessary to gain an understanding of the system to an appropriate level of detail. This will ensure that the results from the model are realistic and can be used to provide a practical solution. This will also add to the validity of the model and the acceptance of the results if all the significant elements which are felt to be crucial to the operation are considered. Furthermore, by involving employees in the process it can add to the acceptance of the results and the willingness to make business changes.

Due to the relatively small number of employees at each office the process maps which were developed are to a high degree an accurate representation of the system. All of the relevant employees were interviewed and this means there is less chance that an vital information was missed. Any relevant material was collected such as reports and written procedures as part of this process.

A decision was made to interview employees both informally and as they performed their normal tasks. This was to try and ensure employees felt they could speak freely. A one on one interview approach was preferred to a group session because employees are more likely to be forthcoming with information. Furthermore, the context and interaction of an individual in their working environments is lost when employees are not observed where they work. An unfamiliarity with the working practices means that it is not appropriate in this instance to use pre-designed questionnaire or questions. An observational approach is the preferred method which allows individuals to describe what they are doing as they work. Notes were taken and questions asked when appropriate as employees carry out their normal routines.

5.7.2 Process map design

The first stage was to complete a high level process map using Hunt’s (1996) methodology outlined in section 3.5.4. This was to gain a basic understanding of the structure of the system and the key activities and components. The inventory manager based at the Head Office in Birmingham was interviewed. This manager’s tasks include the maintaining and updating of stock records, setting up of new products, producing inventory related statistics and dealing with any computer related queries. This was an informal instructive process which was carried out over a number of days.

The high level process map is shown in Figure 5.12. It shows the key activities of the inventory system and who or what they relate to. The start of the process is triggered when a customer places an order and ends when the accounts have been updated. Products which are required to fulfil a Customer Order (CO) are in stock then they are picked, received by the customer and finally an invoice is raised and eventually paid. If they are not in stock then they are placed with a supplier, branch or RDC, known as a 230customer back order for stocked products or a special order for non stocked products. When the products arrive they are then sent on to the customer and the order is fulfilled.

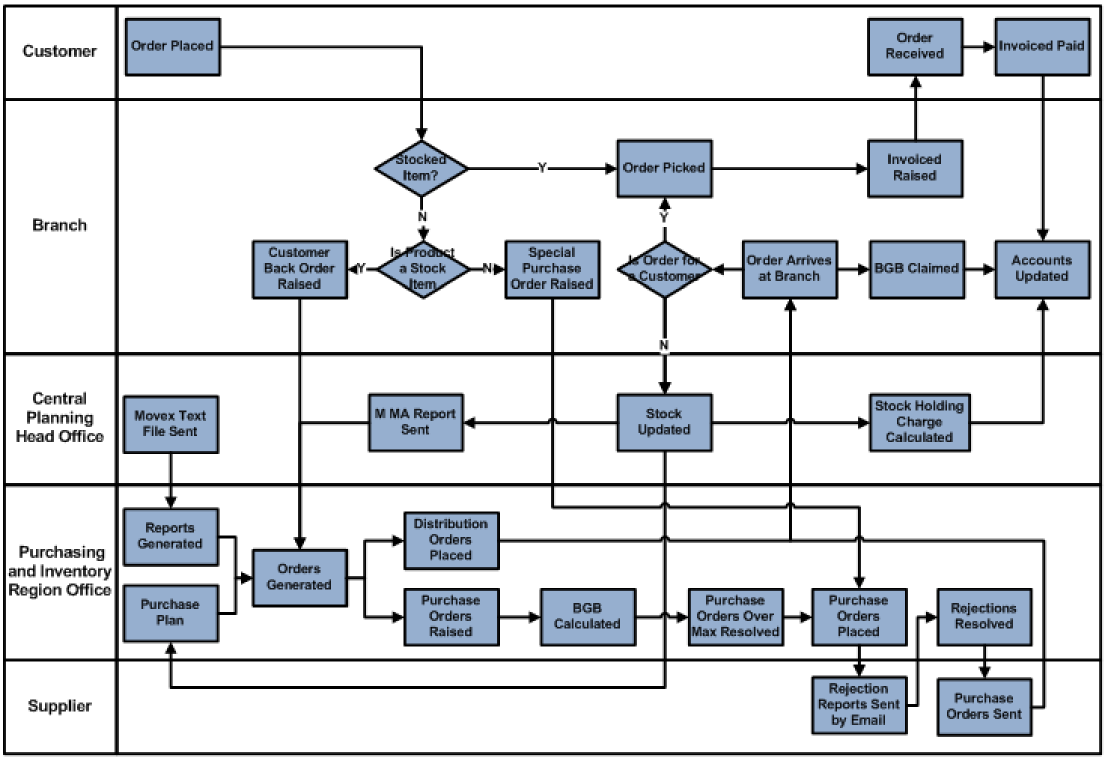
Products must be ordered when the balance of stock on hand reaches a predetermined level of stock, a new product is required or central planning wants to manually increase the level held in stock, which are shown on what is called the M MA report[17]. Purchase orders (PO's) are generated from a number of reports and Movex and are placed once the minimum invoice value set by the respective suppliers are met. Products are ordered directly from supplier, a branch or an RDC. When products arrive at the branch or RDC the stock records are updated.

The high level process map had provided an explanation of how the system functions at a holistic level. It was then necessary to get a detailed picture of how all of processes interact with one another. A second set of process maps were created at this stage. The high level processes are drilled down to produce a greater level of detail. These detailed maps are transformed into programming flowcharts which are used to design the simulation model. This

[17] It is referred to as the M MA report because it contains what the business refers to as M and MA lines. These are fast moving products and new products which haven't received any sales and are have not been formally classified.

was achieved by creating detailed process map at each of the four regional offices.

Figure: 5.12: High level process map



These offices are spread throughout the United Kingdom and based in the South West at Avonmouth, the North West at Warrington, the North East at Leeds and in Scotland at Kirkcaldy. They are responsible for maintaining the level of inventory and the purchasing of replenishment as well as new stock. The commercial, purchasing and inventory managers, the inventory controller and the stock, project and special buyers are each interviewed in turn. An organisation report is shown in CD Appendix D for Avonmouth office. It gives a general outline of the average number of employees for each type of function.

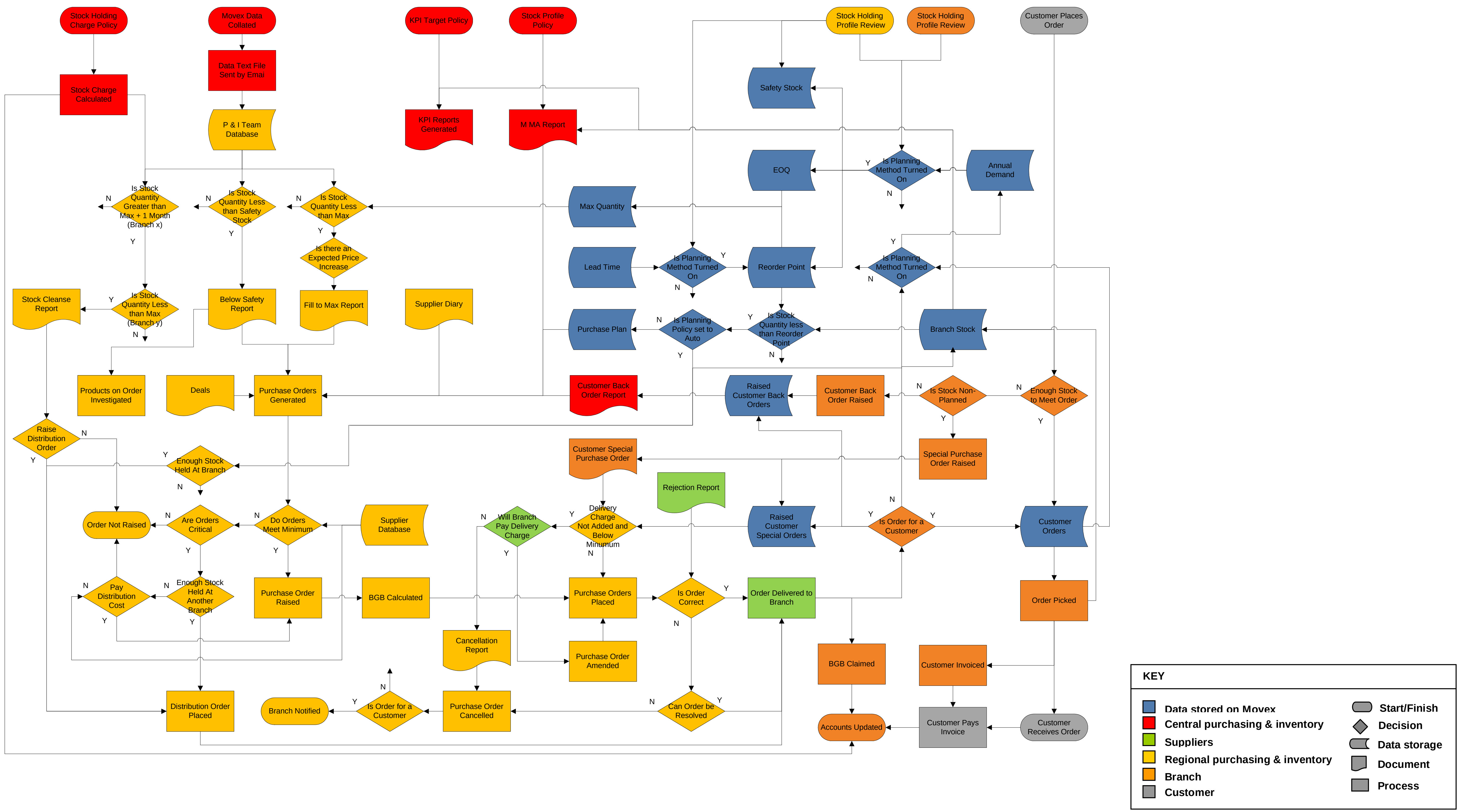
It was expected prior to the review process that there would be a degree of synergy in the way each office functioned, whereby there would be many shared processes and procedures. In fact it became apparent that each office was in reality functioning in isolation. Although the objectives of each office were similar because they were focused on meeting the performance targets which had been set by the head office, the working methods were very different. This became apparent when the review of the purchasing processes and procedures at each office was undertaken. This was emphasised when the purchasing managers were gathered to discuss the findings of the research. It was evident they had not met before in person and were able to discuss for the first time a number of problems each had.

The process maps are a useful tool for finding best practices and common mistakes among the offices. It was suggested in the findings that common standards and methods should be set. A dialogue between the purchasing managers should be maintained on a regular basis where knowledge can be shared and common problems discussed.

The interviews of all of the employees were conducted on a one to one basis, and relevant documents were collected were analysed and transformed into four process maps, one for each regional office. An example of one of these process maps (Leeds) is shown in Figure 5.13. The remaining process maps for Warrington, Avonmouth and Kirkcaldy can be found in CD appendices E-G. A detailed explanation of each process can be found in CD Appendix H.

The process maps are complex but they show all of the processes and how they are interrelated. It is necessary not to over-simplify a model because it could be deemed useless if it is not a credible representation of the actual system. The process of creating these gives a good understanding of the system and is a solid foundation which can be utilised when the model is transformed into programming flowcharts. The colours in the process maps represent the department where they are carried out and the shape shows the type of process. A detailed explanation of all the key activities follows in the next sections.

Figure 5.13:
Detailed process map of
Leeds P & I office

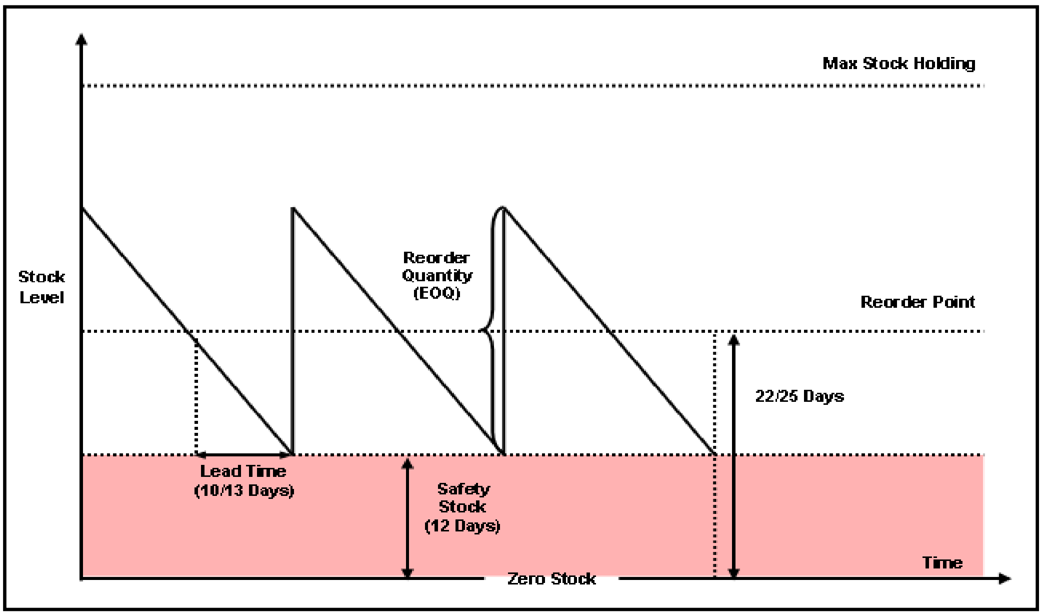


5.8 Stock replenishment model

The Movex software incorporates a continuous review inventory model. The basic premise of the model is that when the level of stock falls below a predetermined amount a request for replenishment is triggered, known as the reorder point (ROP). The ROP is made up of two elements; the safety stock and the cycle stock. The safety stock protects against any unforeseeable increases in customer demand. The cycle stock is the quantity of stock which is expected to be sold during the lead time, often referred to as lead time demand. The lead time is the period of time from when a purchase order is placed till when it is received into the business.

Once the reorder point is triggered a quantity is ordered which when delivered increase the balance of stock. This is either a manually entered number or set using an EOQ calculation. The expected level of demand is calculated from a mathematical forecast. A diagrammatic representation of the model is shown in Figure 5.14.

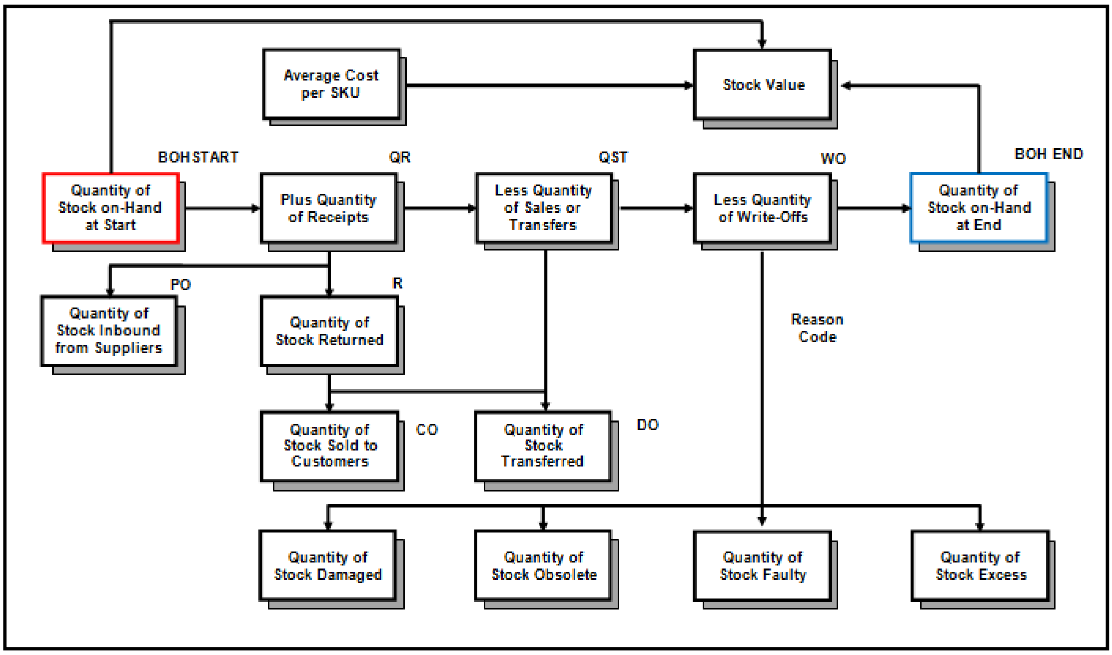
Figure 5.14: Stock replenishment model



Source: P & I Inventory Manager, Head Office (2008).

The software maintains the level of stock for each product. The level of stock is updated for individual products when a product is received, sold or written off. The breakdown of factors which constitute to the level of stock is shown in the flowchart in Figure 5.15 (Slater, 2008) and the corresponding Equations 5.4 – 5.8

Figure 5.15: Stock level flowchart



Equation(s)

BOH END = BOH START + TT	Equation (5.4)
QR = PO + R	Equation (5.5)
DO = DO OUT – DO IN	Equation (5.6)
QST = CO + DO OUT – DO IN	Equation (5.7)
TT = QR - QST – WO	Equation (5.8)

Notation(s)

BOH END = Balance on hand end

BOH START = Balance on hand start

QR = Quantity of receipts

QST = Quantity of sales or transfers

TT = Total transfers

PO = Purchase order

CO = Customer order

R = Returns

DO IN = Distribution orders in

DO OUT = Distribution orders out

WO = Write-offs

5.8.1 Reorder point

When the Movex system went live in 2002 the lead time demand and safety stock levels were calculated using an automated calculation each month. The levels were updated on a weekly or monthly basis after a new forecast had been calculated. The levels vary between products and depend upon the extent of variation in customer sales demand and supplier lead times. The change from an automatic to a manual system occurred throughout 2007 and now the majority of products are manually updated. This was due to a lack of confidence in the forecasts produced by the Movex software and a view was taken that too many products were running out of stock too often. Secondly, the performance targets are weighted in the favour of the availability of stock with lesser penalties for excess stock. The manual setting of these parameters allows the managers a workaround because they can set quantities which make it easier for them to meet their targets, even though this has led to an increasing of the overall stock held.

The cycle and safety stock levels are typically changed every six months after a product profile review has taken place. The P&I managers at each regional office visit each one of their branches within their domain to review all the products which are held there. A discussion takes places with each respective branch manager to decide on the new quantities. The annual demand figures act as the main driver for change and are used to calculate an average daily quantity. The annual demand figures are calculated from the moving average forecast (see Equation 5.9). The forecasts are calculated at the end of month. A report is sent by head office which shows any forecasts that are 2 standard deviations above the average (see CD Appendix I). The buyer checks to make sure that the forecast is correct. The average daily quantity is then used to calculate the safety stock and reorder point levels by multiplying these numbers by a selected number of days.

$$F_{t+1} = \frac{X_t + X_{t-1} + \cdots X_{t-N+1}}{N}$$ **Equation 5.9:** Moving Average

Notation(s)

F_t = Forecast for time t.

X_t = Actual value at time t.

N = Number of values included in average.

Parameter(s)

N = 6 months

Source: Movex User Manual (2009).

Products that have not sold as expected can be turned off so they are not reordered. Once the final profile has been decided on the list of products and their changes are sent to Head Office to be updated. The safety stock and cycle stock calculations use twelve days and either ten or thirteen days respectively (July, 2008). This approach is less scientific than the model suggests and does not take into account variations in demand and lead times. The changes are sent to the head office to be changed once the profile has finished. A summary of the profile review sheet can be seen in CD Appendix J.

Equation(s)

$$\text{D} = \text{Month Forecast x 12} \quad \text{Equation (5.10)}$$

$$\text{S} = \frac{\text{D}}{\text{WD}} \quad \text{Equation (5.11)}$$

$$\text{CS} = \text{SL} \quad \text{Equation (5.12)}$$

$$\text{B} = \text{S x BD} \quad \text{Equation (5.13)}$$

$$\text{ROP} = \text{CS} + \text{B} \quad \text{Equation (5.14)}$$

$$\text{MSH} = \text{EOQ} + \text{ROP} \quad \text{Equation (5.15)}$$

Parameter(s)

$\text{BD} = 12 \text{ days}$

$\text{L} = 10/13 \text{ days}$

$\text{WD} = 260 \text{ days}$

Notation(s)

$\text{CS} = \text{Cycle stock}$

$\text{B} = \text{Safety stock}$

$\text{ROP} = \text{Reorder point}$

$\text{BD} = \text{Safety stock days}$

$\text{D} = \text{Annual demand}$

$\text{S} = \text{Average sales per day}$

$\text{L} = \text{No of days to arrive}$

$\text{WD} = \text{Total no of working days}$

$\text{MSH} = \text{Max stock holding}$

5.8.2 Reorder quantity

Once a reorder point has been triggered Movex suggests a quantity to be ordered. These are either set manually or from an economic order quantity (EOQ) calculation (see Equation 5.16). The equations and parameters are shown below. The EOQ calculation uses ordering and holding cost parameter of £2.50 and 0.20 respectively (July, 2008). There is no evidence available to show why the parameters were originally set to these levels and the skills required to update these parameters are no longer available within the company. This is significant because these parameters affect the level of stock which is held within the business.

The unit cost is the supplier buying cost and the annual demand is a multiplication of the monthly forecast. A multiple order quantity is calculated if the ordering quantity is requested by the supplier to be ordered in multiples. The quantity is rounded up if the supplier has set a minimum order quantity.

$$\mathrm{EOQ} = \sqrt{\frac{2\mathrm{UA}}{\mathrm{CI}}}$$

Equation 5.16: Economic order quantity (EOQ)

Notation(s)

$\mathrm{EOQ} =$ Economic order quantity

$\mathrm{U} =$ Expected annual usage of the material, in units

$\mathrm{C} =$ Delivered unit cost of the material

$\mathrm{I} =$ Inventory carrying cost for the material, expressed as a percentage of inventory value

Parameter(s)

$\mathrm{C} = £2.50$

$\mathrm{I} = 0.20$

Source: Movex User Manual (2009).

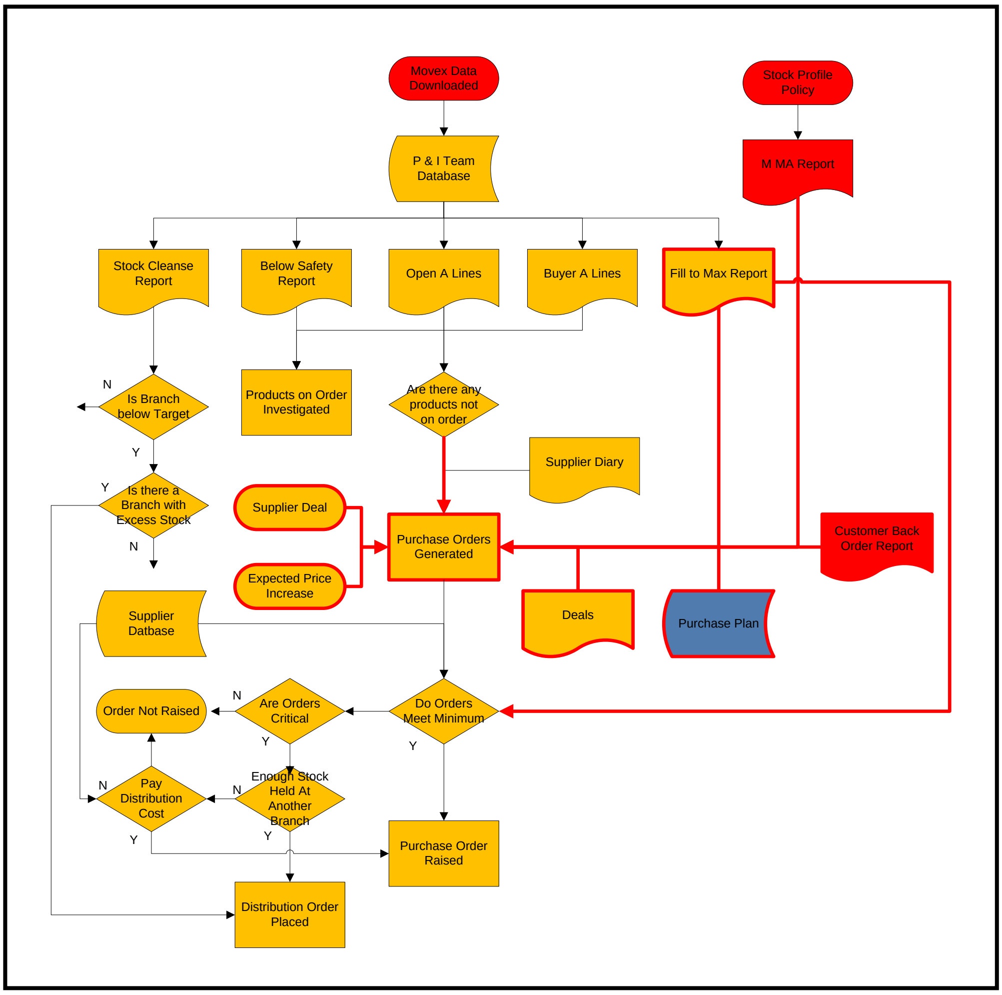
It became evident when talking to employees within the purchasing department that they did not fully understand the fundamental equations of inventory management. This lack of understanding had meant that whenever issues had arisen they were not properly diagnosed or dealt with by adopting the best approach. This lack of knowledge had meant that purchasing employees and managers were resorting to the less technical methods which they were familiar with to solve any problems.

It was believed for example that the computer system was at fault for the unacceptable level of product stock-outs. This was because the system had not been properly setup and a number of variables not set to appropriate levels. As a result of this false assumption a manual method was put in place which used static reorder point levels. Although this reduced stock-outs, stock levels were increased above acceptable levels to the business.

5.8.3 Purchase orders

When products reach the ROP Movex adds a record to the purchase plan. An example of the purchase plan is shown in CD Appendix K. Purchase orders are raised by combining purchase orders by their ordering branch and their supplier. An example of a raised order is shown in CD Appendix L. A completed raised order is placed with the supplier. The purchasing order generation process is shown in Figure 5.16. The stock buyers manage this process. The buyers have to make sure that the minimum values set by each supplier are met. If they are not met a delivery charge is added; so in the majority of occasions the buyers aim to surpass this level. Secondly, the buying values of products can be reduced if larger purchase orders are placed. If a customer back order cannot be ordered for whatever reason the stock buyer liaises with the appropriate branch using the internal e-mail system to communicate the relevant information (see CD Appendix M).

Figure 5.16: Purchase order generation process



The purchase plan is the primary source which contains all of the products which are required to be ordered as soon as possible. Secondary sources contain products which are listed on a number of different reports which are sent from head office on a daily basis. These reports are:

- Fill to max report (see CD Appendix N);
- Customer back order report (see CD Appendix O);
- M MA products report (see CD Appendix P);

The products from the purchase plan are combined with products that are on the customer back orders and M MA products report. The customer back order report lists all the products which were sold but out of stock at the time when the customer placed the order. The M MA report lists products which the central planning office requires to be held. If the value of the purchase order is larger than the supplier minimum quantity then the purchase order can be placed with the supplier. If the value of the purchase order is lower than the minimum then the buyer can search for products from the fill to max report to increase the value. The fill to max report list products which are lower than the maximum holding quantity allowed and at a level higher than the reorder point.

There are a number of buyers in each office who are each responsible for a selection of different suppliers. On a daily basis they create purchase orders from the two sources by matching the products by supplier code and branch code. They have a diary which tells them which supplier they can purchase from on which particular day. A sample of a diary from a buyer at the Leeds P&I office can be seen in CD Appendix Q. This means that even if a product falls into the purchase plan it might not be ordered on that particular day. The priority is to make purchase orders from the purchase plan. The buyer needs to make sure the minimum value quantities are reached for each supplier. If they are not they will remain in the purchase plan in the expectation more products will be added and the value increased.

The P & I offices are sent a number of reports which are used to monitor the level of products and orders which are outstanding with suppliers. These reports are:

- Below safety report (see CD Appendix R);
- Not in stock and none on order report snapshot (see CD Appendix S);
- Days to out of stock (see CD Appendix T);
- Open A Lines (see CD Appendix U);

The below safety report shows any products which have fallen below the safety level. The not in stock and none on order report is self explanatory. The days to out of stock report is an estimation of how long products are likely to remain in stock. If products on these lists are out of stock or are near to being out of stock and haven't been ordered they are ordered as a matter of urgency. The open A line report lists the A line products which are on order but are running low. The buyer rings around the suppliers to chase up these orders.

When the raised purchase orders have been completed and are ready to be sent to the supplier the buyer removes any discounts, referred to as Branch Gained Benefit (BGB). The buyer searches through a list of pre-existing deals to see if any discounts need to be reduced from the total price. An example of the list of supplier deals is shown in CD Appendix V and an individual example is shown in CD Appendix W. At the end of each period each office receives a BGB report which shows all the discounts gained (see CD Appendix X). The prices for cable change on a regular basis and vary between suppliers. The stock buyer is responsible for making sure that the supplier used is offering the cheapest price from the cable best buy report (see CD Appendix Y).

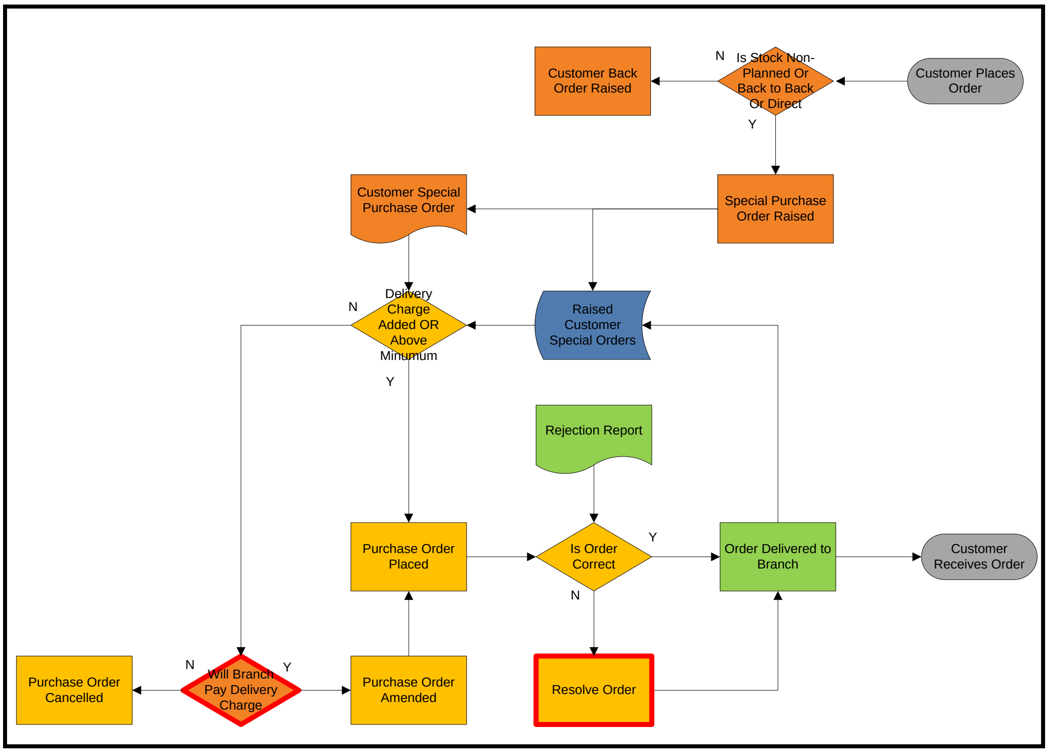
A report is sent from head office, the PO over max report (see CD Appendix Z), which lists any products which if ordered, would take the level of stock over the max holding level. The buyers look through this list to make sure that no mistakes were made in the ordering quantities.

Once this process has been completed the purchase order is placed with the supplier via an EDI link or fax. A transmission confirmation (see CD Appendix AA) and a purchase order confirmation (see CD Appendix AB) are received if the purchase order is successfully received by the supplier. If the supplier is not satisfied with the purchase order then a rejection report is sent to the office and the buyer has to rectify any errors (see CD Appendix AC). The supplier then processes the purchase order and delivers the stock to the relevant branch. The period of time between the placing of the purchase order and the delivery is known as the lead time.

5.8.4 Special orders

Special orders are non-stocked items which are purchased as single products on a one off basis. The processes are shown in Figure 5.17. A special product is added to a customer back order if an order exists from the same supplier and it is expected that the order is likely to be ordered in a reasonable amount of time. If this is not the case a special order is raised by the branch on Movex and a copy of the order emailed to special buyer (see CD Appendix AD). A special buyer is then responsible for placing the order with the supplier. There are many occasions when a rejection report is sent from the supplier if there is a query with the order. If the branch decides that for whatever reason they wish to cancel the order then a cancellation request is sent to the special buyer (see CD Appendix AE). The special buyer will then act as a liaison between the supplier and the branch to solve the problem.

Figure 5.17: Special ordering process



5.8.5 Distribution placed orders

Distribution placed orders are internal transfers of stock between the RDC's and the branches or from branch to branch. If the planning policy on Movex is set to automatic then when the reorder point is triggered a purchase order is raised on the regional distribution centre. If the stock is available then it is sent to branch on internal transfer the next day. If there is insufficient stock available then the stock is sent once the stock becomes available.

Distribution orders can also be placed by the buyers at each P&I office. This could be to reduce any excess stock held at individual branches or to fulfil purchase orders which have not been able to be placed because they do not reach the minimum supplier value and have become critical. An excess stock report is sent daily to each office (see CD Appendix AF). A product is deemed to be in excess if the level of stock is two weeks above the max holding level. If there are products which are required by a branch then the excess stock is internally transferred. The central planners raise distribution orders between regions. An example of this report is shown in CD Appendix AG.

5.8.6 Key performance indicators (KPI's)

The KPI's are designed to maintain low levels of stock whilst maintaining designated customer service levels. The experience gained whilst interviewing and monitoring the purchasing employees showed that performance targets were key drivers of the decision-making process of managers. They are a significant factor in the evolution of the processes in the inventory system. The KPI's and respective targets are shown in Figure 5.18. The KPI's are a selection of stock availability, stock level targets and purchase order measurements. The availability targets are a measure of customer service. Each branch is set a target level of stock at the start of each year. If the branch is over the target value then they are charged 7.5% and if they are under the target they are charged 1%. This charge is added on to the monthly accounts for the branch.

At the end of each week each of the purchasing offices are sent updated reports of performance measures and graphs for that period. The report shows the aggregate performance of all of the regional offices and individual performance of the branches. The offices are penalised points if they haven't reached their targets where applicable and given points for the remaining targets in ranking order of quantity against each office. The offices are then ranked by the total points. An example of the weekly scoreboard report for the offices can be seen in CD Appendix AH. An example of the branch availability report and graph and stock graph is shown in CD appendices AI, AJ and AK respectively. The purchasing managers' report the performance measurements for the period with a comparison to the previous period to their staff. An example of the weekly checklist report is shown in CD Appendix AL.

Figure 5.18: Key performance indicators (KPI's)

KPI	Target	Area of Improvement
Percentage of A lines in stock	98%	Customer service
Percentage of A lines above safety stock	92%	Customer service
Percentage of ABC lines in stock	94%	Customer service
Number of purchase orders outstanding more than 3 months	None	Customer service
Number of distribution orders outstanding greater than 10 days	None	Customer service
Number of customer back order lines outstanding greater than 10 days	None	Customer service
Number of forecast alarms	None	Operation cost
Percentage of current stock value under target stock value	Chosen value	Operation cost

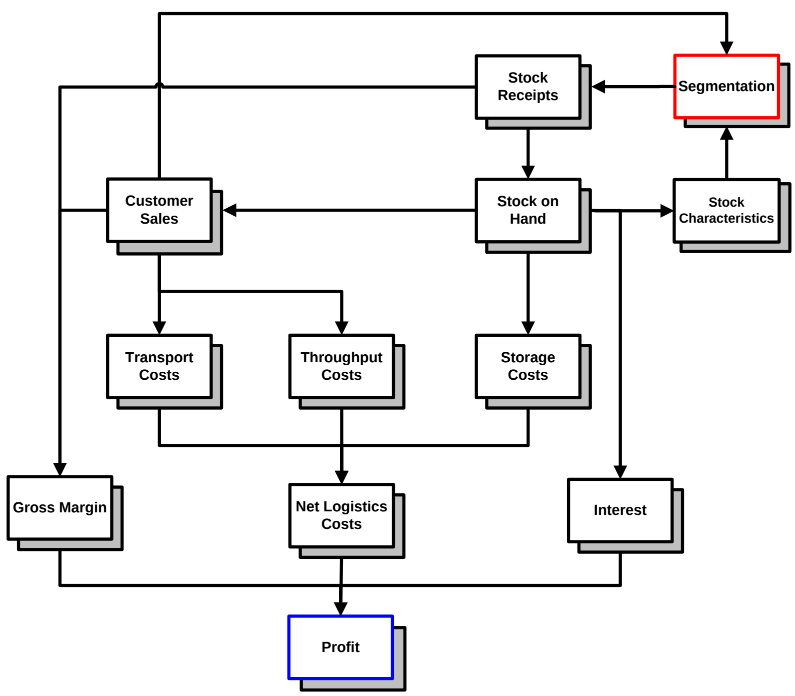
5.9 Segmentation model

An objective of the research is to show how a segmentation approach can be applied to improve product and customer contribution to profit. The premise is to select strategies which reduce resources for products and customers who contribute the lowest proportion of sales. Secondly, the aim is to prioritise resource for products and customers which together contribute the highest proportion of sales. Within the literature review it was suggested that performance of a supply chain was a measurement of its ability to be efficient, reliable and responsive (Hendricks and Singhal, 2003). The segmentation model is designed to correspond to this principle by segmenting products and customers so that the supply chain is efficient, reliable and responsive in the most effective way.

It was discussed in Chapter 2 that a supply chain strategy is concerned with the operation part of the business. A number of key elements of a supply chain strategy provided by Lowson (2002) were shown. A supply chain segmentation strategy is aligned with these key elements. The aim is to provide coordination and integration of all activities, planning and collaboration across the supply chain and optimisation of delivery.

The segmentation model (see figure 5.19) illustrates how the segmentation approach fits in with the financial model. Sales and stock information are used to drive how much stock should be held. This decision directly impacts logistics costs and revenue from customer sales. These two factors contribute to the level of profitability the business receives.

Figure 5.19: Segmentation model



The large number of unprofitable products and customers are a substantial issue for the business. The business has developed a short term strategy which has focused on the pursuit of increasing revenues. This has been achieved within the supply chain operation with the attempt to improve customer service levels through an increase of product availability, choice and delivery speed. This has had the long term effect of reducing profit because of excessive operational costs. The excess costs are from congested and overstocked warehouses within branches. This resulted in low productivity and whilst there has been increase in service levels for some products other products have seen reductions in service levels.

A single supply chain strategic approach has resulted in service level reductions for products and customers which are the most crucial to the success. The business has failed to understand correctly what its customer expectations are and has not targeted the right products and customers. This is summed up in the business mantra which is to “exceed our customers’ and suppliers expectations” (Hagemeyer Annual Report, 2006). It is much better to “meet” its customers’ expectations because as was shown by Christopher (1998) profits are maximised when revenues are balanced against the cost of service.

The assumption is made that all of their customers require the same level of service. There is a finite amount of resources available and these should target specific segments to achieve a level where profits are maximised. A supply chain strategy which is aligned with customer demand and expectations can achieve this. The logistics costs are proportioned against the value of each product and customer. A strategy which segments products and customers depending on their value to the business and various characteristics is used.

The logistically distinct business (LDB) methods which were laid out by Fuller *et al* (1993) provide a useful guide and show how to apply a segmentation strategy. An aim of the research was to develop these into a broader and more comprehensive structure which incorporated a set by step approach.

The purpose of this was to show how a segmentation process can be followed through the strategic, tactical and the operational levels of the business in accordance with the research aims.

The methodological framework is set out below:

1. create segments of customers using suitable sales related criteria;

2. create a customer service level matrix which allocates the level of distribution service which is appropriate for each customer segment. This will depend on the level of sales value. For some segments the aim would be to match or improve on customer expectations, whilst for others an economical approach would be more appropriate;

3. gather detailed information for each SKU. This would aim to include all of the data required in the segmentation process;

4. locate products which have no business value and remove;

5. create segments of products using suitable logistics related criteria;

6. allocate a channel of distribution for each product segment. The aim is to reduce costs for the slowest moving products by achieving economies of scale;

7. create a detailed process map of the inventory system and remove any unnecessary processes;

8. create segments of products using suitable logistics and sales related criteria;

9. using the process maps as a base redesign the inventory system by allocating suitable methods to each segment;

10. allocate a location area for each product segment within the warehouse. The aim is to minimise walking distance for the fast moving products;

11. create a list of measures to monitor supply chain performance. The aim is to strike a balance between cost and service measures. These need to be evaluated to make sure no undesirable practices evolve or negative feedback loops have been created.

The segmentation analysis uses sales demand to align logistics costs. Products and customers are segmented by the total percentage of sales. Products are classified into A, B, C or O (see Figure 5.20) and customers A, B, C and D (see Figure 5.21). These main classifications are used to drive the segmentation analysis in each of the research projects.

Figure 5.20: Product classifications

Product	Class	Sales %
Fast	A	0-80
Medium	B	80-95
Slow	C	95-100
Obsolete	O	Less than 6 Lines

Figure 5.21: Customer classifications

Customer	Class	Sales %
Key	A	0-80
Core	B	80-95
Occasional	C	95-100
Competitors	D	

The next three sections outline the methodology used for each of the research projects.

5.10 Supply chain design

It was shown that A and B lines are on average carrying approximately seven weeks worth of stock. The low levels of stock turnover are a major factor in reducing product profitability. This is because of the low levels of productivity. A major concern is the high level of stock obsolescence within the region, recorded at £1.4 million. These factors have contributed to the RDC at Avonmouth being overstocked and congested.

The analysis of contribution to profit of products showed that many of the products are unprofitable. A large proportion of the slow moving products are incurring logistics costs which are greater than the margins. This is because as Fuller *et al* (1993) had reported logistics costs were being averaged for all products. It is beneficial to reduce the logistics costs for these types of products. The aim of the research was to find a solution which reduce the highlighted supply chain issues and as a result increase the level of contribution to profit. To achieve this a number of specific objectives were drawn up:

- reduce the number of SKUs;
- remove obsolete stock;
- increase the rate of stock turnover;
- increase operational productivity;
- improve working conditions;
- improve supplier delivery reliability;
- improve customer service levels (product fulfilment).

A number of supply chain strategies are available to solve these issues. The list of questions posed by Fuller *et al* (1993) and which were shown in Chapter 2 were used as a starting point to establish which solutions were required for different types of products. A central distribution centre (CDC) could be set up to hold all products and supply all regions from one location. This could provide operational economies of scale and reduce the overall levels of inventory. This strategy has been previously adopted but was abandoned in February 2005 when the distribution centre at Runcorn was closed. This is because the business was not able to provide the level of customer service it deemed satisfactory. To implement this strategy a large investment cost would be required to build or rent a large warehouse. For this reason the approach isn't financially or operationally feasible.

It was decided that an approach which could benefit from both the central and regional models is the most beneficial. Products were segmented by their rate of sales turnover and classified as A, B or C for fast, medium and slow moving respectively. An approach which is similar to what has been shown by Christopher and Towill (2002), Lee (2002), Mason-Jones *et al* (2000), Naylor *et al* (1999) and Payne and Peters (2004) was used to segment the supply chain into an efficient supply chain for C line products and a responsive supply chain for the A and B lines.

A CDC was used to store and deliver the slow moving products. The fast moving products are continued to be held at the regional distribution centres (RDC's). A distribution centre, based at Milton Keynes, which is currently being used by the business and has available storage space was used. This reduced the level of investment which would be required if a new warehouse was opened. The slow moving products are categorised as being either C_1 or C_2. The C_1 type products supplement the faster moving products. The C_2 products are to be removed to the CDC and the C_1 products are to remain at the RDC at Avonmouth.

The congestion in the warehouse, the deficient positioning and the difficulties in locating products because of the poor labelling and inaccuracies of stock levels was creating a low level of operational productivity. The removal of the slow moving stock which freed up space allowed for the RDC to be redesigned. An effective RDC allows for a reduction in staffing levels because of the increase in productivity.

The implementation of the solution was organised into two research projects. There are a number of key stakeholders who contribute to this. The initial stage required consultation to organise the timescales and outline the key tasks. The project manager who was designated to manage the project designed a Gantt chart which outlined the key tasks (see CD Appendix AM). Throughout the project meetings took place to discuss each step and the future plans. Everyone working on the research project was designated individual action plans at each meeting. A copy of the meetings can be found in CD Appendix AN.

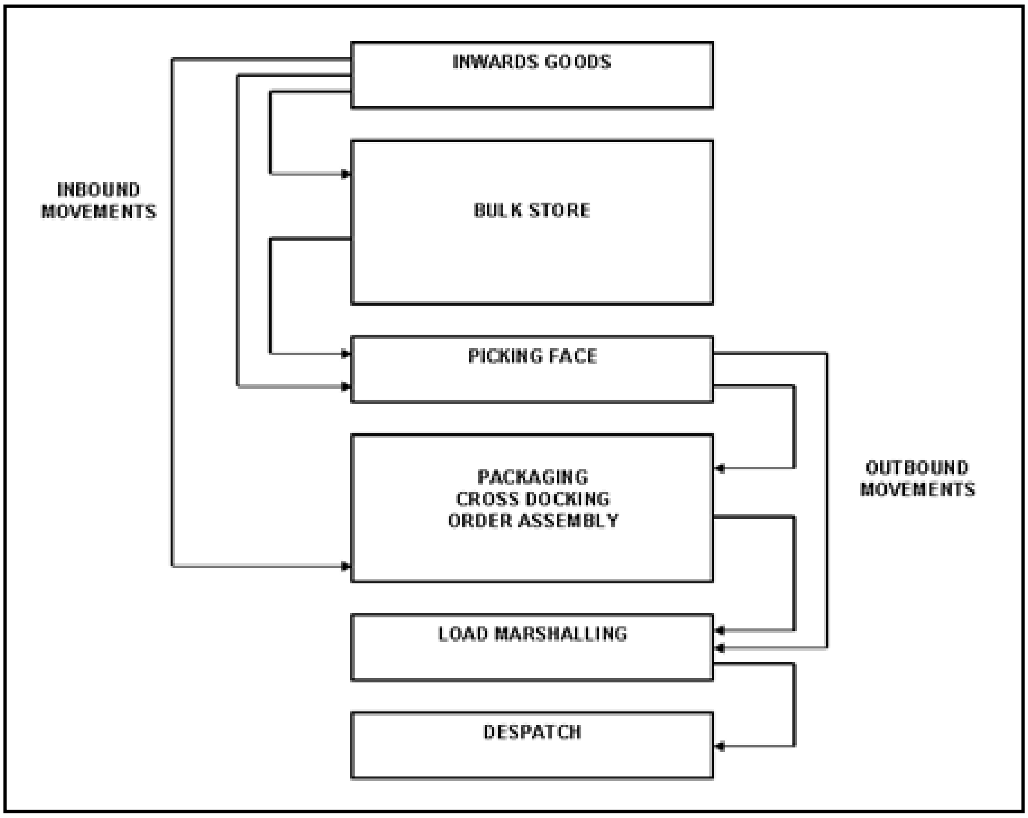
The implementation of the design proposals takes place in a number the following logical steps:

1. Movement of C2 lines to Milton Keynes CDC.
2. Stock management and process audit.
3. Allocation of storage media type.
4. Exterior and interior media changes.
5. Allocation of picking and bulk location.
6. Stock take

5.11 Warehouse design

The methodology which is used to locate the products within the South West regional supply chain and the design of Avonmouth RDC is set out in the next section. The design of the warehouse is aligned to the structure shown in Figure 5.22 (Slater, 2008). The movements of products are classed to be either inbound (entering the warehouse) or outbound (leaving the warehouse). Products enter the warehouse at goods inwards where they are prepared to be put-away. They are stored in the bulk store and picking face for a period of time until they are sold. When a customer order is placed the products are picked from the picking face and moved to the outbound area. They are then packed, loaded and dispatched.

Figure 5.22: Conceptual warehouse design



The design of a warehouse should aim to reduce the costs of the operation to a minimum level whilst maintaining an expected level of service. An effective design allows products to easily flow into and out of the warehouse in a logical manner. The objectives of design incorporate the following:

- easy access for product put-away and picking;
- balanced flows;
- minimised travel distances;
- grouping of products with similar characteristic;
- adequate Identification of stock locations;
- health and safety considerations.

Whilst inventory control systems determine how much and when to purchase products from suppliers it is the purpose of warehouse design to determine how and where they should be stored. A decision is made for each product to determine the type of media and the location within the warehouse where it is to be stored. The choices have a direct impact on the efficiency of the operation and its subsequent productivity. The goal is to minimise the distance travelled by operatives in the activities of put-away and picking, combined with efficient storage. The fastest moving products are handled with the highest frequency so it is best to minimum the distance travelled for these. In summary the effective use of warehouse space is maximised by putting the right products in the right place.

The allocation of media type and locations are dependent upon a product's characteristic. The products are segmented into groups with similar characteristics and then allocated a media type and a location.

5.11.1 Allocation of storage media type

There are many different types of storage media where a product can be stored. The objective is to find a type which best suits the characteristics of the product. The aim is to fit products into the smallest media type to maximise the use of available space. There are generally two types of locations referred to as bulk and picking locations. The picking locations are where products are directly taken to supply a sales order transaction. Any overspill of products is stored in bulk locations. If the largest media type cannot store the total quantity for the SKU then it is allocated into as many bulk locations as is required. There are many different types of storage media that a warehouse can utilise. A selection of the many types by Slater (2008) is listed below:

- Draws (small).
- Draws (medium).
- Draws (large).
- Very small bin (one fifth of a shelf).
- Small bin (two fifths of a shelf).

- Medium bin (three fifths of a shelf).
- Large bin (four fifths of a shelf).
- Shelf.
- Secure shelving (caged).
- Hazardous shelving (caged).
- Drive-in pallet position.
- Vertical storage.
- Cantilever storage.
- Block stack position.

The process of allocating a storage media type first requires data to be collected for each individual SKU. The data that is required is shown in Figure 5.23. It is often the case that data is missing for some products. This tends to be data related to the dimensions of an SKU. Any data that is not available needs to be collected. The measurement of products can be by hand or by using a cube machine. The system records are updated when the information has been collected.

Figure 5.23: Product data

Field	**Description**
Product Number	Unique product number
Product Name	Unique product description
Length (mm)	Length of the product
Width (mm)	Width of the product
Height (mm)	Height of the product
Purchase Order Quantity	Quantity to be purchased
Reorder Point	Trigger point for purchase order to be placed
Maximum Holding	Maximum quantity to be purchased
Weight (kg)	Weight of the product
Type	Type of product

A unique product number identifies an SKU. The description is important because it helps to verify that a media type is correctly allocated. The size, weight and maximum quantity are all used to identify the most efficient media type. The type of product is used if a specific media type is required for some reason and takes precedent over any other method. Large sheet steel for example needs to be stored on cantilever racking because of its size and weight.

If a specific media type is not required then a process is used to find the smallest type. The products dimensions and maximum quantity of stock holding are used to calculate the space requirements (see Equation 5.5c). The maximum holding quantity is calculated from the purchase order quantity and the reorder point (see Equation 5.17a). The maximum quantity of stock represents the largest amount that may be required to be held at any one time. This is an assumption of the equations used in the inventory control system. These were explained earlier in the chapter. A smaller quantity of stock is stored most of the time but the size of the media must be able to fit all eventualities. The space requirements are checked against each storage media type to find the smallest possible fit.

Equation 5.17: Space and weight requirement

Equation(s)

$$\mathrm{MHQ} = \mathrm{POQ} + \mathrm{ROP}$$ Equation (5.17a)

$$\mathrm{Cube} = \mathrm{L\ x\ W\ x\ H}$$ Equation (5.17b)

$$\mathrm{Space\ Requirement} = \mathrm{MHQ\ x\ Cube}$$ Equation (5.17c)

$$\mathrm{Weight\ Requirement} = \mathrm{MHQ\ x\ Weight}$$ Equation (5.17d)

Notation(s)

L = Length

W = Width

H = Height

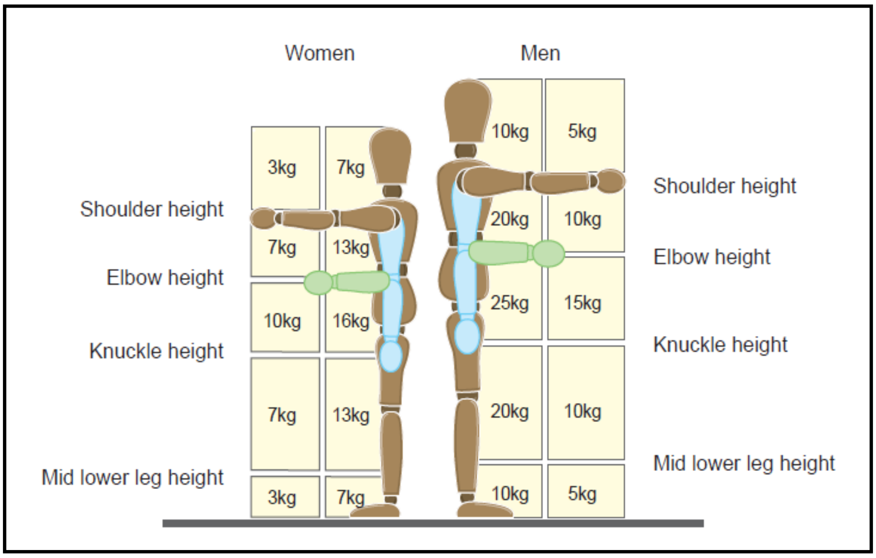
MHQ = Maximum holding quantity

POQ = Purchase order quantity

ROP = Reorder point

The final part of the process is to make sure that health and safety regulations are met. The location of each media types has a maximum handling weight limit. The general guidelines for limits on weight lifting are shown in Figure 5.24 (Health and Safety Executive (2004, p.10). Media types can have multiple weights limits if they exist at different levels. The weight of each SKU is checked against the limits to make sure they do not breach health and safety regulations. If the weight is exceeded the SKU is allocated a new media type. If possible the same media type is allocated if at a different level the weight is not exceeded or a new type is allocated which meets the criteria.

Figure 5.24: General lifting guidelines



5.11.2 Allocation of storage location

A logical process is used to find the most efficient warehouse layout for each SKU. The products are located with respect to the quantity of their sales volume. An analysis of each SKU is undertaken from historical transaction data to obtain the total lines of billing (LOB) sold over a period of time. The LOB represents the frequency of location visitations. This measurement is used as opposed to quantities or values because it better represents the operation handling costs. The measurement is used to segment the products as being either A, B or C, for fast, medium and slow moving products respectively.

A storage location within the warehouse is classified as being:

- A 'fast moving' location adjacent to the packing and order assembly area;
- A 'medium moving' location adjacent to the fast moving product zone;
- A 'slow moving' location (C lines).

The fastest moving locations are situated in an area that requires the minimum amount of travelling distance. The product classifications are matched to a location classification of the same type. This process reduces the total amount of distance travelled by warehouse operatives and as a result increases productivity.

The design of the warehouse is effective at the time of implementation. The dynamics of products change with time so the effective design of the warehouse has to be maintained. The space which is allocated can become full if the ordering quantities are increased. As products arrive for put-away the following priorities are used to try and allocate a location:

1. Picking location.
2. Free reserve position directly above the picking location.

3. Free reserve position in the same bay directly above the picking location on the same row.

4. Free reserve position in the adjacent bay either side of the picking location on the same row.

5. Free reserve position directly opposite the picking position.

6. Free reserve position in the bay directly opposite the picking position.

7. Free reserve position in the bays adjacent to the bay directly opposite the picking position.

8. Free reserve position in the bays either side of the bay opposite the picking position.

9. Anywhere in a free reserve position on the row in the aisle to the front of the picking position (where front is defined as towards the packing and order assembly area).

10. Anywhere in a free reserve position on the row in the aisle to the rear of the picking position (where rear is defined as away from the packing and order assembly area).

11. Anywhere in a free reserve position on the opposite row in the aisle to the front of the picking position (where front is defined as towards the packing and order assembly).

12. Anywhere in a free reserve position row in the aisle to the rear of the picking position (where rear is defined as away from the packing and order assembly area).

13. Anywhere in the same warehouse zone as the picking position.

14. Placed in a ‘sin-bin’ for manual positioning by the warehouse supervisor.

Source: Slater (2008).

A free position is defined as either empty or is able to store the total inbound quantity of the SKU (even if a quantity of that SKU is stored in the location). A free reserve position represents a location which is used for bulk storage.

5.12 Inventory system design

5.12.1 System outline

The inventory system envelopes all of the policies, processes and entities involved in the management, maintenance and the flow of business stock. These components of the system are interdependent and interrelated and its state is altered when changes are made to its parameters and variables. The behaviour of the system is directly affected by the environment it operates within and by external factors. In the context of this study the boundary of the environment encompasses all of the components of the internal business supply chain.

The system is principally controlled by a computer software package called Movex which the business uses. This software is not fully automated and requires an element of human interaction. Furthermore, there are a large number of personnel who are tasked with a number of different inventory activities and are required to make management decisions on an ongoing basis. The inventory system maintains the level of stock at all branches. Each branch is maintained by one of the Purchasing and Inventory (P&I) offices. A complete list of all the branches and the P&I offices and RDC's which serve them can be seen in CD Appendix AO.

There are two types of branch, a spoke and an ordering branch. For a spoke branch most of their products are ordered directly from a designated RDC. These types of internal orders are known as a Distribution Orders (DO's). The RDC delivers the products to the branch the day after the order is placed. Movex automatically produces this type of order once the reorder point (ROP) has been triggered. The regional purchasing office places purchase orders for the majority of products that are held at an ordering branch with the relevant supplier. The supplier delivers the products which have been ordered to the branch.

The intention was to find areas of improvement through analysis and to suggest solutions. The outcomes could then be evaluated by measuring changes to supply chain performance. A simulation model of the inventory system was designed to understand the interactions between the components and to test a number of different scenarios.

5.12.2 Formulation of the problem

The mapping of all the processes provided a valuable insight into how the inventory system was designed. The analysis of the processes highlighted a number of areas where there were potential issues. A summary of the issues can be seen in Figure 5.25. A significant issue was that stock buyers, branch and P&I mangers were choosing to set the quantities for the system variables instead of allowing the computer system to calculate these automatically. The key variables of safety stock, reorder point and order quantities are manually set for the majority of products. Due to this manual intervention the quantities are not updated on a frequent basis and do not reflect up to date sales demand information. This was one of the contributing factors for the over and under stocking of products. The outcome of the profile review had showed that the levels which were set for key variables had been set too high in attempt to meet product availability targets.

The suppliers to the business offer many one off and short-term discounts. The stock buyers were increasing the size of purchase orders to meet a level of value which was required to obtain the discount. This is creating an increased level of stock holding and obsolescence. There is no clear procedure to remove the obsolete products out of the business and this is adding to the congestion within the network. Furthermore, Newlec lines are being penalised because there are no discounts offered. There is a financial loss to the business because these products have greater margins then products purchased from suppliers.

The KPI's which are designed to improve product availability is leading to knee-jerk management decisions and stock is being purchased before it is required. This is particularly evident in the percentage of A lines above safety stock target. The buyers are constantly trying to buy up to the maximum quantity level and there is a concerted effort to push customer service levels towards 100%, which is seen as the optimum level. There are more penalties against meeting product availability then there is for the level of stock being held. These factors are creating stock levels that are higher than are required and levels of safety stock which are never used.

The bureaucracy involved in the special process is resulting in inefficiencies and a higher level of staff than is required. There are long delays with many customer back orders because the invoice values do not meet the minimum buying value. This is also extending the period of time for smaller stock orders. Logistics costs are ignored during the decision making process. There is a lack of costs attributed to internal distribution movements within the internal supply chain. The stock buyers as a result can freely move stock around the network to fulfil orders. The policy not to pay supplier distribution costs means that products that don't require purchases are being added to orders to make up the minimum quantity.

The findings from the process mapping exercise were presented to the business (see CD Appendix AP). A number of possible solutions were suggested to reduce operational costs. The major problem is in the design of the inventory system. The methods which are used to calculate the reorder points, safety stocks and forecasts are very basic and the same for all types of products. It is clear that more sophisticated methods could yield better results. A simulation model could test various scenarios against the current model to determine the possible impact to the business. The model is to focus on the stock replenishment part of the process and not to include special orders. The effect of BGB is not to be included in the model because it is too complicated and requires a separate in depth study.

A practical objective of this research programme was to find methods to improve a number of selected supply chain performance measures. These measures are as follows:

- stock value;
- stock turnover;
- stock availability;
- stock-out days;
- customer stock-outs;
- number of purchases.

They are to be improved at both an aggregated regional and branch level and at an individual product level. There is a level of difficulty in finding improvements in all of the measures. This is because of the trade-offs that exist between the various measures. An improvement in one method could cause a reduction in another. It would be ideal to show the total effect on contribution to profit but this is difficult to achieve and would involve too many assumptions and therefore wouldn't be an accurate method. The outcome of the results will have a subjective element but logic will be applied to the conclusion to try to argue that contribution to profit would be increased if the strategy is implemented.

Figure 5.25: Summary of issues

Issue	Explanation	Warrington	Avonmouth	Leeds	Kirkcaldy
Forecast Alarms	Has to be resolved by manually by going into each alarm. This takes a considerable amount of man power considering that most products are set to manual and aren't directly affected. Many of these will are slow moving products where the actual value is small but the percentage large.	X	x	x	x
Fill to Max Report	Used to generate orders. Stock holding will therefore be higher than the reorder point system.			x	
Manual Purchase Orders	It takes longer than automatic generated orders.			x	
Spreadsheets	Large number of spreadsheets that take time to produce and much of the information is taken from Movex.	X	x	x	x
Purchase Orders Same Day	Can't verify orders against over max and stock cleanse reports before sending to suppliers.		x		x
Purchase Orders Next Day	Lose a day in the ordering cycle.	X		x	
Diary	Dynamic ordering cycle.		x	x	x
Deals	Purchase orders created to match deals. This increases stock holding. There are gains from BGB.			x	
One of Deals	Increases stock holding and obsolescence. There are gains from BGB	X	x	x	x
Supplier Agreements	Supplier agreements not set up on system so have to be entered manually		x	x	x
Stock Profile Policy	Branches can decide how much stock they can hold. This will increase stock holding. These are only updated approx every 6 months so therefore there is no reaction to changes in demand.	x	x	x	x
Specials	Approximately takes up 4-6 people per P&I office. This task could be completed by the branch.	x	x	x	x
Special Queries	Dealing with price errors, delivery costs, cancellations & other queries takes up the majority of the time involved in the entire special process	x	x	x	x
Lead Time	Lead times on the system are not realistic. If they were set to automatic could increase stockholding or create stock-outs	x	x	x	x
KPIs	These tend to drive up stock. This is especially true in Leeds where they will increase their buying amounts if KPIs fall below their targets. Some of the KPIs are out of the control of purchasing	x	x	x	x
Automatic Forecasting	The moving average calculation doesn't work very well with seasonal, slow moving and some MSIB products.	x	x	x	x
Customer Back Orders	There are long delays with some orders while the minimum order quantity is reached.	x	x	x	x
Distribution Costs	There are a lack of costs attached for moving products around the country. There are therefore a lot of out of region moves.	x	x	x	x
Supplier information	Each P&I office has their own supplier information because the information on Movex is inadequate.	x	x	x	x
Special Prices	Some branches aren't checking prices with suppliers which increase the special queries. Having to place orders with a quote could prevent this.	x	x	x	x
Customer Service Level	Safety stock tends to viewed as the minimum level to achieve the desired customer service level. The average stock holding level is increased as a result.	x	x	x	x
Newlec Lines	These lines caused be penalised as there are no deals.	x	x	x	x
Automatic Replenishment	There are products that could be set up to be automatically ordered reducing the purchasing time spent.	x	x	x	x
Park Royal	This RDC is less accommodating then the over RDCs. They are less likely to share BGB and will not a lot manual distribution orders, which are therefore sent through Crawley		x		
Milton Keynes	Some suppliers won't give deals for KMK purchases so they are being ordered through Avonmouth and then sent to KMK as a distribution order.		x		
Stock Profile	There are two stock profiles for logistics and purchasing. There are mixed procedures and causes confusion.	x	x	x	x
Obsolete Stock	There is no clear procedures for removing obsolete stock	x	x	x	x
P & I Team Database	Setup to perform queries that Movex can't do. Data has to be downloaded from Movex and then uploaded to database	x	x	x	x

5.12.3 Type of Simulation method

The analysis of 50 SKUs which is discussed in Chapter 6 shows the different patterns of behaviour of stock. The different issues which are highlighted can lend themselves to either a System Dynamics (SD) or a Discrete Event Simulation (DES) approach. The external factors have a non-linear element and are better suited to a study which uses an SD methodology. A study of the issues internally generated by the inventory system is suited to a DES methodology. The system has elements of both a continuous and discrete nature. A combined model approach is shown by Banks (1998, p.46):

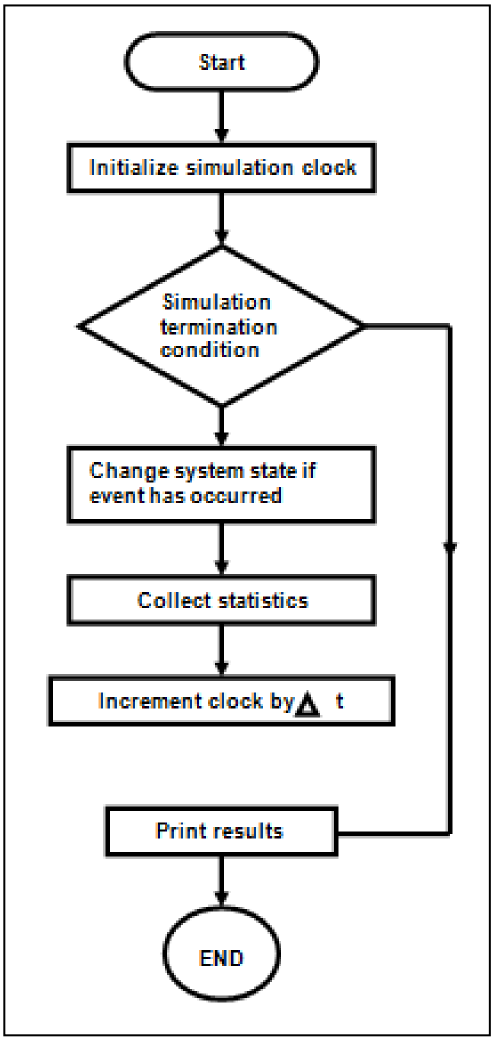
> “The world view of a combined model specifies that the system can be described in terms of entities, global or model variables, and state variables. The behaviour of the model is simulated by computing the values of the state variables at small time steps and by computing the values of attributes of entities and global variables at event times”.

A DES model is designed by creating a number of activities. Activities are activated by the occurrence of an event. The ending of an event determines the activities to be next activated. Once an activity has been initiated it alters the value of objects. The objects as shown by Thierry *et al* (2008, pp.70-71) can be either:

- entities that are transformed by the activities;
- or resources used to make this transformation.

The state of the system is a function of the attribute value of all objects, which can be either static or variable (Thierry et al, 2008). Neelamkavil (1987, p.137) shows the general structure of a DES model (see Figure 5.26). The model uses a uniform increment of time for each run. After each period the model starts back at the beginning. The state of the system is changed if an event has occurred. These changes are then collected via statistics and the results generated at the end of the model run.

Figure 5.26: Discrete event simulation model



5.12.4 Software choice

There are many different simulation software packages available on the market. A list of some of these can be seen in Figure 5.27. These are categorised by the methodological approach on which they are based upon. There is a growing need for the development of hybrid software packages which combine both discrete and continuous event simulation. GoldSim Technology claim that their GoldSim package is a hybrid simulator.

Figure 5.27: Software packages

Continuous	Discrete	Hybrid	Simulation languages	Programming languages
Vensim	Micro Saint	GoldSim	SIMAN	FORTRAN
Stella	Arena		SMSCRIPT	C, C++ C #
PowerSim	WITNESS		SLAM	Visual Basic
	SIMUL8		GPSS	PASCAL
	SIMFACTORY		GENETIK	
	ProModel			
	FlexSim			
	ShowFlow			

The decision to select the most suitable software can be first considered by choosing a product which uses the appropriate simulation methodology. This is because different methodologies are better matched to different types of problems and upon the type of solution being sought. To narrow down the search a number of further can be taken into account. A number of possible factors shown by Greasley (2004, p.29) and Neelamkavil (1987) are listed below. In reality it is possible that a modeller may use the software that they are familiar with.

- quality of vendor (current user base, revenue, length in business);
- technical support (type, responsiveness);
- training (frequency, level, on-site availability);
- modelling services (e.g. consultancy experience);
- cost of ownership (upgrade policy, run-time license policy, multi-user policy;
- the availability of the language;
- ease of installation and use;
- understanding of simulation concepts and ease of learning the language by the local staff;
- accuracy of simulation results;
- facilities for collection, analysis, and display of results;
- availability of user-friendly.

5.12 Chapter summary

This chapter has outlined the methods which were used in the application of the research programme. The qualitative and quantitative methods were shown. The methodology is designed to test the research aims within a case study environment. The case study is split into three research projects and the segmentation framework outlined within this chapter was tested in each study.

The products which are stored within the South West region and the customer base were segmented into the categories as shown. It was proposed that the regional supply chain and the RDC at Avonmouth would be redesigned around these categories. The warehouse methods outlined were used to redesign the current layout. The aim was to make the warehouse more efficient by moving the fastest moving products into better locations. This was to reduce walking distances and improve productivity. The methods used to design a simulation model were shown. This model is designed to test whether a segmentation strategy would produce better results than the current 'one size fits' all approach. The next chapter shows the results and findings of the research case study.

CHAPTER 6

6 A CASE STUDY OF THE APPLICATION OF A SUPPLY CHAIN SEGMENTATION STRATEGY

6.1 Introduction

This chapter shows the results of a case study where a segmentation strategy was applied within the company Newey and Eyre. The case study is carried out as a research programme and split into three research projects. The first two are based within the South West region of Newey and Eyre (N&E) and the second is a study of the companies inventory system.

The initial analysis which was conducted at Warrington RDC provided some indicators of the state of the business. This was taken further and a longer time scale was used. The methodology which was laid out in Chapter 5 was used in the analysis of the South West region. Transaction data from the period of 2006 is used. A minimum period of a year was required to reduce the risk of any long term and seasonal trends being excluded from the analysis. There are two transaction files which are used in this analysis; the entire region of 29 branches including the RDC; and the RDC independent of the region.

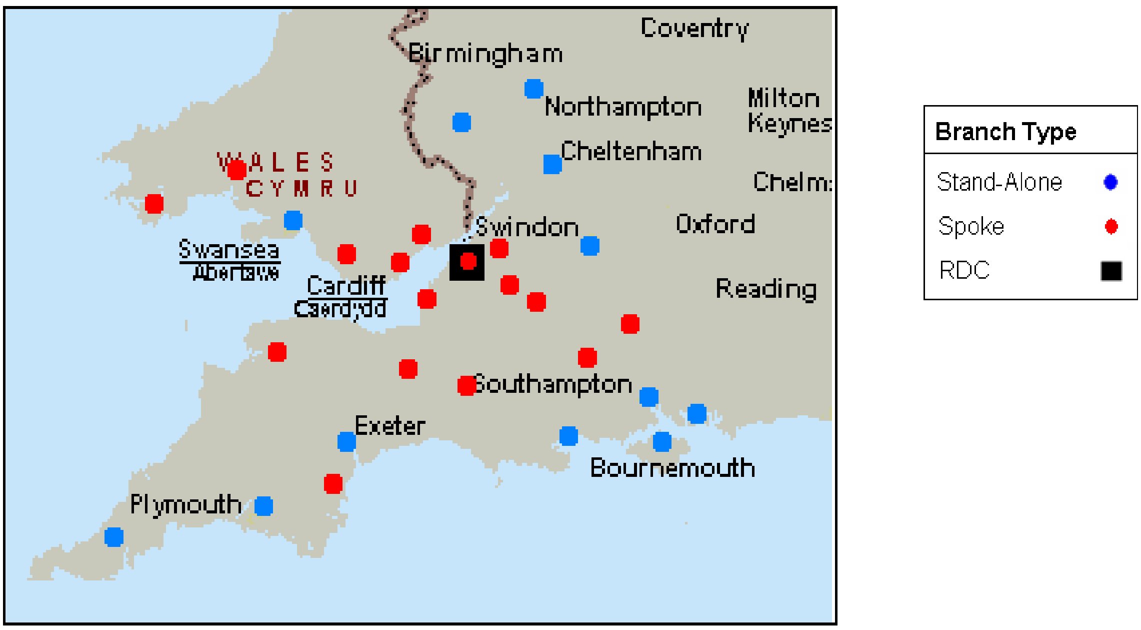
This analysis was used to show how the region was performing in terms of profitability and what effect logistics costs have on margins. This led to two research projects being carried out, within the South West region, to attempt to solve the issues highlighted in the results.

6.2 South west region research project

6.2.1 South West region overview

A map of the South West region[18] which shows the locations of the branches and the RDC at Avonmouth is shown in Figure 6.1. The list of the branches, the types and postcode locations are shown in Figure 6.2. The South West region consists of 29 branches, 22 of which are in England, 1 in Guernsey and the remaining 6 are located in Wales. The branches are either classed as an ordering or spoke branch. An ordering branch sources the majority of its products directly from suppliers and conversely a spoke branch sources the majority of its products from the RDC. The RDC which supports the branch network with replenishment stock is strategically located at Avonmouth. In 2006 the region had a sales turnover in excess of £45m, after selling approximately 24,000 different products to approximately 15,000 different customers.

Figure 6.1: South West network map



[18] The branch at Guernsey is excluded from the diagram.

Figure 6.2: South West network detail

Branch name	Branch code	Type	Postcode
Avonmouth	AAV	RDC	BS11 9QD
Cheltenham	ACQ	Ordering	GL52 6QU
Exeter	ADW	Ordering	EX2 8NY
Guernsey	MEH	Ordering	GY1 2BF
Hereford	AEN	Ordering	HR4 9RT
Newport (IOW)	AFU	Ordering	PO30 5FA
Plymouth	AGJ	Ordering	PL6 7PY
Poole	AGK	Ordering	BH12 3LL
Portsmouth	AGM	Ordering	PO3 5RU
Southampton	AHH	Ordering	SO14 5JP
Swansea	AHS	Ordering	SA1 5JR
Swindon	AHT	Ordering	SN5 8WQ
Truro	AHY	Ordering	TR4 9LE
Worcester	AJK	Ordering	WR3 8SG
Andover	ABD	Spoke	SP10 3LF
Barnstable	ABI	Spoke	EX32 8PA
Bath	ABK	Spoke	BA2 3QS
Bridgend	AJC	Spoke	CF31 3SH
Bristol	ACC	Spoke	BS2 0XJ
Cardiff	ACL	Spoke	CF24 5PB
Carmarthen	AJF	Spoke	SA31 3RB
Newport	AFV	Spoke	NP20 5JJ
Newton Abbott	AFW	Spoke	TQ12 4PB
Pembroke Dock	AGF	Spoke	SA72 4RS
Salisbury	AGY	Spoke	SP2 7HL
Taunton	AHV	Spoke	TA1 2AL
Weston Super Mare	AIE	Spoke	BS24 9DJ
Yate	AIO	Spoke	BS37 5YS
Yeovil	AJX	Spoke	BA22 8HU

6.2.2 Product and customer sales analysis

The transactions for the region cover all of the customer sales throughout the branch network and the RDC at Avonmouth. Distribution sales are excluded from the RDC because they are included as part of the branch transactions. The two graphs represented in Figures 6.3 and 6.4 shows the results of the analysis of cumulative sales for products and customers respectively. The regional sales for both products and customers show a similar result to the analysis undertaken at Warrington RDC.

In 2006 approximately 27,000 different SKUs were sold at least once within the region. A very small number of products and customers are contributing to a large majority of the total sales revenue. The table in Figure 6.5 is broken down by rows incremented by 10% for the cumulative sales of products and customers. The disparity is clear between different products and customers. Less than 10% of products and 5% of customers contribute to 80% of the total share of cumulative sales value. Only 90 customers of the total 14,687 customers contribute to half of the total sales value for the region. These are key products and important customers for the business because they represent such a large quantity of contribution to the total sales value. It is paramount that these products are reliably available and the customers are served efficiently.

The darkest shaded areas of the graph represent the final 5% of the total cumulative sales value. In both instances it is quite clear to see that there are a very large number of products and customers which contribute very little sales value for the business. An analysis was undertaken to calculate the amount of value of stock that is obsolete. Newey and Eyre define an obsolete product as having no sales in the previous six months. The results showed that within the region there is £1.4 million worth of obsolete stock being held.

Figure 6.3: Cumulative product sales South West region (2006)

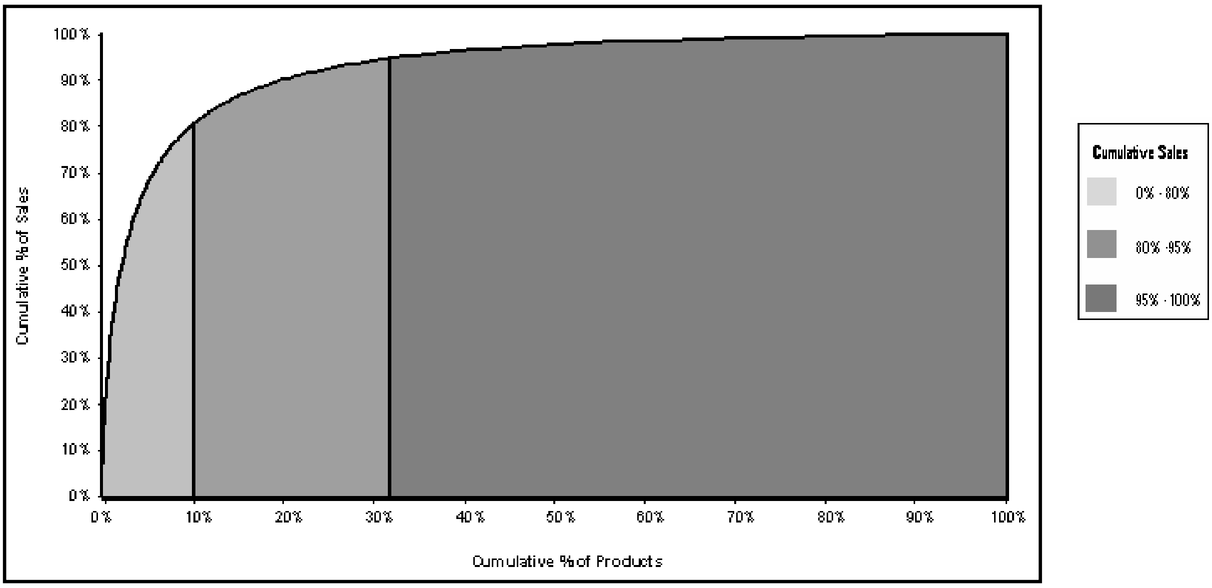


Figure 6.4: Cumulative customer sales South West region (2006)

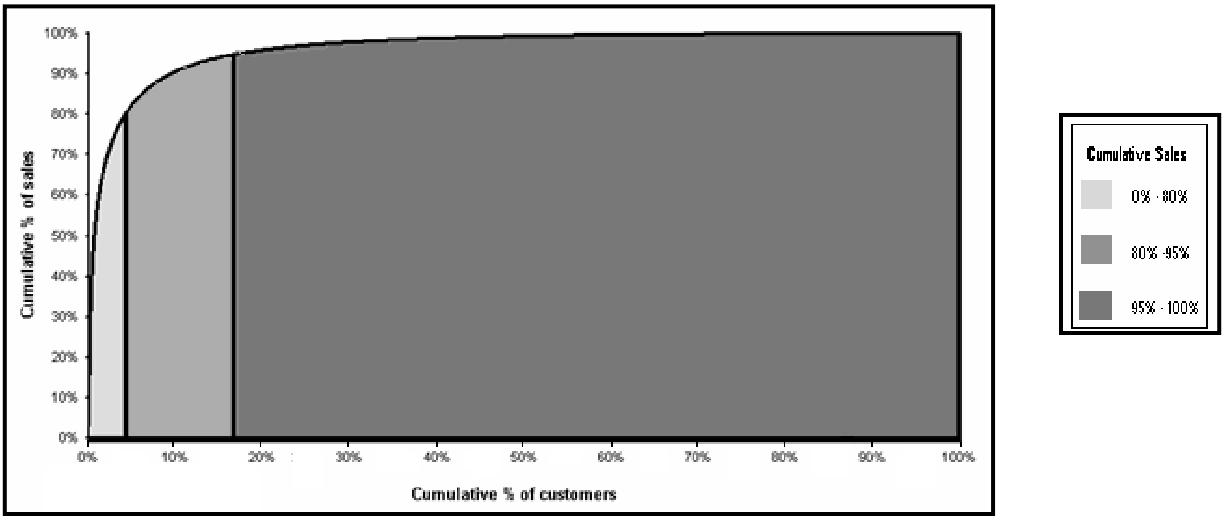


Figure 6.5: Cumulative product and customer cumulative sales
In the South West region (2006)

Cumulative % of sales	No of products	% of products	No of customers
10%	29	0.12%	5
20%	80	0.34$	15
30%	169	0.71%	29
40%	306	1.29%	50
50%	513	2.16%	90
60%	825	3.47%	165
70%	1,339	5.64%	313
80%	2,303	9.70%	611
90%	4,683	19.72%	1,380
100%	23,748	100.00%	14,687

The same method which was applied to the analysis of the region was used to analyse the Avonmouth RDC transaction data. The results of the analysis for product and customer cumulative sales values in 2006 are shown in Figure 6.6 and Figure 6.7. In 2006, 14,816 different SKUs were sold and 9,804 customers placed at least one order. The graphs show a similar trend to which was previously shown in the analysis of total regional sales. A small proportion of products and customers are contributing to a large majority of the total sales value.

The results show that half of the total sales value for Avonmouth RDC is created by less than approximately 5% of products and 2% of customers respectively. The results for customer sales value show a more extreme trend than products sales. Much as 90% of the total sales value is represented by less than 20% of the customers. A summary of the results in split into rows of 10% for products and customers is shown in Figure 6.8.

Figure 6.6: Cumulative product sales at Avonmouth RDC (2006)

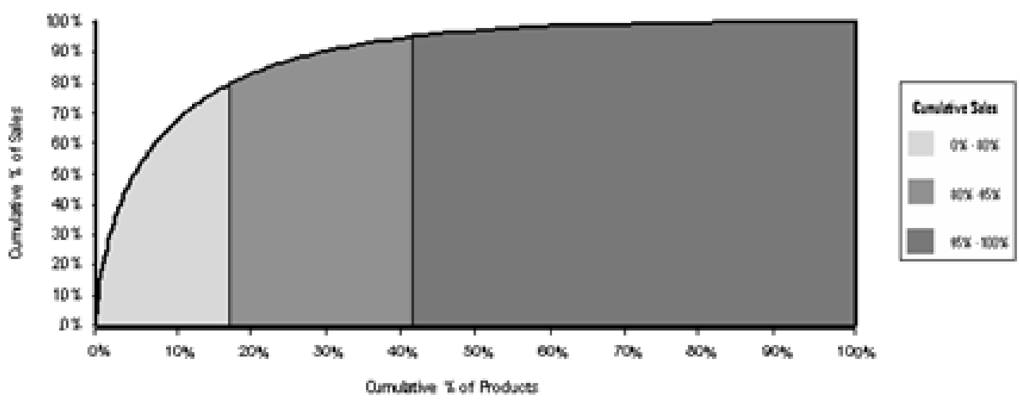


Figure 6.7: Cumulative customer sales at Avonmouth RDC (2006)

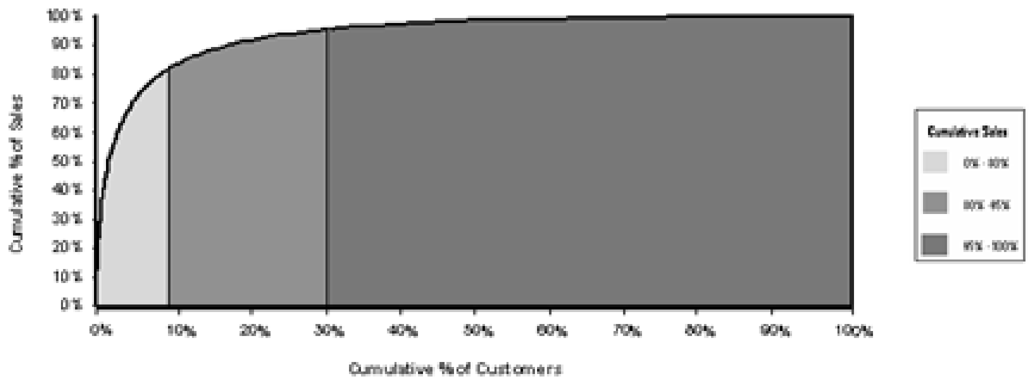


Figure 6.8: Cumulative product and customer cumulative sales at Avonmouth RDC (2006)

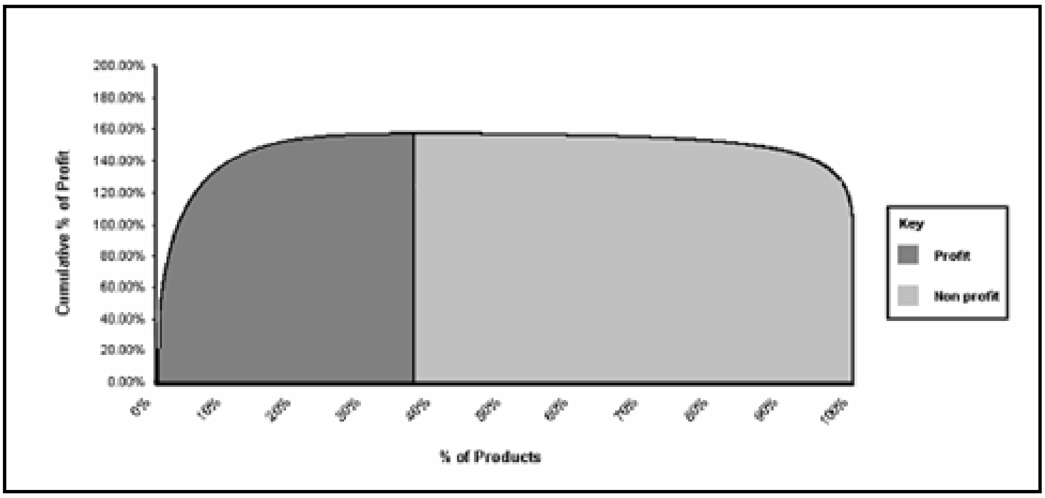
Cumulative % of sales	No of products	% of products	No of customers
10%	48	0.34%	6
20%	141	0.98$	20
30%	280	1.96%	49
40%	472	3.30%	97
50%	744	5.20%	169
60%	1,139	7.96%	284
70%	1,715	11.98%	479
80%	2,624	18.33%	846
90%	4,328	30.23%	1,738
100%	14,318	100.00%	9,804

6.2.3 Contribution to profit analysis

The sales analysis shown in the previous section was unable to show what the actual value in terms of profit is to the business. It is possible for a product to exhibit high level of sales but is actually doing so at a loss to the business. The contribution to profit of each SKU provides a better understanding of the actual value to the business. The contribution to profit for each SKU is calculated by removing the logistics costs of handling, storage and transport from the net margin. The net margin is the difference between the unit cost of purchase and the invoice price it is sold for. The results of cumulative percentage of contribution to profit in 2006 at Avonmouth RDC are shown in the graph in Figure 6.9.

The darkest shaded area represents the products which are returning a profit and the lightest shaded area represents products which are returning a loss. The logistics costs reduced 60% of the product net margins to a negative profit. The same trend was evident in the profit analysis undertaken at Warrington RDC. The results indicate that there is an issue with the amount of logistics costs.

Figure 6.9: Cumulative product contribution to profit at Avonmouth RDC (2006)



A breakdown of logistics costs by month for 2006 is shown in Figure 6.10. The majority of costs are handling costs which on average contribute to approximately 60% of the total costs. The warehouse costs, handling and storage combined account for approximately 85% of the total costs. The warehouse costs are rendering many of the products unprofitable. The data suggests that an oversized workforce because of a low productivity is one of the main reasons for this. The congestion in the warehouse is resulting in low levels of productivity.

Figure 6.10: Logistics costs by month at Avonmouth RDC (2006)

	% of total costs		
Month	**Handling**	**Storage**	**Transport**
January	62.66	20.04	17.30
February	60.30	20.52	19.18
March	59.57	21.86	18.57
April	65.49	15.67	18.84
May	66.77	16.06	17.17
June	61.19	25.87	12.94
July	46.00	42.95	11.05
August	60.63	24.76	14.61
September	61.53	31.21	7.26
October	54.54	33.37	12.09
November	53.28	34.37	11.79
December	51.24	34.96	13.80
Average	**58.65**	**26.80**	**14.55**

6.2.4 Issues

The review of the South West region provided an insight into the business and highlighted some of the issues. The main issue is that excessive logistics costs are rendering 60% of the products unprofitable typically mainly as a result of high warehouse costs. The business strategy which seeks to increase service levels has further added to the increase in logistics costs. There is a perception that excess stock quantities held throughout the supply chain is the primary causal factor for the reductions in productivity, customer service levels and increases in operational costs. The length of time it takes to pick and put away products is very unproductive. There are a large number of employees because the operation is functioning unproductively. A breakdown of the warehouse workforce is shown in Figure 6.11. It is the belief of the business that the workforce can be reduced by 4 employees if the warehouse was functioning more effectively

Figure 6.11: Workforce

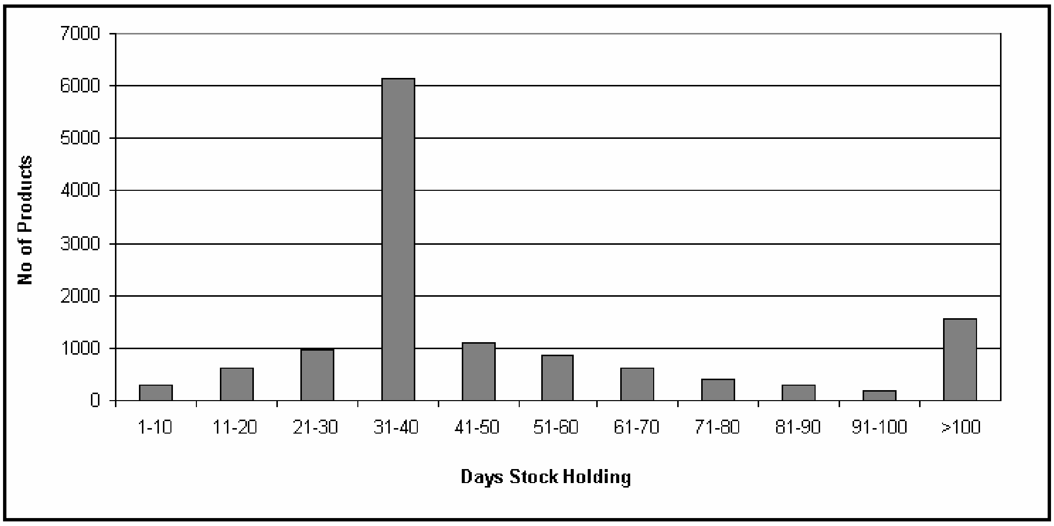
Task	Shift 1		Shift 2	
	Number of Staff	Working hours	Number of staff	Working hours
Put away	7 + 2 Supervisors	6am - 2pm	0	12am - 8pm
Picking	4 + 1 Supervisor	6am - 2pm	11 + 1 Sup	12am - 8pm

- On average there is 10 hours a week worked overtime in put away (shift 1).
- Each person is entitled to a 30 mins break. This is either as a one 20 minute and two 5 minute breaks or a one 30 mins break.

An analysis of inventory levels was undertaken to determine the quantity of stock being held and the rate at the rate of turnover. An analysis of stock turnover shows how quickly the stock is being sold at a particular point in time. In this case the snapshot of the balance of stock on hand is taken from December 2006. The average amount of time it takes for an SKU to be sold is calculated from the balance of stock held divided by an estimation of the average daily sales.

The results of the stock turnover analysis are represented in the graph in Figure 6.12. The diagram shows only the products which are held at the end of December in 2006. The assumption that the business is holding too much stock is justified in the results. The results showed that the 8,168 SKUs had an average stock holding of 170 days. This is 35, 36 and 187 days for A, B, C lines respectively. The average of approximately 7 weeks stock for A and B lines is higher than what is expected by the business. This extra quantity of stock was resulting in a congested warehouse.

Figure 6.12: Stock turnover at Avonmouth RDC (December 2006)



An analysis of the last supplier purchase provides further evidence of the low rate of stock turnover. The results are shown in the graph represented in Figure 6.13. Products that are purchased on a regular basis have a high turnover rate. The results show that on average it is 10 weeks before a purchase is made. This is 4.5, 5.7 and 11 weeks for A, B and C Lines respectively.

An analysis of the percentage of the total stock holding per type of branch is represented in Figure 6.14. This is undertaken to determine which type of branch is holding the most stock. The results of the analysis show that ordering branches hold a higher level of stock then the spoke branches. The ordering branches purchase the majority of their products directly from a supplier. The lead times are greater on average for deliveries by a supplier than from the RDC. The ordering branches control the quantity of replenishment stock which is purchased. The combination of these two factors creates the greater levels of stock held at ordering branches.

Figure 6.13: No of weeks since last supplier purchase
Avonmouth RDC (December 2006)

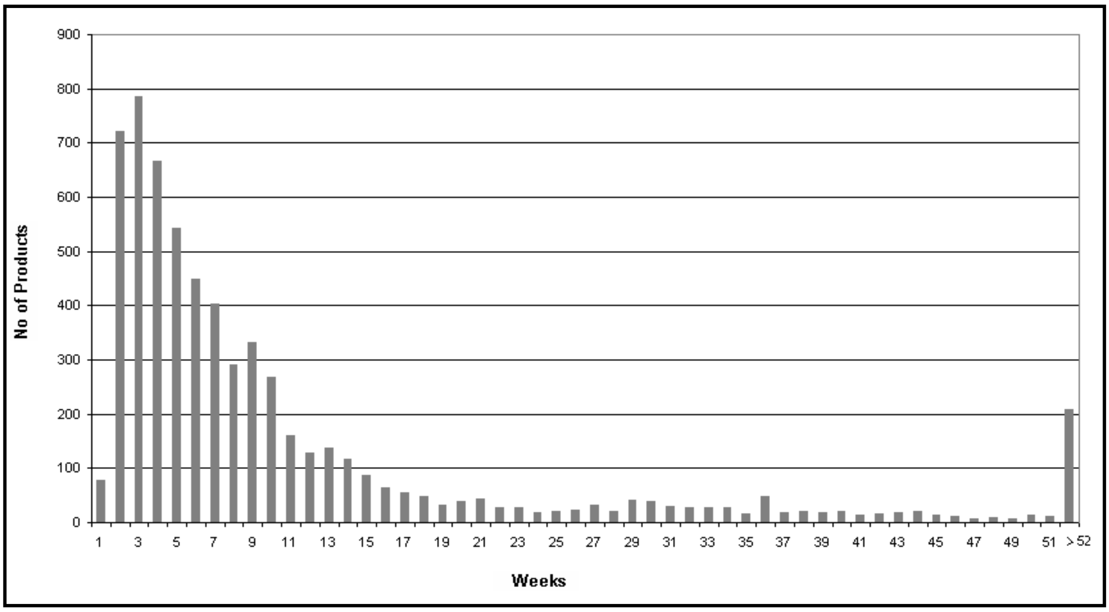
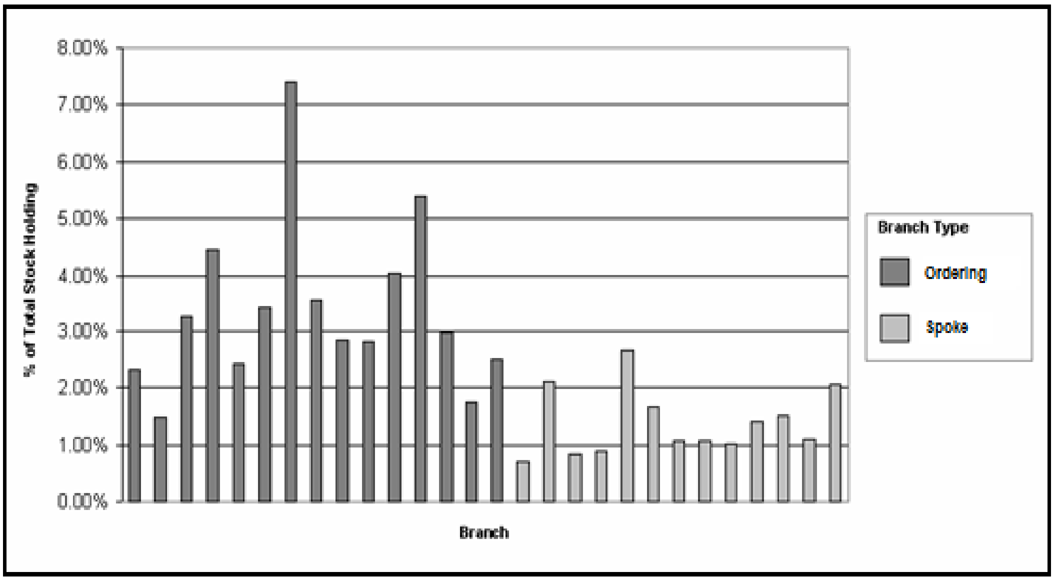


Figure 6.14: Percentage of total stock holding by branch
South West region (2006)



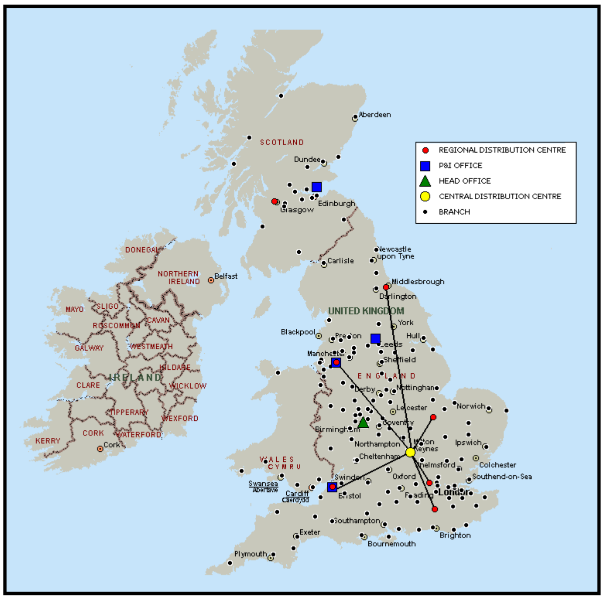
6.2.5 Research project one - Supply chain redesign

The first research project was designed to solve the supply chain issues which were being experiencing in the south west region. The major problem was with the level of stock congestion at the branches and RDC at Avonmouth. This was due to a large number of slow moving and obsolete stock. A segmentation strategy was used to reduce this congestion by showing how to manage the different types of products and customers better.

The concentration of slow moving stock reduces the overall levels held for each SKU. The products which remain at the RDC at Avonmouth have an increased burden of the logistics costs because there are fewer products. The reduction in congestion however should offset this because productivity is increased. A future objective is to implement a solution where the CDC supports all of the regions with slow moving products. The revised geographical layout of the network is shown in Figure 6.15.

The sales turnover of customers showed that a small proportion of key customers are contributing to a large majority of the total value. The service level that the business offers for all its customers is the same. There is a finite amount of operational resource so on many occasions the key customers can suffer a reduced service level if the business attempts to serve all customers with the same level. The results showed that the business is supplying their competitors with the same level of service as their key customers. The competitors are buying small quantities of slow moving stock to fulfil orders that they cannot meet. These types of orders are shown to be unprofitable.

Figure 6.15: Newey and Eyre network



The transport costs can be reduced by matching the type of customer to a differentiated level of service. The service levels represent the speed of delivery service to the type of product. The key customers receive the best service level and the competitors the worst. If the customer is new the branch will decide initially the appropriate service level. The customer service level matrix is shown in Figure 6.16.

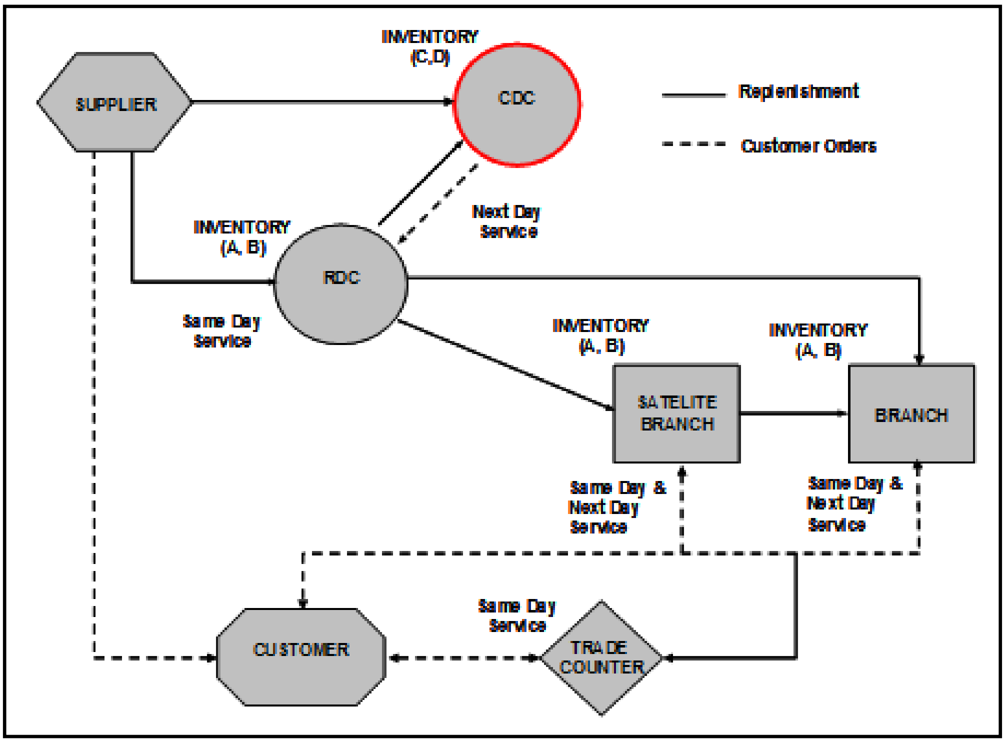
Figure 6.16: Customer service level matrix

Customer	Service Level			
	Same Day	Next Day	2-3 Days	5 Days
Key	A, B, C		S	
Core	A, B	C		S
Occasional	A, B Collection	C		S
Competitors	A, B Collection		C	S

C = Collection
S = Surcharge

The redesign of the supply chain with respect to the locations of the different types of products and the service levels are shown in Figure 6.17. The slow moving products which are required by the branches are sent from the CDC via the RDC to the branch.

Figure 6.17: Proposed design of the regional supply chain



6.2.6 Research project two - Warehouse redesign

The reasons for the movement of C2 lines to the CDC are outlined in the previous section. This has to be implemented before the changes can be made to the RDC. The extra space is required to move around products more freely. There is also no point in reallocating products to new locations if they are then moved at a later date.

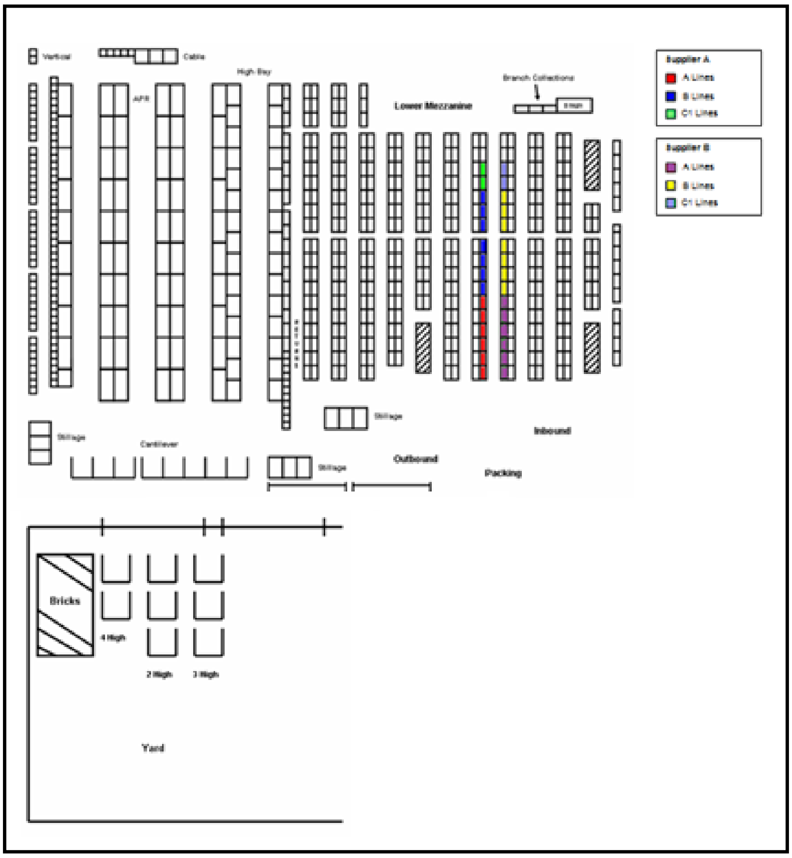
The second stage was to perform a stock management and process audit. The current methods were audited to get an understanding of how the operation was functioning. This helped to identify a number of issues with the working practices. The outcome of this was to change the stock put-away procedures so that once the solution was implemented the products would continue to be effectively managed.

Each SKU is allocated a storage media type using the methodology outlined in Chapter 5. There are ten different media types. The stock type, size and weight requirement of the product are used to determine the correct storage media type. Products such as wire and sheet metal are allocated to a certain media type. If the weight requirement exceeds 40kg it must be allocated to a pallet.

The quantities required for some of the new storage media types is greater than that is currently available. Changes to the exterior and interior are to be made to adapt to the new solution. A canopy is erected outside to store large stillages and free up extra space inside the warehouse. Alterations are required to add more pallet spaces. Extra racking is added to the APR zone of the warehouse so pallet spaces can be increased.

The products are allocated a picking and bulk location by the volume of LOB and grouped by supplier. The products are grouped by suppliers to improve the rate of put-away. This is because deliveries are received individually from suppliers. This has the effect of reducing the picking rate but not overall operational efficiency. The products are then positioned by classification of either A, B or C. The fast moving products are positioned in a favourable position so that the pickers can access them easily with minimum walking distances. The slower moving products are positioned further away. Any products which are classed as obsolete are removed from the RDC and therefore not allocated a position. An example of the design solution of the warehouse is shown in Figure 6.18. It shows how the products are grouped by supplier and product classification.

Figure 6.18: Avonmouth RDC lower warehouse ground floor and yard



6.2.7 Findings

The research project was deemed to be successful and it was decided that it would be implemented to the rest of the supply chain. The contribution to profit analysis can then be undertaken to determine the effect the solution had on logistics costs. The total line and cost reduction for C lines for the business will then be known. It is expected that the total number of C lines within the business will be reduced from the consolidation process which will take place. The fixed logistics costs will be further reduced when the C lines products from the remaining RDC's and branches are relocated to the CDC.

These solutions do not solve all of the inventory issues which were highlighted. The turnover levels will be reduced with a reduction in lines. To reduce these levels further a research project was required which evaluates how the products are managed by the inventory system.

The implementation of the solutions created some immediate benefits. The benefits from the changes to the operation are visually observable. The removal of the slow moving and obsolete products has created extra space. It is easier to walk around the warehouse because the congestion has been removed. The warehouse is better organised so productivity levels are increased. The redesign of the warehouse and the movement of stock to the CDC has freed up space and increased the efficiency of the operation. The increases in efficiencies and reduced level of picking have seen an improvement in the levels of productivity. Manning levels have been reduced by 15%.

As part of the location process the products are amalgamated into one easily identifiable location. The products are counted and any differences in the balance of stock changed. An inventory controller is employed on an ongoing basis to test the accuracy of stock. These two methods have increased the ease of which the right products can be easily located. Prior to the research project the stock accuracy[19] was 82%. The changes have seen the accuracy of stock rise to 98%.

6.3 Research project three - Inventory system

6.3.1 Inventory system overview

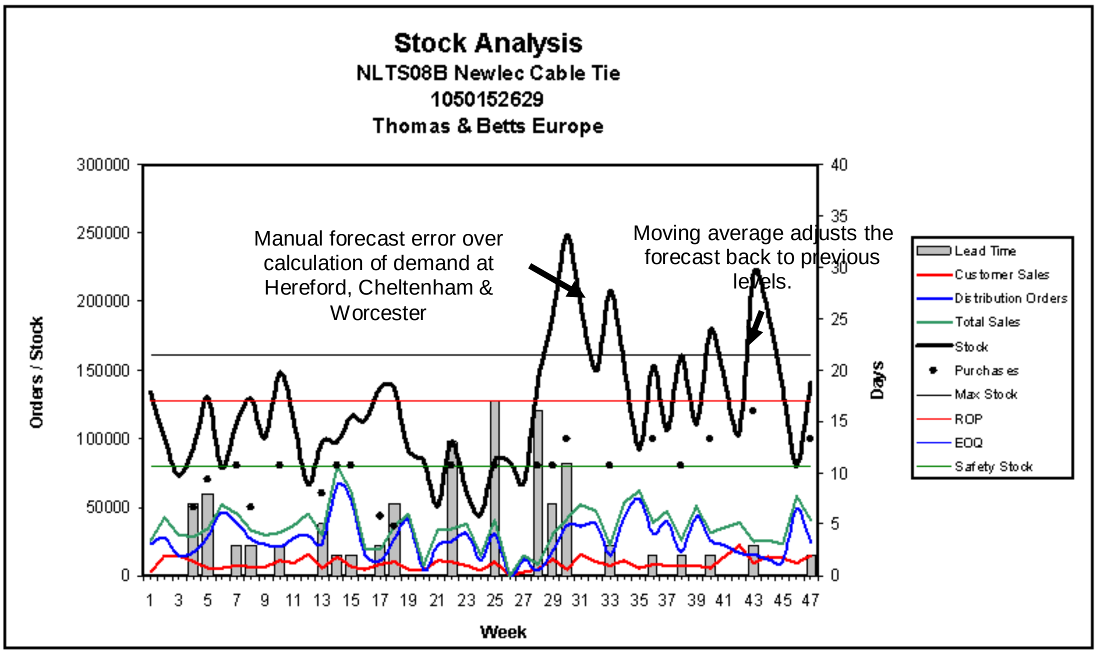
The final case study presents an investigation of the current inventory system and results of a simulation model which shows the improvements which can be gained from a segmentation methodology. The research project which was presented previously showed that a reduction in the total number of Stock Keeping Units (SKU's) had be gained. This did not solve the problem of the level of stock for each individual SKU. An analysis of 50 randomly sampled SKUs was undertaken to provide some insight into the behaviour of stock levels. The sampled results (see Appendix 3) show that the behaviour of

[19] Stock accuracy is a measure of the level of accuracy between what is recorded on the computer system and what is actually held in the warehouse.

stock levels is erratic. The stocks range from periods of low levels which result in stock-outs to periods where there are excess levels. There are high variations in lead times and purchasing order quantities. The turnover of stock is low for the majority of the products.

An analysis of six of the SKUs was undertaken to determine the underlying reasons for the erratic stock behaviour. An example of one of these graphs is shown in Figure 6.19. The graphs of the remaining five SKU's can be found in appendices 4-8. The SKU is representative of the typical patterns exhibited. The stock buyers are interviewed to provide reasons for any large changes and increases to stock levels and periods of stock-outs. The reasons are either a result of external factors or are internally generated. The external factors included changes to raw material prices and to Government legislation such as the WEE Directive.

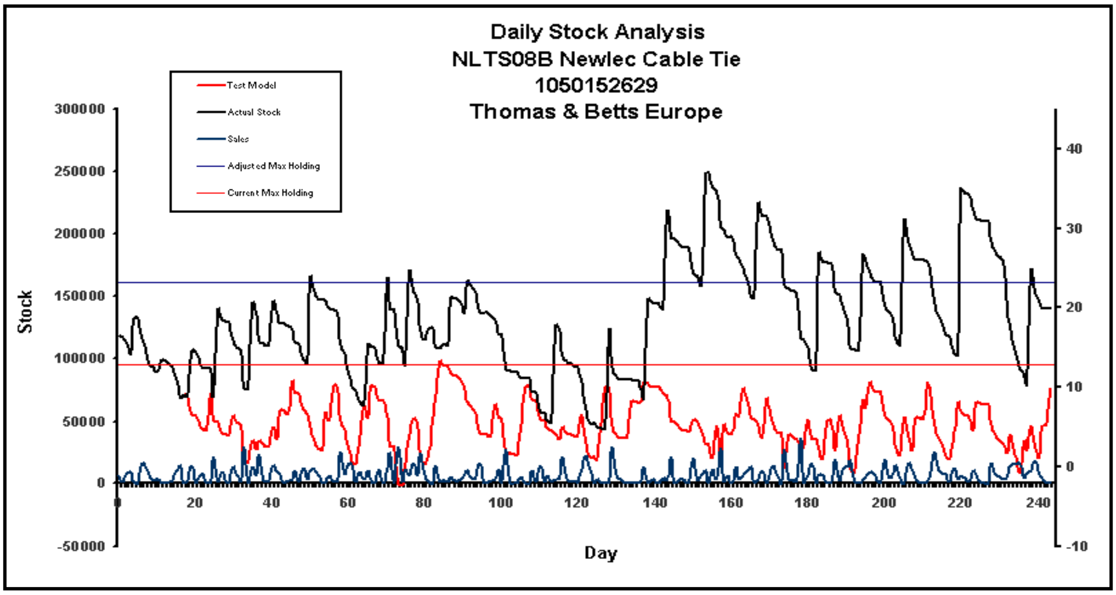
Figure 6.19: Stock analysis (SKU 1)



The internal factors related to the design of the inventory control system and how employees are interacting with it. The methods used for forecasting, order quantities and safety stocks are having a large influence on the total level of stock held. The buyers are making manual changes to quantities to try and react to external factors or to improve on key performance indicators. There are changes to safety stock levels for example to try and react to large swings in supplier lead times. Furthermore, mistakes in stock counting mean the wrong level of stock is recorded on the computer system.

The actual sales data from the six SKUs were used to test the effect on the levels of stock holding by applying different forecasting techniques and parameters. A spreadsheet model was designed to compare the current model against the test model for each of the products. A period of a year is used for the sales data. The test model used an exponential smoothing forecast an EOQ and normal distributed safety stock techniques. An example of an SKU which was tested is shown in Figure 6.20. The remainder of the products can be seen in appendices 9-13. The product was assigned a moving average forecasting technique and an estimated lead time of 10 days. The quantities for safety stock and purchase order quantity are manually calculated. It is clear in the graph that the level of stock on hand is reduced significantly and is less erratic. This is because the techniques used are better matched to the type of product then in the current system, where a mathematical approach is not used.

Figure 6.20: Comparison of actual and test model (SKU 1)



Method	Current model	Test model
Forecast	Moving average	Exponential smoothing
Safety stock	Manual input	Normal distribution
Order quantity	Manual input	EOQ
Lead time	10	4

The summary of results for the six test products are shown in Figure 6.21. All of the SKUs showed a reduction in stock levels. This was at the cost of extra stock-outs for some of the products. This could be because one of the techniques was not best suited to the type of product. The overall results showed a decrease in stock levels of 31%. The test shows that it is possible to use different inventory control models to better maintain the average levels of stock, provided that a small increase in stock-outs are acceptable.

Figure 6.21: Summary of stock reduction analysis

SKU	Stock reduction	Extra stock-outs
1	55%	0
2	0.15%	0
3	49%	2
4	54%	1
5	0.05%	1
6	54%	1

The spreadsheet model has some limitations. It is a time consuming process to design a model for each product and a small number of parameters are used. The model makes many assumptions about the design of the inventory system and is biased to a degree against the results of the current model. This test, albeit a simple one and conducted using only a few products showed that changes to the inventory system could yield some potential benefits. A more detailed analysis was required which uses a larger number of products and a better representation of the inventory system.

The implementation changes to both the design of the supply chain and to the layout of the regional distribution centre (RDC) improved productivity and reduced overall stock levels. By improving service levels for key customers and reducing levels for customers which add little value, operational costs were reduced further whilst the correct level of service was maintained or improved. The combination of these measures ultimately substantially reduced working capital requirements and increased profit in the long term.

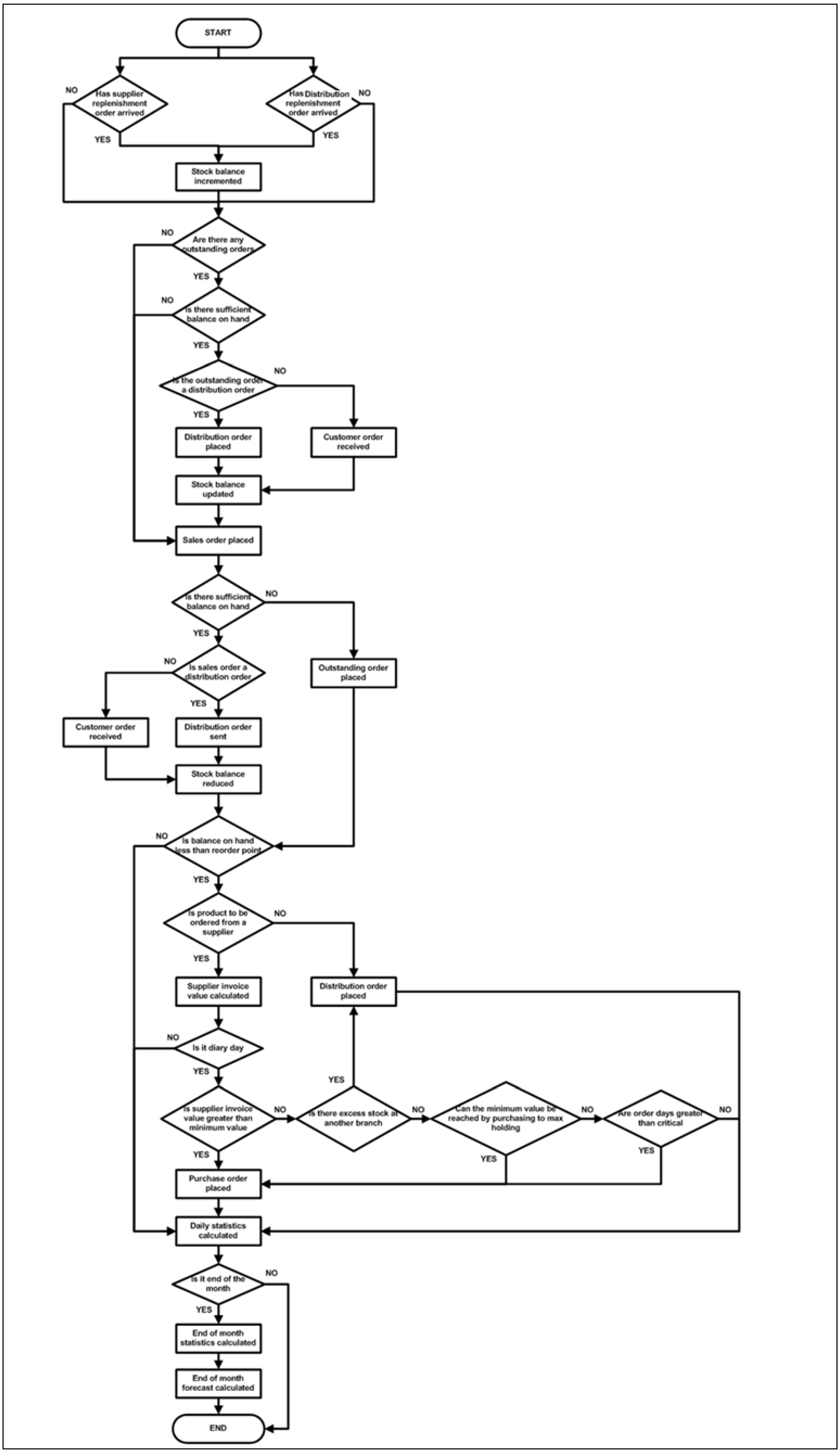
The first part of the research programme was implemented in the company's South West region. Though this had led to significant improvements for the business, this alone will not solve all of the stock related problems. There are systematic problems which are embedded within the inventory system which need addressing. The analysis of 50 SKU's which was discussed previously indicated that the level and behaviour of inventory can be significantly improved.

The next stage was to undertake an evaluative study of the inventory system to determine what the issues are and which activities and components should formulate the model. The remainder of this chapter is concerned with the research project which was undertaken of the inventory system at Newey and Eyre.

6.3.2 Model conceptualisation

The initial stage of designing a simulation was to conceptualise the problem in the form of a flowchart. This could then be transformed into programming flowcharts and pseudo code. The flowchart of the system needed to represent as much as possible the actual system by including all of the relevant activities and processes. This would make sure that the results were valid and the model had credibility. There are instances where some processes are too complex to model. The model cannot legislate for all possible management decisions. A number of assumptions had to be therefore used. The conceptual flowchart model is shown in Figure 6.22. It represents all of the activities that are formulated in the problem.

Figure 6.22: Conceptual model flowchart



It was beneficial to break the processes down into a number of easily understood subsystems or activities. The simulation model could then be designed in respect to these key activities. An explanation of the key activities and equations is shown below:

1. Supplier and distribution replenishment orders received

If a purchase order is received the balance of stock on hand is incremented by the quantity of stock delivered. It is assumed that all purchase order which are due on a particular day arrive at the start of the day. The order which is delivered into the warehouse is either a purchase order delivered by a supplier or a distribution order delivered within the internal supply chain.

2. Outstanding order placed

Once the balance of stock on hand has been updated with all of the purchase orders which have arrived, the lists of outstanding orders are checked. If there is there is a sufficient quantity of stock to cover the outstanding order then the order is fulfilled and the outstanding order is removed. If the outstanding order is a distribution order then it is added to the distribution on order list. The arrival time for the outstanding order is set as the distribution arrival time (see Equation 8.1).

3. Sales order placed

The sales orders list is made up of customer and distribution orders. The Customer orders are imported from a data file which contains transactions for a two year period. The distribution orders are replenishment orders which have been placed by a branch on another branch or an RDC. The sales order is checked against the balance of stock on hand. If there is sufficient stock the sales order is dispatched in full and received by the customer. If the order is a distribution order then it is placed and added to the distribution on order list.

Distribution orders are delivered the next working day (see Equation 6.1). If there is not a sufficient level of stock then the sales order is added to the outstanding orders list. If the stock level is greater than zero then it is assumed that the customer receives this quantity and the remaining is received when it becomes available.

Equation 6.1: Distribution arrival time

$$\text{Distribution arrival time} = \text{Current date} + 1 \text{ working day}$$

4. Supplier replenishment order raised

At the point in time when the reorder point is triggered (see Equation 6.2) a replenishment order is raised. A product is matched to a raised order by its supplier code. The value which is to be ordered is calculated and added to the raised order value. The quantity to be ordered from the supplier is made up of a recommended order quantity and any outstanding orders (see Equation 6.3). The value of the quantity to be ordered is added to the raised invoice value.

Equation 6.2: Replenishment order raised

$$\text{Current balance on hand} + \text{Quantity on order} - \text{Outstanding order} < \text{Reorder Point}$$

Equation 6.3: Purchase outstanding quantity

$$\text{Purchase outstanding quantity} = \text{INT (Outstanding orders / Order multiple)} + 1 \text{ x Order multiple.}$$

The invoice values for products, by supplier, are calculated and accumulated as they reach their respective reorder points (see Equation 6.4). There are some suppliers which require a minimum invoice value to be reached before a purchase order can be placed.

If it is not reached a delivery surcharge is charged. The buyers within the company try to make sure that they do not pay this charge. A purchase order is not placed straight away if the minimum invoice level is not reached. If the buyers believe the raised order has become critical (estimated as five days) or the stock balance for individual products have fallen below the safety stock then they will attempt to increase the invoice value by ordering up to the max holding level (see Equation 6.5).

The method which aims to find cost advantages by realising economies of scale by grouping products for replenishment is known as a joint replenishment. In this instance the company had not attempted to formally address the problem of joint replenishment. The grouping of products is a decision process which is built upon some basic logic and differs between buyers. If there is not a mechanism in place which accounts for the delay in time which exists between when the reorder point is triggered and when a purchase order is actually placed there is an increased risk of a stock-out occurring.

In principle it is more difficult for a reorder point system to address joint replenishment, which is currently used by the company, in comparison to a periodic review system where products are reviewed and purchase orders are placed at defined intervals. This is because products tend to be purchased less frequently and can be formally grouped into shared characteristics such as a supplier. The period of review in this system can be manipulated to control the quantities being purchased. This means that a level of control can be gained over cost savings produced from economies of scale.

As part of the review process it is recommended that the issue of joint replenishment is examined. This would involve the undertaking of a research project that compared possible methods using statistical analysis. The complicated nature of this study due to the trade-offs involved and the large amount of possible permutations may best lend itself to a study which incorporates a simulation model.

Equation 6.4: Raised order invoice value

Raised order invoice value = (Multiple order quantity + Purchase outstanding quantity) x Cost price.

Equation 6.5: Raised order invoice value (max holding)

Raised order invoice value = ((Max holding - Current BOH) + Purchase outstanding quantity) x Cost Price.

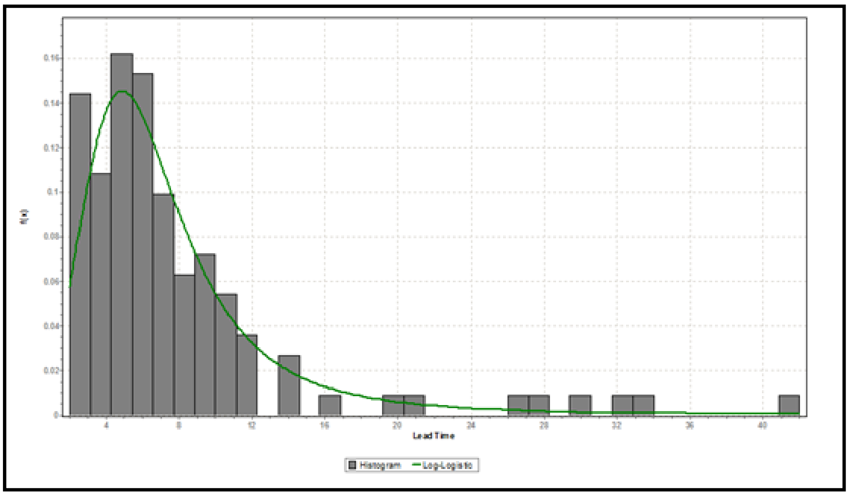
5. Supplier and distribution replenishment order placed

There are specific days when a purchase order can be placed with its supplier. These are dates are held by the buyers in their supplier diaries. If the day in their diary is the same as the current day then a purchase order can be made with the supplier if the supplier minimum invoice value has been met. If the supplier minimum value is not reached then the branches in the region are checked for excess stock. The excess stock is calculated as being two-weeks stock above the max holding level (see Equation 6.6). A distribution order is raised if there is enough stock to meet the requirements. There is enough stock if the level of stock does not fall below the max holding level (see Equation 6.7). In the event that an order does not meet the specifications and the critical days have been reached then the purchase order is placed regardless.

The purchase arrival time is calculated from the expected lead time (see Equation 6.8). Each supplier has a different lead time. An analysis of lead times was undertaken for a number of products. A typical example of this analysis is shown in for a major supplier in Figure 6.23 for 2006. The diagram shows a histogram of the lead times over a period of time. The lead times for the particular products range from 1 day to 8 weeks.

A distribution was fitted to the curve to determine the best type of fit. In this case the Gamma distribution fitted the data the most accurately. This was typical for the majority of the products analysed. Due to this analysis, lead times within the model are calculated using a Gamma Distribution. The average and standard deviation of lead times, which are required for the calculation, are taken from analysis of products six months historical deliveries. If the product is set up to be ordered from an RDC then a distribution order is placed.

Figure 6.23: Thorn Lightning Ltd distribution fit (2006-2007)



Equation 6.6: Excess stock

$$\text{Excess stock} = \text{Max holding} + (\text{Actual daily sales x 10 working days})$$

Equation 6.7: Sufficient excess stock

$$\text{Sufficient excess stock} = \text{Current Balance on Hand} - \text{Max Holding} >= \text{Distribution order quantity}$$

Equation 6.8: Purchase arrival time

$$\text{Purchase arrival time} = \text{Current date} + \text{Lead time}$$

6. Daily and month statistics

The information that the simulation model stores is used to calculate a number of statistics. The statistics are calculated each day, month and at the end of the simulation model. They are recorded as individual products and aggregated by branches and region. The key equations which are used to calculate the statistics are listed below:

Equation 6.9: Actual daily sales

$$\text{Actual daily sales} = \text{Total sales} / \text{Number of days}$$

Equation 6.10 Stock turnover

$$\text{Stock turnover} = \text{Current BOH} / \text{Actual daily sales}$$

Equation 6.11: Stock value

$$\text{Balance on hand value} = \text{Current balance on hand x Cost price}$$

Equation 6.12: Stock-out

$$\text{Current balance on hand} = 0$$

$$\text{Availability} = 0$$

$$\text{Stock-Out} = 1$$

Equation 6.13: Customer stock-out

$(\text{Current balance on hand} = 0)$ and $(\text{Customer sales order} - \text{current balance on hand} > 0)$

$\text{Customer stock-out} = 1$

7. End of month forecast

At the end of each month a forecast and a forecast alarm is calculated provided the forecast to be applied and forecast alarm are set to true. Each product is allocated either a moving average or a single or double exponential smoothing forecast type. The calculations for these are listed in Chapter 5. If the forecast produces a result which is than two standard deviations above the mean then the mean is used for the forecast.

The monthly forecast is used to calculate annual sales (see Equation 6.14) and daily sales (see Equation 6.15). The mean absolute deviation (see Equation 6.16) and new mean absolute deviations (see Equation 6.17) are calculated to show the forecast error. The daily sales, annual sales and forecast errors are used in the calculations of lead time demand, order quantity and safety stock. The lead time demand and safety stock calculations are based upon either a Normal or Poisson distribution. A customer service level is allocated for each product. The equations for these are listed in chapter 5. A correlation coefficient is calculated using month sales. The result from this calculation is used to determine the levels of the forecasting parameters. This is explained in more detail later on in chapter

Equation 6.14: Annual sales

$\text{Annual sales} = \text{Forecast x 12 months}$

Equation 6.15: Daily sales

$$\text{Daily sales} = \text{Annual sales} / \text{Total number of days in the year}$$

Equation 6.16: Mean absolute deviation

$$\text{Mean absolute deviation} = \text{ABS (Month forecast} - \text{Actual month sales)}$$

Equation 6.17: New mean absolute deviation

$$\text{New mean absolute deviation} = (\alpha \text{ x Mean absolute deviation}) + (1 - \alpha) \text{ x Mean absolute deviation}$$

6.3.3 Simulation model

The inventory system is complex and has a large number of constituent elements and therefore cannot be understood intuitively or modelled by simple analytical modelling. A number of issues have been identified with analytical modelling:

- limited to testing a small number of SKU's;
- interaction between SKUs cannot be modelled;
- difficult to test a number of different scenarios;
- a large number of assumptions have to be made to reduce complexity;
- cannot model the interaction between entities in the supply chain;
- cannot model all of the SKUs to get an aggregate view of the changes to performance measures;
- the model results would not represent a realistic reflection of what would be produced by the actual system.

It is shown by Neelamkavil (1987) that the interactions between elements can be so complex that by analysing the subsystems in isolation the outcomes of what is being studied may not be maintained. The analysis of single SKU's would not show the relationship that exists between products and the effect on aggregate statistics could not be realistically shown.

A simulation model is required to model the complexity of the system. The model was designed to test possible solutions and to compare these against the current model. Furthermore, it would be easier to convince management of implementation changes if the model realistically represents the current inventory system. It was decided that the value of investment and the resource required to design and test the model should provide sufficient benefits in the long term as a result of the conclusions.

An in depth evaluation of the current inventory system took place before the model can be built. The specific objectives and areas of analysis were formulated once the initial evaluation has taken place. Furthermore, the evaluation provides an understanding of the structure and the process relationships which exist within the system. The information was gathered by interviewing the inventory personnel and from physical evidence. The results are put together in a series of pictorial process maps.

6.3.3.1 Discrete event simulation (DES) software

A general purpose DES software package provided the platform to build the model. The selection of a suitable software package was part of the simulation process; this was outlined in section 3.5.3. A list of the many different software packages was shown in Figure 5.28. The software tool Micro Saint was selected to undertake this task. The decision to use this particular software was taken from a combination of cost, availability of a student license, model flexibility and access to assistance from experts if required. The model was designed using the methodology which is outlined in Chapter 5. The aim of the model was to generate results which once analysed show the impact that the proposed solution would have on stock levels for individuals SKUs and the overall effect on supply chain performance levels. An explanation of the software can be found in Appendix 14.

6.3.4 Model transformation

The final stage of the design process was to transform the conceptualised model into a discrete event simulation model. The key activities were designed as a series of programming flowcharts and pseudo code. These could then be directly assimilated into the Micro Saint software. The basic structure of the simulation model is shown in Figure 6.24. The network diagram and initialisation settings were constructed from this flowchart. The flowchart shows the interaction of activities for a complete cycle of the clock. Each cycle of the clock represents 1 day. The detail for each of the activities is shown in the flow charts and pseudo code in appendices 15-25. The pseudo code shown in these Figures is added to code sections within the activity window in Micro Saint.

A screen shot of the completed network diagram is shown in Figure 6.25. The activities are transcribed from the key activities outlined in the basic model structure flowchart. The activities flow from one to another following the paths in the diagram. When the final activity has completed the clock is incremented by one and the model returns to the first activity

Figure 6.24: Basic structure of the model flowchart

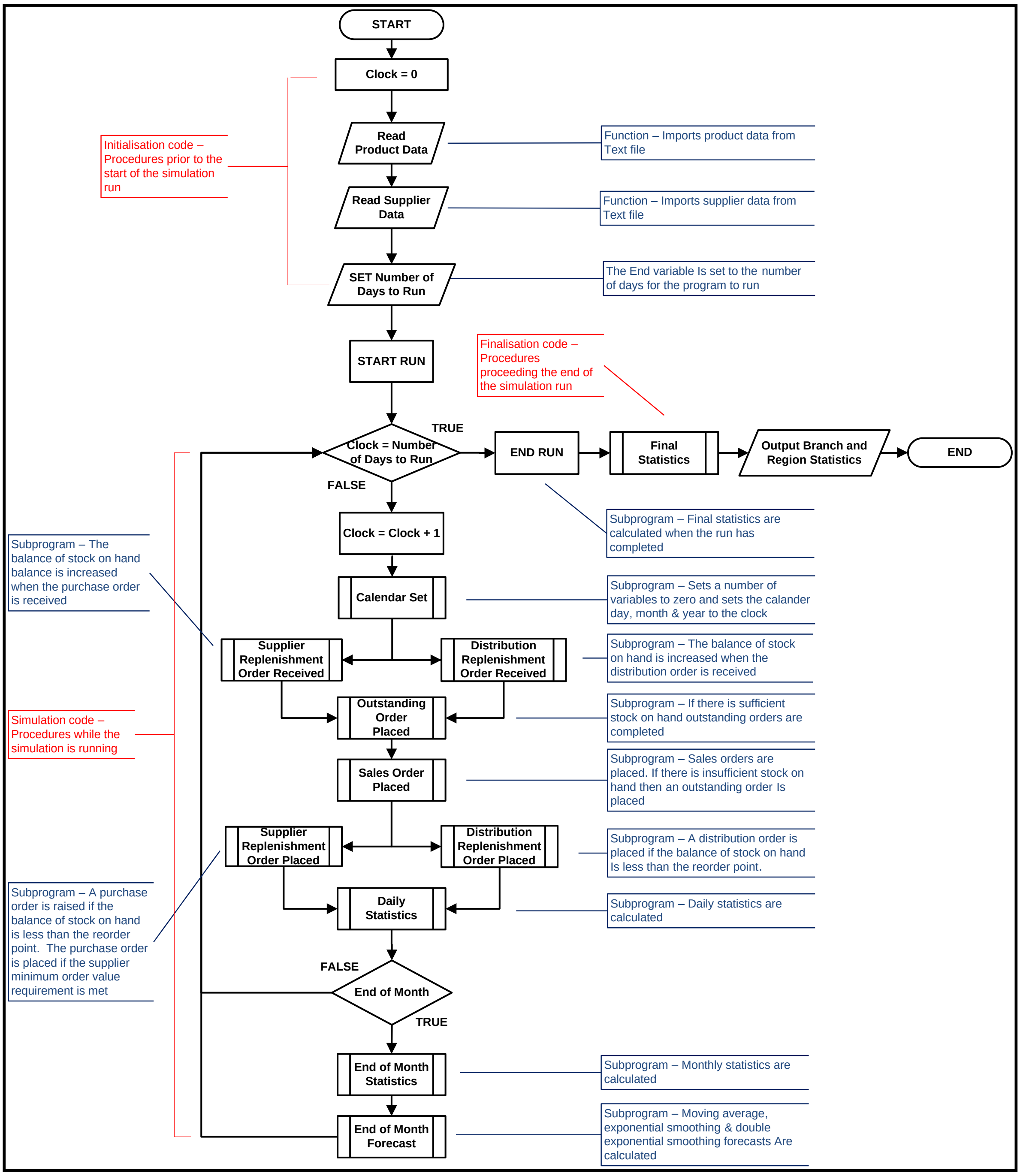


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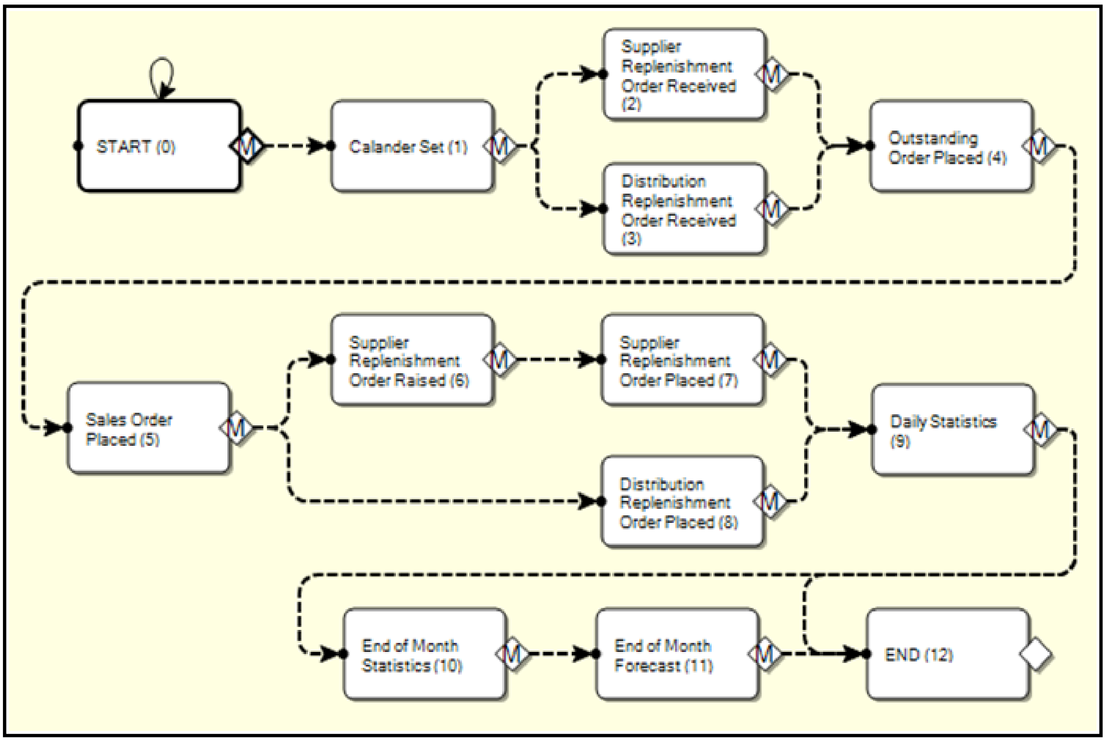
Figure 6.25: Network diagram



Before the first activity is initiated an import data function is run. The import data function imports a product and a supplier text file which contains the information for each product and supplier. Information from a third text file is accessed as part of the sales order placed activity. The file contains historical transaction data for each product over two periods. The text files and fields are shown in Figure 6.26.

Figure 6.26: Import text files

Product Data	**Supplier data**	**Transaction data**
Branch Code	Branch Code	Branch Code
Branch Name	Branch Name	Product Code
Product Code	Diary day 1	Transaction Day
Product Name	Diary day 2	Transaction Quantity
Reordered	Minimum Invoice Value	
Start Balance on Hand	Ordered Quantity	
Multiple Sales Quantity		
Standard Deviation Sales		
Sales Coefficient Variance		
Class		
Order Quantity		
Multiple Order Quantity		
Order Multiple		
Maximum Order Quantity		
Safety Stock		
Reorder Point		
Cost Price		
Estimated Lead Time		
Supplier Code		
Supplier Name		
Average Lead Time		
Standard Deviation Lead Time		
Lead Coefficient of Variance		
Purchase Order Method		

6.3.5 Data collection

The data that was imported into the simulation model was taken from three purchasing and inventory regions. These regions are managed from their respective purchasing offices which are based in Leeds for the North-East and Yorkshire and Anglia and Avonmouth for the South West. The regions operate within their own supply chains supplied from local suppliers and a regional RDC. Apart from a relatively few distribution orders the regions operate in isolation of one another. The data that was downloaded from Movex was separated into the three areas and each area has three files; a product, sales and purchasing file. The sales and purchasing data are taken from the period June 2006 to June 2008.

A summary of the data is shown in Figure 6.27 and a breakdown of the number of products and branches in each region is shown in CD appendices AQ-AS. The data from the North-East region was specifically used for estimating parameters. The data from the Anglia and South West regions was used for the comparative testing. This data was only used to test for the level of parameters so that any bias is removed.

Figure 6.27: Summary of data

Region	No of SKU's	No of branches	No of purchases	No of sales	No of suppliers	P&I Office
North-East	29,998	18	370,349	£16,092,998	183	Leeds
Anglia	26,001	15	263,277	£1,631,034	195	Leeds
South-West	18,309	18	260,790	£1,337,512	201	Avonmouth

6.3.5.1 Variables

The simulation model uses a large quantity of variables (see appendices 26 – 38). The majority of the variables are stored within classes. These are called custom objects within the Microsoft .Net Framework which Micro Saint Sharp uses. Some of the classes are used as a type array. This is so there is a record of each product and each branch. By using the custom objects in Micro Saint it reduces the total number of variables which would otherwise be required if a variable for each product is used. This also keeps the model organised and easier to understand. Variables that are not located within the classes are stored globally. The classes and array structures are as follows:

1. Settings.
2. Product Data [No branches, No products].

3. Supplier Data [No suppliers].
4. Raised Order [No branches, No suppliers].
5. Forecast [No branches, No products].
6. Forecast Alarm [No branches, No products].
7. Coefficient Data Year[No Branches, No Product, Month]
8. Coefficient Data Month[No Branches, No Products]
9. Product Graph.
10. Stock-Out.
11. Product Statistics [No branches, No suppliers].
12. Branch Statistics.
13. Region Statistics.
14. Coefficient Data [No branches, No products, No months]
15. Coefficient Data 2 [No branches, No products]

The parameters and variables within the settings class are set initially. They control various aspects of the model such as the number of days for the model to run. The product data, forecast, forecast alarm classes store information for each product. The supplier data and raised order classes store information for each supplier. These variables are manipulated when the model is running and the data is used in many equations. The product graph class stores the information which is used to create the individual product graph. The stock-outs, product, branch and region statistic classes stores all the information which are used for the various snapshots. The snapshots record the results of the model and can be exported when the model has finished.

6.3.5.2 Estimating parameters

Within the structure of the simulation model there are a number of fixed and variable parameters. These parameters are shown in Figure 6.28. The fixed parameters do not change throughout the running of the model and the values are set at the start of each run. The variable parameters are manipulated when the model is running. The days in year parameter is set to the amount of working days in the year. The critical days parameter is an assumption that is used to control how many days can elapse before an order has to be placed with a supplier. In practice this varies between buyers but for simplicity an approximation is used based upon an average of observations.

The deviation parameter is currently used by the company to control the number of standard deviations which are used to trigger a forecast alarm. The estimated safety days quantity is the number of days which are currently used by the company to control the number of days of safety stock to hold for each product. This is set to twelve days for all products. The beta factor, deviation factor and alpha factor are parameters used with the safety stock calculations. The holding and ordering costs are parameters used within the EOQ calculation. These can be set to be fixed or to be variable to a product.

Figure 6.28: Parameters

Parameter	**Quantity**	**Equation**	**Explanation**
Days in year	260	-	Number of working days in a year
Critical days	5	-	Maximum days before an order is placed
Deviation	2	Forecast alarm	Number of standard deviations to be used for month demand
Estimated days	12	Safety stock	Number of days used to calculate safety stock
Beta factor	0.5	Lead time deviation	Factor used because safety stock is not directly proportional to increase in lead time
Deviation factor	1.25	Standard deviation	Factor which relates standard to mean absolute deviation
Alpha factor	0.2	New mean absolute deviation	Weighting factor to smooth deviation trend
Holding cost	0.2	Ordering quantity	Estimated cost of holding one unit of stock for a year
Ordering cost	2.50	Ordering quantity	Estimated cost of placing an order
SES alpha factor	0.2	SES	Factor to smooth the level
BES alpha factor	0.2	DES	Factor to smooth the level
BES beta factor	0.2	DES	Factor to smooth the trend
σ_1	-	Safety Stock	Standard deviation of lead time
σ_2	-	Safety Stock	Standard deviation of sales
k	2.05	Safety stock	Service factor

The SES and BES alpha factors and BES beta factors are parameters used with the forecasting equations. These can be set to be fixed or variable to a product. The results which the model produces are dependent upon the values set for the variable forecasting and reorder point parameters. The different strategies are tested by manipulating these values. The estimation of these parameters is therefore an important stage in the development of the model. The next section describes how the values for these parameters were initially set.

The forecasting calculations within the simulation model use a number of parameters which require values to be initially set. This model uses both single (see Equation 6.12) and double (see Equation 6.13) exponential smoothing methods to calculate a new forecast. A double exponential smoothing method is used for products which have a sales pattern with an upward or downward trend. The single exponential smoothing (SES) calculation uses an alpha factor and the double exponential smoothing (DES) calculation uses an alpha and beta factor to control the weight of smoothing for the base and the trend of the forecast respectively. The values for these parameters can range between zero and one. The nearer that the value for the smoothing factor is set to one; the more weight is given to the previous forecast. If the value for the parameter is set to one then the new forecast is said to equal the previous forecast.

The pattern of sales exhibited by each product controls which type of forecasting method and also which parameters are the most suitable. The selection process should aim to reduce the forecast error. There are a number of different techniques which can be used to determine these parameters. The preferred method is to find a solution that is simple and can be calculated within a reasonable amount of time. The large number of products dictates that a simple method is desirable and one which does not require a large amount of resource. The method should be easy to be managed by the inventory personnel on an ongoing basis.

There are a number of different options available. A non-mathematical solution could involve producing graphs of sales patterns for all of the products. This type of pattern could then be matched to the correct type of forecasting technique. This would be a simple process but to produce and match each product visually in practice would be very time consuming. A mathematical approach can be used which uses historical data to simulate different forecasts and compares them based upon the forecasting error. This can be achieved using a spreadsheet method or some kind of business forecasting software. A spreadsheet based method is not a practical solution in this context because of the large number of products. Forecasting software is a fast practical solution once set up. This method however does still require the data to be imported which can take a considerable amount of time. This approach also requires a certain level of expertise and expenditure.

It was determined that if possible a simple mathematical equation would be used to fit the sales pattern to a forecasting technique and also to find suitable parameter values. This approach is only used for products which are purchased from supplier and are not required to fulfil products within the business. A single exponential smoothing forecasting with a low alpha factor is used for these products.

The first step in this process was to determine whether a SES or DES forecast would be the most suitable method for each product. In principle a product which has a negative or growth trend pattern can be forecasted effectively using a DES forecast. A correlation coefficient (Tersine, 1994, p.50) was used to determine the degree of linear relationship between observed variables (see Equation 8.18). This produces a value in the range between minus one and one. The higher the correlated coefficient the more the variable being studied resembles a straight line pattern. A value of zero would indicate that there is no linear relationship between the variables. Tersine (1994, p.51) shows how the different values of the coefficient correlation can be interpreted (see Figure 6.29).

Equation 8.18: Correlation coefficient

$$r = \sqrt{\frac{[n\sum_{i=1}^{n} t_i Y_i - (\sum_{i=1}^{n} t_i)(\sum_{i=1}^{n} Y_i)]^2}{[n\sum_{i=1}^{n} t_i^2 - (\sum_{i=1}^{n} t_i)^2]\,[n\sum_{i\,n=1}^{n} Y^2{}_i - (\sum_{i=1}^{n} Y_i)^2]}}$$

Notation(s)

$Y = \text{Month sales}$

$t = \text{Month}$

$n = \text{Number of months}$

Figure 6.29: Interpretation of the coefficient of correlation

Absolute value of correlation coefficient	**Interpretation**
0.90-1.00	Very high correlation
0.70-0.89	High correlation
0.40-0.69	Moderate correlation
0.20-0.39	Low correlation
0.00-0.19	Very low correlation

The assumption that a product with a high correlated coefficient is best matched to a DES forecast was tested using data from the North-East data set. A sample of 3,071 products was used with sales data taken over a twelve-month period. A value was calculated for each product. The simulation model was used to calculate a SES and a DES forecast with a number of different permutations for the factor values of alpha and beta. The model produced forecast errors for each forecast and these were compared to find the lowest MAD value.

The results of this analysis are shown in Figure 6.30. It was clear that there was a direct link between the coefficient correlation value and the type of forecasting technique. Products which had a high correlation had a lower MAD on average when a DES forecasting method was used. This is expected as sales patterns which have a higher correlation exhibit either an upward or downward trend. As the coefficient correlation value falls towards 0 a SES method becomes more suitable. The results indicated that products with a coefficient of 0.60 or more had a lower MAD when using a DES method.

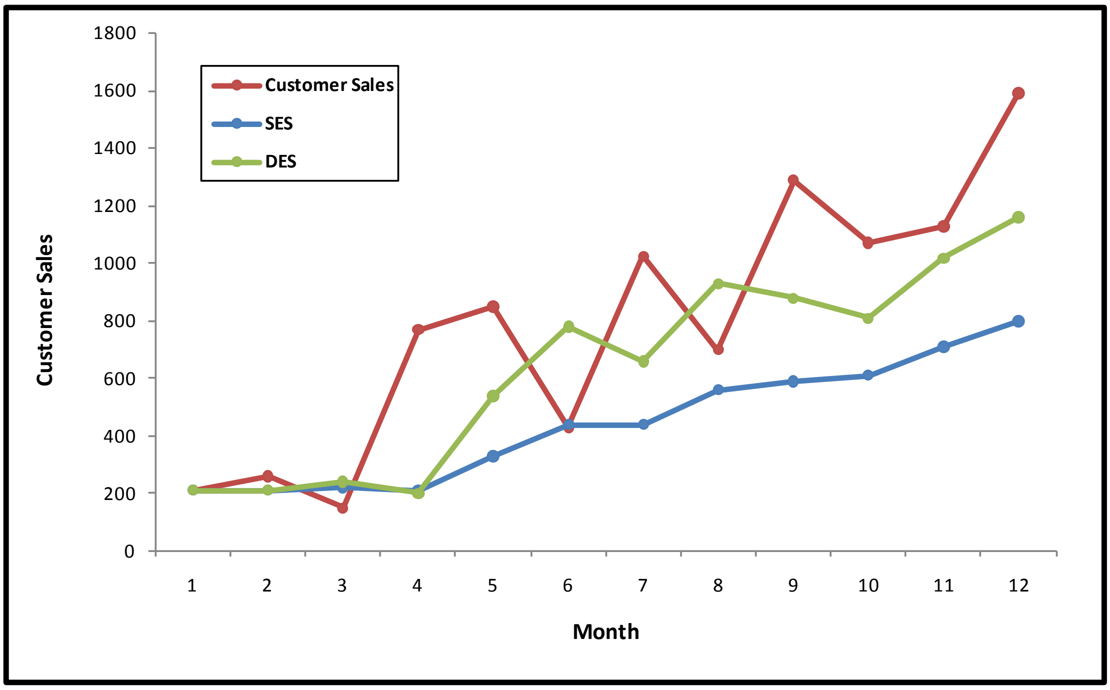
Figure 6.30: Percentage of products which have a lower MAD for different values of the correlation coefficient

Absolute Correlation coefficient	DES	SES
1.00	100	0
0.90	100	0
0.80	75	25
0.70	71	39
0.60	60	40
0.50	45	55
0.40	39	61
0.30	24	76
0.20	22	78
0.10	20	80
0.00	15	85

An example of a product with a coefficient correlation value of 0.8 is shown in Figure 6.31. The product exhibits growth over the twelve month period. The results of the SES and DES forecast which were generated by the model are shown in the graph. The DES forecast reacts better to the trend and produces a lower MAD forecast error.

This process was extended to include the estimation of the beta factor. The beta factor is used to smooth the trend. The values of 0.25 and 0.5 were chosen to be used for alpha and beta. Higher alpha factors then those selected were not used because this can lead to a higher risk of stockouts and overstocking. Many different alpha factors were not used because of the large number of testing permutations this would involve. A best fit parameter one month would not necessarily be the best fit the next month.

Figure 6.31: Product with a coefficient correlation of 0.8



It is expected that a trend which has a stepper decline or incline would be better suited to using a higher beta factor. This hypothesis was tested using products which had an absolute correlation coefficient of 0.6 or more. The results of the analysis are shown in Figure 6.32. Products which had an absolute correlation coefficient of 0.90 or more produced a lower Mean Absolute Deviation (MAD) when using a beta factor of 0.5. A product therefore with a higher correlated linear trend produces a better forecast when using a higher alpha.

Figure 6.32: Percentage of products which have a lower MAD for different values of the correlation coefficient and beta factors using a DES forecast

Absolute correlation coefficient	Beta factors	
	0.25	0.5
1.00	0	100
0.90	25	75
0.80	43	57
0.70	42	58
0.60	30	70

The next stage of the process was to find an estimate of the values for alpha. These values range between zero and one. A value of one would create no smoothing and the current forecast would be set to the previous observation. A value of 0 would create total smoothing and the current forecast would be set to the first observation. There is a lack of literature which suggests methods for selecting values for this parameter.

There are suggestions on the type of patterns that are best matched to a higher or lower factor. Bernard (1999) for example suggests that phase in parts should have an alpha factor of between 0.1 and 0.2 and a phase out part an alpha factor of between 0.50 and 0.8. It is also suggested that for parts which have a stable sales usage but which are suspect to random fluctuations are better suited with alpha factors of 0.5 or higher. A mathematical approach is not put forward and a visual solution is time consuming.

It has been suggested that high alpha factors are better suited to patterns which exhibit a high degree of variance and vice-versa. This is intuitive because a high alpha factor will make the forecast react more quickly to sharp changes in the pattern. A coefficient of variance calculation (see Equation 6.19) was used to test to see if this was apparent in the data set. The products with a 12 month coefficient correlation of 0.6 were removed from the original product list. This reduced the data set to 2666 products.

Equation 6.19: Coefficient of variance

$$\mathrm{CV} = \frac{\sigma}{\mu}$$

Notation(s)

$\mathrm{CV} = \text{Coefficient of variance}$

$\sigma = \text{Standard deviation of sales}$

$\mu = \text{Mean of sales}$

A coefficient of variance was calculated for each product over a twelve month period. A sales forecast was generated using alpha factors ranging from 0.1 to 0.9 in 0.1 increments. The forecasting method with the lowest forecasting error was found using a MAD calculation. The results showed that there was no easily identifiable relationship between the degree of sales variance and the value of alpha.

To try and determine why this was the case a sample of products which had different values was analysed visually using graphs. The aim was to try and better understand why certain patterns were better matched to higher or lower alpha factors. This analysis showed that the variance over a period of time was not the key factor in determining the value of the alpha factor. The relationship between consecutive sales periods appeared to be the controlling factor.

A graph which represents two different types of sales patterns is shown in Figure 6.33. The points which are highlighted in blue show a large change in upward sales followed by a large change in downward sales. A forecast with a high alpha will react to the upward change but because of the one period time lag the sales will have fallen. This creates a large forecast error. The sales pattern represented by the red line has short term periods of growth and decline. A forecast with a high alpha is much better suited to this type of situation.

An experiment was designed to ascertain whether a correlation coefficient calculation could be applied to find short term trends. The same set of data was used to determine whether there was a relationship between the value of alpha and the correlation coefficient. A moving average four-month period was used to calculate the correlation coefficient. The results of the analysis are shown in Figure 6.34. The majority of products which had an absolute correlation of greater than 0.60 were better matched to an alpha factor of greater than 0.5. The majority of products which had an absolute correlation of less than 0.70 were better matched to an alpha factor of 0.25. This showed that the alpha parameter could be found using the correlation coefficient calculation using a short term period of sales.

Figure 6.33: Product sales patterns

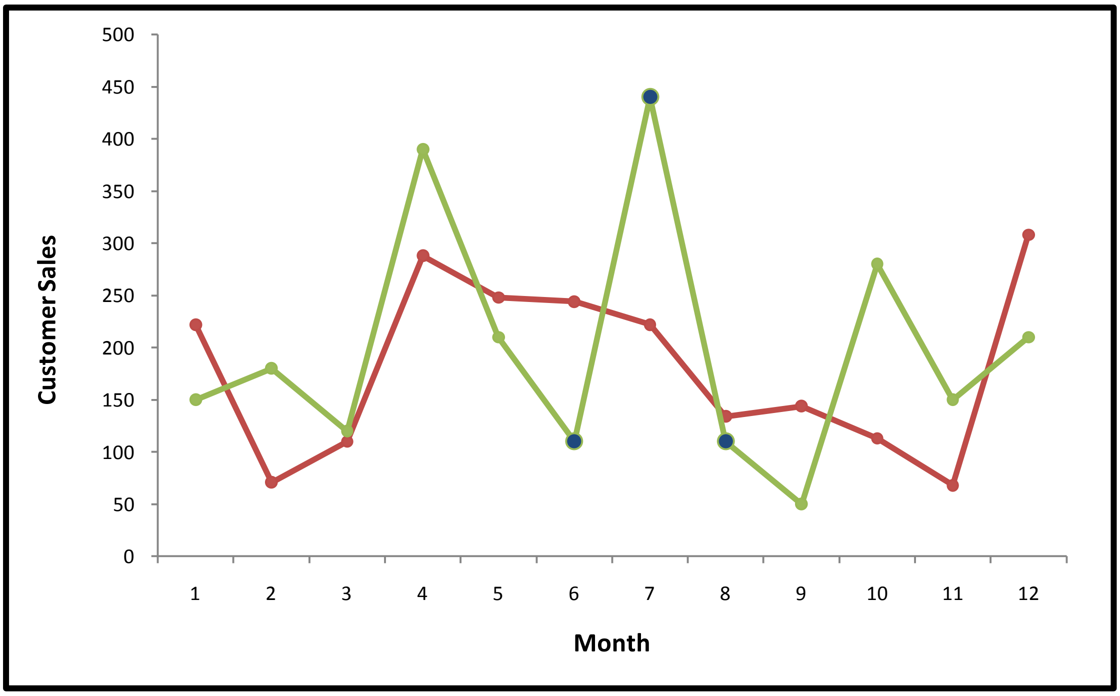


Figure 6.34: Percentage of products which have a lower MAD for different values of the correlation coefficient and alpha factors using a SES forecast

Absolute correlation coefficient	Alpha factors	
	0.25	0.5
1.00	-	-
0.90	0	100
0.80	38	62
0.70	40	60
0.60	56	44
0.50	69	31
0.40	79	21
0.30	79	21
0.20	100	0
0.10	-	-
0.00	-	--

The next stage was to estimate the parameters which are used within the reorder point calculations. This equation is made up of a quantity for the lead time demand and a quantity for safety stock. The equations are shown in Equations 6.20a – 6.20g.

Equation(s)

$\mathrm{ROP} = \mathrm{LTD} + \mathrm{SS} + \mathrm{AOD}$ Equation (6.20a)

$\mathrm{LTD} = \mathrm{s}(\mathrm{k}\sigma_1 + \mathrm{l} + \mathrm{AOD})$ Equation (6.20b)

$\mathrm{SS}_1 = \mathrm{k}\sigma_2\left(\sqrt{\mathrm{l}}\right)$ Equation (6.20c)

$\mathrm{SS}_2 = \mathrm{k}\left(\sqrt{\mathrm{m}}\sqrt{\mathrm{l}}\right)$ Equation (6.20d)

$\mathrm{MAD} = \mathrm{ABS}(\mathrm{Forecast} - \mathrm{Actual\ Sales})$ Equation (6.20e)

$\mathrm{New\ MAD} = (\alpha\ \mathrm{MAD}) + (1 - \alpha)\mathrm{New\ MAD}$ Equation (6.20f)

$\sigma_2 = \mathrm{d}(\mathrm{New\ MAD})$ Equation (6.20g)

Notation(s)

ROP = Reorder point

SS_1 = Safety stock (normal distributed safety stock)

SS_2 = Safety stock (poisson distributed safety stock)

AOD = Average order days

MAD = Mean absolute deviation

σ_1 = Standard deviation lead time

σ_2 = Standard deviation sales

α = Alpha factor

l = No of days to arrive

m = Mean sales

k = Number of SD's above the mean corresponding to the desired service level

d = Deviation factor

s = Average sales per day

Fixed parameter(s)

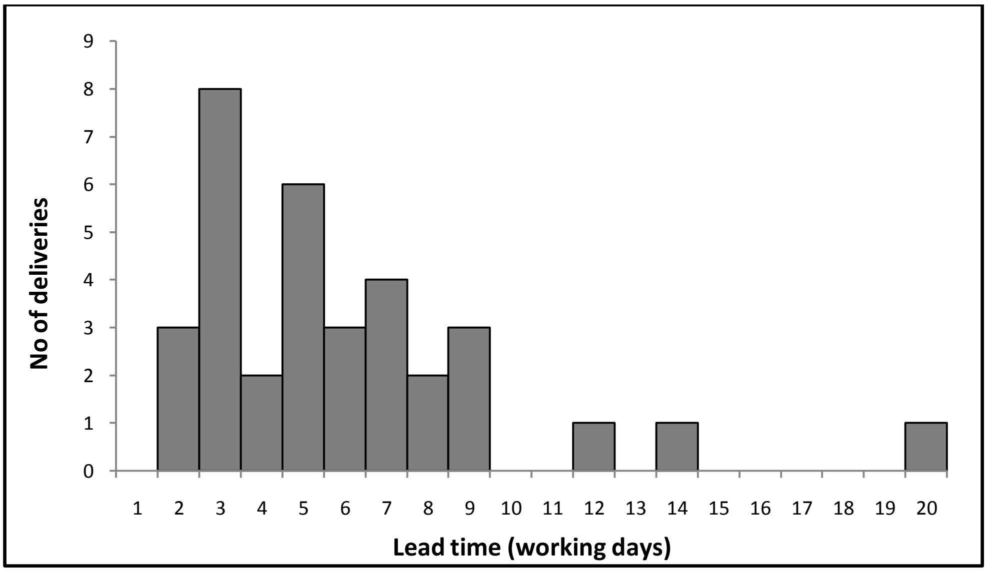
$\alpha = 0.2$

$\mathrm{d} = 1.25$

The lead time demand is the expected quantity which is sold over the period of the lead time. It was necessary to add a quantity for the delay in the order processing because this is not accounted for in the traditional equations. The delay occurs between the point at which the reorder point is triggered and that when the purchase order is placed with the supplier. This can be due to either waiting for the correct day to order or because the minimum supplier quantity cannot be met. This delay is recorded for each supplier transaction and an average is updated each month. The current system does not require this because there is a sufficient margin of error in the calculations used.

The lead time is calculated using a service level. This is because the lead times for each product are not fixed and vary with each delivery. An example of lead times for a product is shown in Figure 6.35. The size of this variation varies for each product.

Figure 6.35: Delivery lead times for a product (June 2006 – June 2008)



The quantity of safety stock is controlled by three factors, the variance of forecast error and the lead time and the classification the product. The key component of the safety stock calculation is the desired service level. This is controlled by parameters which are set for each classification of product. There are three classifications of product ‘A’, ‘B’ and ‘C’. The ‘A’ category products represent the most critical, reducing in significance from ‘B’ to ‘C’ being the least critical. There are a number of different methods available which can be used to determine this type of categorisation. There is no one best approach and different companies use different methods. The methods reflect the strategic focus of the business. A company that is heavily customer focused might for example rank their ‘A’ category products on lines sold or customer surveys. Many companies calculate the sales turnover of each product and rank products by the revenue they bring to the business.

The company currently ranks their products by sales turnover into ‘A’, ‘B’ and ‘C’ categories. This is to try and maximise total sales turnover by making sure their best selling products are in stock. The safety stock calculation which is currently used does not include a categorisation of products. The proposed system uses a combined categorisation approach. This is to reflect both the importance to the business in terms of sales and the importance to the customer in terms of lines sold. There are some products for example which add little in terms of sales turnover but are important to the customer. If these types of products are out of the stock sales orders could be lost in the short term or customers in the long term. Fuses and electrical sockets are examples of these types of products. These types of products tend to have a small buying cost so the total holding value isn’t increased significantly using this method.

The combined categories are shown in Figure 6.36. ‘A’, ‘B’ and ‘C’ categories are represented by a cumulative percentage of 80%, 95% and 100% respectively.

Figure 6.36: Combined customer service level categories

Sales turnover	Lines of billing		
	A	**B**	**C**
A	AA	AB	AC
B	BA	BB	BC
C	CA	CB	CC

It would be preferable to use profitability instead of sales turnover. The implementation changes which have been investigated as part of the first research project have meant that the operation is currently in a state of change. This means that logistics costs associated with products are too difficult to accurately calculate at this stage. The two categories are combined to form the final customer service category (see Figure 6.37). This category is formed from the combined category with the higher of the two categories taking precedence. Figures 6.38 and 6.39 show how this splits the products within the branches of the South West and Anglia regions.

Figure 6.37: Final customer service level categories

Combined category	Final category
AA	A
AB	A
AC	A
BA	A
BB	B
BC	B
CA	A
CB	B
CC	C

Figure 6.38: South West region branches

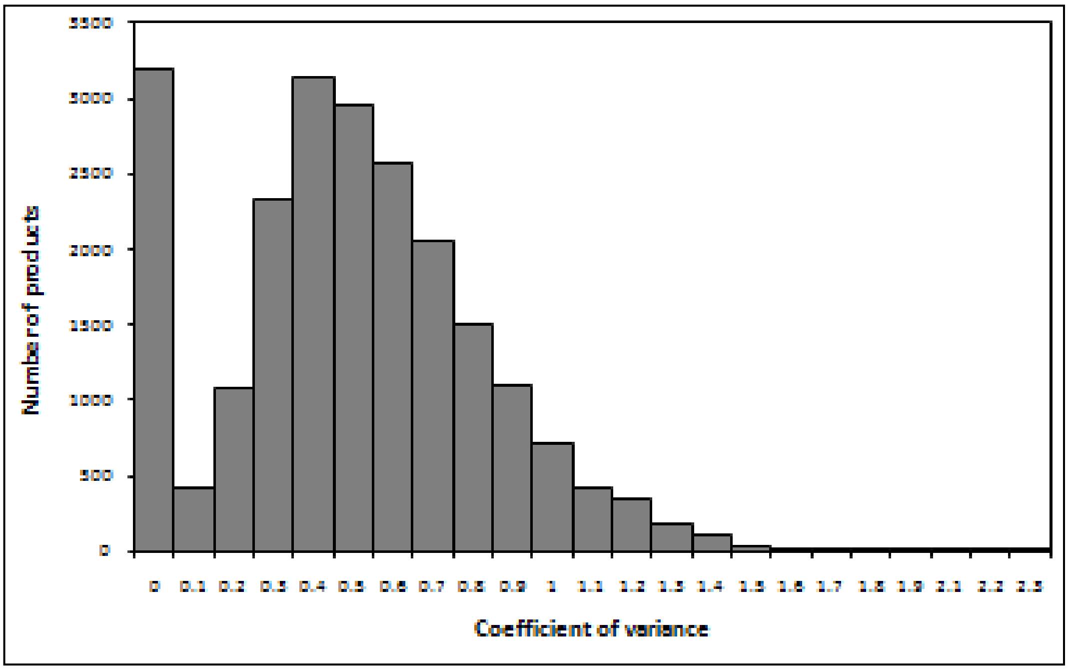
Branch	A	B	C	Total
Avonmouth	1850	781	709	3340
Bath	355	232	161	748
Bridgend	519	351	385	1255
Bristol	679	470	358	1507
Cardiff	327	242	254	823
Carmarthen	404	303	264	971
Exeter	289	189	164	642
Guernsey	231	147	127	505
Newport	395	272	268	935
Newton Abbot	614	399	263	1276
Pembroke Dock	595	393	270	1258
Plymouth	378	215	207	800
Swansea	428	259	231	918
Swindon	225	140	133	498
Truro	317	165	141	623
Weston Super Mare	283	206	163	652
Yate	338	188	197	723
Yeovil	287	258	290	835
Total	8514	5210	4585	18309

Figure 6.39: Anglia region branches

Branch	A	B	C	Total
Peterborough	2092	727	1386	4205
Bishops Stortford	361	170	481	1012
Boston	456	172	378	1006
Bury St Edmunds	704	284	715	1703
Cambridge	1217	504	989	2710
Great Yarmouth	743	325	769	1837
Ipswich	798	334	717	1849
Kettering	371	164	370	905
Kings Lynn	753	316	658	1727
Luton	584	241	628	1453
Milton Keynes	367	193	402	962
Northampton	887	358	758	2003
Norwich	771	399	1101	2271
Spalding	496	218	570	1284
Wisbech	415	183	475	1073
Total	11015	4588	10397	26000

The third factor in the safety stock calculation is controlled by a safety level of stock which is required to hedge against lead times exceeding an expected average. A mean and standard deviation is calculated for each product to determine a coefficient of variance. The spread of coefficient of variance values for products in the North-East is shown in Figure 6.40. The value from this calculation determines the level of safety stock required. Any products which have a value of above 0.5 are allocated some extra level of safety stock.

Figure 6.40: Coefficient of variance of lead times in the North-East region



6.3.6 Findings

The simulation model was used to compare the design structure of the current inventory system against a number of different scenarios. The current inventory system uses a moving average forecasting method to calculate monthly forecasts. This forecast is used only as a guide for managers it does not automatically update key system variables. The stock level of the products which the business holds in their RDC's or branches are controlled by the quantities which are stored within the key variables of reorder point, safety stock, lead time demand and the order quantity. The quantities for these variables are only changed after the completion of a product review, which occurs on average every six months.

The first set of scenarios compares the current inventory system design against a number of non-segmented scenarios. These scenarios apply the same methods or calculations for all products regardless of any characteristics, such as product class. The results of this analysis should show which of these methods provides the best outcome if a non-segmented approach is applied. There are many different permutations of parameters that are possible to test for this scenario. A selection 22 permutations were chosen which would take a reasonable amount of time to run through the model and could logically be possible solutions.

The combinations of parameters and methods for each of these scenarios are shown in Figure 6.41. The business currently aims for a 98% customer service level so this was a suitable choice for the customer service parameter. The customer service level represents the ability of the business to fulfil an order in full when requested by a customer. This same service level is used for the lead time. There is a combination of moving average, exponential smoothing and double exponential smoothing techniques so that different forecasting methods are tested. A forecast alarm which uses two standard deviations is used to smooth any large increases in sales.

The order quantities used are either a fixed or economic order quantity (EOQ) based calculation. The fixed quantities are taken from the current settings within the system. The safety stock quantities are calculated using a normal distribution statistic, a fixed quantity or an estimated twelve days work of stock. The company currently uses an estimated twelve days worth of stock to calculate safety stock. The lead time demand is calculated using either an estimated ten days lead time or an average lead time. The average lead time was calculated from historic purchases analysed over the period of a year for each product.

The parameters for these scenarios are initialised at the start of each run. The Anglia and South West regional sales, supplier and product data sets were imported into the model. The data for each product is imported when the model initialised. The sales data is imported at each increment of the clock or each day when at the time when a sales order is placed. The supplier data is imported into the model at the initialisation stage and is referred to when a product reaches its respective reorder point and an order therefore is required to be placed with a supplier. To reduce the risk of errors appearing in the results from erroneous data the simulation model is run through its cycle twice for each scenario. It was not necessary to run the model more than twice because the difference in results was insignificant. A statistical probability calculation is used to calculate supplier lead times so the results will be different for each simulation run. An average is taken from the two results.

Figure 6.41: Non-segmented scenarios

Scenario	Forecasting parameters			Reorder point parameters				Service levels parameters	
	Type	Alpha	Beta	Order quantity	Safety stock (SS)	Reorder Point (ROP	Lead Time Demand (LTD)	Sales	Lead Time
1	None	-		Fixed	Fixed	Fixed	Fixed	-	-
2	MA	-		EOQ	12 Days	SS + LTD	Fixed	-	-
3	MA	-		Fixed	12 Days	SS + LTD	10 Days	-	-
4	MA	-		EOQ	12 Days	SS + LTD	10 Days	-	-
5	MA	-		EOQ	12 Days	SS + LTD	Average	-	-
6	MA	-		EOQ	Normal Distribution	SS + LTD	Estimated	98%	-
7	MA	-		EOQ	Normal Distribution	SS + LTD	Average	98%	-
8	MA	-	-	EOQ	Normal Distribution	SS + LTD	Normal Distribution	98%	98%
9	ES	0.2	-	EOQ	12 Days	SS + LTD	Fixed	-	-
0	ES	0.2	-	Fixed	12 Days	SS + LTD	10 Days	-	-
11	ES	0.2	-	EOQ	12 Days	SS + LTD	10 Days	-	-
12	ES	0.2	-	EOQ	12 Days	SS + LTD	Average	-	-
13	ES	0.2	-	EOQ	Normal Distribution	SS + LTD	Estimated	98%	-
14	ES	0.2	-	EOQ	Normal Distribution	SS + LTD	Average	98%	-
15	ES	0.2	-	EOQ	Normal Distribution	SS + LTD	Normal Distribution	98%	98%
16	DES	0.2	0.2	EOQ	12 Days	SS + LTD	Fixed	98%	-
17	DES	0.2	0.2	Fixed	12 Days	SS + LTD	10 Days	-	-
18	DES	0.2	0.2	EOQ	12 Days	SS + LTD	10 Days	-	-
19	DES	0.2	0.2	EOQ	12 Days	SS + LTD	Average	-	-
20	DES	0.2	0.2	EOQ	Normal Distribution	SS + LTD	Estimated	98%	-
21	DES	0.2	0.2	EOQ	Normal Distribution	SS + LTD	Average	98%	-
22	DES	0,2	0.2	EOQ	Normal Distribution	SS + LTD	Normal Distribution	98%	98%

The simulation model was run for a period of two years which corresponds to the historical transactions of the data sets. The results were recorded only for the last twelve months. This was to remove any bias which would have existed due to some of the parameters being estimated from data in the first twelve months. This also allowed sufficient time for the moving average forecast and for the start balance of stock on hand to reach a level consistent with the model.

The model records information at both an aggregate level for the region and branches and also for individual SKUs. The results were exported from the simulation model into a spreadsheet where they were analysed. The primary information which was recorded is for a number of KPI's. A breakdown of these measures is shown below. The model is also capable of gathering further pieces of information such as order quantities and safety stock quantities if required.

- total stock value (A, B, C);
- total number of critical purchase orders;
- total number of max purchase orders;
- total number of purchase orders;
- total number of excess distribution orders;
- total number of distribution orders;
- total number of replenishment orders;
- total number of stock-outs (A, B, C);
- total number of customer stock-outs (A, B, C);
- average stock turnover (A,B,C);
- stock availability percentage (A, B, C);
- customer availability percentage (A, B, C).

The product availability which was agreed by the business is shown in Figure 6.42. These targets are different from the previous targets which did not distinguish between product classes. The A lines are the most important to the business as they represent 80% of lines sold and 80% of sales revenue. The C lines add very little value for the business so no target is set for these and the aim is to minimise the stock held for these products.

A summary of the results for the non-segmented scenarios at a regional level are shown in Figure 6.43 and 6.44 for the Anglia and South West region respectively. The full results are shown in Appendix 39 and Appendix 40. There are 22 different scenarios and the results are broken down by KPI measures. The Anglia and South West regions are based upon data of approximately 26,000 and 18,000 products respectively. The simulation model provides a large quantity of data. Some of this data will become more useful when it can be continually monitored and targeted against previous months. At this stage it is important to find a solution which, at the minimum, meets the product availability targets whilst minimising stock levels.

The first scenario in the tables represents the current settings for the inventory system. The results show that the product availability for ‘A’ lines is 94.98% and 96.87% for Anglia and the South West respectively. These do not meet the current or the proposed targets. In practice however the values for the A lines are higher because the buyers increase the fixed ordering quantities and make purchase orders before the reorder point is reached. It would seem from the results that the buyers are justified from the point of view of meeting the targets in this practice. The B lines for Anglia do not meet the target and for both regions the C lines have a higher availability then the A lines. Due to the single approach to buying methods there is no discernable difference across all of the lines.

Figure 6.42: Product availability targets

Class	Target
A	98
B	95
C	-

The product availability results which meet the targets for A and B lines are shaded in grey. The scenarios which generally have met these targets have a statistical safety stock calculation. This would be expected because it is more likely that a better result is gained if a considered mathematical equation is applied, rather than an equation which uses a fixed quantity or is manually entered by a buyer. The scenarios which meet the targets and have the minimum level of stock values are 5 and 6 for Anglia and the South West respectively. These scenarios use a moving average forecasting technique and an EOQ formula to calculate the order quantity. They use a different combination of safety stock and lead time methods to calculate the reorder point.

The next stage of the testing process was to set the model to run a segmentation strategy. There are two different scenarios, the first uses product classification and sales variability and the second adds a lead time variability factor. The techniques and methods are shown in Figures 6.45 and 6.46. The results once exported from the model are then compared against the non-segmented scenarios from the previous set of results.

Figure 6.43: Non-segmented results for the Anglia region

Scenario	Average daily stock branch value (£'s)				Product availability (%)			
	A	B	C	Total	A	B	C	Total
1	53,088	6,938	11,431	71,457	94.98	94.72	96	95.34
2	45,784	8,664	14,820	69,268	94.9	96.03	97.08	95.96
3	65,091	7,904	12,141	85,137	95.54	94.66	96.2	95.66
4	66,014	10,092	16,179	92,285	96.94	96.93	97.45	97.14
5	66,877	10,100	16,029	93,007	97.01	97.05	97.56	97.23
6	93,468	13,911	19,532	126,911	98.5	98.53	98.26	98.4
7	95,941	14,269	19,544	129,754	98.51	98.54	98.27	98.41
8	125,761	16,691	21,632	164,083	98.99	98.81	98.43	98.73
9	46,264	9,200	15,917	71,381	95.02	96.66	97.45	96.27
10	65,698	8,451	12,706	86,855	96.07	95.69	96.75	96.28
11	68,029	11,089	17,677	96,795	97.44	97.72	97.97	97.69
12	69,093	11,153	17,805	98,051	97.47	97.8	98.04	97.75
13	95,746	14,971	21,127	131,843	98.63	98.73	98.47	98.57
14	97,449	15,212	21,436	134,097	98.64	98.75	98.46	98.58
15	127,847	18,054	23,886	169,787	99.11	99.02	98.63	98.89
16	45,286	8,452	14,590	68,328	94.66	95.83	97	95.8
17	67,380	8,002	12,306	87,688	95.28	94.56	96.15	95.52
18	66,542	9,934	15,968	92,443	96.44	96.43	97.32	96.79
19	68,174	9,973	15,974	94,121	96.49	96.62	97.44	96.9
20	96,182	14,074	19,700	129,956	98.51	98.44	98.28	98.4
21	97,588	14,408	19,823	131,820	98.52	98.51	98.3	98.42
22	129,503	16,904	22,209	168,617	98.98	98.83	98.48	98.75

Figure 6.44: Non-segmented results for the South West region

Scenario	Average daily stock branch value (£'s)				Product availability (%			
	A	B	C	Total	A	B	C	Total
1	40,797	7,248	4,924	52,969	96.87	96.71	97.91	97.1
2	34,243	8,787	5,868	48,898	97.08	97.98	98.63	97.74
3	48,868	7,849	4,724	61,442	97.3	96.67	97.92	97.28
4	50,915	9,911	6,000	66,826	98.34	98.35	98.75	98.44
5	47,826	9,859	5,964	63,649	98.35	98.38	98.74	98.45
6	61,957	12,103	6,556	80,616	98.77	98.86	98.92	98.84
7	58,970	12,104	6,544	77,618	98.7	98.84	98.93	98.8
8	77,196	13,873	6,810	97,880	99.11	98.99	98.97	99.04
9	34,672	9,251	6,181	50,104	97.19	98.17	98.8	97.88
10	48,932	8,194	4,851	61,978	97.5	97.1	98.19	97.57
11	50,860	10,549	6,356	67,764	98.51	98.66	98.9	98.65
12	48,511	10,474	6,364	65,349	98.52	98.7	98.9	98.67
13	62,767	12,714	6,992	82,474	98.81	98.99	99.03	98.92
14	60,329	12,698	6,939	79,965	98.77	98.97	99.02	98.89
15	77,222	14,540	7,285	99,047	99.14	99.11	99.05	99.11
16	34,153	8,665	5,857	48,675	96.98	97.83	98.63	97.65
17	50,214	7,880	4,756	62,849	97.09	96.68	97.93	97.2
18	50,944	9,790	5,973	66,707	97.94	98.15	98.67	98.19
19	48,276	9,769	5,968	64,012	97.95	98.18	98.65	98.2
20	63,266	12,186	6,622	82,074	98.74	98.82	98.91	98.81
21	60,414	12,114	6,620	79,149	98.69	98.81	98.9	98.78
22	77,918	13,882	6,944	98,744	99.03	98.95	98.94	98.99

Figure 6.45: Segmented scenario run 1

Characteristics		Forecasting			Methods				Service Levels	
Class	Sales Variance	Type	Alpha	Alarm	Order Quantity	Safety Stock (SS)	Reorder Point (ROP)	Lead Time Demand (LTD)	Sales	Lead Time
A	High	SES / DES	0.25	Yes	EOQ	Normal Distribution	SS + LTD	Average	98%	-
	Low	SES / DES	0.5	No	EOQ	Normal Distribution	SS + LTD	Average	98%	-
B	High	SES / DES	0.25	Yes	EOQ	Poisson Distribution	SS + LTD	Average	-	-
	Low	SES / DES	0.5	No	EOQ	Poison Distribution	SS + LTD	Average	-	-
C	High	SES / DES	0.25	Yes	Order Multiple	0	1	0	-	-
	Low	SES / DES	0.5	No	Order Multiple	0	1	0	-	-

Figure 6.46: Segmented scenario run 2

Characteristics			Forecasting			Methods				Service Levels	
Class	Sales Correlation	Lead Variance	Type	Alpha	Alarm	Order Quantity	Safety Stock (SS)	Reorder Point (ROP)	Lead Time Demand (LTD)	Sales	Lead Time
A	High	High	SES / DES	0.25	No	EOQ	Normal Distribution	SS + LTD	Average	98%	90%
		Low	SES / DES	0.25	No	EOQ	Normal Distribution	SS + LTD	Average	98%	-
	Low	High	SES / DES	0.5	Yes	EOQ	Normal Distribution	SS + LTD	Average	98%	90%
		Low	SES / DES	0.5	Yes	EOQ	Normal Distribution	SS + LTD	Average	98%	-
B	High	High	SES / DES	0.25	No	EOQ	Poisson Distribution	SS + LTD	Average	-	85%
		Low	SES / DES	0.25	No	EOQ	Poisson Distribution	SS + LTD	Average	-	-
	Low	High	SES / DES	0.5	Yes	EOQ	Poisson Distribution	SS + LTD	Average	-	85%
		Low	SES / DES	0.5	Yes	EOQ	Poisson Distribution	SS + LTD	Average	-	-
C	High	High	SES / DES	0.25	No	Order Multiple	0	1	Average	-	-
		Low	SES / DES	0.25	No	Order Multiple	0	1	Average	-	-
	Low	High	SES / DES	0.5	Yes	Order Multiple	0	1	Average	-	-
		Low	SES / DES	0.5	Yes	Order Multiple	0	1	Average	-	-

The current purchasing model uses a fixed set of values for the key variables of reorder points and order quantities. These quantities are loosely extrapolated from a moving average forecast. The segmentation strategy applies different methods for the different product classes. It was decided that an exponential smoothing method would be used instead of a moving average method because although it can provide similar results[20] it requires less data storage and the formula is easier to manipulate by changing the parameters. Makridakis (1989) believes that empirical evidence shows that exponential smoothing is an "accurate, effective and reliable method".

A single exponential smoothing technique is used for products which have no trend and a double exponential smoothing forecasting technique for products which have a trend. A correlation coefficient is used to determine whether a trend exists. The alpha and beta parameters are either set to 0.25 or 0.5 depending on the degree of trend and variability of sales. These are calculated from the scale of the correlation coefficient. The alpha factors are updated every four months and the beta factors every six months. A forecast alarm is applied for any product which uses a 0.5 alpha factor. The mean demand is used for any product which has a monthly demand of 2 standard deviations or above for products which have a 0.25 alpha factor.

There are a number of possible forecasting methods which could be applied. These range from basic statistical models to the more complex autoregressive techniques such as the Box-Jenkins and Parzens methods (see Makridakis, 1989). It was decided in this case however that these methods are not suitable because they are either too basic or overly complicated and in practice would be difficult to implement at this stage or would not provide the desired results. The Movex system has the built in capability to perform exponential smoothing calculations and to incorporate this approach would be relatively simple.

[20] There is an approximate relationship between the alpha factor and the number of moving average periods $\alpha = \frac{2}{n+1}$ (Tersine, 1994, p.57). An exponential smoothing calculation with an alpha factor of 0.1 and 0.2 is roughly the same as a moving average with 19 and 9 periods respectively (Chary, 2004).

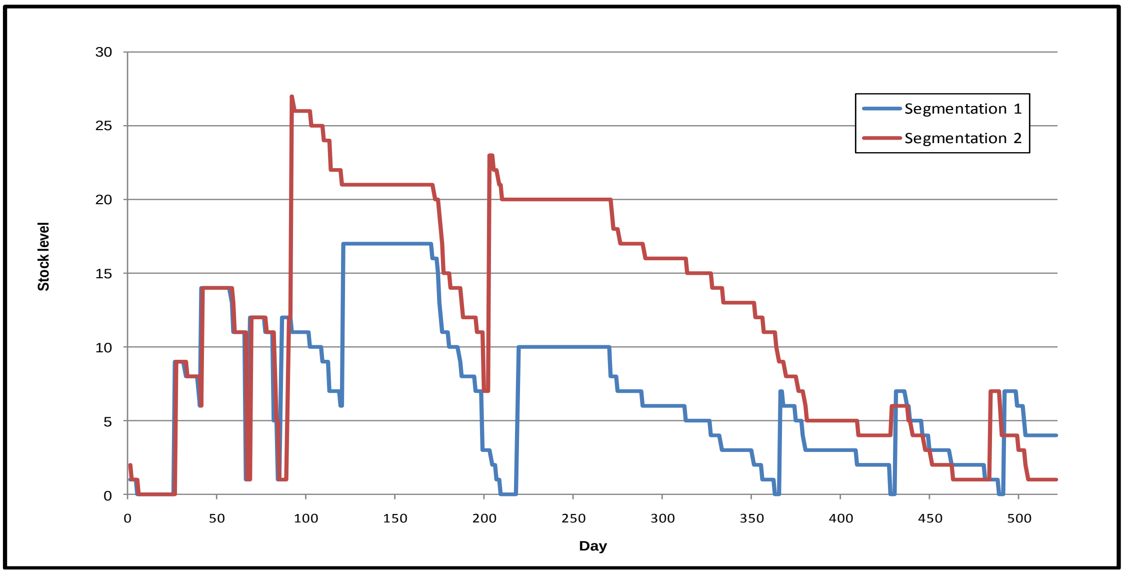
The safety stock quantities were calculated using a Normal or Poisson distributed statistic for A and B lines respectively. There is no safety stock for C lines to minimise the level of stock held for these products. A and B line products which have a lead time coefficient of variance of 0.5 or more, have a normally distributed lead time demand service level of 90% and 85% respectively. It is not necessary, for example, to set the lead time service level to 98% because the probability is multiplied by the customer service level. The order quantities are calculated using EOQ calculation with a holding cost of 0.1 and 0.3 for A and B lines respectively. The C line products are ordered in the minimum order multiples.

The results for the South West region showed a higher level of stock turnover and stock availability then the Anglia region. This is because of the significant level of overstocking which was prevalent for this region prior to the start of the research project. This was the main reason why the South West region was selected to be carried out first. The stock levels for this reason will return to the normal level after a longer period of time when the slow moving stock are sold off or disposed of.

The segmentation strategy for the Anglia region outperforms the non-segmented and current model. The segmentation strategy which does not use a lead time variability calculation has not met the ‘A’ line target service level. When this calculation was added the product availability reached the target at 98.11%. A comparison of stock levels for an individual ‘A’ line SKU for the two segmentation runs is in shown in Figure 6.47. The product has a lead time coefficient of 3.55. This means it has a standard deviation which is 3.55 times the mean. The graph shows that the segmentation 1 strategy which does not use a service level for the lead time continually runs out of stock. This is because the lead time varies significantly and this is not accounted for. The lead time service level in the segmentation 2 strategy buffers against this and therefore the product has an increased level of availability.

The segmentation approach provides a lower average forecast level for both regions. The non-segmented approach meets the 'A' line (98.5% & 98.35%) and 'B' line (98.53% & 98.38%) service expectations for the Anglia and the South West regions respectively. The target for the business is to reduce the 'B' lines down to 95% and this strategy has failed to do this and therefore producing an excess level of stock for these lines. The segmentation strategy produces a product availability of 95.2% and 96.57% for the Anglia and the South West region. These values are nearer to the target level. It is desirable to reduce the 'B' lines further in the South West.

Figure 6.47: Stock levels for an SKU using different segmentation strategies



The segmentation strategy reduces for the total average branch daily held stock value down from £126,911 to £112,712 for all lines for the Anglia region and from £63,649 to £60,786 for the South West region. This is because the segmentation strategy aims to reduce the average stock held for the 'B' and 'C' lines. For example there is a significant reduction in 'C' lines within the Anglia region from an average of £19,532 to £9,253. Although the current model has a lower average daily stock value it does not meet any of the targets. In reality though, the targets are met and the stock value is much higher. This is because the buyers purchase stock before it reaches the reorder point and manually change the order quantities. If this strategy is proven to be successful for the two regions being studied it could be extrapolated through the entire N&E business. This could result in further decreases in stock values.

A summary of the results for the segmentation strategy are shown in Figure 6.48. The full results can be seen in Appendix 41. Included in the table are the results for the current inventory model and the best results from the non-segmentation scenarios. The simulation model can export results for each of the branches for the entire run or on a monthly basis. This is useful because it shows which branches are underperforming and which ones are meeting their targets. The results for the branches within the Anglia region are shown in Figure 6.49. It can be seen that three of the branches out of the 15 in the region are not meeting their 98% target levels for ‘A’ lines. In practice these would be investigated to see why this has occurred.

Figure 6.48: Segmented results for the Anglia and South West regions

Region	Scenario	Average daily stock branch value (£'s)				Product availability (%)			
		A	A	C	Total	A	B	C	Total
Anglia	Current	94.98	94.98	11,431	71,457	19.17	37.51	150.01	72.26
	Non-segmented	98.5	98.5	19,532	126,911	38.12	80.13	257.79	128.66
	1	97.5	97.5	9,226	106,400	37.73	46.53	113.93	67.75
	2	98.11	98.11	9,253	112,712	39.5	47.74	113.92	68.73
South West	Current	96.87	96.87	4,924	52,969	12.68	29.28	167.44	56.14
	Non-segmented	98.35	98.35	5,964	63,649	23.89	58.47	282.61	95.19
	1	98.34	98.34	4,182	55,717	25.38	39.78	117.92	51.06
	2	98.63	98.63	4,180	60,786	26.36	40.06	118.07	51.61

Figure 6.49: Simulation results for branches within the Anglia region using a segmented strategy

Branch	Number of lines				Average daily stock branch value (£'s)				Product availability (%)			
	A	B	C	Total	A	B	C	Total	A	B	C	Total
PETERBOROUGH (RDC)	2,092	727	1,386	4,205	717,576	33,634	29,350	780,560	98.13	91.75	84.66	92.39
NORWICH	771	399	1,101	2,271	140,078	11,863	15,030	166,971	97.84	94.42	90.83	93.84
CAMBRIDGE	1,217	504	989	2,710	175,355	13,816	17,580	206,751	98.24	94.82	92.74	95.37
KINGS LYNN	753	316	658	1,727	93,412	7,480	9,412	110,304	98.21	94.43	92.24	95.04
NORTHAMPTON	887	358	758	2,003	138,737	9,489	16,316	164,542	98.12	95.3	93.51	95.65
GREAT YARMOUTH	743	325	769	1,837	57,222	8,301	9,174	74,697	98.04	95.32	93.83	95.48
WISBECH	415	183	475	1,073	14,460	1,944	2,199	18,603	97.78	97.46	95.67	96.79
BURY ST EDMUNDS	704	284	715	1,703	49,482	5,311	7,023	61,816	98.02	96.23	95.21	96.54
IPSWICH	798	334	717	1,849	52,578	6,713	7,911	67,202	98.04	96.28	94.33	96.22
LUTON	584	241	628	1,453	64,019	6,741	11,337	82,097	98.16	96.19	95.05	96.39
SPALDING	496	218	570	1,284	24,436	2,522	3,726	30,684	98.02	94.89	93.86	95.33
BOSTON	456	172	378	1,006	22,731	2,620	2,542	27,893	97.55	95.94	93.63	95.8
BISHOPS STORTFORD	361	170	481	1,012	17,316	2,014	2,491	21,821	98.31	95.98	95.66	96.66
MILTON KEYNES	367	193	402	962	35,455	2,956	2,798	41,209	98.15	96.31	94.96	96.45
KETTERING	371	162	370	903	12,244	1,377	1,902	15,523	98.34	97.46	97.09	97.67

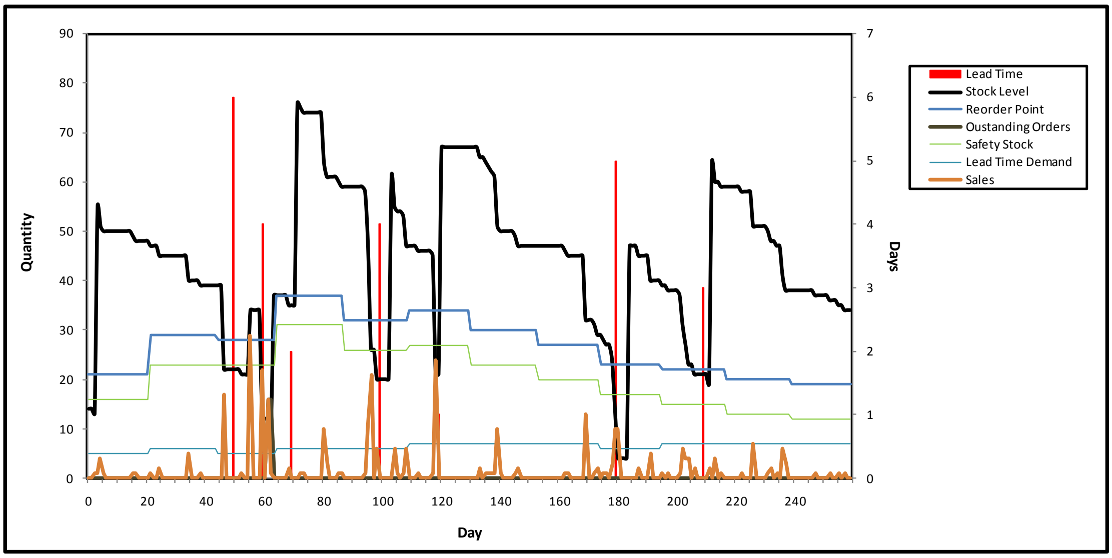
6.3.7 Validation

The results from the simulation model are an indication of what would be expected if the changes to the inventory system are made. It is not possible to emulate a system to a 100% level of accuracy so the system has to operate to an agreed degree of satisfaction. The recommendations to the business have been made and it is for the business to implement the proposed changes. There are discussions which need to take place with Intentia, the company which produces the Movex software, to make the programming changes which are required. The changes to the system are required to automatically update the forecasting parameters using a correlation coefficient equation. Once the system has been fully implemented the changes can be fully validated by evaluating the KPI's produced.

A validation approach of expert opinion was used within this section prior to changes being suggested to Intentia. There are a number of ways which the results from the simulation model could be validated before the system is implemented. It was important to get the viewpoint of an expert of the inventory system based within the company. This would give credence to the results and if any mistakes were located these could be rectified. A meeting was organised with the inventory manager who is based at Newey and Eyre's Head Office in Birmingham. The design of the model, using the process maps and programming flowcharts, had been previously discussed with the same person and fully verified.

This meeting was organised purely to go through the graphs and tables which were produced by the model. A sample of products with different degrees of variability and product classifications was chosen for the analysis. The products were graphed to show how the level of stock changed over time for the different scenarios. An example of one of the sample products is shown in Figure 6.50. The data for the graph was exported from the results produced by the simulation model. The dark black line indicates the balance of stock on hand on a daily basis. This moves up and down as customer and distribution orders are placed and purchase orders are received. A purchase order is raised when the balance reaches the reorder point. The time it takes for the delivery to arrive from the supplier is indicated by the lead time. The simulation model can produce this data for any of the products that were used in the simulation runs.

Figure 6.50: Individual stock analysis



The data and graphs from these products were examined and it was concluded that the results that were produced were as expected. The aggregate results also were reflective of what would be expected. There can be some confidence therefore that the results from the simulation accurately represent the current inventory system.

6.3.8 Recommendations

The results from the simulation model had predicted that by making changes to the inventory system the overall value of stock could be reduced whilst improving customer service levels for key 'A' classified products. This would create a financial benefit as revenues are increased and logistics costs are decreased. A summary of the recommendations are listed below:

1. Make the recommended changes immediately to the inventory system.

2. Cost benefit analysis for changes to the stock management software.
3. Review the correlation coefficient, coefficient variance values and system parameters every 6 months.
4. Review the classification of products every 6 months.
5. Complete stock analysis of products sampled across the supply chain.
6. Make the recommended changes to the monthly regional KPI's.
7. Continue publishing KPI's on a monthly basis.
8. Update policies and procedures documentation.
9. Training for inventory personnel.
10. A 6 months review of the profiling and layout at Avonmouth RDC.
11. Roll out the successful Avonmouth RDC pilot project to remaining RDC's and large stock branches; (ideal after changes to inventory systems).
12. Complete project review after 18 months.
13. Continue to search for improvements for the inventory system.

These recommendations have been discussed with N&E and they are investigating when implementation will be practical. It was recommended to the business that the desired changes be immediately made to the design of the inventory system. This was so the system would operate using a segmented approach as opposed to the single approach currently being used. The changes are required in the methods used for forecasting, the reorder point calculation and a new calculation to estimate system parameters. The requirements for the forecasting methods and reorder point calculations can be changed immediately with no cost because the modules for these are actively available as part of the Movex software package.

To incorporate the changes to the reorder point calculation which involves adding in the formulas to calculate the average order days cycle and lead time variability require changes to the Movex software. Calculations also need to be added to automatically calculate the coefficient of variance, correlation coefficient and product classifications. A cost benefit analysis is currently being undertaken to establish whether these changes should take place. If it is decided that these changes will not take place then these parameters can be estimated using manual analysis of historical data. It is suggested that whichever method is used it is good practice to continually review these parameters and calculations by conducting periodic analysis of individual products.

The changes which evidently will occur to working practices, policies, procedures, and processes, will require training to be given to inventory personnel and an updating of the relevant documentation. The personnel should be encouraged to understand how the system works to improve trust in the timings and buying quantities which are suggested by the computer system. It is recommended that buying personnel do not manually interfere with the process and change the quantities of the key variables. If it is felt that the Movex is failing to correctly automatically replenish products to a sufficient level then this should be flagged to the line manager for further investigation.

The changes to the inventory system need to be continually evaluated by producing and monitoring monthly KPIs. The selection of appropriate KPIs and the levels to which these are set remains a difficult management decision. It is important that a balance is struck between a push to promote better working practices and reduce costs whilst not undermining and setting unrealistic targets, which can damage staff morale. It was shown within the case study that a KPI can be designed with the attention to improve the business but actually results in a detrimental impact due to unforeseen consequences.

The many supply chain trade-offs have to be taken into account when designing KPIs so that overall profit is maximised It was evident that the business in this case had designed the majority of their KPIs to maximise customer service levels and increase sales. There was a lack of targets which were concerned with reducing operational costs and as a result stock holding was increased in order to improve availability of product. This had created over congested warehouses and as a result services levels were reduced. If a balance is found which leverages cost against service then the managers will seek to find strategies and methods which can improve on all areas. The concept of supply chain segmentation for example is a method which can achieve this.

The combination of changes to the inventory system and to the business KPI's aim to; promote best working practices, remove the temptation to find system workarounds, reduce unnecessary high levels of stock, create a balance for the need to decrease stock levels whilst maintaining customers service levels, and eradicate the need to manually change system variables.

The KPI's should be continued to be published every month and if any of the targets do not meet the requirements then the inventory managers should revaluate and adjust the system parameters where necessary. These managers should continually work towards improving the inventory system. It is recommended that the KPI's are changed to represent the following:

- total stock value (A, B, C);
- total number of critical purchase orders;
- total number of max purchase orders;
- total number of purchase orders;
- total number of excess distribution orders;
- total number of distribution orders;
- total number of replenishment orders;
- total number of stock-outs (A, B, C);

- total number of customer stock-outs (A, B, C);
- average stock turnover (A,B,C);
- stock availability percentage (A, B, C);
- customer availability percentage (A, B, C).

The ideal programme structure would have been to implement the changes to the business using a top down approach. This requires starting at the strategic level and working down through the tactical level and finally to the operation. This is because changes to a higher level will affect the levels below. For instance a strategic decision to change customer service levels will effect what happens at a tactical and operational level. The depth of stock levels will be directly affected and therefore locations previously allocated could be inadequate or become wasteful if the operational changes are carried out first.

It was necessary in this case for this research project to begin with making changes to the operation at the RDC in Avonmouth. This was because of the urgent need to reduce the congestion and get the operation to a level where it could meet service levels. It is recommended that once the changes to the inventory system are made a further review of the design of the RDC at Avonmouth is undertaken. This would not be as extensive as the first review and should only require design changes to a limited number of products. It is recommended that when all of the changes have been implemented a thorough review is undertaken by the business to test the success of the research project.

6.4 Chapter summary

This chapter has shown how a segmentation methodology can be successfully applied to different levels of the business. The application of the methodology and findings from three research projects was shown.

The solution implemented led to design changes to the region supply chain and RDC at Avonmouth. A segmentation approach was used to match strategies to different classifications of products and customers. Products in the region were located according to their sales pattern to the RDC, branch or CDC. Customers were allocated a delivery service level based upon their sales pattern. The Avonmouth RDC was used to implement an effective warehouse design. The immediate results had shown that productivity had increased.

The results showed that by applying a segmentation method a number of benefits are gained. Products can be classified by their business-value and targeted separately. This means that 'A' line products can be increased and the slow moving products reduced. This increases the revenue because products which are required by the customer are in stock more often. The overall level of stock is reduced because the slow moving products are reduced. These two categories combined add up to more products then 'A' line products so there is a reduction in the quantities held. This will help to reduce congestion in the RDC's and branches. By adding calculations for the average period of the order cycle and compensating for variances in lead times the reorder point levels are set to more realistic values.

A propose solution which was based upon a segmentation strategy was developed. It is recommended that the N&E inventory system is changed to reflect the proposed segmentation design. The inventory system should be evaluated on an ongoing basis by monitoring the proposed KPI's and analysing a sample of individual SKU's. If at any stage the KPI's fall below the target levels then changes should be made to the design of the system. The system is designed so that changes can be easily made by altering the system parameters. It might also be desirable to lower or raise stock levels to reflect a change in the business strategy. This can be achieved by moving products into different segments by altering the boundaries of segmentation or by altering the system parameters.

CHAPTER 7

7 CONCLUSION

7.1 Research study summary

The concept of supply chain segmentation was fully researched and a methodology was designed and tested using a case study research strategy. The research study was undertaken using a structured approach which followed a clear research strategy and process. The relevant subject literature was evaluated and areas for development were identified. It was documented that previous approaches had applied a segmentation strategy to isolated parts of the supply chain and a clear framework hasn't been developed.

The concept of supply chain segmentation is illustrated as a theoretical model and a generic framework is laid out. This was put into practice in a working environment. It was found that the variability of lead times was a factor that when considered in the segmentation process could improve the accuracy of the calculations used within the inventory system. It was shown that customers could be segmented and service levels identified for each sector. This increased revenue for key customers and reduced operational costs for customers which add less value.

A large quantity of data was collected and analysed in the form of graphs and tables. Qualitative information was collected and presented using a process mapping process approach. It was discovered that no one employee within the business had the required system knowledge of all of the processes involved. This meant that the process mapping stage was an integral part of this research study because it meant that all of the processes of the system could be completely understood and incorporated into the mathematical models.

The analysis and findings of the case study which were undertaken as part of this research study intended to set out and prove the hypothesis and fulfil the research aims. This hypothesis was as follows:

This research study tests the hypothesis that the stock management aspects of supply chain strategy, tactics and operation can be applied by stock and customer segmentation analysis to improve overall supply chain performance.

This hypothesis was engaged through the formulation and subsequent realisation of the specific research aims, objectives and questions. These were designed to reflect the subject, the nature of the problem being investigated and provide an avenue for practical solutions to be found. The design of this research study was laid out within the Introduction chapter of this thesis. The research aims which were carried out and fulfilled are as follows:

- to evaluate the principles of supply chain management and strategy and review the current literature which either indirectly or directly can be classed as a supply chain segmentation approach;

- to provide a methodological framework building on the research of Fuller *et al* (1993) which incorporates a supply chain segmentation approach bringing together established supply chain management techniques;

- to show that a segmentation strategy can be applied throughout the business at all planning levels;

- to test the Smith and Slater (2001) variability index which is used to categorise products into six segments and to determine if the variability of lead times is a significant factor.

- to investigate how customers can be included in the segmentation process;

- to investigate which factors can be used to create segments of products and how they relate to the different planning levels;

- to show the practical and financial benefits of the application of a supply chain segmentation strategy.

It is believed that the research study has fully achieved these aims and the relevant evidence is provided to support this assertion. It has to be noted that the final outcome of the implementation changes to the inventory system will be determined when completed at a future date. The hypothesis was vigorously tested by carrying out the research aims and objectives, and answering the research questions which were posed at the start of the research study; all of which are laid out and can be found in the introductory chapter.

A comprehensive review was undertaken of the existing literature within the main subject area together with all of the other relevant areas. These included subjects which were shown to overlap or were deemed important to the outcome of this study. This review is written up in its entirety within Chapter 2 and Chapter 3 of this thesis. This chapter gives context to the study, evaluates the existing literature and highlights any gaps.

The methods used as part of a supply chain segmentation strategy are taken from different subject areas such as supply chain design, and inventory and logistics management. The historical context, definitions and explanations for each of the subjects are covered. There are few authors who embrace supply chain segmentation as a subject in its own right. These papers are reviewed and explained in the context of this thesis. This thesis expands on this work and provides a working example of how this strategy can be applied within a business.

A segmentation methodology which combines aspects of existing studies with new approaches has been developed. A theoretical framework was followed and the findings from the outcome of the implementation are shown within the case study chapter. The methodology and the results which show the practical implications of conducting such an approach are shown to add to the existing literature. Throughout the duration of this study the outcomes and findings have been continually expressed within a number of academic papers and articulated at a number of conferences.

The following sections evaluate the contributions to theory and practice, successes and limitations of this research study and areas for possible research to continue.

7.2 Findings

This research study has led to a number of key findings. From a practical point of view the evidence presented has shown that the application of a segmentation strategy within the context of this research study has created significant benefits for the business. The improvements to customer service levels and reduction in the cost of the operation will continue to manifest in increased profits in the long term. From an academic perspective it has been shown that a segmentation subject area is limited to a small number of studies and is mainly focused on the design of supply chains. A number of the key findings are listed below:

- businesses commonly apply some degree of segmentation which tends to be disparately within individual business functions and not as holistic strategy;

    - a basic understanding and framework for a supply chain segmentation strategy was suggested by Fuller (1993);

    - in recent years supply chain segmentation has been adopted as a method for supply chain design (Christopher and Towill, 2002; Fisher, 1997; Lee, 2002; Mason-Jones *et al*., 2000; Naylor *et al*., 1999: Payne and Peters, 2004);

    - Lovell *et al* (2005) embrace supply chain segmentation as a strategy in its own right and have applied this approach within a company.

    - Smith and Slater (2001) suggest a six segment stock analysis approach to categorise products.

- Individuals within Newey and Eyre do not understand all of the processes involved in the systems investigated.

- there is a wide range of diversity within the external market and within organisations;
  - customers have different requirements and contribute a different level of value for the business;
  - products have a different perceived level of value for the customer and contribute a different level of value for the business;
  - the diversity of products and customers should be a key driver in the formulation of supply chain strategies;
- there is a trade-off between the cost of being able to supply a product and the sales revenue it produces;
  - a ‘diseconomy’ is created when uniform standards and policies are applied (Fuller *et al*., 1993, p.90);
  - resources for products and customers should be prioritised by their value they contribute;
  - a supply chain segmentation strategy balances supply chains costs against the value created for the business;
  - a segmentation strategy improves profitability by reducing operational costs and matching customer service levels;
- the parameters which are used within the single and double exponential smoothing forecasting calculations can be estimated using a 4 month and 6 month correlation coefficient calculation respectively.
- a single supply chain strategy within the business had led to logistics costs exceeding margins rendering many customers and products unprofitable. These high levels of logistics costs were due to the following:

- high overall storage costs;
- low rate of operation productivity;
- high level of stock obsolescence;
- low level of stock liquidity;
- high rate of stock-outs for key lines;

▪ A number of benefits were created by applying differentiated strategies to different segments of products and customers using different factors;

- the removal of slow moving stock to a centralised RDC reduced levels of stock and congestion;
- transport costs were reduced by changing delivery service levels for different segments of customers;
- warehouse productivity was increased by reprofiling products and redesigning the layout of the warehouse by segmenting products by throughput and product characteristics;
- the results of the simulation model showed that the level of stock could be reduced and customer service levels matched by segmenting products into 12 segments by value, sales variability and lead time variability;

▪ a supply chain segmentation methodology can be applied throughout the different management areas of the supply chain;

- manufacturing;
- storage;
- handling;

- transportation;
- purchasing;
- marketing.

7.3 Limitations of research

The implementation of the methodology within a working environment provided a great benefit to the outcome of this thesis. It has allowed the theoretical aspect of this study to be fully tested and evaluated. The company has allowed an open access to information and a platform for which the research programme could be tested and implemented. This was without presenting barriers to the scalable changes which took place. It was necessary to concentrate on a single case study because of the time and effort required to carry out a programme of this size.

Although every effort has been applied to reduce bias and triangulate a number of sources of information within this single case study this clearly only represents a narrow perspective. The complex nature of the study which was particularly prevalent in the design of the simulation model can only be inferred to be applicable in the wider environment. The generic nature of this strategy does however lend to the confidence that this is in fact is the case. It could however be shown that the theoretical framework is not suitable for companies operating within different markets or for companies situated differently on the supply chain.

An objective of the case study was to implement methods to improve the profitability of the company by making changes to operational methods. This is a financial objective and there are many ways to measure whether a business is well run and successful. It could be argued that a successful business is one where the employees are intrinsically happy. This does not mean that the two strategies are mutually exclusive. A segmentation strategy can lead to increased happiness through the improvements which were made to working practices. It has to be noted that the welfare of employees was not considered as a measure within the context of this study. This is both a strategy that could be pursued to improve profitability and also as the main driver to achieve different priorities a business may want to pursue. Research undertaken by Gavin and Mason, 2004 shows the importance of happiness in the workplace and its effect on productivity. A survey of small business conducted on behalf of the Institute of Personnel and Development concluded that their result showed that “the more satisfied workers are with their jobs the better the company is likely to perform in terms of subsequent profitability and particularly productivity (Patterson *et al*., 1998, p.x).

The empirical study which was conducted of the inventory system was limited to testing a small selection of the many possible scenarios. This was coupled with a finite selection of the values for the forecasting parameters and parameters used in the segmentation analysis. This occurred in part because some level of limitation is inevitable, and secondly to make sure the analysis was conducted in a reasonable time frame. There could be a criticism that the best possible solutions were not found and some areas were not fully investigated as a result. This is true in some respect but the findings although not totally exhaustive were shown to provide benefits for the business. This limitation of permutation testing provides an opportunity for avenues which can be investigated in further work.

This test case can be used as a pilot study in which the framework outlined within this study can be generalised and adapted to work in different environments. It is the aspiration that future work is undertaken to continue to test this strategy further within a number of different companies and industries and by comparing a number of different scenarios.

7.4 Contribution to theory

The main aim of this research was to contribute to the existing research on supply chain segmentation. This concept was at the centre, underpinning the strategic development of the study. The case study provided the basis for which to present the benefits of this strategy. This strategic concept was implemented to different aspects of the operation and a theoretical framework is laid out.

The approach was to combine a number of supply chain methods from existing supply chain management literature in a way that has not been previously reported in the academic literature. These can be categorised into three main streams; supply chain design, warehouse design and inventory management. These areas of research have been discussed at length within this thesis.

The main contributions to theory made within this study are related to subject areas of supply chain segmentation and inventory management. The design of the supply chain and warehouse utilises existing theory in the context of the concept of supply chain segmentation. The next two sections set out and summarise these contributions to theory.

7.4.1 Supply chain segmentation

The existing literature on supply chain segmentation is limited. There are few academic papers which embrace this as a subject even though the positive benefits have been emphasised (A.T. Kearney, 2008; Fuller *et al*, 1993; Lovell *et al*., 2005). The methods and reasoning of this strategy have been applied to isolated areas of management and not interpreted as a theory of segmentation. These approaches are embedded as theories within smaller subject areas and have not been amalgamated into a holistic strategy and set out as theoretical framework. The concept in recent years has been applied mainly to the design of supply chains (Christopher and Towill, 2002; Lee, 2002; Mason-Jones *et al*., 2000; Naylor *et al*., 1999; Payne and Peters, 2004). The outline of a methodology for supply chain segmentation was set out by Fuller *et al* (1993). It is argued in the article that products and customers can be segmented into distinct logistics pipelines. This approach is adapted by Fisher (1997) who shows that products can be segmented as two different types. It is shown that these segments are best serviced by either a functional or innovative supply chain. Lovell *et al* (2005) argues that a segmentation strategy should involve characterising product and customers by using many more factors.

This thesis has set out to build upon this concept and elaborate on the basic methodology set out by Fuller *et al* (1993). It adds to the existing practical application which was shown by Lovell *et al* (2005) by going further. A more detailed framework is outlined and the financial benefits clearly stated. The framework was designed to be generic and it is expected that it can be successfully used in different businesses. This is an assumption at this stage and would require further testing.

The segmentation process is shown at the different levels of the business and increased to use many different factors. Smith and Slater (2001) outline a number of key logistics characteristics and develop a ‘set of goals and operating procedures’ based upon these. It is shown that a stock segmentation methodology can reduce operational costs and maintain customer service levels. This analysis is developed further to include the added dimension of lead time variability and increasing the number of segments to 12 as opposed to the 6 used by Smith and Slater (2001).

7.4.2 Inventory management

It was discovered that the methods found within the existing literature for estimating forecasting parameters did not prove to be either successful or practical for this study. Makridakis and Wheelwright (1989) state that optimal parameters can be found by comparing forecast errors. This method in practice is difficult to implement with a large number of products and requires a considerable resource for testing.

The desired approach was to segment products and by using their characteristics apply a suitable forecasting parameter. It is suggested by Bernard (1999) that larger forecasting parameters should be applied to products which have a low variability of demand but are subject to periods of radical change. The literature did not provide methods for distinguishing different types of products. To analyse demand patterns for all of the different products is not a practical solution because this would require an unacceptable amount of time and resource. A statistical coefficient of variance formula and a variability formula proposed by Smith and Slater (2001) were tested. It was shown that segmenting products using these formulas did not result in minimising forecasting errors.

An examination of a sample of different sales patterns and how they related to different forecasting parameters highlighted that the variability between periods was a more important factor then the overall variability of the pattern. It was shown that the values for alpha and beta can be chosen by the average degree of correlation between sales periods. In addition a method for determining the reorder point calculation was developed in terms of three dimensions, product classification, sales volume and lead time variability. An average order cycle quantity was added for the delay in the ordering process. This method for determining the reorder point combines a number of existing calculations to form a different approach. It is expected that these formulas can be fully utilised into existing inventory systems to improve the accuracy of forecasting and to increase the predictions of stock replenishment.

7.4.3 Papers presented

The theoretical conclusions of this research study have been written and verbally presented at the following conferences: The European Logistics Association Doctoral Conference in July 2008 in Grainau, Germany, The Logistics Research Network (LRN) conference in September 2008, 2009 and 2010. A paper has been submitted to the International Journal of Logistics: Research and Applications.

7.5 Contribution to practice

The supposition is that supply chain segmentation is an effective strategy which can be applied within any inventory managed business. It can be applied throughout the levels of the business to areas of a strategic; tactical or operational basis. In practice a study of this nature can have a significant benefit for companies. By better managing products and customers in accordance with their value, profit levels can be maximised in the long term. A reduction in stock levels and an improvement in customer service levels for key customers will reduce financial burdens and increase revenues. A reduction in the total quantity of stock held and the level of this stock can reduce congestion and improve productivity.

A business can maximise the efficiency of the warehouse operation by using the characteristics of its products to calculate the storage requirements. This is achieved by obtaining the most suitable storage types and allocating the most efficient storage location. The levels of savings which can be obtained will depend heavily upon the company and the extent to which the supply chain operation is currently being managed. The greater the extent of mismanagement the higher the level of benefits which can be gained.

It is possible that the methodology can be implemented within individual areas of the supply chain such as the design of the warehouse or the purchasing department. This may lead to some short term gains but not produce the desired effect in the long term. The implications are that a problem in another area which continues to be mismanaged could eventually recreate the problem which was solved. This is why it is recommended that the strategy is implemented throughout the business so the complete benefits can be realised.

This study has a significant operational and financial benefit if this type of strategy is implemented. This type of study requires a lot of change and implementations to take place within the business. The methods which were used to calculate the type of forecasting method, the forecasting parameters and the reorder point calculations are an easy solution for businesses to employ. For many companies this could provide an effective cost solution. This could benefit companies which use sophisticated expensive solutions or companies which use a more basic approach. A reorder point calculation which includes the effect of lead time variability and order cycles can improve the accuracy of the replenishment cycle. Companies which heavily compensate for these two factors by increasing safety stock levels could reduce their stock significantly if this approach is used.

7.6 What has been personally learnt

The process of completing a PhD has been difficult but enjoyable and an invaluable experience. The wide reaching scope of this research study has provided numerous benefits. A mix of technical knowledge, interpersonal skills, and improved judgment and decision making competences has been developed through the fulfilment of this study. The academic and practical aspects have added different types of skills and knowledge.

The most obvious area of attainment is the knowledge which has been learnt as part of the researching process. Extensive knowledge has been attained within the area of the research study. This was gained from the comprehensive researching of the literature and methodology. The scientific approach of investigation through observation and analysis of evidence, which was used to test the hypothesis, has developed cognitive critical thinking skills. The aim was to use a logical approach which questions the quality, reliability and relevance of the material. This is important because this way of thinking can be translated both as a benefit in my personal life and for future work endeavours. By using this exhaustive method a decision making process which finds the right and reliable solutions can be sought to the problems at hand.

A significant area of improvement was developed in communication skills. The method of and extensive writing undertaken has improved the clarity of writing and the ability to argue and put forward a logical and structured point of view. The interpretation of this work at various conferences has helped to develop confidence and an improvement in speaking clearly and authoritatively on the subject.

The practical aspects of this study have helped to develop different skills. An extensive knowledge has been gained of different areas of supply chain management whilst carrying out and implementing the work. The hands on approach adopted has added to the experience and given a great insight into working practices and how theory works in practice. By working on a large scale study of this nature I have been able to improve my existing project management competencies. A number of skills such as interviewing techniques, working as part of a team, time planning, have all been improved as a result of the challenges which were met. This is a set of skills which is a necessity in the modern business environment. A number of new technical skills have been learnt and improved, particularly within the areas of mathematics and computer programming and simulation modelling. These skills could provide to be a useful asset in any future work undertaken.

The most valuable aspect of this study has been to work with fellow professionals and the knowledge gained by doing so. This has been invaluable and an effective method of learning.

7.7 Further research

The limitations which were previously discussed lend themselves to areas for further research. The segmentation methodology which was applied within the company can be translated to be tested in a number of different companies. The changes which were implemented to the design of the supply chain, the layout of the warehouse and the management of inventory are not specific to this one company. The concept of a supply chain segmentation strategy is generic but can be applied using different methods to fit to the problem.

The products and customers of this particular company or within the electrical wholesale industry in general may well have unique characteristics. There is scope for further research to be carried out to test the variation in the characteristics of products and customers in different companies and industries and to different types of business. This would be prevalent for businesses which operate a global supply chain as opposed to a national supply chain.

The segmentation approach which was tested within the simulation model used a number of well established forecasting techniques and methods. Although this provided a satisfactory solution for the business there are a host of possible different approaches that could be used which could possibly provide better solutions for this company or within different companies. The methods could be expanded to include more sophisticated forecasting techniques with more segments that could incorporate seasonal sales patterns and product groupings. Further segmentation which uses more categories could use more specific parameters. This trade-off between the number of segments and the complexity of the solution could be investigated.

An established problem within supply chains is the “Bullwhip” or “Forrester Effect”. This is where stock is amplified down through the supply chain. There is scope for research to be carried which tests the different segments against the effect on stock amplification and how particular segments could be targeted to reduce that effect. It would be expected that the segments of products within this study which had a high level of sales and lead time variability would have an increased level of amplification. A study could be undertaken to determine what the effects of using higher forecasting parameter values for different segments of products. A mathematical based solution could attempt to use the segmentation framework to find the points at which the supply chain performance is maximised by tested a large quantity of different segmentation approaches and permutations of parameters. This could be adapted to find a method which uses a profit orientated approach, such as the customer action matrix which uses an Activity based costing (ABC) system (see Figure 2.34) put forward by Sabath and Whipple (2004).

It was discovered that buyers in a number of instances were making purchases which were above what was being suggested by the purchasing system. This was to make a minimum quantity which was required to claim a discount from the suppliers, known as branch gained benefit (BGB). This increases the stock which is held but it less clear whether there is a financial benefit from the discounts against the added warehouse costs. It is also not clear what effect this has on the supply chain as a whole in terms of stock and cost and whether it increases the bullwhip effect. This was not considered within this research study because it is a substantial amount of work. There is an opportunity for a further substantial piece of research to be carried out to investigate the effect BGB has on the company and the supply chain.

7.8 Concluding remarks

This research study in its completion has developed into a substantial piece of work. The study was structured using an academic theoretical framework which was implemented successfully within a working business environment. A supply chain segmentation strategy is a practical method so it was important to show the benefits of what this could achieve when it is implemented. This study was planned and carried out by combining a social research methodology with the disciple of project management.

The findings of the study demonstrated that supply chain segmentation can provide significant financial benefits for an organisation. The hypothesis was found to be true by interpreting and analysing the evidence which was gathered and subsequently analysed and validated. This was a rigorous process which fulfilled the research aims, objectives and questions. The implementation of the study within the business has significantly improved the operation and increased profitability. Due to some aspects of the research programme still being implemented the long term success of the study will need to be determined in the future.

The theoretical framework which was applied combined established academic principles with some new approaches. This study has added to the literature which currently exists in the field of supply chain segmentation. This study is original in the design of the segmentation methodology and adds to existing elements within the field of inventory management. It is an original piece that combines components of supply chain management into a single strategy which has a clear framework to be interpreted into a practical environment. This methodology can be implemented throughout the levels of the business to reduce overall operational costs and meet desired customer service expectations.

The segmentation approach which was used by Smith and Slater (2001) was built upon to add the dimension of lead time variability. This increased the accuracy of the reorder point for products which had a high variability of lead time. In the field of inventory management regression techniques are developed to determine the level of parameters which control the level of stock. This approach is a simple and effective method for determining the alpha and beta factors.

This research study has provided some groundwork for future research. The supply chain segmentation methodology which was proved successful in this context requires further research within different companies and industries. This will provide further evidence of the benefits that can be gained from this approach. This work can be built upon to test more scenarios and the benefits of increasing the segmentation analysis. The aim for the future is to publish more academic papers in scientific journals so that it can be tested and challenged by the academic community.

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APPENDICES

APPENDIX 1: Rexel Group consolidated pro forma income statement

(in millions of euros)	Year ended December 31, 2008	2007	Change in %
Sales	**13,735.0**	**13,728.6**	**0.1%**
Same number of working days			*(0.2)%*
Gross profit	3,262.5	3,316.8	(1.6)%
as a % of sales	*23.8%*	*24.2%*	
Distribution and administrative expenses	(2,624.1)	(2,600.5)	0.9%
Operating income before other income and other expenses (EBITA)	638.4	716.3	(10.9)%
Adjusted EBITA	***712.6***	***736.3***	(3.2)%
as a % of sales	*5.2%*	*5.4%*	
Adjusted EBITA excluding the non-recurring items in Q1 2007	**712.6**	**720.3**	**(1.1)%**
as a % of sales	*5.2%*	*5.2%*	

Source: Rexel Annual Report (2008).

APPENDIX 2: Process of building theory from case study research

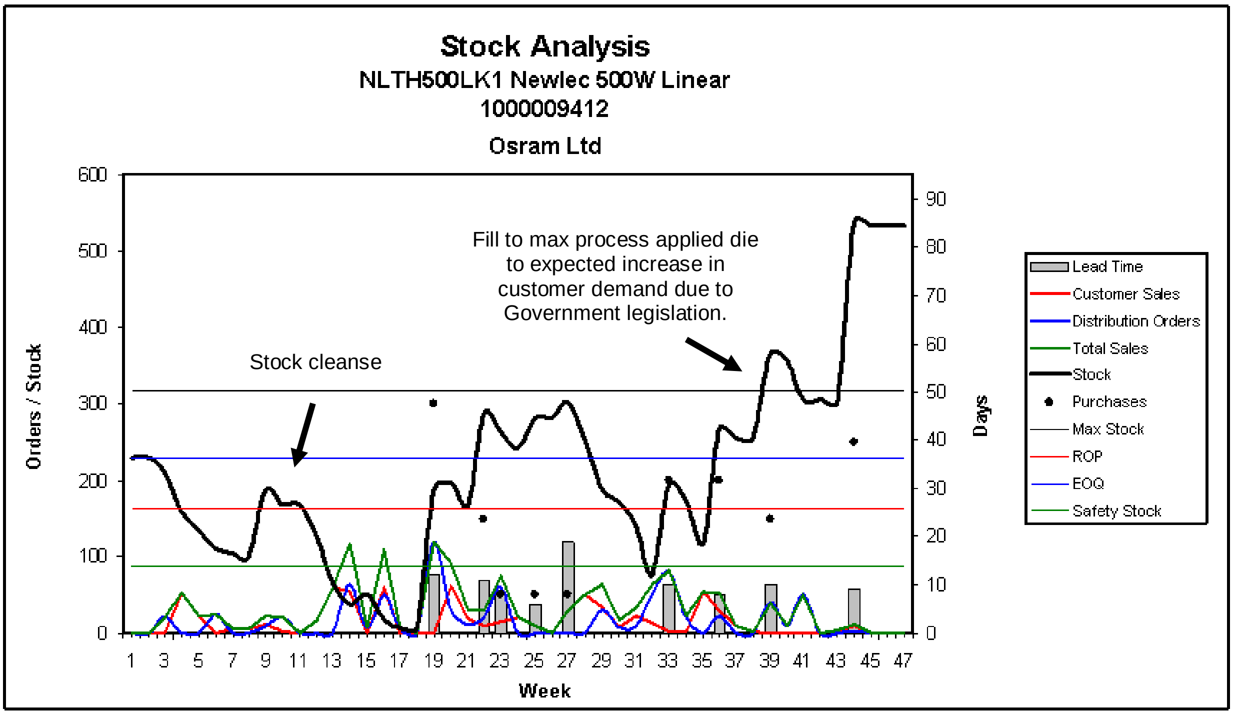
Step	Activity	Reason
Getting Started	Definition of research question	Focuses efforts
	Possibly a priori constructs	Provides better grounding of construct measures
	Neither theory nor hypotheses	Retains theoretical flexibility
Selecting Cases	Specified population	Constraints extraneous variation and sharpens external validity
	Theoretical, not random, sampling	Focuses efforts on theoretically useful cases – ie those that replicate or extend theory by filling conceptual categories
Crafting Instruments and Protocols	Multiple data collection methods	Strengthens grounding of theory by triangulation of evidence
	Qualitative and quantitative data combined	Synergistic view of evidence
	Multiple investigators	Fosters divergent perspectives and strengthens grounding
Entering the Field	Overlap data collection and analysis, including field notes	Speeds analyses and reveals helpful adjustments to data collection
	Flexible and opportunistic data collection methods	Allows investigators to take advantage of emergent themes and unique case features
Analysing Data	Within-case analysis	Gains familiarity with data and preliminary theory generation
	Cross-case pattern search using divergent techniques	Forces investigators to look beyond impressions and see evidence through multiple lenses
Shaping Hypotheses	Iterative tabulation of evidence for each construct	Sharpens construct definition, validity and measurability
	Replication, not sampling, logic across cases	Confirm, extends and sharpens theory
	Search evidence for "why" behind relationships	Builds internal validity
Enfolding Literature	Comparison with conflicting literature	Builds internal validity, raises theoretical levels and sharpens construct definitions
	Comparison with similar literature	Sharpens generalising, improves construct definition, and raises theoretical level
Reaching Closure	Theoretical saturation when possible	Ends process when marginal improvement becomes small

Source: Eisenhardt (1989, p.533).

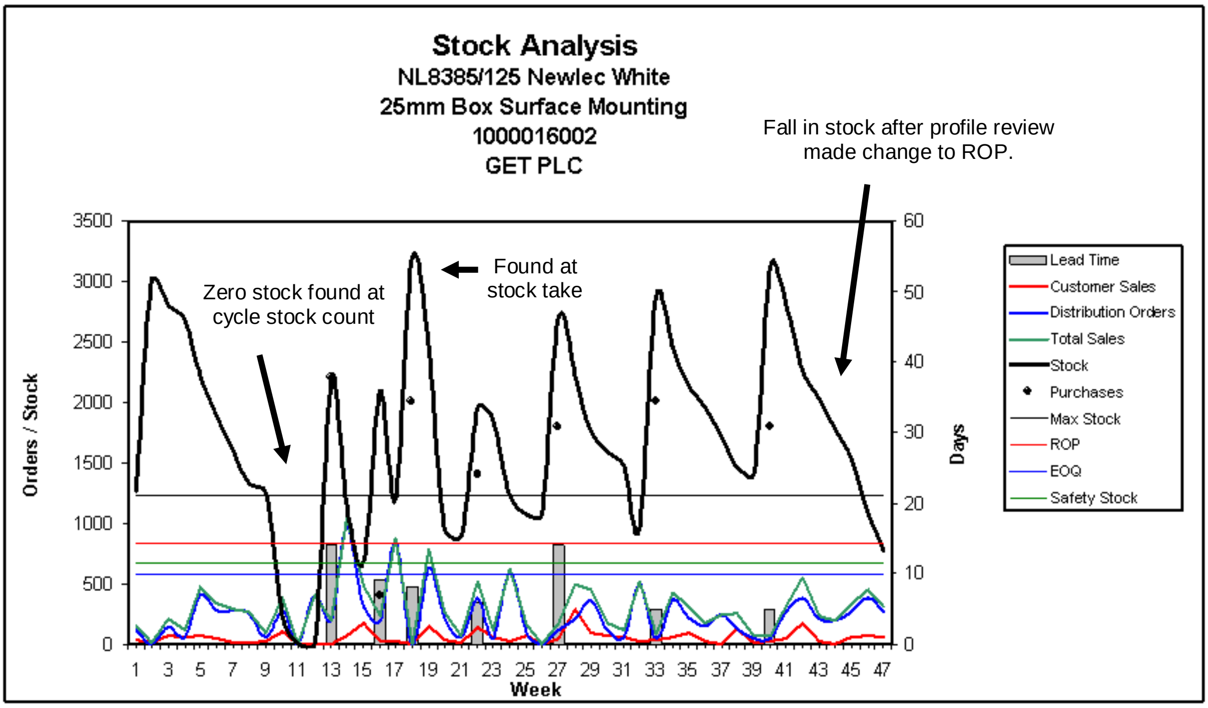
APPENDIX 3: Comparison of actual and test model

Product No	Actual	Test	% Difference	Unit Cost	Difference	Difference Value	Type
1	11,180	3,784	66.157%	£3.1977	7,396	£23,651	Fast
2	5,140	2,132	58.521%	£2.6200	3,008	£7,880	Fast
3	10,383	6,874	33.797%	£0.0556	3,509	£195	Fast
4	223,489	127,264	43.056%	£0.0556	96,225	£5,350	Fast
5	7,662	2,802	63.432%	£0.8010	4,860	£3,893	Fast
6	225,866	171,928	23.881%	£0.0018	53,938	£97	Fast
7	7,659	6,927	9.553%	£0.0400	732	£29	Fast
8	1,064	737	30.761%	£0.6910	327	£226	Fast
9	781	471	39.636%	£0.6910	309	£214	Fast
10	8,894	5,639	36.601%	£0.1748	3,255	£569	Fast
11	187,443	118,149	36.968%	£0.0035	69,294	£243	Fast
12	2,283	857	62.464%	£1.1340	1,426	£1,617	Fast
13	4,151	2,691	35.175%	£0.1800	1,460	£263	Fast
14	4,966	3,246	34.647%	£0.3320	1,721	£571	Fast
15	11,852	7,192	39.317%	£0.1630	4,660	£760	Fast
17	2,810	702	75.006%	£3.1977	2,108	£6,740	Fast
18	732	409	44.198%	£4.3077	324	£1,394	Fast
19	400	160	59.881%	£10.8000	239	£2,586	Fast
20	3,963	3,190	19.485%	£0.2710	772	£209	Fast
21	50	42	16.651%	£8.0900	8	£68	Medium
22	583	848	-45.273%	£12.8772	-264	-£3,401	Medium
23	8	8	-2.113%	£180.4338	0	-£29	Medium
24	213	213	0.000%	£7.5068	0	£0	Medium
25	11	9	17.127%	£152.3793	2	£291	Medium
26	45	26	40.853%	£32.2380	18	£589	Medium
27	8	33	-322.222%	£7.5240	-25	-£190	Medium
28	116	150	-29.610%	£6.8112	-34	-£233	Medium
29	20	29	-41.743%	£12.0680	-8	-£101	Medium
30	325	344	-5.977%	£12.7458	-19	-£247	Medium
31	2	5	-128.387%	£134.0400	-3	-£410	Medium
32	17	14	15.901%	£34.7018	3	£94	Medium
33	19	18	5.540%	£20.7172	1	£22	Medium
34	17	33	-91.411%	£5.8500	-16	-£92	Medium
35	13	78	-477.886%	£6.4500	-64	-£415	Medium
36	9	7	16.260%	£20.7840	1	£29	Slow
37	4	15	-292.969%	£16.0767	-12	-£186	Slow
38	7	7	0.000%	£26.4088	0	£0	Slow
39	2	2	-15.311%	£198.9971	0	-£49	Slow
40	4	6	-54.428%	£37.8779	-2	-£73	Slow
41	1	6	-366.265%	£158.9450	-5	-£743	Slow
42	5	11	-137.584%	£151.0110	-6	-£953	Slow
43	1	4	-449.425%	£29.4963	-3	-£89	Slow
44	-3	2	193.195%	£42.6108	-5	-£214	Slow
45	125	125	0.000%	£6.0045	0	£0	Slow
46	-4	25	656.627%	£15.6895	-29	-£460	Slow
47	5	5	5.651%	£6.8569	0	£2	Slow
48	5	5	0.657%	£12.7146	0	£0	Slow
49	4	4	19.444%	£45.1070	1	£39	Slow
50	2	5	-204.505%	£28.2076	-3	-£99	Slow
Grand Total	**722,329**	**467,230**				£49,636	

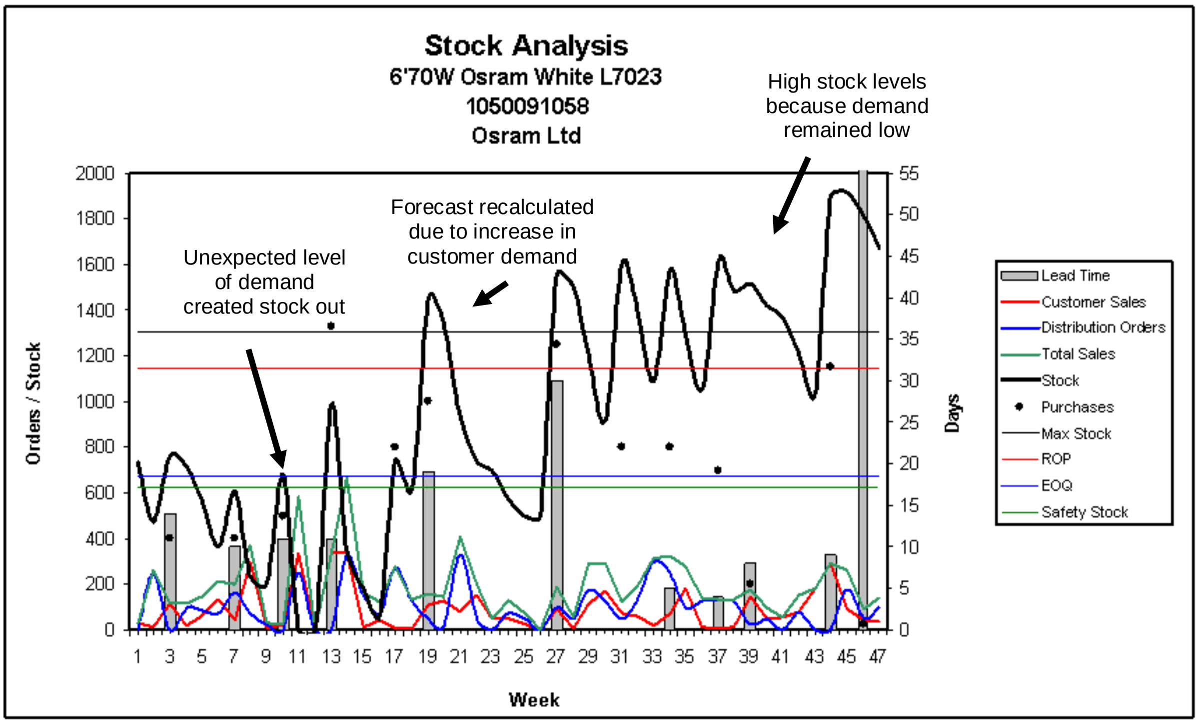
Appendix 4: Stock analysis (SKU 2)



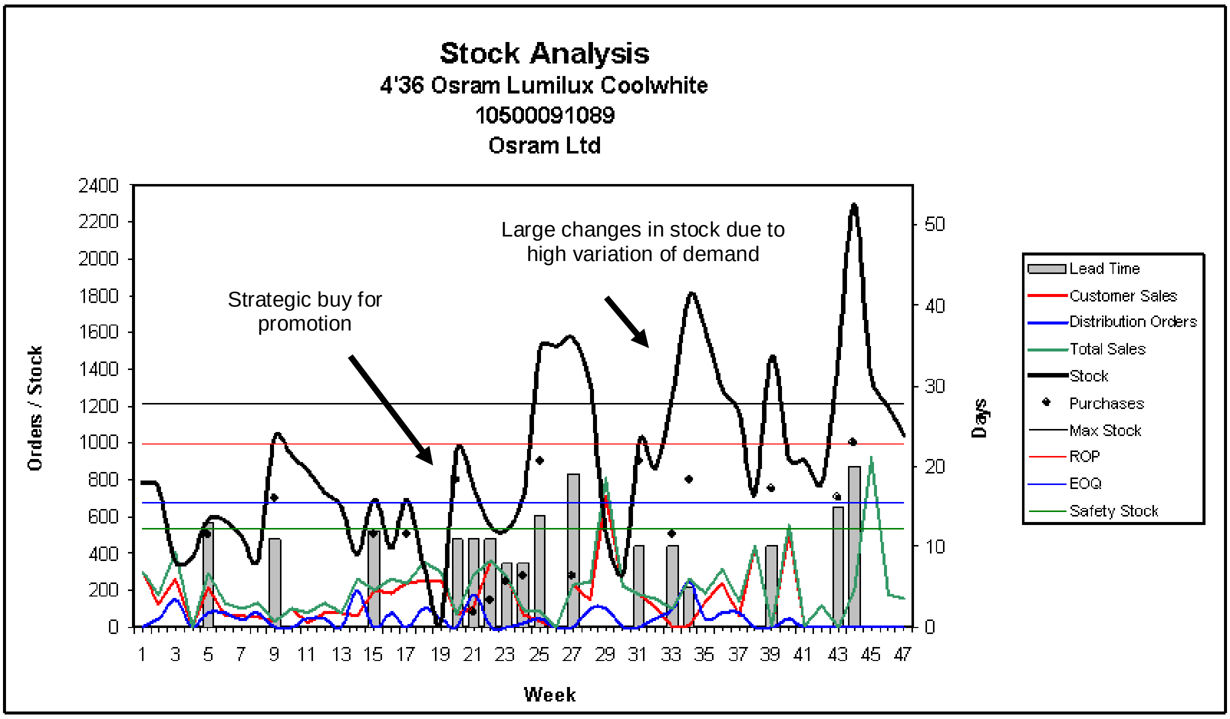
Appendix 5: Stock analysis (SKU 3)



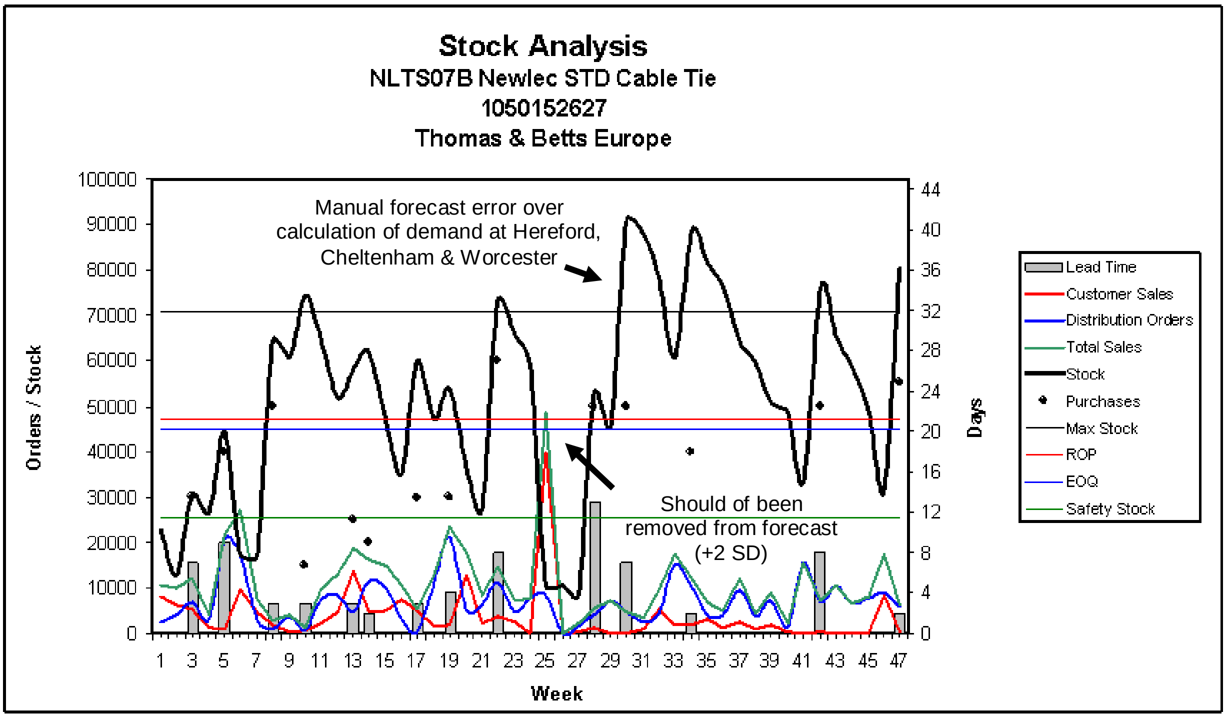
Appendix 6: Stock analysis (SKU 4)



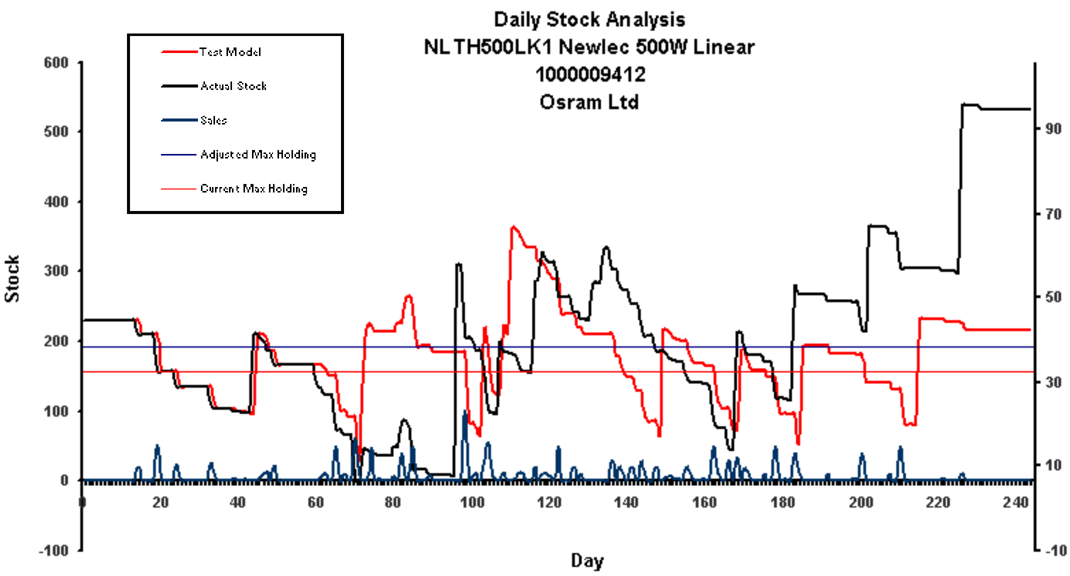
Appendix 7: Stock analysis (SKU 5)



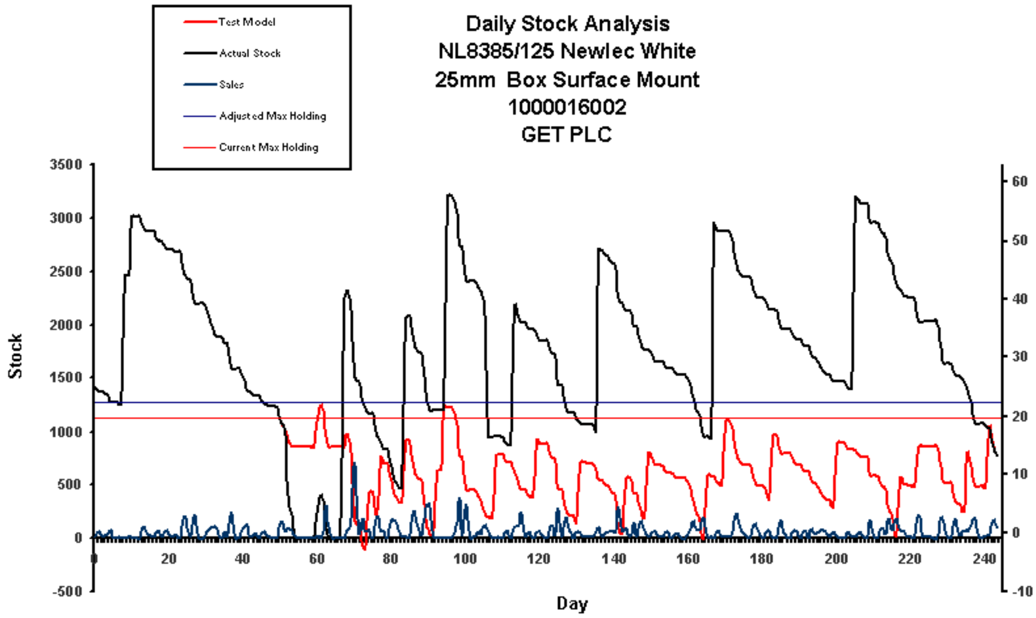
Appendix 8: Stock analysis (SKU 6)



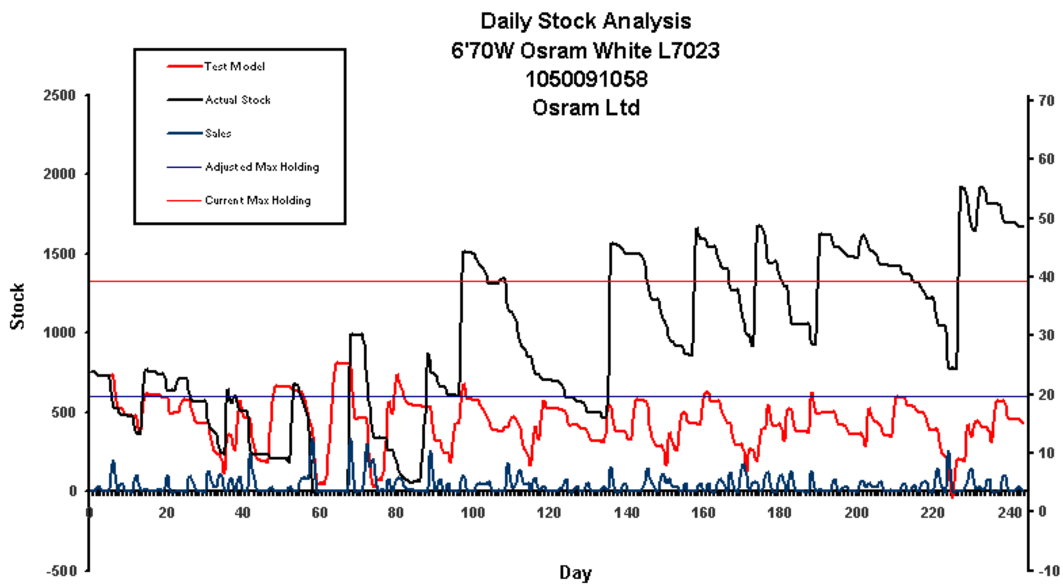
APPENDIX 9: Comparison of actual and test model (SKU 2)



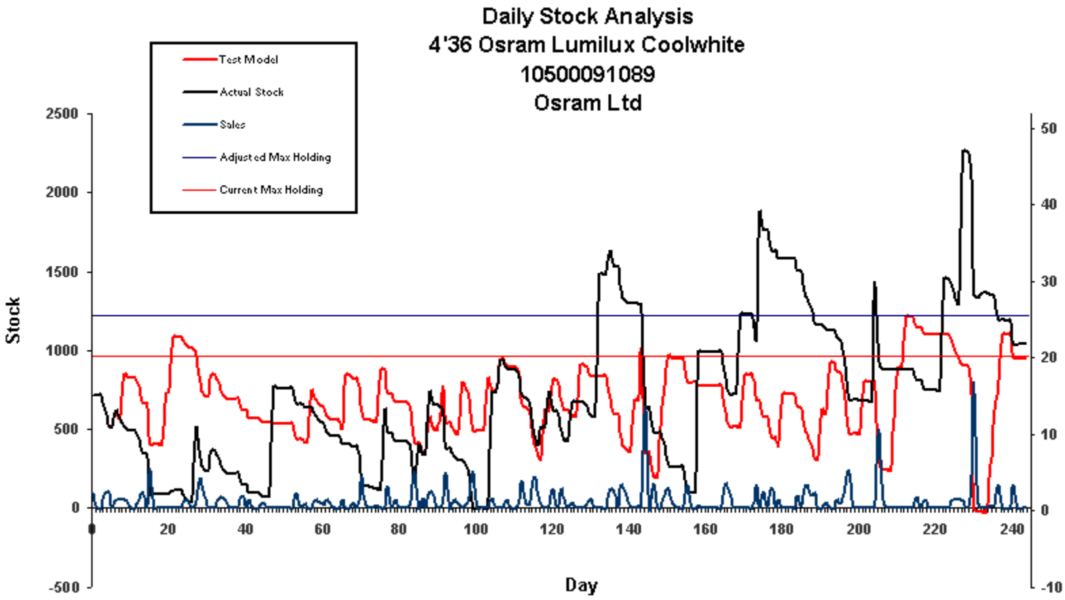
APPENDIX 10: Comparison of actual and test model (SKU 3)



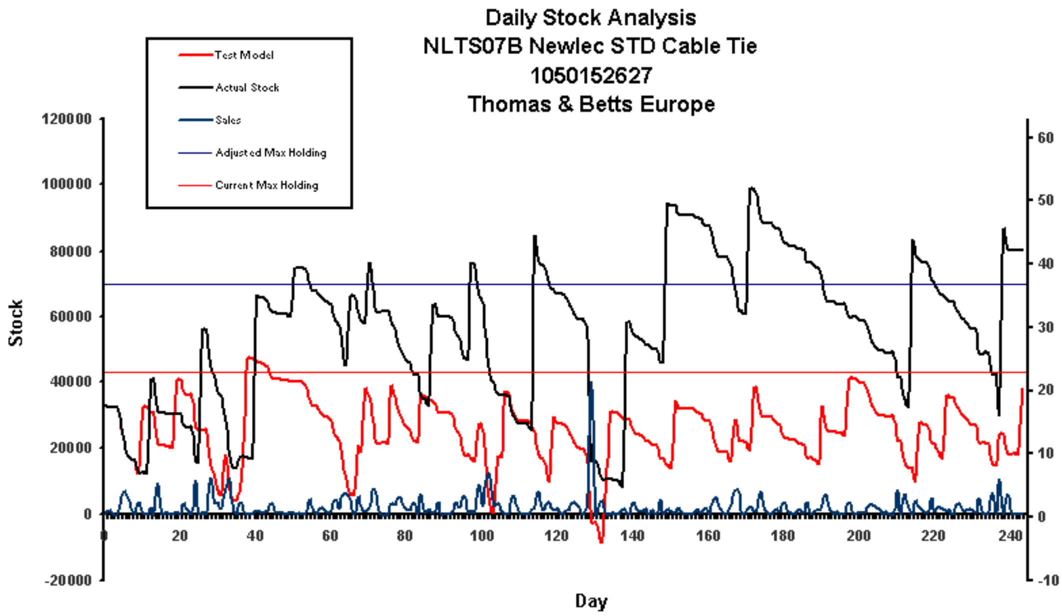
APPENDIX 11: Comparison of actual and test model (SKU 4)



APPENDIX 12: Comparison of actual and test model (SKU 5)



APPENDIX 13: Comparison of actual and test model (SKU 6)



APPENDIX 14: Micro Saint software explanation

Micro Saint has all the capabilities available to build a complex DES model. It is not industry specific and the generic features means that any type of discrete event system can be modelled. The object-orientated programming (OOP) environment which the software uses allows for flow charts to be easily represented as a network of tasks. The software incorporates the Microsoft C# programming language which can be utilised to construct complex expressions and algorithms. The main elements of the software described in the Micro Saint User Manual (2005) are listed and explained below:

1. **Task network:**

   executes a sequence of tasks with variability under conditions and in sequences specified;

2. **Entities:**

   conceptual objects that travel through a task network;

3. **Variables:**

   represent dynamic states or characteristics, with values that change as effects of tasks, queues or scenario events;

4. **Functions:**

   return values or perform procedures when they are called in tasks, queues, scenario events, or other functions;

5. **Snapshots:**

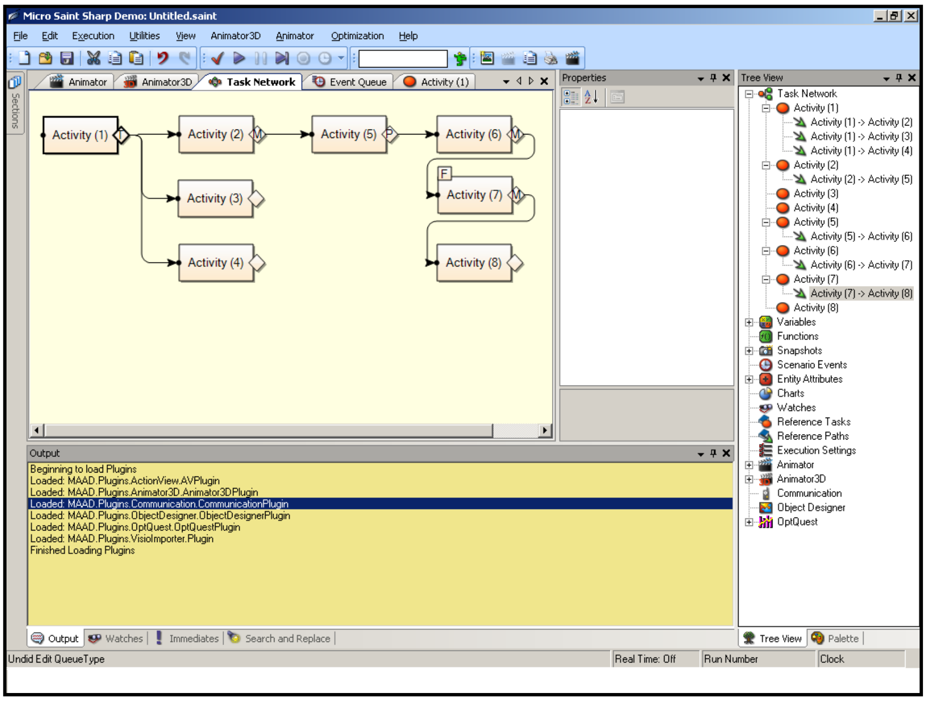
   collect the values of particular variables when triggered by conditions that you specify;

6. **Scenario events:**

   schedule to occur at specific clock times to change values of variables or trigger tasks.

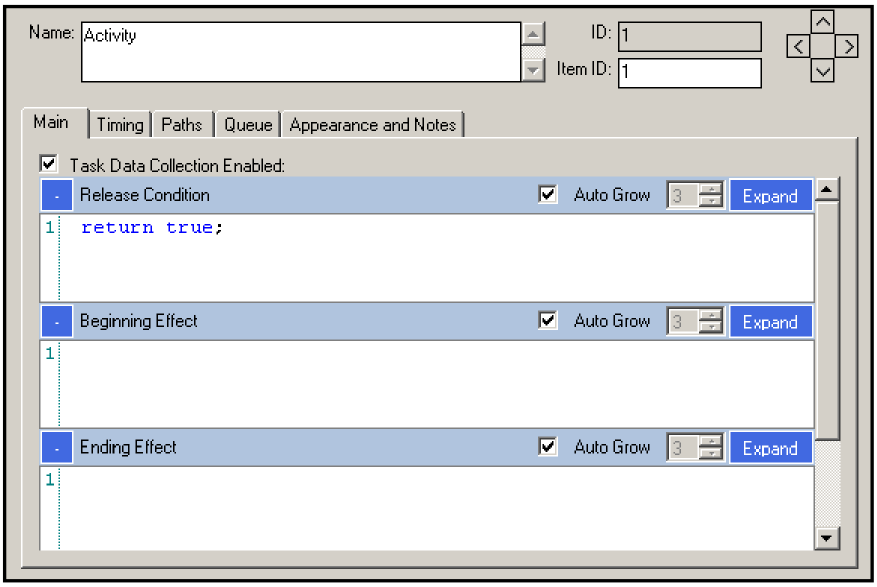
The activities of a flow diagram are represented by a task network diagram. The layout of the front end screen and an example of a task network diagram is shown below. The structure is designed by dragging tasks objects from the palette tab into the task network. Activities that are linked are joined by paths.

Micro Saint Window



The logic of the model is created by adding rules and expressions for each of the activities. These are set up in the activity window, an example is shown in below. The timing, paths, queues, conditions and effects of each activity are manipulated by adding expressions and changing the parameters within the various tabs.

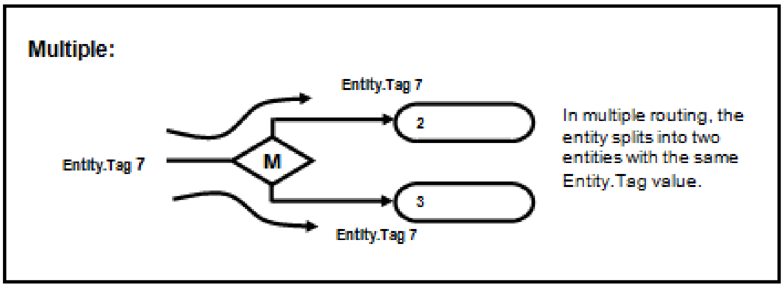
Activity window

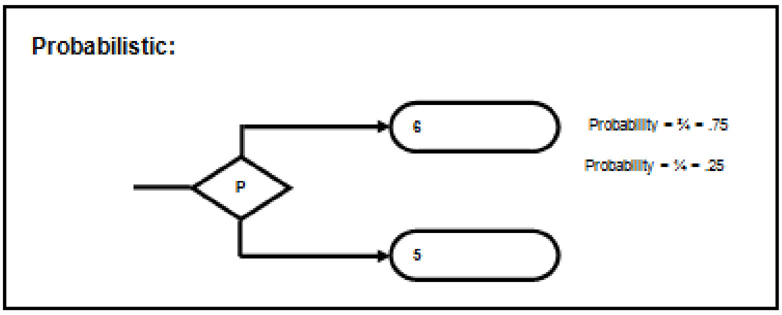


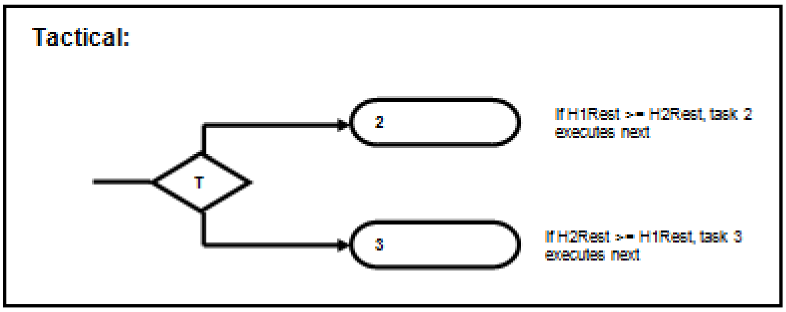
The timing of an activity determines the length of time each activity takes to execute. This is usually expressed by a pattern determined from a probability distribution. The path of an activity determines which activity is evaluated next. There are three different types of path: tactical, probabilistic, or multiple. Examples of these are shown in below (Micro Saint User manual, 2005) p.101-102). Queues are where entities are accumulated before they are executed. There are four types of queues listed in the Micro Saint User Manual (2005):

- None – entities wait until they are released. Entities are not sorted;
- FIFO (First in First Out) – the next entity to be selected from the queue is the one that is in the queue the longest;
- LIFO (Last in First Out) – the next entity to be selected from the queue is the entity that entered the queue most recently;
- Sorted – the next entity to be selected form the queue is based on a priority value.

Timing expressions







Expressions are defined using a combination of local and global variables which are either system or user defined. The following types are available (Micro Saint User manual, 2005, p.112):

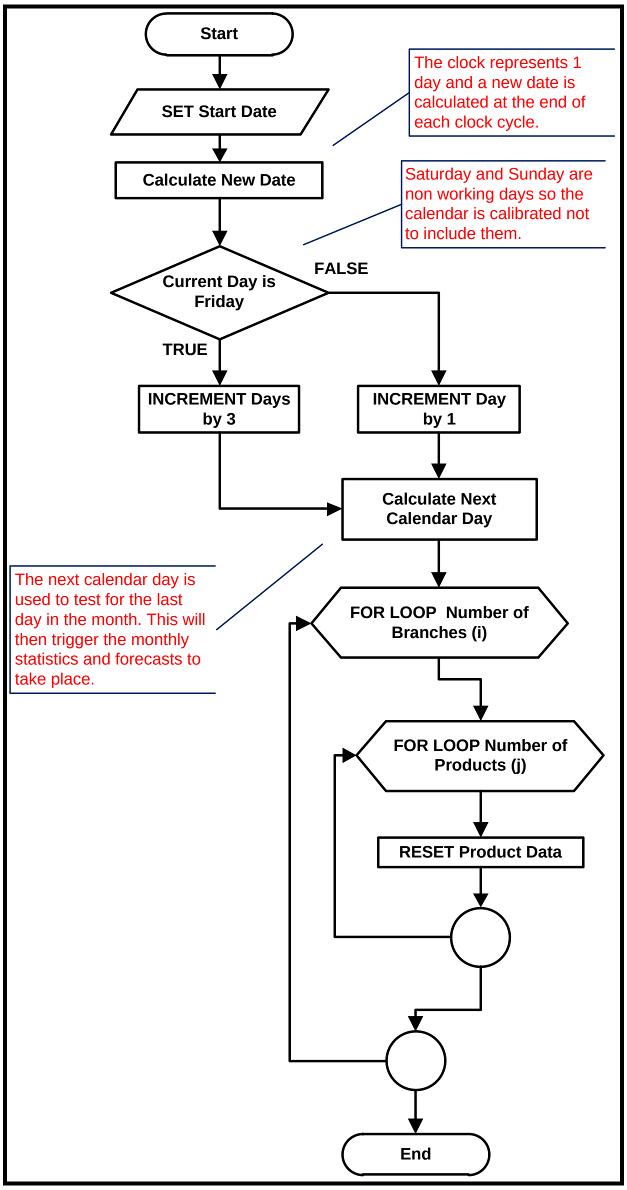
- integer (-2 billion to +2 billion);
- floating point (5.0 x 10^{-324} to 1.7 x 10^{308});
- string;
- boolean;
- object;
- hashtable;
- arbitrary;
- entity;

Snapshots and graphs are used to record the results which are generated by the simulation model. Micro Saint proposes the following steps which are required to build and analyse a simulation model (Micro Saint User manual, 2005):

1. Determine the questions you want to answer.
2. Analyse the process you want to model,
3. Draw the network diagram,
4. Define the variables and system changes,
5. Define how the jobs, decisions and the queues operate.
6. Define any custom functions called in the jobs, queues, or scenario events.

7. Check for errors.
8. Run and debug the model.
9. Add data collection.
10. Analyse the data.

APPENDIX 15: Calendar set flowchart



Pseudo Code: Calendar Set

IF Todays Date IS GREATER THAN 0

SET Date EQUAL TO SYSTEM CLOCK

SET Division EQUAL TO Todays Date DIVIDED BY 5.000001

SET Week Number EQUAL TO TRUNCATE OF DIVISION

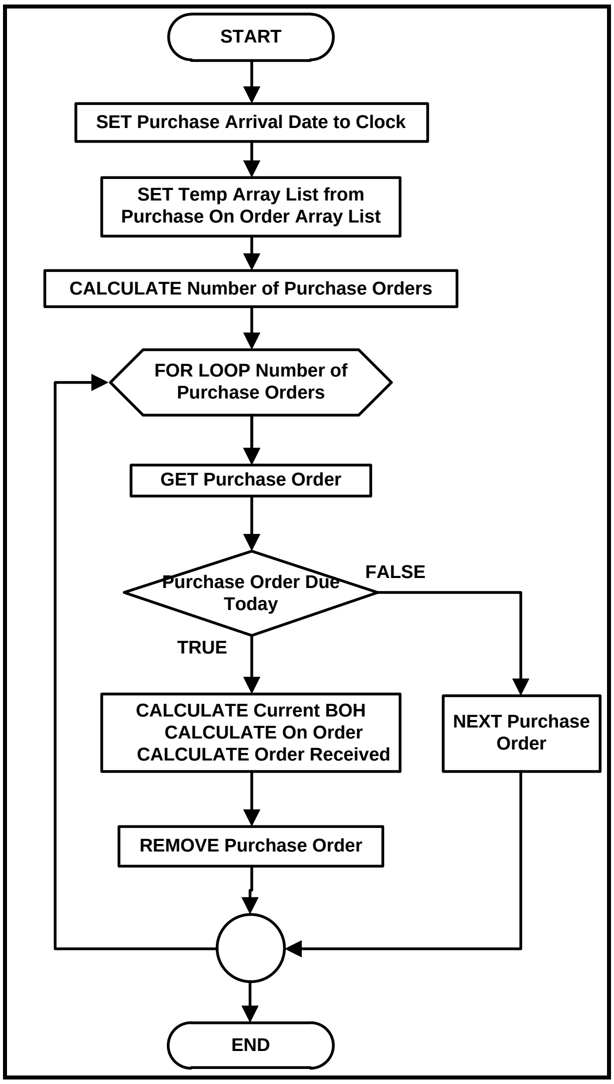
SET Adjusted Date TO Date PLUS Week Number MULTIPLIED BY 2

SET Todays Date EQUAL TO SYSTEM DATE CALCULATION ADD Adjusted Date

END IF

RESET Product Data TO 0

APPENDIX 16: Supplier replenishment order received flowchart



Pseudo Code: Supplier replenishment order received

LOOP THROUGH Purchase Orders IN LIST

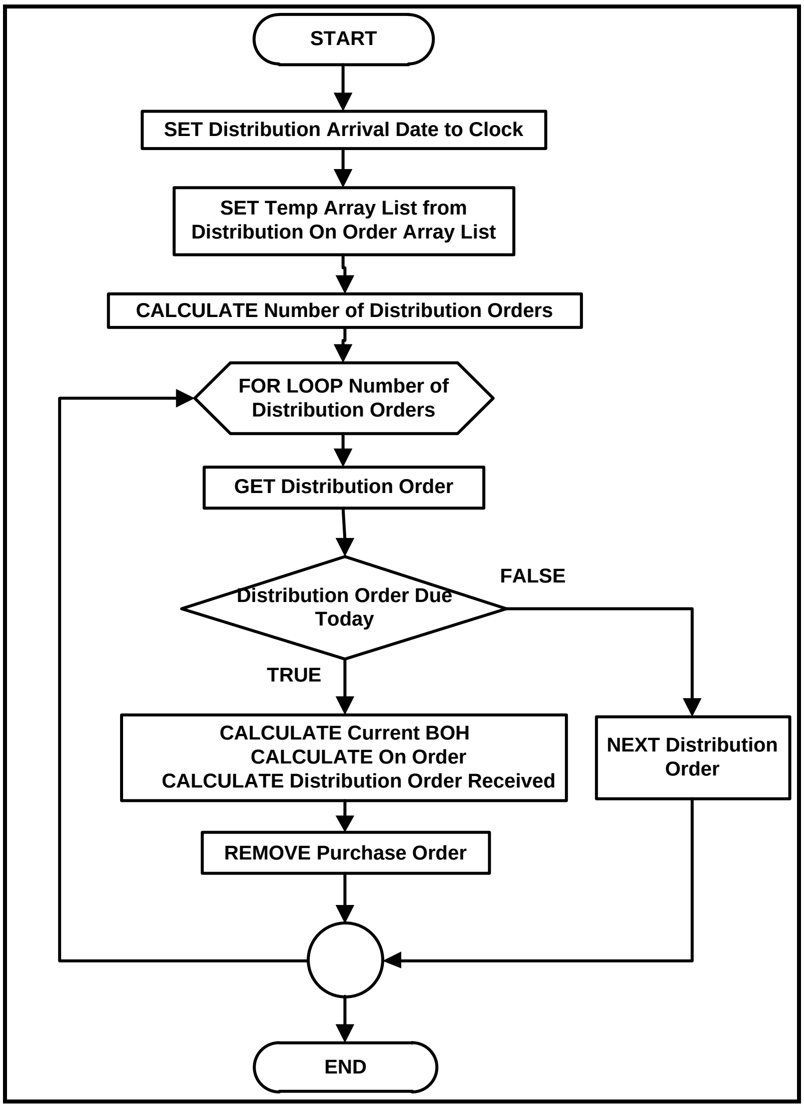
IF Todays Date EQUAL TO Purchase Order Arrival Date

ADD Purchase Order Qty TO Current BOH
ADD Purchase Order TO Order Received
MINUS Purchase Order Qty FROM Qty on Order

REMOVE Purchase Order IN LIST

END LOOP

APPENDIX 17: Distribution replenishment order received flowchart



Pseudo Code: Distribution replenishment order received

LOOP THROUGH Distribution Orders IN LIST

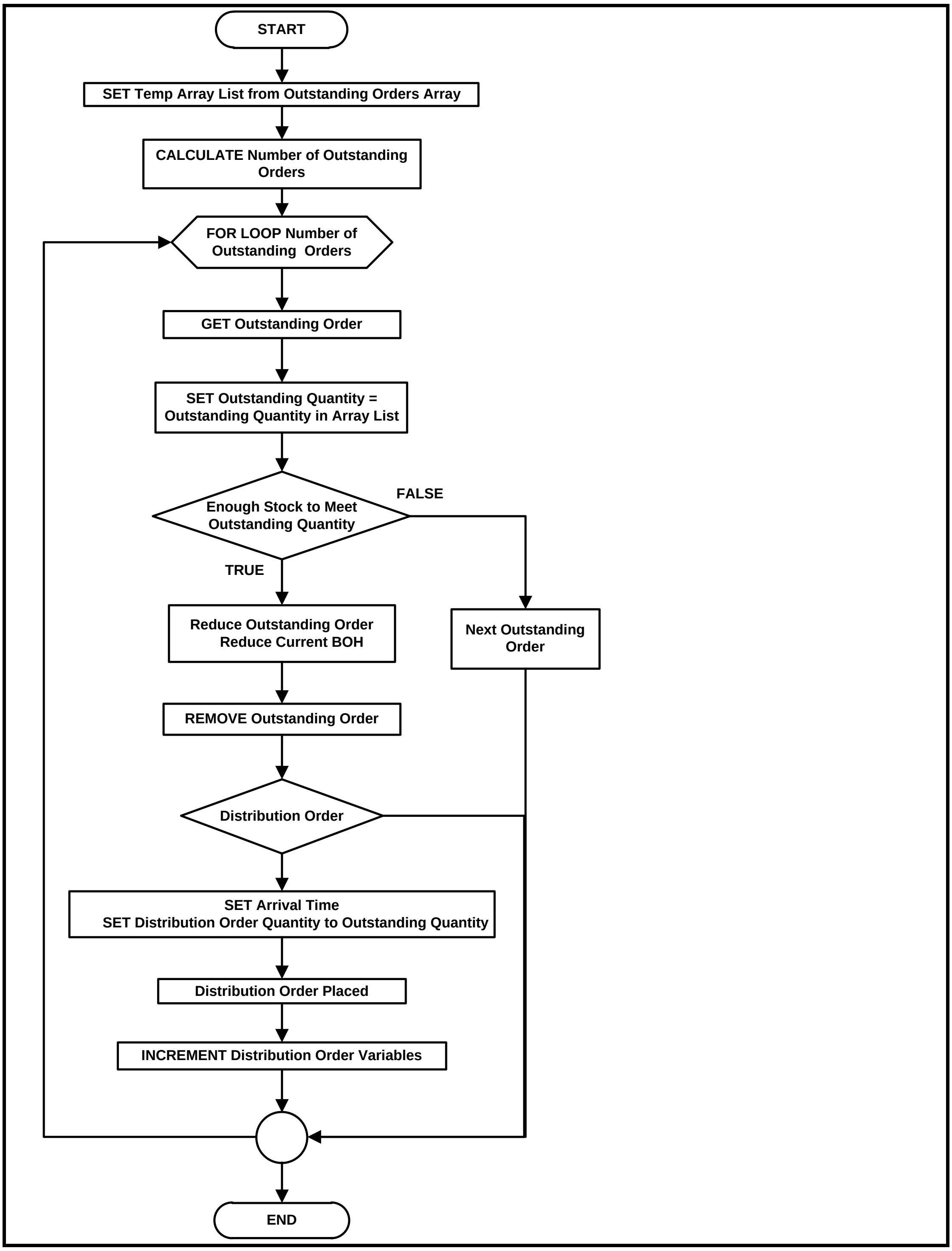
IF Todays Date EQUAL TO Purchase Order Arrival Date

ADD Purchase Order Qty TO Current BOH
ADD Purchase Order TO Order Received
MINUS Purchase Order Qty FROM Qty on Order

REMOVE Distribution Order IN LIST

END LOOP

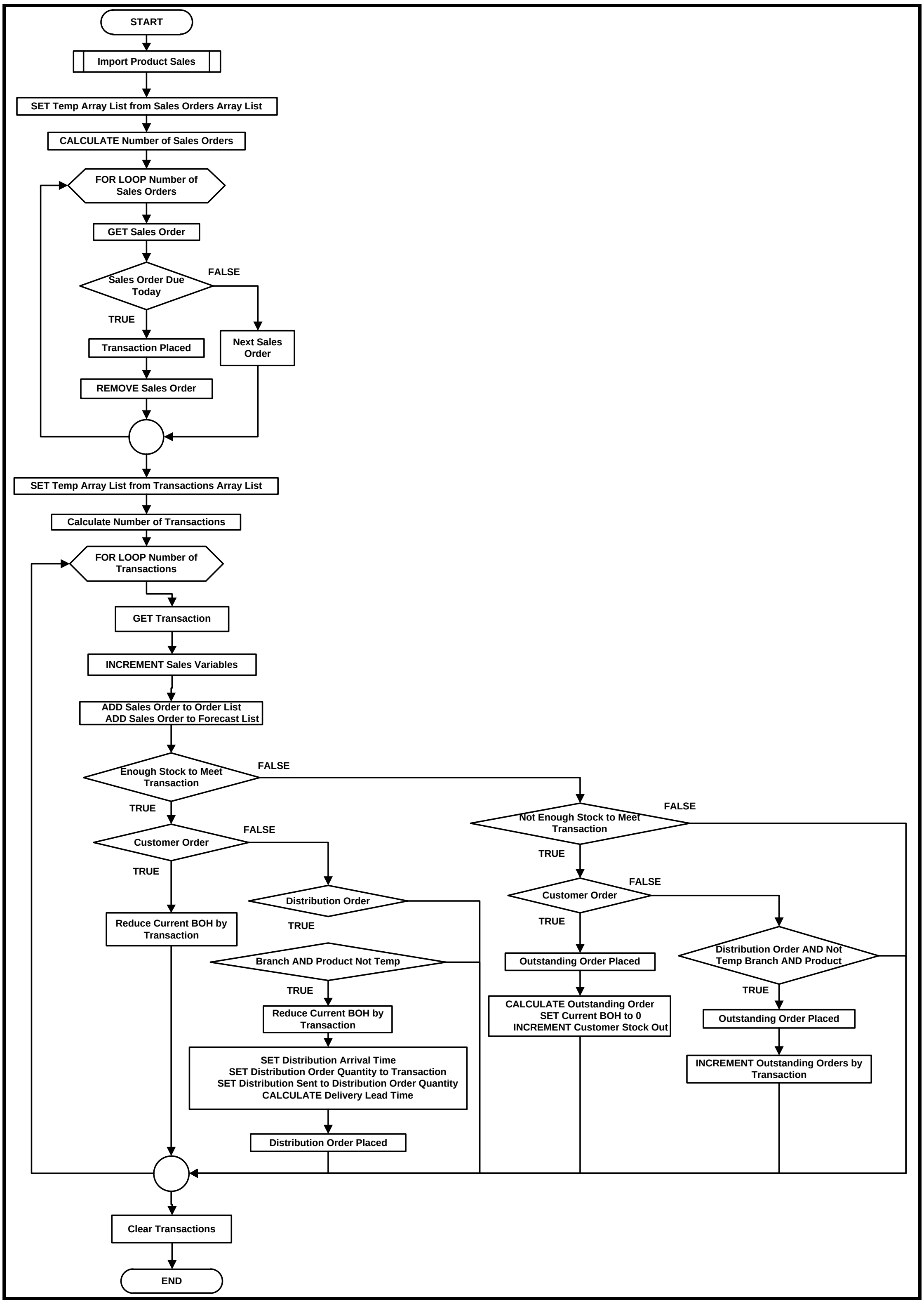
APPENDIX 18: Outstanding order placed flowchart



Pseudo Code: Outstanding order placed

```
LOOP THROUGH Outstanding Orders IN LIST

    IF Current BOH GREATER THAN Outstanding Qty

        MINUS Outstanding Qty FROM Outstanding Orders
        MINUS Outstanding Qty FROM Current BOH

        REMOVE Outstanding Order FROM LIST

        IF Outstanding Order IS A Distribution Order

            ADD Outstanding Qty TO Distribution Order Qty
            ADD Distribution Order Qty TO Distribution Sent Order
            SET Distribution Arrival Time EQUAL TO Todays Date
            SET Delivery Lead Time EQUAL TO Delivery Arrival Time
            MINUS Todays Date

            ADD Distribution Order TO Distribution Order LIST

        END IF

    END IF

END LOOP
```

APPENDIX 19: Sales order placed flowchart

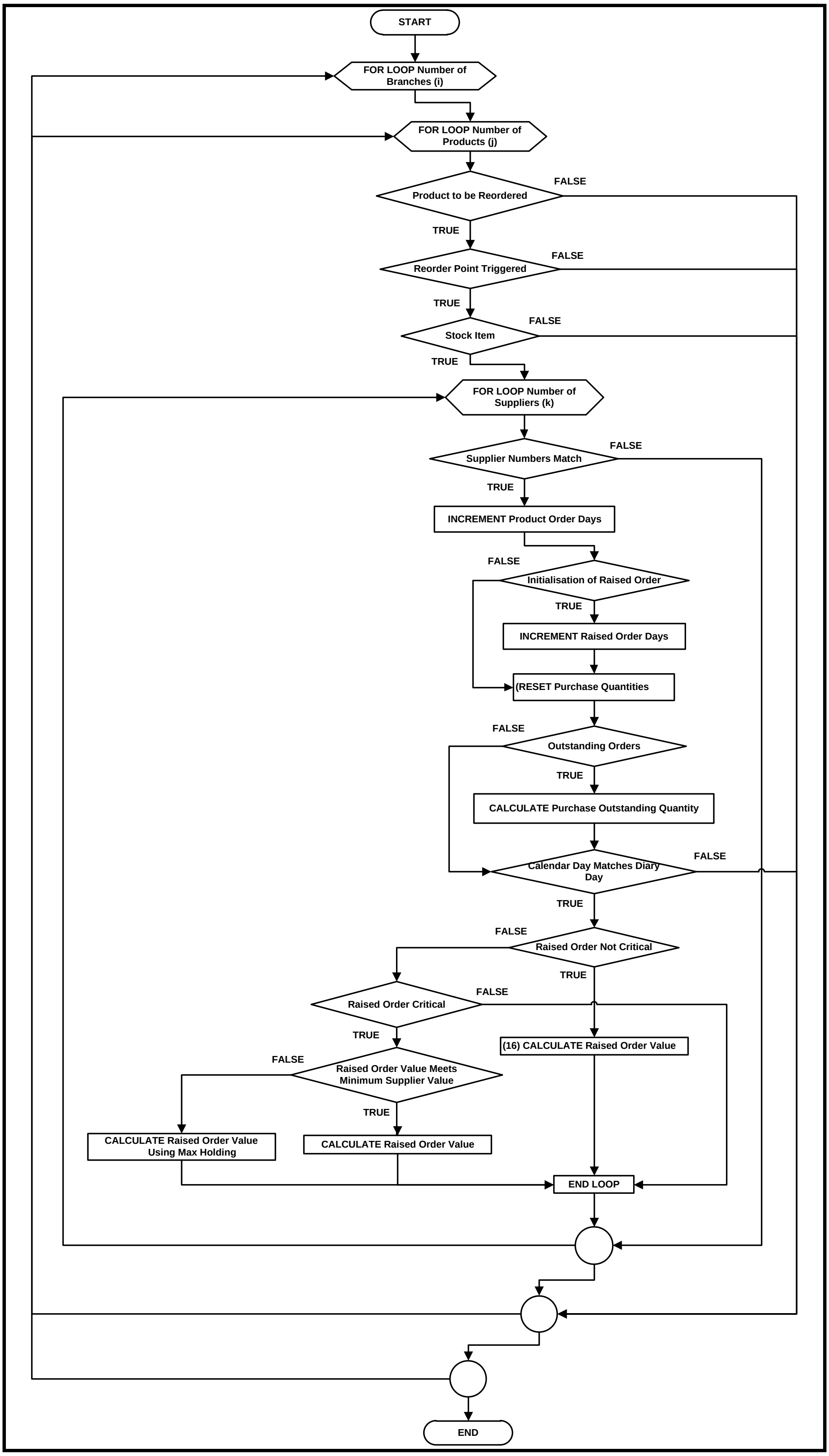


Pseudo Code: Sales order placed

```
IMPORT SALES DATA

LOOP THROUGH Customers orders IN LIST

        IF Todays Date EQUAL TO Customer Order Date

        ADD Customer Sales Order TO Order LIST
        REMOVE Customer Sales Order FROM LIST

        END IF

END LOOP

LOOP THROUGH Orders IN LIST

        ADD Order Qty TO Total Sales
        ADD Order Qty TO Cumulative Sales
        ADD Order Qty TO Total Month Sales
        ADD Oorder TO Forecast LIST

        IF Current BOH IS GREATER THAN OR EQUAL TO Order Qty

                IF Order IS A Customer Order
                        MINUS Order Qty FROM Current BOH
                        ADD 1 TO Customer Order Statistic
                END IF

                IF Order IS A Distribution Order AND Product IS TO BE Reordered
                        MINUS Order Qty FROM Current BOH
                        SET Distribution Arrival Time EQUAL TO Todays Date PLUS 1
                        SET Distribution Order Qty EQUAL TO Order Qty
                        SET Distribution Sent EQUAL TO Distribution Order Qty
                        SET Delivery Lead Time EQUAL TO Delivery Arrival Time
                        MINUS Todays Date

                        ADD Distribution Order TO Distribution Order LIST
                END IF
```

```
        IF Current BOH LESS THAN Order Qty

                IF Order IS Customer Order
                        ADD Outstanding Order TO Outstanding Orders LIST
                        SET Outstanding Order EQUAL TO Order Qty MINUS Current
                        BOH
                        SET Current BOH EQUAL TO  0
                        ADD 1 TO Customer Stock-Out Statistics
                        ADD 1 TO Customer Order Statistics
                END IF

                IF Order IS A Distribution Order
                        ADD Outstanding Order TO Outstanding Order LIST
                        ADD Order Qty TO Outstanding Order
              END IF

         END IF

END LOOP
```

APPENDIX 20: Supplier replenishment order raised flowchart



Pseudo Code: Supplier replenishment order raised

Information:

Purchase Order Method = 0 (Distribution order) - replenished from a specified branch or RDC.
Purchase Order Method = 1 (Purchase order) - replenished from a specified supplier.
Purchase Order Method = 2 (Special distribution order) – replenished outside of the regional supply chain. It is assumed that there is a sufficient level to fulfil the order.
Reorder = 0 (Non-stock product)
Reordered = 1 (Stock product)

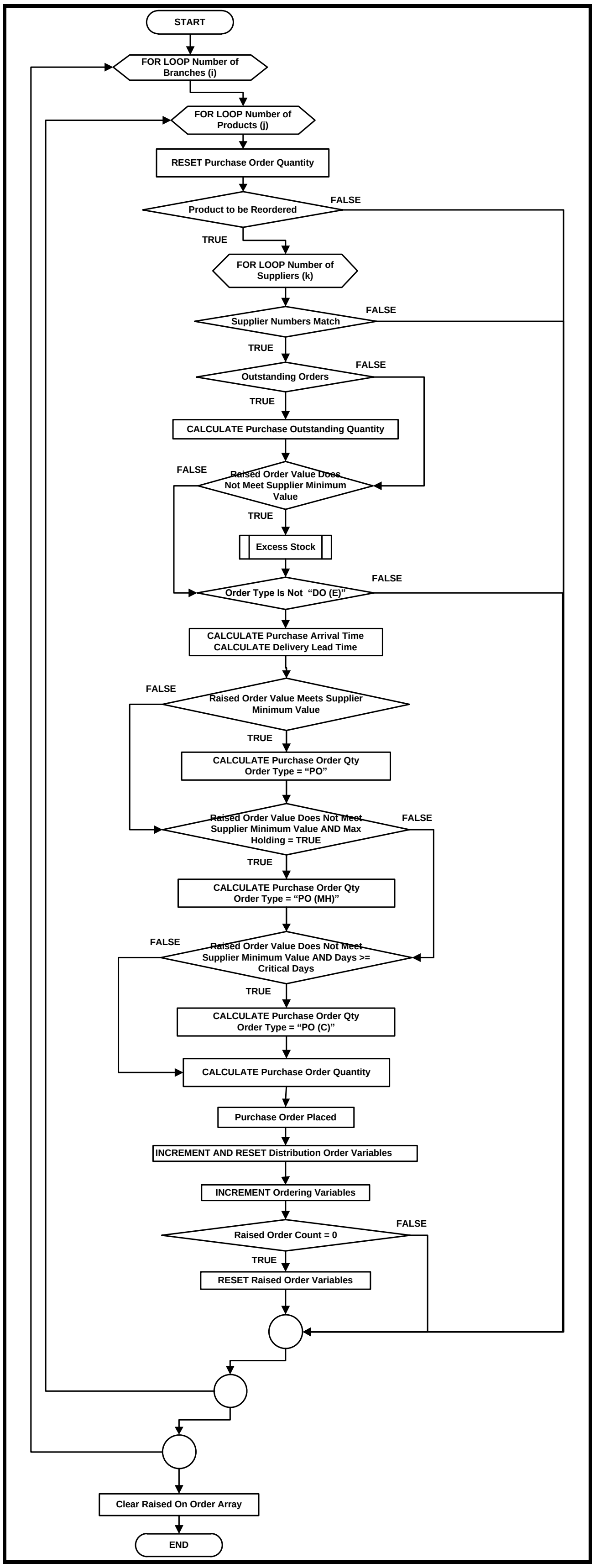
A product is ordered if it is a stock product and it is to be ordered from a supplier. At least one forecast has had to have been completed. This is to prevent a large quantity of products being ordered in the first month.

```
LOOP THROUGH Products

        IF Purchase Order Method IS EQUAL TO 1 AND Reordered IS EQUAL TO 1 AND Forecast Triggered  IS EQUAL TO TRUE

                IF Current BOH PLUS On Order MINUS Outstanding Order IS LESS THAN Reorder Point

                        LOOP THROUGH Suppliers IN LIST

                                IF Supplier Codes MATCH
                                        ADD 1 TO Order Days

                                        IF Raised Order Start IS EQUAL TO FALSE
```

```
        ADD 1 TO Raised Order Days
        SET Raised Order Data EQUAL TO TRUE
END IF

RESET Purchasing Outstanding Qty EQUAL TO 0
ADD 1 TO Raised Order Count

IF Outstanding Order IS GREATER THAN 0
        SET Purchase Outstanding Quantity EQUAL TO Order Multiple OF Outstanding Order
END IF

IF Todays Date EQUAL TO Supplier Diary Day

        IF Raised Order Days LESS THAN Critical Days
                ADD (Multiple Order Qty PLUS Purchase Outstanding Qty) MULTIPLIED BY Cost Price TO Raised
                Order Inv Value
        END IF

        IF Raised Order Days GREATER THAN Critical Days AND Max Holding Purchase EQUAL TO TRUE

                IF Raised Order Inv Value LESS THAN Supplier Min Inv Value
                        ADD (Max Holding MINUS Current BOH)  PLUS Purchase Outstanding Qty MULTIPLIED
                        BY Cost Price TO Raised Order Inv Value
                        SET Max Holding Purchase EQUAL TO TRUE

                        ELSE
```

```
                                    ADD Multiple Order Qty PLUS Purchase Outstanding QTY To Raised Order Inv
                                    Value MULTIPLIED BY Cost Price
                                    SET Max Holding Purchase EQUAL TO FALSE
                                END IF
                            END IF
                        END IF
                    END IF
                END LOOP
            END IF
        END IF
    END IF
END LOOP

SET Raised Order Start EQUAL TO FALSE
```

APPENDIX 21: Supplier replenishment order placed flowchart



Pseudo Code: Supplier replenishment order placed

```
LOOP THROUGH Products

        IF Purchase Order Method IS EQUAL TO 1 AND Reordered IS EQUAL TO 1 AND Forecast Triggered  IS EQUAL TO TRUE

                IF Current BOH PLUS On Order MINUS Outstanding Orders IS LESS THAN Reorder Point

                        LOOP THROUGH Suppliers

                                IF Supplier Codes MATCH AND Todays DATE IS EQUAL TO Diary Day

                                        IF Outstanding Orders IS GREATER THAN 0
                                                SET Purchase Outstanding Quantity EQUAL TO Outstanding Orders

                                                IF Invoice Value IS LESS THAN Min Invoice Value
                                                        CHECK FOR Excess Stock
                                                END IF

                                                IF Order Type IS "Excess Order" AND Invoice Value GREATER THAN OR EQUAL TO Min Invoice
                                                Value OR Days IS GREATER THAN OR EQUAL TO Critical Days OR (Current BOH LESS THAN
                                                Safety Stock AND Current Model IS EQUAL TO True)

                                                        SET Purchase Arrival Time IS EQUAL TO Todays Date PLUS Lead Time
```

SET Delivery Lead Time IS EQUAL TO Purchase Arrival Time MINUS Todays Date

IF Invoice Value GREATER THAN OR EQUAL TO Min Invoice Value AND Max Holding Purchase IS EQUAL TO FALSE

SET Purchase Order Quantity EQUAL TO Multiple Order Qty PLUS Purchase Outstanding Qty

SET Order Type EQUAL TO "Purchase Order"

ADD 1 TO Purchase Order Statistics

END IF

ELSE IF Max Holding Purchase IS EQUAL TO TRUE AND Invoice Value IS GREATER THAN Min Invoice Value

SET Purchase Order Qty EQUAL TO Max Holding MINUS Current BOH PLUS Purchase Outstanding Qty

SET Order Type EQUAL TO "Purchase Max Holding”

ADD 1 TO Purchase Orders Max Statistics

END IF

ELSE IF Invoice Value IS LESS THAN Min Invoice Value AND Days GREATER THAN OR EQUAL TO Critical Days OR (Current BOH LESS THAN Safety Stock AND Current BOH LESS THAN Safety Stock AND Current Model IS EQUAL TO TRUE

Purchase Order Quantity IS EQUAL TO Multiple Order Qty PLUS Purchase Outstanding Qty

SET Order Type EQUAL TO “Purchase Order Critical”
ADD 1 TO Purchase Orders Critical Statistics
END IF

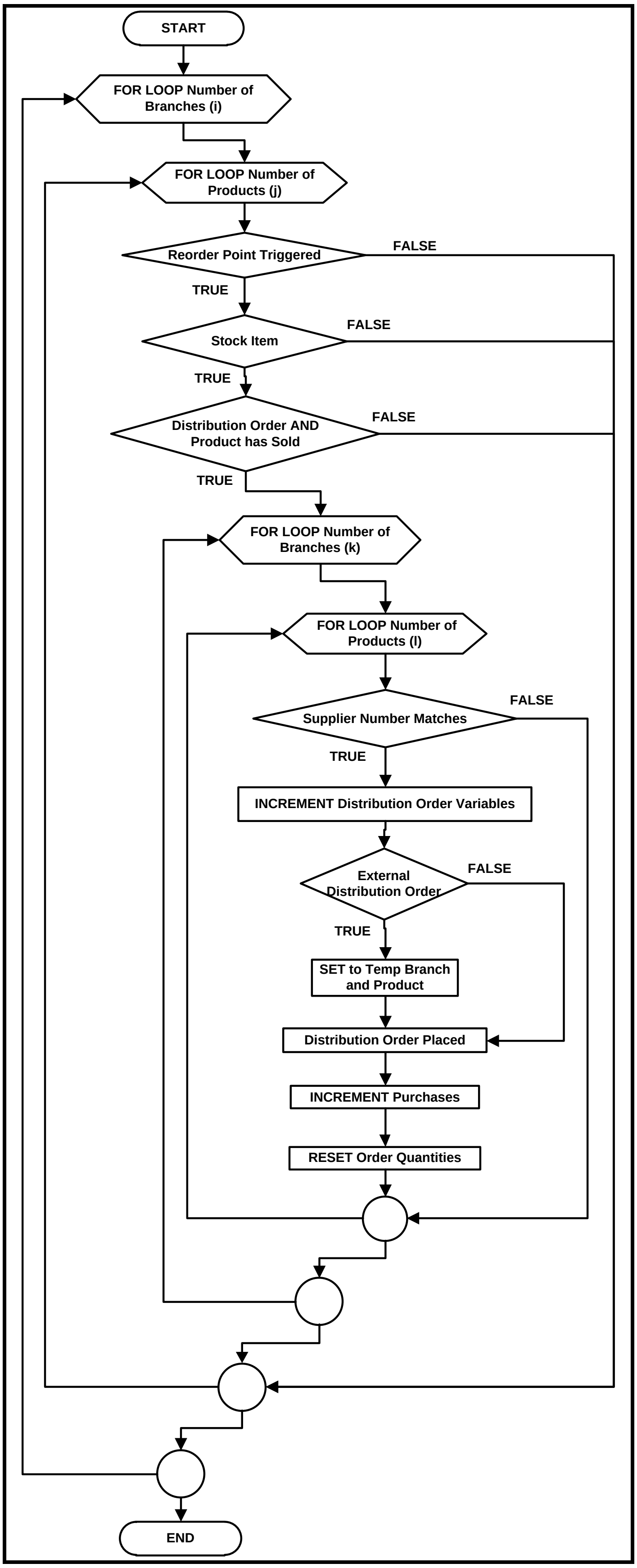
IF Purchase Order Qty MINUS Purchase Outstanding Qty PLUS Current BOH IS LESS THAN Reorder Point
SET Purchase Order Qty EQUAL TO Reorder Point + Purchase Outstanding Qty
END IF

IF Purchase Order Qty IS GREATER THAN Maximum Order Qty AND Max Order Qty IS NOT EQUAL TO 0
Purchase Order Qty IS EQUAL TO Maximum Order Qty
END IF

SET Purchase Order Qty EQUAL TO Order Multiple OF Purchase Order Quantity
ADD Purchase Order TO Purchase On Order LIST
ADD Purchase Order Qty TO On Order
ADD Purchase Order Qty TO Order Placed
ADD 1 to No Order Statistics
RESET Max Holding Purchase EQUAL TO FALSE
RESET Purchase Outstanding Qty = 0
RESET Purchase Order Quantity = 0
MINUS 1 From Raised Order Count

```
                                                ADD Order Days MINUS 1 TO Cumulative Order Days
                                                ADD 1 TO Order Days Count
                                                SET Average Order Days IS EQUAL TO Cumulative Order Days DIVIDED BY Order Days
                                                Count
                                                RESET Order Days TO 0

                                                IF Raised Order Count IS EQUAL TO 0
                                                        RESET Raised Order Days TO 0
                                                END IF
                                        END IF
                                END IF
                        END IF
                END LOOP
        END IF
    END IF
END LOOP

RESET Raised Order Invoice Value TO 0
RESET Raised Order Count TO 0
```

APPENDIX 22: Distribution replenishment order placed flowchart

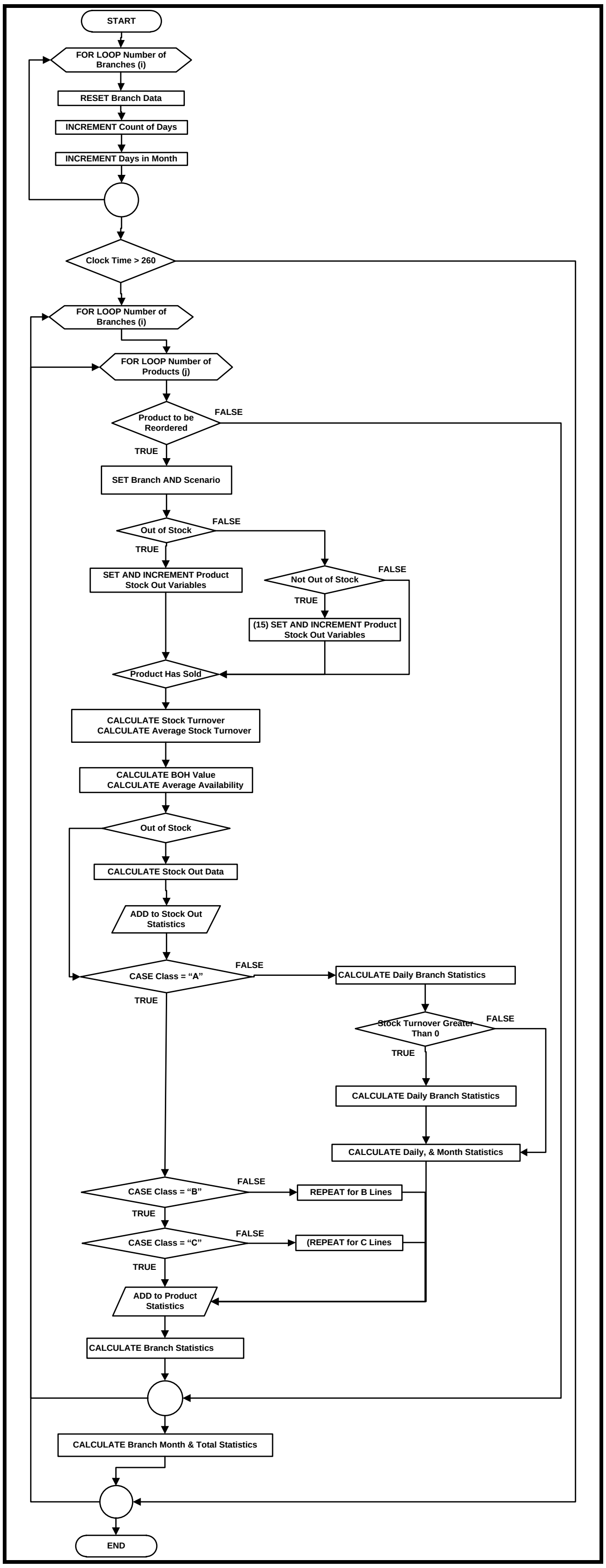


Pseudo Code: Distribution replenishment order placed

```
LOOP THROUGH Products

    IF Current BOH PLUS On Order MINUS Outstanding Orders IS LESS THAN Reorder Point

        IF Purchase Order Method IS EQUAL TO 0 OR Purchase Order Method IS EQUAL TO 2 AND Reordered IS EQUAL TO 1

            LOOP THROUGH Stock Products

                IF Product Codes AND Supplier Codes MATCH OR Purchase Order Method IS EQUAL TO 2

                    IF Forecast Triggered IS EQUAL TO TRUE

                        IF Outstanding Orders IS GREATER THAN 0
                            SET Purchase Outstanding Qty IS EQUAL TO Order Multiple OF Outstanding Orders
                        END IF

                        SET Distribution Order Qty EQUAL TO Multiple Order Quantity PLUS Purchase Outstanding Qty

                        IF Distribution Order Qty MINUS Purchase Outstanding Qty + Current BOH IS LESS THAN Reorder
                        Point
                            SET Distribution Order Qty EQUAL TO Reorder Point PLUS Purchase Outstanding
                            Quantity
```

```
                        END IF

                        IF Purchase Order Method IS EQUAL TO 2
                            SET Order Branch EQUAL TO 0
                            SET Order Product EQUAL TO 0
                        END IF

                        ADD Distribution Order TO Distribution On Order LIST
                        ADD Distribution Order Qty TO Order Placed
                        ADD Distribution Order Qty TO On Order
`                       SET Order Type TO "Distribution Order"
                        ADD 1 TO No Orders Statistics
                        ADD 1 TO Distribution Orders Statistics
                        RESET Purchase Outstanding Qty TO 0
                        RESET Distribution Order Quantity TO 0
                    END IF
                END IF
            END LOOP
        END IF
    END IF
END LOOP
```

APPENDIX 23: Daily statistics flowchart



Pseudo Code: Daily statistics

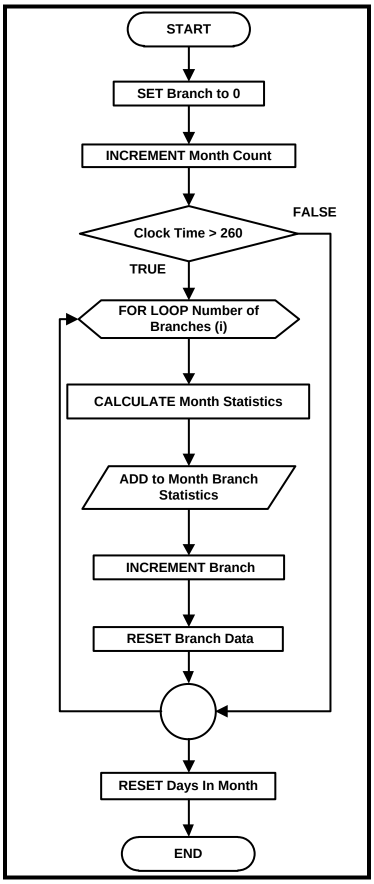
The statistics are recorded after the first year (260 days).

```
LOOP THROUGH Branches

RESET  Branch Statistics TO 0
ADD 1 TO Day Count
ADD 1 TO Days In Month

LOOP THROUGH Products

        IF Cumulative Sales IS GREATER THAN 0

                ADD 1 TO Days Sales Count
                Actual Daily Sales IS EQUAL TO Cumulative Sales DIVIDED BY Days Sales Count
        END IF

IF Todays Date IS GREATER THAN 260

        LOOP THROUGH PRODUCTS

                IF Reordered IS EQUAL TO 1
```

```
SET Scenario EQUAL TO Model Run Number

IF Current BOH IS EQUAL TO 0
        SET Available EQUAL TO 0;
        SET Stock-Out EQUAL TO 1
        ADD 1 TO Cumulative Stock-Outs
        ADD 1 TO Stock-Out Count
        SET Stock Turnover EQUAL TO 0
END IF

ELSE IF Current BOH IS GREATER THAN 0
        SET Available EQUAL TO 1
        SET Stock-Out EQUAL TO 0
        SET Cumulative Stock-Outs EQUAL TO 0
        ADD 1 to Available Count
END IF

IF Actual Daily Sales IS GREATER THAN 0
        SET Stock Turnover  EQUAL TO Current BOH / Actual Daily Sales
        ADD Stock Turnover TO Cumulative Stock Turnover
        ADD 1 TO Stock Turnover Count
        Cumulative Avg Stock Turnover Statistic IS EQUAL TO Cumulative Stock Turnover / Stock Turnover Count
END IF
```

```
                    BOH Value IS EQUAL TO Current BOH MULTIPLIED BY Cost Price
                    Cumulative Avg Availability IS EQUAL TO PERCENTAGE OF Available Count DIVIDED BY Available Count PLUS Stock-Out
                    Count

                    IF CLASS IS EQUAL TO "A"
                        CALCULATE Branch Statistics FOR A Lines
                    END IF

                    IF CLASS IS EQUAL TO "B"
                        CALCULATE Branch Statistics FOR B Lines
                    END IF

                    IF CLASS IS EQUAL TO "C"
                        CALCULATE Branch Statistics FOR C Lines
                    END IF

                END IF
            CALCULATE Total Branch Statistics
        END LOOP
```

APPENDIX 24: End of month statistics flowchart



Pseudo Code: End of month statistics

ADD 1 TO Month Count

IF Todays Date IS GREATER THAN 260

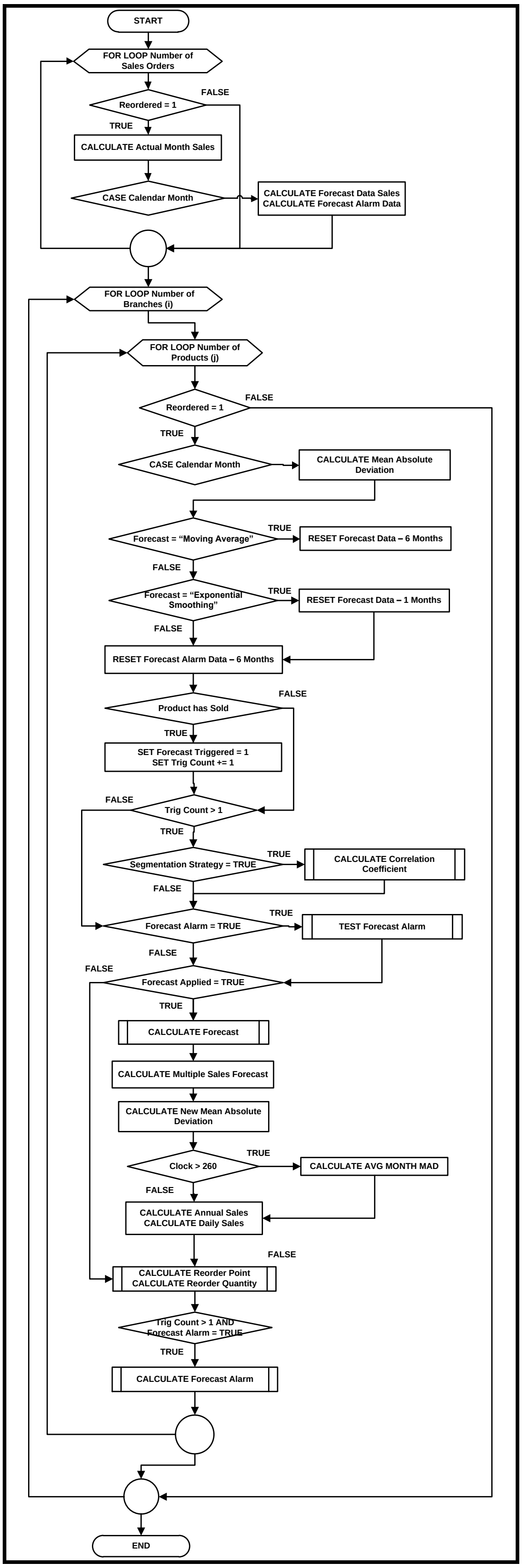
LOOP THROUGH Branches

CALCULATE Month Branch Statistics FOR A Lines
CALCULATE Month Branch Statistics FOR B Lines
CALCULATE Month Branch Statistics FOR C Lines
CALCULATE Total Month Branch Statistics

END LOOP
END IF

RESET Days In Month TO 0

APPENDIX 25: End of month forecast flowchart



Pseudo Code: End of month statistics

```
SET Total Month Count EQUAL TO 1

LOOP THROUGH Sales Orders IN Forecast LIST

        IF Reordered IS EQUAL TO 1
                ADD Order Qty TO Actual Month Sales
                ADD Order Qty TO Forecast Data Month Sales
                ADD Order Qty TO Forecast Alarm Data Month Sales
        END IF
END LOOP

LOOP THROUH Products

        IF Reordered IS EQUAL TO 1
                SET Forecasting MAD = Actual Month Sales - Forecast

                IF Forecasting Method IS EQUAL TO “Moving Average”
                        RESET Forecast FOR Todays Date – 6 Months TO 0
                END IF

                IF Forecasting Method IS EQUAL TO “Exponential Smoothing”
                        RESET Forecast FOR Todays Date – 1 Months TO 0
                END IF

                RESET Forecast Alarm FOR Todays Date – 6 Months TO 0
        END IF

        IF Cumulative Sales IS GREATER THAN 0
                SET Forecast Triggered EQUAL TO TRUE
                ADD ONE TO Forecast Trig Count
        END IF

        IF Trig Count IS GREATER THAN 0

                IF Segmentation Strategy IS EQUAL TO TRUE
                        CALCULATE Correlation Coefficients
                END IF
```

```
                IF Forecast Alarm IS EQUAL TO TRUE AND Trig Count IS GREATER
                THAN 1
                        TEST Forecast Alarm
                END IF

                IF Forecast Applied IS EQUAL TO TRUE

                        IF Forecasting Method IS EQUAL TO "Moving Average"
                                CALCULATE Moving Average FORECAST
                        END IF

                        IF Forecasting Method IS EQUAL TO "Exponential Smoothing"
                                CALCULATE Exponential Smoothing Forecast
                        END IF

                        SET Forecast TO Multiple of Multiple Sales Quantity

                        IF Forecast IS EQUAL TO 0
                                Annual Sales = 1
                                Daily Sales = 0
                        END IF

                        CALCULATE New Forecasting

                        IF Todays Date IS GREATER THAN 260 Days
                                ADD Forecast MAD TO Cum Month MAD
                                SET Avg Month MAD EQUAL TO Cum Month MAD /
                                Month Count
                        END IF

                        SET Annual Sales EQUAL TO Forecast MULTIPLIED BY 12
                        SET Daily Sales EQUAL TO Annual Sales / Days In Year
                END IF

                CALCULATE Reorder Point
                CALCULATE Order Qty
                CALCULATE Forecast Alarm
        END IF
END LOOP
```

APPENDIX 26: Settings

Variable	**Type**	**Description**	**Initial Value**
Capture Product Statistics	Boolean	Record product snapshots	TRUE
Critical Days	Integer	Number of maximum days before order is placed	5
Current Model	Boolean	Apply	FALSE
Day	Integer	First calendar day	02
Month	Integer	First calendar month	07
Year	Integer	First calendar year	2006
Days In Year	Integer	Number of working days in year	260
Deviation Factor	Floating Point	Deviation factor used in New mean absolute deviation calculation	1.25
Estimated Safety Stock Days	Integer	Estimated safety stock days	12
Forecast Alarm Deviations	Integer	Number of deviations for forecast alarm	2
MAD Alpha Factor	Floating Point	Alpha factor used in mean absolute deviation calculation	0.2
Max Holding Purchase	Boolean	Apply purchasing which uses max holding	TRUE
Month Working Days	Integer	Number of working days in month	20
Number Branches	Integer	Number of branches	20
Number Days Run	Integer	Number of days to run model	521
Run Graph	Boolean	Record graph data	TRUE
Safety Beta Factor	Floating Point	Beta factor to be used in safety stock calculation	0.5
Segmentation Strategy	Integer	Apply segmentation strategy	0

APPENDIX 27: Product data class

Variable	Type	Description
Actual Daily Sales	Floating Point	Average number of sales per day (cumulative sales / number of days)
Average Order Days	Integer	Average time to order after reorder point is triggered (Cumulative order days / Order days count)
Average Lead Time	Floating Point	Average lead time (calculated from historical data)
Branch Code	String	Unique branch code
Branch Name	String	Unique branch name
Class	String	Classification of sales volume and value (A,B or C)
Correlation Coefficient	Floating Point	4 months correlation coefficient
Correlation Coefficient Trend	Floating Point	6 months correlation coefficient
Cost Price	Floating Point	Cost to buy from supplier
Cumulative Order Days	Integer	Cumulative count of days to place order since reorder point is triggered
Cumulative Sales	Integer	Cumulative total of sales (CO + DO)
Current Balance on Hand	Integer	Level of stock on hand
Days Sales Count	Integer	Cumulative count of days since first sale
Delivery Lead Time	Integer	Time to deliver current order
Distribution Order Product	Integer	Product is used for distribution orders
Distribution Sent	Integer	Distribution order quantity of stock currently on order
Estimated Lead Time	Integer	Constant set lead time
Forecast	Integer	Month sales forecast
Forecast Applied	Boolean	Apply forecast calculation or not
Forecasted Annual Sales	Integer	Annual sales forecast (Forecast x 12)
Forecasted Daily Sales	Floating Point	Daily sales forecast (Annual sales forecast / days in year)
Forecasted Method	String	Which forecast method to use (MA, SES or DES)
Holding Cost	Floating Point	Estimated percentage cost of storage
Lead Coefficient Variance	Floating Point	Measure of lead time dispersion (Standard deviation / Mean)

APPENDIX 27: Product data class (continued)

Variable	Type	Description
Lead Time Demand	Integer	Quantity of stock expected to sell through lead time
Lead Time Method	Integer	Which lead time demand calculation to use
Max Holding	Integer	Maximum stock held (Reorder Point + Order Quantity)
Max Holding Purchase	Boolean	Apply max holding calculation or not
Maximum Order Quantity	Integer	Maximum quantity of stock to be reordered
Multiple Order Quantity	Integer	Quantity of stock to be reordered including order multiple (CEILING(order quantity / order multiple) x order multiple)
Multiple Sales Quantity	Integer	Multiple quantity customer have to purchase
On Order	Integer	Purchase order quantity currently of stock currently on order
Order Days	Integer	Count of days to place order since reorder point is triggered
Order Days Count	Integer	Cumulative count of purchase orders
Order Multiple	Integer	Multiple quantity have to purchased in from supplier
Order Placed	Integer	Quantity of stock order placed
Order Quantity	Integer	Quantity of stock to be reordered
Order Quantity Method	Integer	Which order quantity calculation to use
Order Received	Integer	Quantity of stock received in
Order Type	String	Method used in order
Ordering Cost	Floating Point	Estimated cost of placing an order
Outstanding Orders	Integer	Quantity of stock-outstanding
Product Code	String	Unique product code
Product Name	String	Unique product name
Purchase Order Method	Integer	Purchase order or a distribution order
Reorder Point	Integer	Reorder trigger (lead time demand + Safety Stock)
Reorder Point Method	Integer	Which type of reorder point calculation to use

APPENDIX 27: Product class (continued)

Variable	Type	Description
Reordered	Integer	Product to be reordered or not
Safety Stock	Integer	Buffer against stock-outs
Safety Stock Method	Integer	Which safety stock calculation to use
Sales Coefficient Variance	Floating Point	Measure of sales dispersion (Standard deviation / Mean)
Service Level	Integer	Customer service level
Service Level Lead	Integer	Lead time service level
Standard Deviation Lead Time	Floating Point	Standard deviation of lead time (calculated from historical data)
Standard Deviation Sales	Floating Point	Standard deviation of sales (calculated from historical data)
Stock Turnover	Floating Point	Average days to sell (Current BOH / Daily Sales)
Supplier Code	String	Unique supplier code
Supplier Name	String	Unique supplier name
Total Month Sales	Integer	Cumulative month sales
Total Sales	Integer	Total daily sales

APPENDIX 28: Supplier class

Variable	Type	Description
Diary Day 1	String	Day buyers can order from supplier
Diary Day 2	String	Day buyers can order from supplier
Minimum Invoice Value	Floating Point	Minimum invoice value to be reached else charged for delivery
Supplier Code	String	Unique supplier code
Supplier Name	String	Unique supplier name

APPENDIX 29: Raised order class

Variable	Type	Description
Count	Integer	Number of products in raised order
Days	Integer	Number of days since reorder point is triggered for the raised order
Invoice value	Floating Point	Total invoice value for all products
Start	Boolean	Is it first day of raised order

APPENDIX 30: Forecast class

Variable	Type	Description
Actual Month Sales	Integer	Actual Month Sales
Jan	Integer	Sales for January
Feb	Integer	Sales for February
March	Integer	Sales for March
April	Integer	Sales for April
May	Integer	Sales for May
June	Integer	Sales for June
July	Integer	Sales for July
Aug	Integer	Sales for August
Sept	Integer	Sales for September
Oct	Integer	Sales for October
Nov	Integer	Sales for November
Dec	Integer	Sales for December
Forecast SES Alpha Factor	Floating Point	Alpha factor used in single exponential smoothing calculation
Forecast DES Alpha Factor	Floating Point	Alpha factor used in double exponential smoothing calculation

APPENDIX 30: Forecast class (continued)

Forecast DES Beta Factor	Floating Point	Beta factor used in double exponential smoothing calculation
First Month	Integer	First month sales
Forecast Triggered	Boolean	Forecast has been calculated
Month Sales	Integer	Month sales
Previous Level	Floating Point	Previous month level of sales
Previous Trend	Floating Point	Previous month trend of sales
Current Level	Floating Point	Current month trend of sales
Current Trend	Floating Point	Current month trend of sales
Forecasting MAD	Integer	Absolute deviation (ABS(actual sales – forecast)
Forecasting New MAD	Integer	Smoothed absolute deviation (alpha factor x Forecasting MAD) + (1 – alpha factor) x (forecasting new mad)
Cumulative Month MAD	Long Integer	Cumulative month deviation
Six Month Sales	Integer	Six month sales
Trig Count	Integer	Number of forecast months
Average Month MAD	Integer	Average month deviation (cumulative month deviation / number of months)

APPENDIX 31: Forecast alarm class

Variable	**Type**	**Description**
Jan	Integer	Sales for January
Feb	Integer	Sales for February
March	Integer	Sales for March
April	Integer	Sales for April

APPENDIX 31: Forecast alarm class (continued)

May	Integer	Sales for May
June	Integer	Sales for June
July	Integer	Sales for July
Aug	Integer	Sales for August
Sept	Integer	Sales for September
Oct	Integer	Sales for October
Nov	Integer	Sales for November
Dec	Integer	Sales for December
Forecast Alarm 1	Integer	Lowest level of forecast alarm
Forecast Alarm 2	Integer	Highest level of forecast alarm
Mean Sales	Integer	Average month sales

APPENDIX 32: Graph class

Variable	**Type**	**Description**
Current BOH	Integer	Current stock balance on hand
Reorder Point	Integer	Current reorder point level
Safety Stock	Integer	Current safety stock level
Sales	Integer	Current sales

APPENDIX 33: Stock-out class

Variable	Type	Description
Branch	Integer	Unique branch code
Product	Integer	Unique product code
Product Number	String	Unique product number
Cumulative stock-out	Integer	Cumulative stock-outs

APPENDIX 34: Statistics class

Variable	Type	Description
Available	Integer	Currently available for customer sale
Available Count	Integer	Count of days available for customer sales
Balance on hand value	Integer	Current value of stock (Current balance on hand x cost price)
Cumulative Average Availability	Floating Point	Cumulative average availability
Cumulative Average Stock Turnover	Floating Point	Average stock turnover
Cumulative Stock-Outs	Integer	Cumulative count of days currently out of stock
Cumulative Stock Turnover	Floating Point	Cumulative average stock turnover
Customer Orders	Integers	Cumulative number of customer orders placed
Customer Stock-Outs	Integer	Cumulative count of customer orders stock-outs
Distribution Orders	Integer	Count of distribution orders
Distribution Orders Excess	Integer	Count of distribution orders which used excess branch stock
No Purchases	Integer	Count of number of orders
Purchase Orders	Integer	Count of orders which reached minimum invoice value
Purchase Orders Critical	Integer	Count of purchase orders which were critical
Purchase Order Maximum	Integer	Count of orders which used maximum holding to meet minimum invoice value

APPENDIX 34: Statistics class (continued)

Scenario	Integer	The scenario being run
Stock-Out	Integer	Currently out of stock
Stock-Out Count	Integer	Total count of days out of stock
Stock Turnover Count	Integer	Cumulative stock turnover

APPENDIX 35: Branch statistics class

Variable	Type	Description
A Line Count	Integer	Daily total number of A lines
A Line Count Stock Turnover	Integer	Daily total number of A lines with balance on hand > 0
A Line Cumulative Stock Turnover	Integer	Daily total cumulative A lines stock turnover
A Line Cumulative Avg Stock Turnover	Floating Point	Daily total average A line stock turnover (A line cumulative stock turnover / A line count stock turnover)
A Line Cumulative Availability	Floating Point	Daily total cumulative available A lines
A Line Cumulative Avg Availability	Floating Point	Daily total A Line average availability (total cumulative availability / total cumulative availability + total cumulative stock-outs)
A Line Customer Orders	Integer	Daily total A line customer orders
A Line Customer Stock-Outs	Integer	Daily total number of A line customer stock-outs
A Line Orders	Integer	Daily total A line orders
A Line Stock-Outs	Integer	Daily total number of A line stock-outs
A Line Cumulative Stock-Outs	Integer	Daily total cumulative A line stock-outs
A Line Value	Integer	Daily total A line value
B Line Count	Integer	Daily total number of B lines
B Line Count Stock Turnover	Integer	Daily total number of B lines with balance on hand > 0

APPENDIX 35: Branch statistics class (continued)

B Line Cumulative Stock Turnover	Integer	Daily total cumulative B lines stock turnover
B Line Cumulative Avg Stock Turnover	Floating Point	Daily total average B line stock turnover (B line cumulative stock turnover / B line count stock turnover)
B Line Cumulative Availability	Floating Point	Daly total cumulative available B lines
B Line Cumulative Avg Availability	Floating Point	Daily total B Line average availability (total cumulative availability / total cumulative availability + total cumulative stock-outs)
B Line Customer Orders	Integer	Daily total B line customer orders
B Line Customer Stock-Outs	Integer	Daily total number of B line customer stock-outs
B Line Orders	Integer	Daily total number of B line orders
B Line Stock-Outs	Integer	Dally total number of B line stock-outs
B Line Cumulative Stock-Outs	Integer	Daily total cumulative B line stock-outs
B Line Value	Integer	Daily total B line value
C Line Count	Integer	Daily total number of C lines
C Line Count Stock Turnover	Integer	Daily total number of C lines with balance on hand > 0
C Line Cumulative Stock Turnover	Integer	Daily total cumulative C lines stock turnover
C Line Cumulative Avg Stock Turnover	Floating Point	Daily total average C line stock turnover (C line cumulative stock turnover / C line count stock turnover)
C Line Cumulative Availability	Floating Point	Daily total cumulative available A lines
C Line Cumulative Avg Availability	Floating Point	Daily total C Line average availability (total cumulative availability / total cumulative availability + total cumulative stock-outs)
C Line Customer Orders	Integer	Daily total C line customer orders
C Line Customer Stock-Outs	Integer	Daily total number of C line customer stock-outs
C Line Orders	Integer	Daily total number of C line orders
C Line Stock-Outs	Integer	Daily total number of C line stock-outs
C Line Cumulative Stock-Outs	Integer	Daily total cumulative C line stock-outs
C Line Value	Integer	Daily total C line value
Scenario	Integer	Scenario number

APPENDIX 35: Branch statistics class (continued)

Variable	Type	Description
Daily Total Line Availability	Floating Point	Average total line availability (A + B + C / number of lines)
Daily Total Line Customer Stock-Outs	Integer	Total line customer stock-outs (A + B + C)
Daily Total Line Orders	Integer	Total line Orders (A + B + C)
Daily Total Line Stock-Outs	Integer	Total line stock-outs (A + B + C)
Daily Total Line Stock Turnover	Floating Point	Average total line stock turnover (total line cumulative turnover / total line cumulative count of lines)
Daily Total Line Value	Integer	Average total line value (A + B + C)
Month A Line Count Stock Turnover	Integer	Month total number of A lines with balance on hand > 0
Month A Line Cumulative Stock Turnover	Integer	Month total cumulative A lines stock turnover
Month A Line Cumulative Avg Stock Turnover	Floating Point	Month total average A line stock turnover (A line cumulative stock turnover / A line count stock turnover)
Month A Line Cumulative Avg Availability	Floating Point	Month total cumulative available A lines
Month A Line Cumulative Availability	Floating Point	Month total A Line average availability (total cumulative availability / total cumulative availability + total cumulative stock-outs)
Month A Line Cumulative Stock-Outs	Integer	Month total cumulative A line stock-outs
Month A Line Customer Stock-Outs	Integer	Month total number of A line customer stock-outs
Month A Line Orders	Integer	Month total number of A line orders
Month A Line Stock-Outs	Integer	Month total number of A line stock-outs
Month A Line Value	Integer	Month total A line value
Month B Line Count Stock Turnover	Integer	Month total number of B lines with balance on hand > 0
Month B Line Cumulative Stock Turnover	Integer	Month total cumulative B lines stock turnover
Month B Line Cumulative Avg Stock Turnover	Floating Point	Month total average B line stock turnover (B line cumulative stock turnover / B line count stock turnover)
Month B Line Avg Availability	Floating Point	Month total cumulative available B lines

APPENDIX 35: Branch statistics class (continued)

Variable	Type	Description
Month B Line Cumulative Availability	Floating Point	Month total B Line average availability (total cumulative availability / total cumulative availability + total cumulative stock-outs)
Month B Line Cumulative Stock-Outs	Integer	Month total cumulative B line stock-outs
Month B Line Customer Stock-Outs	Integer	Month total number of B line customer stock-outs
Month B Line Purchases	Integer	Month total number of B line purchases
Month B Line Stock-Outs	Integer	Month total number of B line stock-outs
Month B Line Value	Integer	Month total B line value
Month C Line Count Stock Turnover	Integer	Month total number of C lines with balance on hand > 0
Month C Line Cumulative Stock Turnover	Integer	Month total cumulative C lines stock turnover
Month C Line Cumulative Avg Stock Turnover	Floating Point	Month total average C line stock turnover (C line cumulative stock turnover / C line count stock turnover)
Month C Line Avg Availability	Floating Point	Month total cumulative available C lines
Month C Line Cumulative Availability	Floating Point	Month total C Line average availability (total cumulative availability / total cumulative availability + total cumulative stock-outs)
Month C Line Cumulative Stock-Outs	Integer	Month total cumulative C line stock-outs
Month C Line Customer Stock-Outs	Integer	Month total number of C line customer stock-outs
Month C Line Orders	Integer	Month total number of C line orders
Month C Line Stock-Outs	Integer	Month total number of C line stock-outs
Month C Line Value	Integer	Month total C line value
Month Total Lines Cumulative Availability	Floating Point	Average Month total line availability (A + B + C / number of lines)
Month Total Line Cumulative Avg Stock Turnover	Floating Point	Average Month total line stock turnover (total line cumulative turnover / total line cumulative count of lines)
Month Total Lines Customer Stock-Outs	Integer	Month Total line customer stock-outs (A + B + C)
Month Total Lines Purchases	Integer	Month Total line purchases (A + B + C)
Month Total Lines Stock-Outs	Integer	Month Total line stock-outs (A + B + C)
Month Total Lines Value	Integer	Average Month total line value (A + B + C)
Total A Line Count Stock Turnover	Integer	Total number of A lines with balance on hand > 0

APPENDIX 35: Branch statistics class (continued)

Variable	Type	Description
Total A Line Cumulative Stock Turnover	Integer	Total cumulative A lines stock turnover
Total A Line Avg Stock Turnover	Floating Point	Total average A line stock turnover (A line cumulative stock turnover / A line count stock turnover)
Total A Line Avg Availability	Floating Point	Total cumulative available A lines
Total A Line Cumulative Availability	Floating Point	Total A Line average availability (total cumulative availability / total cumulative availability + total cumulative stock-outs)
Total A Line Customer Stock-Outs	Integer	Total number of A line customer stock-outs
Total A Line Orders	Integer	Total number of A line orders
Total A Line Cumulative Stock-Outs	Integer	Total number of A line stock-outs
Total A Line Stock-outs	Integer	Total cumulative A line stock-outs
Total A Line Cumulative Value	Integer	Total A line value
Total A Line Avg Day Value	Integer	Total average A line value
Total B Line Count Stock Turnover	Integer	Total number of B lines with balance on hand > 0
Total B Line Cumulative Stock Turnover	Integer	Total cumulative B lines stock turnover
Total B Line Avg Stock Turnover	Floating Point	Total average B line stock turnover (B line cumulative stock turnover / B line count stock turnover)
Total B Line Avg Availability	Floating Point	Total cumulative available B lines
Total B Line Cumulative Availability	Floating Point	Total B Line average availability (total cumulative availability / total cumulative availability + total cumulative stock-outs)
Total B Line Customer Stock-Outs	Integer	Total number of B line customer stock-outs
Total B Line Purchases	Integer	Total number of B line purchases
Total B Line Cumulative Stock-Outs	Integer	Total number of B line stock-outs
Total B Line Stock-outs	Integer	Total cumulative B line stock-outs
Total B Line Cumulative Value	Integer	Total B line value
Total B Line Avg Day Value	Integer	Total average B line value
Total C Line Count Stock Turnover	Integer	Total number of C lines with balance on hand > 0

APPENDIX 35: Branch statistics class (continued)

Variable	**Type**	**Description**
Total C Line Cumulative Stock Turnover	Integer	Total cumulative C lines stock turnover
Total C Line Avg Stock Turnover	Floating Point	Total average C line stock turnover (C line cumulative stock turnover / C line count stock turnover)
Total C Line Avg Availability	Floating Point	Total cumulative available C lines
Total C Line Cumulative Availability	Floating Point	Total C Line average availability (total cumulative availability / total cumulative availability + total cumulative stock-outs)
Total C Line Customer Stock-Outs	Integer	Total number of C line customer stock-outs
Total C Line Orders	Integer	Total number of C line orders
Total C Line Cumulative Stock-Outs	Integer	Total number of C line stock-outs
Total C Line Stock-outs	Integer	Total cumulative C line stock-outs
Total C Line Cumulative Value	Integer	Total C line value
Total C Line Avg Day Value	Integer	Total average C line value
Total Line Count	Integer	Total number of lines (A + B +C)
Total Line Orders	Integer	Total number of orders (A + B + C)
Total Line Customer Stock-Outs	Integer	Total line number of customer stock-outs (A + B + C)
Total Line Avg Day Value	Integer	Total line average daily value (A + B + C)
Total Line Avg Availability	Floating Point	Total line average availability (A + B + C / number of lines)
Total Line Avg Stock Turnover	Floating Point	Total line average stock turnover (total line cumulative turnover / total line cumulative count of lines)
Total Line Stock-Outs	Integer	Total line number of stock-outs (A + B + C)
Total Purchase Orders Critical	Integer	Total number of purchase orders which are critical
Total Distribution Orders	Integer	Total number of distribution orders
Total Purchase Orders	Integer	Total number of purchase orders
Total Distribution Orders Excess	Integer	Total number of excess distribution orders
Total Purchase Orders Max	Integer	Total number of purchase order to maximum holding
Branch Name	String	Unique name of branch

APPENDIX 36: Region statistics class

Variable	Type	Description
A Line Availability	Floating Point	Average A line availability (total A line branch availability / number of branches)
A Line Avg Branch Day Value	Integer	Average A line stock held value (total A Line branch value / number of branches)
A Line Avg Stock Turnover	Floating Point	Average A Line stock turnover (total A line branch stock turnover / number of branches)
A Line Customer Orders	Integer	Total A line customer orders
A Line Customer Stock-Outs	Integer	Total A line customer stock-outs (total A line branch customer stock-outs)
A Line Orders	Integer	Total A line orders (total A line branch orders)
A Line Stock-Outs	Integer	Total A line stock-outs (total A line branch stock-outs)
A Lines	Integer	Total A lines (total branch A lines)
B Line Availability	Floating Point	Average B line availability (total B line branch availability / number of branches)
B Line Avg Branch Day Value	Integer	Average B line stock held value (total B Line branch value / number of branches)
B Line Avg Stock Turnover	Floating Point	Average B Line stock turnover (total B line branch stock turnover / number of branches)
B Line Customer Orders	Integer	Total B line customer orders
B Line Customer Stock-Outs	Integer	Total B line customer stock-outs (total B line branch customer stock-outs)
B Line Orders	Integer	Total B line orders (total B line branch orders)
B Line Stock-Outs	Integer	Total B line stock-outs (total B line branch stock-outs)
B Lines	Integer	Total B line (total branch B lines)
C Line Availability	Floating Point	Average C line availability (total C line branch availability / number of branches)
C Line Avg Branch Day Value	Integer	Average C line stock held value (total C Line branch value / number of branches)
C Line Avg Stock Turnover	Floating Point	Average C Line stock turnover (total C line branch stock turnover / number of branches)
C Line Customer Orders	Integer	Total C line customer orders
C Line Customer Stock-Outs	Integer	Total C line customer stock-outs (total C line branch customer stock-outs)
C Line Orders	Integer	Total C line orders (total C line branch orders)
C Line Stock-Outs	Integer	Total C line stock-outs (total C line branch stock-outs)
C Lines	Integer	Total C line (total branch C lines)

APPENDIX 36: Region statistics class (continued)

Total Distribution Orders	Integer	Total distribution orders (A + B + C)
Total Lines	Integer	Total lines (A +B + C)
Total Line Customer Orders	Integer	Total line customer orders (A + B + C)
Total Line Customer Stock-Outs	Integer	Total line customer stock-outs (A + B + C)
Total Line Avg Availability	Floating Point	Total line average availability (A + B + C availability / A + B + C availability + A + B + C stock-outs) x 100
Total Line Avg Branch Day Value	Integer	Total line average branch daily value (A + B + C)
Total Line Avg Stock Turnover	Floating Point	Total line average stock turnover (A + B + C turnover / A + B + C count of lines)
Total line Orders	Integer	Total line number of orders (A + B + C)
Total purchase Orders	Integer	Total line purchase orders (A + B + C)
Total Line Stock-Outs	Integer	Total line number of stock-outs (A + B + C)
Total Purchase Orders Critical	Integer	Total line critical purchase orders
Total Purchase Orders Maximum	Integer	Total line purchase orders to maximum
Total Distribution Orders Critical	Integer	Total line critical distribution orders
Scenario	Integer	Scenario number
Avg Month MAD	Floating Point	Average Month MAD

APPENDIX 37: Coefficient class

xyPd1	Floating Point	Coefficient equation 1
y2Pd1	Floating Point	Coefficient equation 2
yPd1	Floating Point	Coefficient equation 3

APPENDIX 38: Coefficient 2 class

Coefficient Correlation	Floating Point	Coefficient correlation
Cumulative Coefficient Correlation	Floating Point	Cumulative coefficient correlation
Sum x	Floating Point	Sum of month
Sumx2	Floating Point	Sum of month squared
Sum x2 Pd2	Floating Point	Sum of month squared period 2
Sum x Pd2	Floating Point	Sum of month period 2
Sum xy	Floating Point	Sum of month x sales
Sum xy Pd2	Floating Point	Sum of month x sales period 2
Sum y	Floating Point	Sum of sales
Sum y2	Floating Point	Sum of sales squared
Sum y2 Pd2	Floating Point	Sum of sales squared period 2
Sum y Pd2	Floating Point	Sum of sales period 2
Month Sum x	Floating Point	Sum of month
Month Sum x2	Floating Point	Sum of month squared
Month Sum xy	Floating Point	Sum of month x sales
Month Sum y2	Floating Point	Sum of sales squared

APPENDIX 39: Non-segmented results
for the Anglia region

Scenario	Number of lines				Average forecast error	No of PO's	No of PO's (Max)	No of PO's (Critical)	No of DO's	No of DO's (Excess)	Total Replen' orders	Average daily stock branch value (£'s)				Average product turnover			
	A	B	C	Total								A	B	C	Total	A	B	C	Total
1	11,015	4,586	10,397	25,998	0	96,590	5,219	3,156	23,877	685	129,527	53,088	6,938	11,431	71,457	19.17	37.51	150.01	72.26
2	11,015	4,586	10,397	25,998	54	49,836	2,928	273	8,094	325	61,456	45,784	8,664	14,820	69,268	29.89	65.25	239.34	116.43
3	11,015	4,586	10,397	25,998	51	75,432	4,646	1,190	20,205	499	101,972	65,091	7,904	12,141	85,137	19.46	36.77	128.63	64.14
4	11,015	4,586	10,397	25,998	55	48,653	2,849	230	8,028	330	60,090	66,014	10,092	16,179	92,285	32.25	68.95	237.62	116.71
5	11,015	4,586	10,397	25,998	54	48,533	2,855	233	8,043	327	59,991	66,877	10,100	16,029	93,007	32.01	67.96	236.14	115.9
6	11,015	4,586	10,397	25,998	54	46,169	2,711	214	8,155	218	57,467	93,468	13,911	19,532	126,911	38.12	80.13	257.79	128.66
7	11,015	4,586	10,397	25,998	54	45,856	2,752	229	8,144	228	57,209	95,941	14,269	19,544	129,754	37.93	80.34	259.51	129.27
8	11,015	4,586	10,397	25,998	54	42,463	2,575	215	8,153	196	53,602	125,761	16,691	21,632	164,083	41.57	85.43	271.47	136.16
9	11,015	4,586	10,397	25,998	62	47,623	2,582	163	7,098	39	57,505	46,264	9,200	15,917	71,381	31.98	74.73	270.95	131.15
10	11,015	4,586	10,397	25,998	59	76,235	4,731	1,194	20,386	481	103,027	65,698	8,451	12,706	86,855	20.6	39.72	133.7	67.05
11	11,015	4,586	10,397	25,998	62	46,870	2,601	141	7,120	51	56,783	68,029	11,089	17,677	96,795	35.09	80.14	271.8	132.93
12	11,015	4,586	10,397	25,998	62	46,788	2,578	142	7,125	54	56,687	69,093	11,153	17,805	98,051	34.96	79.33	269.82	132.07
13	11,015	4,586	10,397	25,998	62	44,399	2,664	130	7,087	44	54,324	95,746	14,971	21,127	131,843	40.8	90.39	296.48	146.33
14	11,015	4,586	10,397	25,998	62	44,220	2,588	139	7,098	47	54,092	97,449	15,212	21,436	134,097	40.78	90.21	297.24	146.57
15	11,015	4,586	10,397	25,998	62	40,974	2,415	154	7,111	50	50,704	127,847	18,054	23,886	169,787	45.24	96.81	312.01	155.15
16	11,015	4,586	10,397	25,998	57	52,088	3,140	304	8,666	424	64,622	45,286	8,452	14,590	68,328	29.48	64.44	242.41	117.35
17	11,015	4,586	10,397	25,998	54	73,010	4,531	1,191	19,891	493	99,116	67,380	8,002	12,306	87,688	19.57	37.35	128.38	64.3
18	11,015	4,586	10,397	25,998	57	50,489	2,971	250	8,644	425	62,779	66,542	9,934	15,968	92,443	32	69.24	244.39	119.44
19	11,015	4,586	10,397	25,998	57	50,189	3,041	257	8,636	410	62,533	68,174	9,973	15,974	94,121	31.88	68.24	245.03	119.46
20	11,015	4,586	10,397	25,998	57	46,635	2,722	246	8,698	267	58,568	96,182	14,074	19,700	129,956	38.38	81.52	274.51	135.29
21	11,015	4,586	10,397	25,998	57	46,368	2,791	229	8,726	254	58,368	97,588	14,408	19,823	131,820	38.23	81.87	273.99	135.13
22	11,015	4,586	10,397	25,998	57	42,847	2,619	196	8,715	254	54,631	129,503	16,904	22,209	168,617	42.45	87.92	290.94	144.35

APPENDIX 39: Non-segmented results for the Anglia region (continued)

Scenario	Product stock-outs (days)				Customer stock-outs				Customer availability (%)				Product availability (%)			
	A	B	C	Total	A	B	C	Total	A	B	C	Total	A	B	C	Total
1	161,297	69,395	117,949	348,641	47,144	9,311	10,435	66,890	93.04	87.44	85.87	91.89	94.98	94.72	96	95.34
2	182,051	55,670	86,198	323,919	64,518	7,218	7,020	78,756	90.47	90.26	90.49	90.45	94.9	96.03	97.08	95.96
3	133,381	66,687	109,524	309,592	37,619	8,968	10,052	56,639	94.44	87.90	86.39	93.13	95.54	94.66	96.2	95.66
4	100,076	40,542	73,008	213,626	29,033	5,351	5,861	40,245	95.71	92.78	92.06	95.12	96.94	96.93	97.45	97.14
5	95,457	38,758	68,866	203,081	26,801	5,183	5,565	37,549	96.04	93.01	92.46	95.45	97.01	97.05	97.56	97.23
6	46,646	17,978	46,164	110,788	16,046	2,383	3,449	21,878	97.63	96.78	95.33	97.35	98.5	98.53	98.26	98.4
7	45,694	17,916	46,035	109,645	16,299	2,494	3,488	22,281	97.59	96.63	95.28	97.30	98.51	98.54	98.27	98.41
8	27,943	13,867	41,046	82,856	8,242	1,959	3,084	13,285	98.78	97.36	95.82	98.39	98.99	98.81	98.43	98.73
9	179,741	49,241	76,267	305,249	63,857	6,588	6,153	76,598	90.57	91.11	91.67	90.71	95.02	96.66	97.45	96.27
10	123,075	55,762	93,393	272,230	36,737	8,056	8,570	53,363	94.57	89.13	88.39	93.53	96.07	95.69	96.75	96.28
11	88,397	32,110	57,675	178,182	27,302	4,492	4,444	36,238	95.97	93.94	93.98	95.61	97.44	97.72	97.97	97.69
12	83,992	30,231	55,536	169,759	25,946	4,306	4,475	34,727	96.17	94.19	93.94	95.79	97.47	97.8	98.04	97.75
13	43,473	15,864	41,381	100,718	15,483	2,192	3,025	20,700	97.71	97.04	95.90	97.49	98.63	98.73	98.47	98.57
14	41,922	15,615	41,015	98,552	15,136	2,230	2,922	20,288	97.76	96.99	96.04	97.54	98.64	98.75	98.46	98.58
15	25,453	11,592	35,865	72,910	8,174	1,695	2,537	12,406	98.79	97.71	96.56	98.50	99.11	99.02	98.63	98.89
16	188,882	59,058	89,581	337,521	65,679	7,818	7,451	80,948	90.30	89.45	89.91	90.19	94.66	95.83	97	95.8
17	139,198	68,127	111,868	319,193	37,870	9,064	10,379	57,313	94.41	87.77	85.94	93.05	95.28	94.56	96.15	95.52
18	115,894	47,672	77,833	241,399	31,665	6,243	6,492	44,400	95.32	91.58	91.21	94.62	96.44	96.43	97.32	96.79
19	111,873	45,344	74,035	231,252	30,531	6,120	6,275	42,926	95.49	91.74	91.50	94.80	96.49	96.62	97.44	96.9
20	46,214	19,007	46,153	111,374	15,735	2,580	3,497	21,812	97.68	96.52	95.26	97.36	98.51	98.44	98.28	98.4
21	44,877	18,304	45,381	108,562	15,112	2,574	3,466	21,152	97.77	96.53	95.31	97.44	98.52	98.51	98.3	98.42
22	28,125	13,856	40,276	82,257	8,262	1,994	3,078	13,334	98.78	97.31	95.83	98.38	98.98	98.83	98.48	98.75

APPENDIX 40: Non-segmented results for the South West region

Scenario	Number of lines				Average forecast error	No of PO's	No of PO's (Max)	No of PO's (Critical)	No of DO's	No of DO's (Excess)	Total Replen' orders	Average daily stock branch value (£'s)				Average product turnover			
	A	B	C	Total								A	B	C	Total	A	B	C	Total
1	8,514	5,210	4,585	18,309	0	44,994	2,505	722	76,394	47	124,662	40,797	7,248	4,924	52,969	12.68	29.28	167.44	56.14
2	8,514	5,210	4,585	18,309	98	27,275	1,678	91	19,327	23	48,394	34,243	8,787	5,868	48,898	22.54	57	282.45	94.43
3	8,514	5,210	4,585	18,309	86	34,118	2,129	254	61,620	26	98,147	48,868	7,849	4,724	61,442	12.5	28.48	154.92	52.91
4	8,514	5,210	4,585	18,309	98	26,213	1,667	76	19,210	19	47,185	50,915	9,911	6,000	66,826	24.08	58.54	282.14	95.21
5	8,514	5,210	4,585	18,309	98	26,564	1,638	73	19,228	15	47,518	47,826	9,859	5,964	63,649	23.89	58.47	282.61	95.19
6	8,514	5,210	4,585	18,309	98	25,121	1,622	76	19,502	14	46,335	61,957	12,103	6,556	80,616	25.2	60.87	290.44	98.14
7	8,514	5,210	4,585	18,309	99	25,423	1,643	84	19,509	15	46,674	58,970	12,104	6,544	77,618	24.97	60.75	289.57	97.85
8	8,514	5,210	4,585	18,309	99	23,505	1,580	66	19,630	16	44,797	77,196	13,873	6,810	97,880	26.77	62.48	293.27	99.88
9	8,514	5,210	4,585	18,309	109	26,758	1,638	75	17,651	7	46,129	34,672	9,251	6,181	50,104	23.53	63.22	309.81	103.22
10	8,514	5,210	4,585	18,309	96	34,612	2,102	290	62,497	32	99,533	48,932	8,194	4,851	61,978	12.89	29.82	157.68	54.13
11	8,514	5,210	4,585	18,309	110	25,895	1,623	61	17,760	6	45,345	50,860	10,549	6,356	67,764	25.34	65.82	311.65	104.88
12	8,514	5,210	4,585	18,309	110	26,263	1,594	49	17,776	4	45,686	48,511	10,474	6,364	65,349	25.22	65.65	312.7	104.97
13	8,514	5,210	4,585	18,309	109	24,708	1,589	65	17,849	6	44,217	62,767	12,714	6,992	82,474	26.48	67.76	320.87	107.91
14	8,514	5,210	4,585	18,309	109	25,118	1,590	66	17,846	6	44,626	60,329	12,698	6,939	79,965	26.24	67.64	320.26	107.65
15	8,514	5,210	4,585	18,309	109	23,231	1,546	69	17,979	6	42,831	77,222	14,540	7,285	99,047	28.08	69.2	323.74	109.6
16	8,514	5,210	4,585	18,309	103	28,425	1,778	117	21,388	21	51,729	34,153	8,665	5,857	48,675	21.99	56.29	286	94.84
17	8,514	5,210	4,585	18,309	93	32,802	2,079	259	59,928	22	95,090	50,214	7,880	4,756	62,849	12.54	28.55	154.98	53.02
18	8,514	5,210	4,585	18,309	104	26,825	1,718	111	21,048	23	49,725	50,944	9,790	5,973	66,707	23.56	58.2	288.31	96.39
19	8,514	5,210	4,585	18,309	104	27,213	1,736	109	21,084	20	50,162	48,276	9,769	5,968	64,012	23.29	57.75	289.75	96.42
20	8,514	5,210	4,585	18,309	103	25,344	1,679	93	21,444	24	48,584	63,266	12,186	6,622	82,074	24.89	61.08	299.15	100.01
21	8,514	5,210	4,585	18,309	103	25,734	1,703	90	21,435	22	48,984	60,414	12,114	6,620	79,149	24.69	61	299.31	99.96
22	8,514	5,210	4,585	18,309	103	23,667	1,623	77	21,493	24	46,884	77,918	13,882	6,944	98,744	26.42	62.31	301.82	101.61

APPENDIX 40: Non-segmented results
for the South West region (continued)

Scenario	Product stock-outs (days)				Customer stock-outs				Customer availability (%)				Product availability (%)			
	A	B	C	Total	A	B	C	Total	A	B	C	Total	A	B	C	Total
1	78,570	49,519	26,026	154,115	28,017	11,773	4,167	43,957	94.89	86.85	83.62	93.37	96.87	96.71	97.91	97.1
2	84,253	34,081	18,357	136,691	32,679	6,677	2,109	41,465	94.04	92.54	91.71	93.75	97.08	97.98	98.63	97.74
3	62,390	47,738	26,092	136,220	22,850	11,957	4,401	39,208	95.83	86.65	82.70	94.09	97.3	96.67	97.92	97.28
4	44,871	26,224	16,402	87,497	15,927	5,373	1,925	23,225	97.09	94.00	92.43	96.50	98.34	98.35	98.75	98.44
5	45,023	26,284	16,568	87,875	16,664	5,485	1,958	24,107	96.96	93.88	92.30	96.36	98.35	98.38	98.74	98.45
6	28,905	16,546	13,650	59,101	11,766	3,748	1,505	17,019	97.85	95.82	94.08	97.43	98.77	98.86	98.92	98.84
7	31,227	17,104	13,343	61,674	12,999	3,849	1,498	18,346	97.63	95.70	94.11	97.23	98.7	98.84	98.93	98.8
8	19,902	14,062	12,783	46,747	8,224	3,269	1,411	12,904	98.50	96.35	94.45	98.05	99.11	98.99	98.97	99.04
9	82,303	30,944	15,888	129,135	32,220	6,188	1,741	40,149	94.12	93.09	93.16	93.94	97.19	98.17	98.8	97.88
10	58,772	43,070	22,849	124,691	22,204	10,826	3,804	36,834	95.95	87.91	85.05	94.44	97.5	97.1	98.19	97.57
11	41,049	22,025	14,547	77,621	15,250	4,580	1,528	21,358	97.22	94.89	93.99	96.78	98.51	98.66	98.9	98.65
12	41,282	21,630	14,385	77,297	15,778	4,693	1,543	22,014	97.12	94.76	93.93	96.68	98.52	98.7	98.9	98.67
13	28,268	14,879	12,041	55,188	11,470	3,385	1,188	16,043	97.91	96.22	95.33	97.58	98.81	98.99	99.03	98.92
14	29,709	15,225	12,291	57,225	12,690	3,450	1,219	17,359	97.68	96.15	95.21	97.38	98.77	98.97	99.02	98.89
15	19,217	12,546	11,773	43,536	8,066	2,890	1,134	12,090	98.53	96.77	95.54	98.18	99.14	99.11	99.05	99.11
16	86,508	36,240	18,467	141,215	33,287	7,374	2,338	42,999	93.92	91.77	90.81	93.51	96.98	97.83	98.63	97.65
17	67,327	48,301	25,982	141,610	24,343	12,260	4,536	41,139	95.56	86.31	82.17	93.79	97.09	96.68	97.93	97.2
18	54,706	30,094	17,675	102,475	19,208	6,307	2,206	27,721	96.49	92.96	91.33	95.82	97.94	98.15	98.67	98.19
19	55,352	29,470	17,906	102,728	19,916	6,364	2,275	28,555	96.37	92.89	91.06	95.69	97.95	98.18	98.65	98.2
20	29,013	17,084	13,616	59,713	11,501	3,918	1,575	16,994	97.90	95.63	93.81	97.44	98.74	98.82	98.91	98.81
21	30,706	17,347	13,596	61,649	12,684	4,050	1,569	18,303	97.69	95.48	93.83	97.24	98.69	98.81	98.9	98.78
22	21,289	14,611	12,888	48,788	8,668	3,521	1,487	13,676	98.42	96.07	94.15	97.94	99.03	98.95	98.94	98.99

APPENDIX 41: Segmented results for the Anglia and South West regions

Region	Scenario	Number of lines				Average forecast error	No of PO's	No of PO's (Max)	No of PO's (Critical)	No of DO's	No of DO's (Excess)	Total Replen' orders	Average daily stock branch value (£'s)				Average product turnover			
		A	B	C	Total								A	B	C	Total	A	B	C	Total
Anglia	Current	11,015	4,586	10,397	25,998	No forecast	96,590	5,219	3,156	23,877	685	129,527	53,088	6,938	11,431	71,457	19.17	37.51	150.01	72.26
	Non-segmented	11,015	4,586	10,397	25,998	54	46,169	2,711	214	8,155	218	57,467	93,468	13,911	19,532	126,911	38.12	80.13	257.79	128.66
	1	11,015	4,586	10,397	25,998	52	58,349	3,688	1,021	12,281	720	76,059	90,034	7,140	9,226	106,400	37.73	46.53	113.93	67.75
	2	11,015	4,586	10,397	25,998	52	56,147	3,727	1,042	12,272	719	73,907	95,674	7,785	9,253	112,712	39.5	47.74	113.92	68.73
South West	Current	8,514	5,210	4,585	18,309	No forecast	44,994	2,505	722	76,394	47	124,662	40,797	7,248	4,924	52,969	12.68	29.28	167.44	56.14
	Non-segmented	8,514	5,210	4,585	18,309	98	26,564	1,638	73	19,228	15	47,518	47,826	9,859	5,964	63,649	23.89	58.47	282.61	95.19
	1	8,514	5,210	4,585	18,309	95	28,697	1,833	192	26,518	43	57,283	44,479	7,056	4,182	55,717	25.38	39.78	117.92	51.06
	2	8,514	5,210	4,585	18,309	95	27,596	1,767	172	26,620	47	56,202	48,884	7,722	4,180	60,786	26.36	40.06	118.07	51.61

Region	Scenario	Product stock-outs (days)				Customer stock-outs				Customer availability (%)				Product availability (%)			
		A	B	C	Total	A	B	C	Total	A	B	C	Total	A	B	C	Total
Anglia	Current	161,297	69,395	117,949	348,641	47,144	9,311	10,435	66,890	93.04	87.44	85.87	91.89	94.98	94.72	96	95.34
	Non-segmented	46,646	17,978	46,164	110,788	16,046	2,383	3,449	21,878	97.63	96.78	95.33	97.35	98.5	98.53	98.26	98.4
	1	76,411	67,722	202,291	346,424	20,678	9,234	20,184	50,096	96.95	87.54	72.67	93.93	97.5	95.1	93.52	95.49
	2	64,228	60,326	201,139	325,693	15,222	8,033	20,218	43,473	97.75	89.16	72.62	94.73	98.11	95.52	93.55	95.71
South West	Current	78,570	49,519	26,026	154,115	28,017	11,773	4,167	43,957	94.89	86.85	83.62	93.37	96.87	96.71	97.91	97.1
	Non-segmented	45,023	26,284	16,568	87,875	16,664	5,485	1,958	24,107	96.96	93.88	92.30	96.36	98.35	98.38	98.74	98.45
	1	39,973	44,820	42,274	127,067	15,226	9,874	7,291	32,391	97.22	88.98	71.34	95.11	98.34	96.35	96.94	97.72
	2	32,358	39,833	41,957	114,148	11,618	8,974	7,236	27,828	97.88	89.98	71.55	95.80	98.63	96.57	96.97	97.92

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APPENDIX A: Selected contributions to the development of logistics knowledge

Date	Event	Significance
1901	John F. Crowell, *Report of the Industrial Commission on the Distribution of Farm Products*, vol. 6 (Washington, DC: U.S. Government Printing Office)	The first text to address the costs and factors affecting the distribution of farm products
1916	Arch W. Shaw, *An Approach to Business Problems* (Cambridge, MA: Harvard University Press)	Discussed the strategic aspects of logistics
1916	L. D. H. Weld, *The Marketing of Farm Products* (New York: Macmillan)	Introduced the concepts of marketing utilities and channels of distribution
1922	Fred E. Clark, *Principles of Marketing* (New York: Macmillan)	Defined marketing as those efforts that affect transfers in the ownership of goods and care of their physical distribution
1927	Ralph Borsodi, *The Distribution Age* (New York: D. Appleton)	One of the first textbooks to define the term *logistics* as it is presently used
1954	Paul D. Converse, "The Other Half of Marketing," Twenty-Sixth Boston Conference on Distribution, Harvard Business School	A leading business and educational authority pointed out the need to examine the physical distribution side of marketing
1956	Howard T. Lewis, James W. Culiton, and Jack D. Steele, *The Role of Air Freight in Physical Distribution*, (Boston, MA: Harvard Business School)	Introduced the concept of total cost analysis to logistics
1961	Edward W. Smykay, Donald J. Bowersox, and Frank H. Mossman, *Physical Distribution Management*, (New York: Macmillan)	One of the first texts on physical distribution; discussed the systems approach and the total cost concept in detail
1961	*Transportation Journal*, Volume 1, Number 1	The first transportation-specific academic journal
1964	*Logistics and Transportation Review*, Volume 1, Number 1	The second transportation-specific academic journal
1964	James L. Heskett, Nicholas A. Glaskowsky, Jr., and Robert M. Ivie, *Business Logistics*, (New York: Ronald Press)	One of the first texts on logistics
1969	Donald J. Bowersox, "Physical Distribution Development, Current Status, and Potential," *Journal of Marketing*, vol. 33, no. 1	Integrated logistics management concept examined from an historical perspective
1970	*International Journal of Physical Distribution and Logistics Management*, Volume 1, Number 1	The first logistics-specific academic journal
1972	Michael Schiff, *Accounting and Control in Physical Distribution Management* (Chicago, IL: National Council of Physical Distribution Management)	Created an awareness of the importance of accounting and financial information to successful logistics management
1973	Ronald H. Ballou, *Business Logistics Management* (Englewood Cliffs, NJ: Prentice Hall)	Used as a senior-level undergraduate textbook, currently in third edition

APPENDIX A: Selected contributions to the development of logistics knowledge (continued)

Date	Event	Significance
1976	Douglas M. Lambert, *The Development of an Inventory Costing Methodology: A Study of the Costs Associated with Holding Inventory* (Chicago, IL: National Council of Physical Distribution Management)	Identified the cost components of one of the largest logistics expense items and developed a method whereby firms can calculate their inventory carrying costs
1976	Bernard J. La Londe and Paul H. Zinszer, *Customer Service: Meaning and Measurement*, (Chicago, IL: National Council of Physical Distribution Management)	First in an ongoing series of books on contemporary logistics issues published by NCPDM, which changed its name to the Council of Logistics Management (CLM) in 1985
1976	John J. Coyle, Edward J. Bardi, and C. John Langley, Jr., *The Management of Business Logistics* (New York: West)	Used as an introductory logistics textbook, currently in sixth edition
1978	*Journal of Business Logistics*, Volume 1 Number 1, published by the National Council of Physical Distribution Management	The second logistics-specific journal
1978	A.T. Kearny, Inc., *Measuring Productivity in Physical Distribution* (Oak Brook, IL: National Council of Physical Distribution Management)	Second in an ongoing series of books on contemporary logistics issues published by NCPDM
1982	Douglas M. Lambert and James R. Stock, *Strategic Logistics Management*, (Homewood, IL: Irwin)	Used as a senior level undergraduate and MBA textbook. Currently in third edition
1984	A.T. Kearney, Inc., *Measuring and Improving Productivity in Physical Distribution* (Oak Brook, IL: National Council of Physical Distribution Management)	Third in an ongoing series of books on contemporary logistics issues published by NCPDM
1984	Graham Sharman, "The Rediscovery of Logistics," *Harvard Business Review*, vol. 62, no. 5	Identified the need for top management to recognize the importance of logistics to the corporation
1985	Michael E. Porter, *Competitive Advantage*, (New York: The Free Press)	Introduced the value-chain concept to aid management in developing a competitive advantage in the market
1986	C. John Langley, Jr., "The Evolution of the Logistics Concept," *Journal of Business Logistics*, vol. 7, no. 1	Identified a taxonomy of logistics implementation strategies within the firm
1989	Bernard J. La Londe, Martha C. Cooper, and Thomas G. Noordewier, *Customer Service: A Management Perspective* (Oak Brook, IL: Council of Logistics Management)	Fourth in the ongoing series of books on contemporary logistics issues published by CLM
1989	Donald J. Bowersox, Patricia J. Daugherty, Cornelia L. Droge, Dale S. Rogers, and Daniel L. Wardlow, *Leading Edge Logistics Competitive Positioning for the 1990's* (Oak Brook, IL: Council of Logistics Management)	Fifth in the ongoing series of books on contemporary logistics issues published by CLM
1989	Benard J. La Londe and Martha C. Cooper, *Partnerships in Providing Customer Service: A Third Party Perspective* (Oak Brook, IL: Council of Logistics Management)	Sixth in the ongoing series of books on contemporary logistics issues published by CLM

APPENDIX A: Selected contributions to the development of logistics knowledge (continued)

Date	Event	Significance
1990	*International Journal of Logistics Management*, Volume 1, Number 1	The third logistics-specific journal
1990	Mary Kay Allen and Omar K. Helferich, *Putting Expert Systems to Work in Logistics* (Oak Brook, IL: Council of Logistics Management)	Seventh in the ongoing series of books on contemporary logistics issues published by CLM
1991	Peter A. Smith, Jack Barry, Joseph L. Cavinato, John J. Coyle, Steven C. Dunn, and William L. Grenoble, *Logistics in Service Industries* (Oak Brook, IL: Council of Logistics Management)	Eighth in the ongoing series of books on contemporary logistics issues published by CLM
1991	Patrick M. Byrne and William J. Markham, *Improving Quality and Productivity in the Logistics Process* (Oak Brook, IL: Council of Logistics Management)	Ninth in the ongoing series of books on contemporary logistics issues published by CLM; introduced quality
1992	Martha C. Cooper, Daniel E. Innis, and Peter R. Dickson, *Strategic Planning for Logistics* (Oak Brook, IL: Council of Logistics Management)	Tenth in the ongoing series of books on contemporary logistics issues published by CLM
1993	Kevin A. O'Laughlin, James Cooper, and Eric Cabocel, *Reconfiguring European Logistics Systems* (Oak Brook, IL: Council of Logistics Management)	Eleventh in the ongoing series of books on contemporary logistics issues published by CLM
1993	Ronald Kopicki, Michael J. Berg, and Leslie Legg, *Reuse and Recycling—Reverse Logistics Opportunities* (Oak Brook, IL: Council of Logistics Management)	Twelfth in the ongoing series of books on contemporary logistics issues published by CLM
1995	The Global Logistics Research Team at Michigan State University, *World Class Logistics: The Challenge of Managing Continuous Change* (Oak Brook, IL: Council of Logistics Management)	Thirteenth in the ongoing series of books on contemporary logistics issues published by CLM
1995	J. T. Mentzer and Kenneth Kahn, "A Framework of Logistics Research," *Journal of Business Logistics*, vol. 16, no. 1	Highlighted the need for more rigorous theory testing within the logistics literature
1995	Robert A. Novack, C. John Langley, and Lloyd M. Rinehart, *Creating Logistics Value* (Oak Brook, IL: Council of Logistics Management)	Fourteenth in the ongoing series of books on contemporary logistics issues published by CLM; introduced value
1995	David G. Waller, Robert L. D'Avanzo, and Douglas M. Lambert, *Supply-chain Directions for a New North America* (Oak Brook, IL: Council of Logistics Management)	Fifteenth in the ongoing series of books on contemporary logistics issues published by CLM
1996	Donald J. Bowersox and David J. Closs, *Logistical Management: The Integrated Supply-Chain Process* (New York: McGraw-Hill)	The first text to include supply chain in the title
1996	*Supply-Chain Management Review*, Volume 1, Number 1	The first journal to include supply chain in the title

Source: Kent & Flint (1997, pp.17 -19).

APPENDIX B: Benchmarking questionnaire

Logistics Benchmarking questionnaire

Introduction

Contact name	
Job title	
Company name	
Date	

The questionnaire is designed for use by all organisations that are current members of the Logistics Benchmarking Club – Logmark.

The questionnaire consists of four sections:

- Inventory measures
- Operational measures
- Transport measures
- HR measures

As you progress through the questionnaire there a number of points which should be considered:

1. There maybe questions that you feel are not relevant to your organisation, or cannot be answered for other reasons. Should this be the case please type N/A in the appropriate box and move on to the next question.

2. Carefully read the question and the definitions before completion to ensure the correct interpretation of what is required.

3. Wherever possible, the data provided should cover the full year January 03-December 03.

4. If you have any queries regarding definitions or data requirements, please contact Chris Holmes:

   Office – 01773 724081
   Mobile – 07810 836 496
   E-mail – christopher.holmes@logistics.nhs.co.uk

Logmark – version1
Created January 2004

APPENDIX B: Benchmarking questionnaire (continued)

Operational measures

5. What % of product lines ordered are actually supplied to customers?

Customer order lines actually delivered, excluding lines unavailable due to stock outs
———————————————
Total number of customer order lines including the lines that are unavailable due to stock outs

6. What % of your customer deliveries are made to the correct time window?

Total number of customer deliveries made to the correct delivery window (+- 1 hour or less)
———————————————
Total number of customer deliveries

7. What is your total operating cost per line?

Total pay and non pay costs excluding loading of goods and transport
———————————————
Total lines picked for customer orders

7a. What is your operating cost per pick unit?

Total pay and non pay costs excluding loading of goods and transport
———————————————
Total units picked for customer orders

Non-pay costs to include, but not be exclusive to:

- ***Staff costs***
- ***Controllable operating costs:***
  - ***Equipment hire***
  - ***Warehouse maintenance & repairs etc***
- ***Facility costs – rent & rates etc***
- ***Administration costs***

Logmark – version1
Created January 2004

APPENDIX B: Benchmarking questionnaire (continued)

8. What is your average line pick per man-hour?

Total number of product lines supplied for customer orders

Total operational hours, productive and non-productive, including overtime, agency/temporary labour & management & supervision but excluding loading of goods and sickness & absence hours

8a. What is your average unit pick per man-hour?

Total number of pick units supplied for customer orders

Total operational hours, productive and non-productive, including overtime, agency/temporary labour & management & supervision but excluding loading of goods and sickness & absence hours

Total operational hours to include, but not be exclusive to:

- ***Management - all management involved with operating the DC, including the DC management team***
- ***All operational hours***
- ***All administration hours involved in the operating of the DC***
- ***All service hours – cleaning etc.***

9. What is the average number of lines within a customer order?

Total number of customer orders

Total number of lines ordered

10. What is the total number of units within an order line?

Total number of units picked

Total number of lines picked

Logmark – version1
Created January 2004

APPENDIX B: Benchmarking questionnaire (continued)

11. What is the average % of stock outs, as a % of failed lines

Number of product lines for customer orders which are on the warehouse management system which are not physically available to pick

Number of products lines ordered by customers

11a. What is the average % of stock outs, as a % of pick units

Number of pick units for customer orders which are on the warehouse management system which are not physically available to pick

Number of pick units ordered by customers

12. What is the average line picking error %?

Number of inaccurate lines picked for customer orders prior to checking & despatch

Total number of lines picked for customer orders

12a. What is the average pick unit picking error rate?

Number of inaccurate pick units for customer orders prior to checking & despatch

Total number of pick units picked for customer orders

Logmark – version1
Created January 2004

APPENDIX B: Benchmarking questionnaire (continued)

Transport measures

13. What is the transport cost (£) per line supplied?

Total transport pay and non-pay costs including loading

Total number of lines picked for customer ordered

13a. What is the transport cost (£) per pick unit supplied?

Total transport pay and non-pay costs including loading

Total number of pick units picked for customer ordered

13b. What is the transport cost (£) per delivery location?

Total transport pay and non-pay costs including loading

Total number of delivery points actually delivered to (if the same delivery point is delivered to twice in a week, the number of deliveries points counted should be two)

Non-pay costs to include, but not be exclusive to:

- ***Vehicle standing costs***
- ***Vehicle running costs***
- ***Spot hire vehicles***
- ***Contracted transhipment***

Logmark – version1
Created January 2004

APPENDIX B: Benchmarking questionnaire (continued)

14. What is the % utilisation of the vehicle fleet?

    Total vehicle hours used to make customer deliveries

    Total vehicle hours available (number of vehicles x 24 hours per day x 7 days per week).

15. What is the % fill of the vehicle fleet?

    Total number of units delivered (cages, pallets etc)

    Total capacity of the vehicle fleet (pallets, cages etc)

Logmark – version1
Created January 2004

APPENDIX C: Benchmarking questionnaire results

Results of the Logistics benchmarking exercise 2003

Inventory measures

1 % Inbound deliveries received to the correct delivery window

Average	Highest	Lowest	Response rate
88.48%	97.75%	73.82%	77.78%

2 % Order satisfied

Average	Highest	Lowest	Response rate
87.81%	97.65%	74.00%	55.56%

3 Average Supplier lead time (in days)

Average	Highest	Lowest	Response rate
10.5	16.0	2.0	66.67%

Operational measures

4 % Product lines ordered actually supplied to customers

Average	Highest	Lowest	Response rate
96.16%	99.80%	96.00%	88.89%

5 % Customer deliveries made to correct window

Average	Highest	Lowest	Response rate
98.12%	100.00%	94.00%	88.89%

6 Total operating cost per line

Average	Highest	Lowest	Response rate
£1.58	£2.77	£0.45	66.67%

6a Total operating cost per pick unit

Average	Highest	Lowest	Response rate
£0.56	£1.96	£0.07	44.44%

7 Average line pick per man hour

Average	Highest	Lowest	Response rate
20.32	70.00	4.12	88.89%

APPENDIX C: Benchmarking questionnaire results (continued)

7a Average units picked per man hour

Average	Highest	Lowest	Response rate
220.00	437.00	18.28	77.78%

8 Average % of stock outs as a % of failed lines

Average	Highest	Lowest	Response rate
1.12%	4.00%	0.0001%	88.89%

8a % Stock outs as a % of pick units

Average	Highest	Lowest	Response rate
0.56%	1.09%	0.00001%	77.78%

9 Average line picking error %

Average	Highest	Lowest	Response rate
0.87%	1.50%	0.04%	100.00%

9a Average units picking error %

Average	Highest	Lowest	Response rate
0.38%	1.00%	0.02%	66.67%

Transport measures

10 Transport cost per line supplied

Average	Highest	Lowest	Response rate
£2.24	£5.35	£0.25	55.56%

10a Transport cost per pick unit supplied

Average	Highest	Lowest	Response rate
£1.53	£4.43	£0.01	44.44%

10b Transport cost per delivery location

Average	Highest	Lowest	Response rate
£44.67	£60.00	£34.18	55.56%

11 % Utilisation of vehicle fleet

Average	Highest	Lowest	Response rate
43.11%	98.80%	26.00%	77.78%

APPENDIX C: Benchmarking questionnaire results (continued)

HR measures

12 Number of lost time accidents resulting in absence from work of 1-3 days

Average	Highest	Lowest	Response rate
11	32	1	100.00%

12a Number of lost time accidents resulting in absence from work greater than 3

Average	Highest	Lowest	Response rate
18	70	0	100.00%

12b Number of days absent due to accidents at work

Average	Highest	Lowest	Response rate
206	674	3	88.89%

13 Average sickness %

Average	Highest	Lowest	Response rate
4.81%	7.60%	0.30%	100.00%

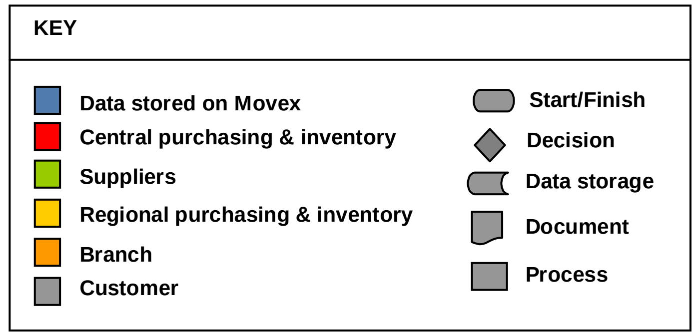
APPENDIX D: Avonmouth office organisation report

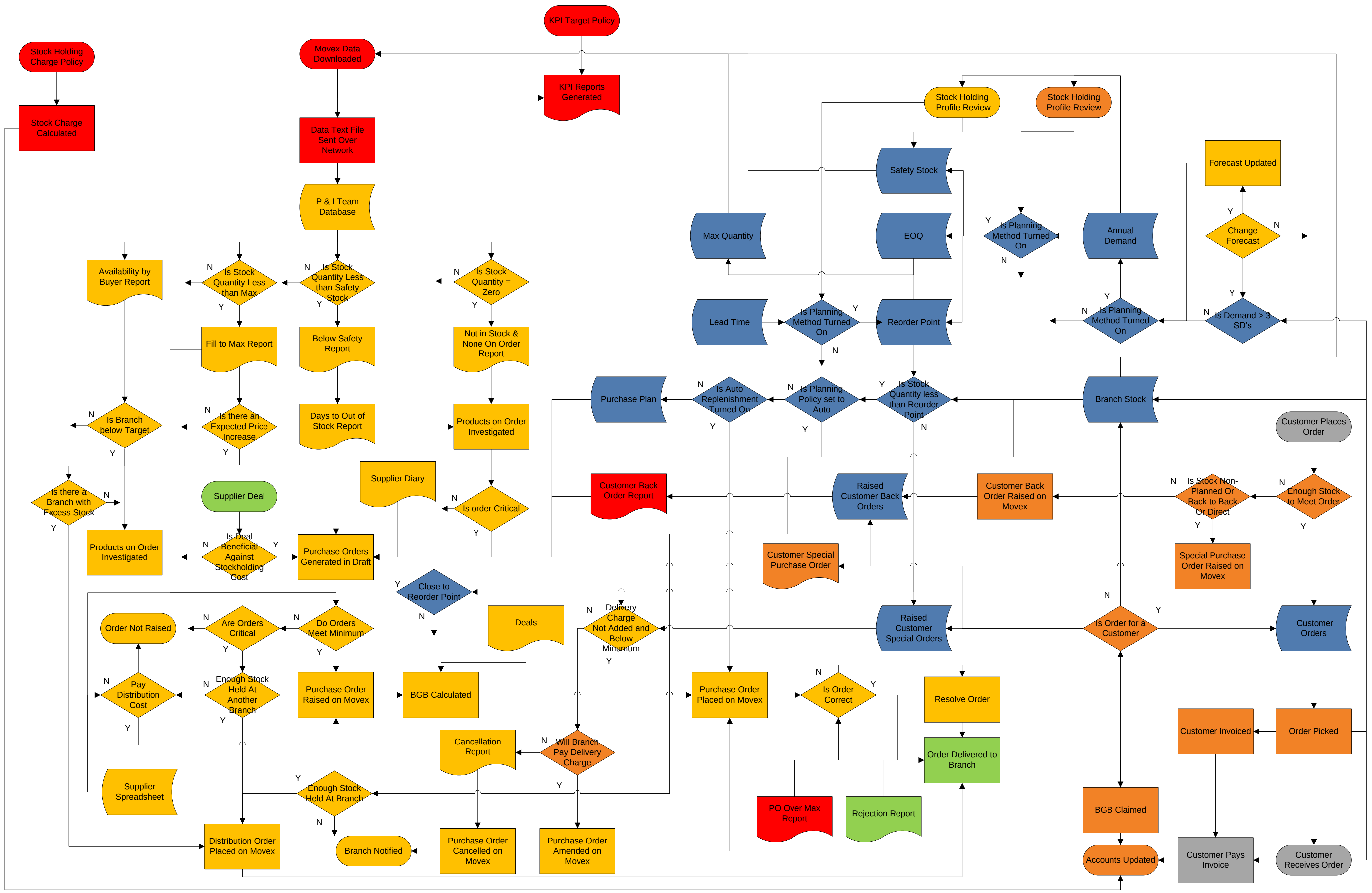
NEWEY & EYRE PURCHASING & INVENTORY OFFICE AVONMOUTH FROM FEB 2008 PHONE 0117 316 7577 FAX 0117 982 3678					
NAME	TITLE	USER ID	DD NUMBER	MOBILE	FAX NUMBER
Gary Tromans	Commertial Manager	TROMAG	0117 316 7512	07710 142329	0117 982 3678
Glyn Hutson	Purchasing & Inventory Manager	HUTSOG	0117 316 7514	07867 904614	0117 982 3678
Phil Pugh	Inventory Controller	PUGHP	01792 630206	07718 150030	01792 642827
Colin Haynes	Team Leader	HAYNEC	0117 316 7521		0117 982 3678
Louise Emery	Inventory Planner /Buyer Specials	EMEREL	0117 316 7638		0117 982 3678
Chris Thompson	Inventory Planner /Buyer Projects Office Specials and Expediting	THOMPC1	0117 316 7520		0117 982 3678
Micheal Skeens	Inventory Planner /Buyer Specials	SKEENM	0117 316 7515		0117 982 3678
Matthew Cierocki	Inventory Planner /Buyer Specials	CIEROM	0117 316 7621		0117 982 3678
Colin Aston	Team Leader Stock	ASTONC	0117 316 7559		0117 982 3678
Keith Sutherwood	Inventory Planner /Stock Buyer HVAC/Tools/Instruments/PPE/Domestic	SUTHEK	0117 316 7622		0117 982 3678
Roger Vokins	Inventory Planner/ Stock Buyer Lighting and Security	VOKINR	0117 316 7517		0117 982 3678
Andrew Helm	Inventory Planner /Stock Buyer Wiring Devices and Distribution	HELMA	0117 316 7623		0117 982 3678
Justin Pow	Inventory Planner /Stock Buyer Cable Management/KMK all stock	POWJ	0117 316 7625		0117 982 3678
Dave Pollard	Inventory Planner /Stock Buyer Cable/Cable Management	POLLAD	01202 722299		01202 716161

Address details
Newey & Eyre Ltd
Unit 3 Avonbridge Trading Estate
Atlantic Road , Avonmouth
Bristol BS11 9QD

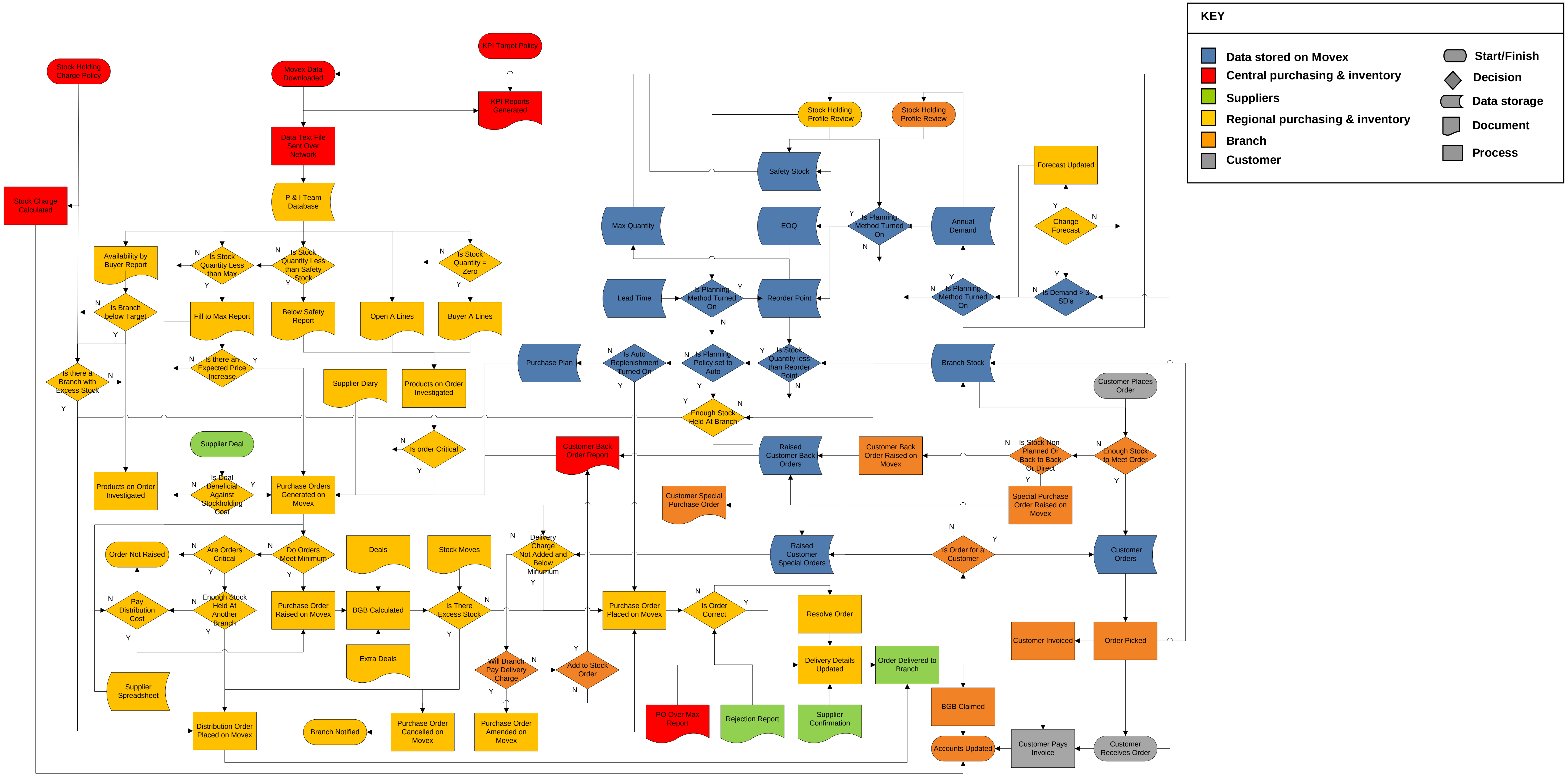
Email P&loffice south west

APPENDIX E: Detailed process map of Avonmouth purchasing and inventory office

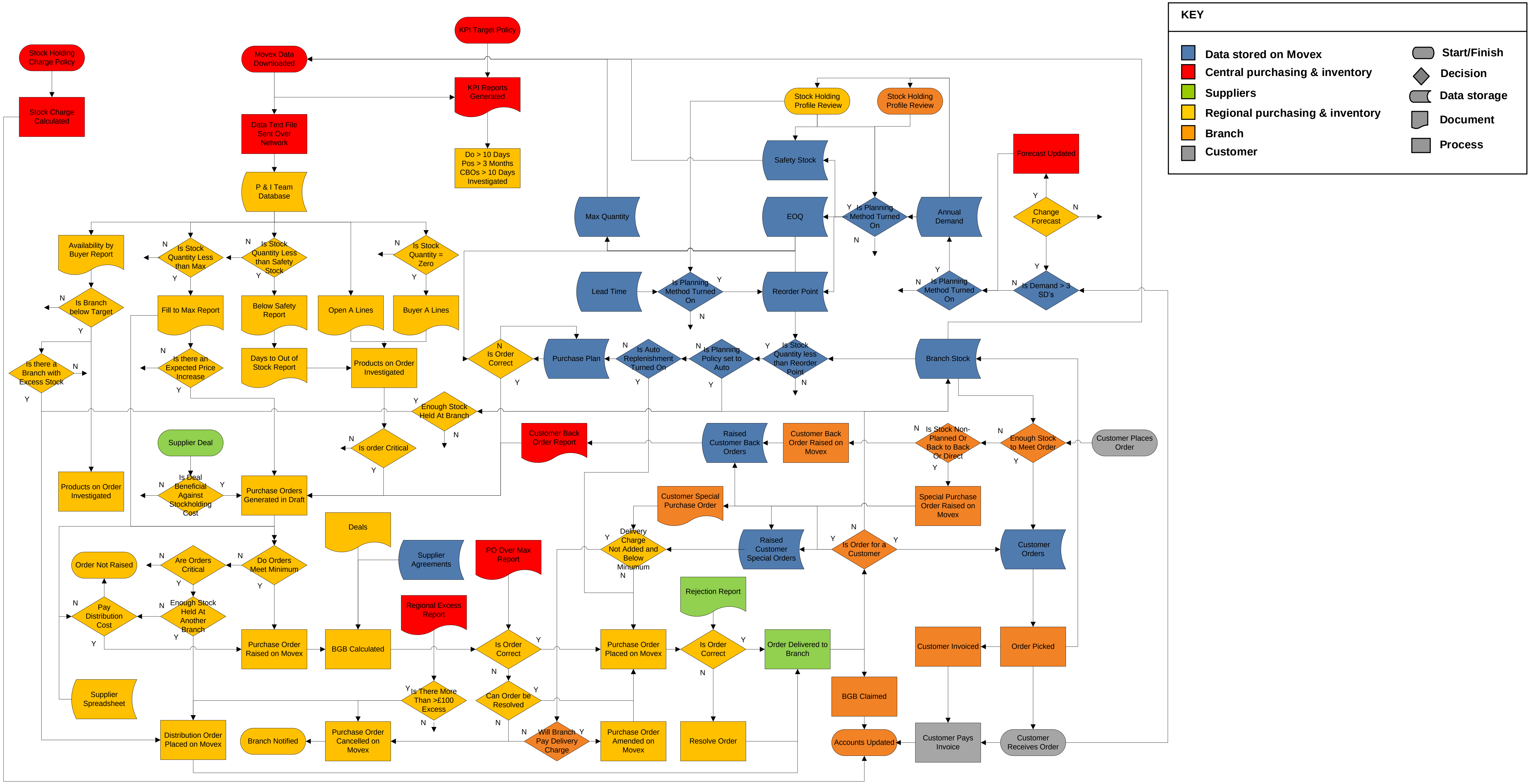




APPENDIX F: Detailed process map of Kirkcaldy purchasing and inventory office



APPENDIX G: Detailed process map of Warrington purchasing and inventory office



APPENDIX H: Process map explanations

Section 1: Data stored on Movex 

Process Number	Process Name	Explanation
1.	Customer Orders	A customer can place an order at any branch. When there is enough stock to complete the order the order is placed.
2.	Raised Customer Back Orders	If a customer places an order for a stock item which isn’t available a customer back order is raised on Movex.
3.	Raised Customer Special Orders	If a customer places an order for a direct or is an order that can’t be added to a stock order then a special order is raised in Movex. These usually take the form of a 10X item code.
4.	Branch Stock	The level of stock per SKU held at each branch. When a product is sold to a customer the level is reduced. When a product arrives at a branch, by means of a purchase order or a distribution order the stock level is added to.
5.	Annual Demand	This is a forecast for the annual sales demand. It is calculated by using a moving average of the previous 6 months sales. This is updated monthly.
6.	EOQ	This is the amount of stock to be purchased when the level of stock hits the reorder point. This is currently a manual calculation in the form of: ▪ EOQ = (Annual Demand / 12) x Months Stock. ▪ Months Stock currently equal to 1 Month.
7.	Lead Time	This is the time it takes from placing a purchase order to the time it takes to arrive. The majority of lead times are set to 10 days. The lead time forms part of the reorder point calculation but at present it is set to manual and not used.
8.	Reorder Point	This is the trigger point by which a purchase order is suggested and will appear in the purchase plan. This is currently a manual calculation in the form of: ▪ ROP = (Annual Demand / 12) x Months Stock. ▪ Months Stock currently equal to 1 Month.

APPENDIX H: Process map explanations (continued)

Process Number	Process Name	Explanation
9.	Max Quantity	This is the uppermost level of stock holding. This is an automatic calculation in the form of: ▪ Max Quantity = EOQ + Reorder Point.
10.	Safety Stock	This is to cover any unexpected level of sales during the period after the reorder point has been hit. This is seen however as the min stock level. This is currently a manual calculation in the form of: ▪ Safety Stock = (Annual Demand / 260 Days) x Safety Stock days. ▪ Safety Stock days currently set to 12 days.
11.	Purchase Plan	A list of suggested SKUs to be purchased which have hit the reorder point.
12.	Supplier Agreements	This can be set up on Movex so that the BGB is automatically calculated. Warrington has done this where possible.
13.	Auto replenishment	Some products are set to auto replenishment and when the reorder point is triggered a purchase order is automatically sent to the RDC.
14.	Is demand > 3 SD's	The system checks whether demand is greater than 3 standard deviations more than the expected demand.
15.	Planning Method	This can be either set to manual (0) or automatic (1). If it is set to automatic then Movex performs the calculations. The majority of calculations are set to manual. This means that the levels of stock are set between the branches and P & I.

APPENDIX H: Process map explanations (continued)

Section 2: Central P & I

Process Number	**Process Name**	**Explanation**
16.	Stock Profile Policy	Products are classified centrally using data taken from the lines of billing sold. The main classifications are: ▪ M - Held in all branches ▪ H - Held at Hubs ▪ W - Slow moving ▪ # - Obsolete
17.	KPI Target Policy	Purchasing and Inventory targets are set centrally. The targets are: ▪ A Line Availability – 98% ▪ A Line Depth – 92% ▪ ABC Line Availability – 94% ▪ Stock Purchase Orders > 3 Months ▪ Distribution Orders > 10 Days ▪ Customer Back Orders > 10 Days ▪ Debit Notes > 5 Days ▪ Stock Actual Value against Stock Target Value
18.	Stock Holding Charge Policy	Stock held at each branch pays a holding charge per month. A 1% charge is given for stock under and 7.5% above the target. ▪ Target Stock Value = Cost x Growth x 58 Days ▪ Cost = Previous 12 Months Sales – (Specials – Directs) - Margin
19.	Movex Data Downloaded	Data is collated from Movex daily for each product that is purchased and split for each regional P & I office.
20.	Data Text File Sent over Network	The data from Movex is sent in a text file to each regional P & I office.

APPENDIX H: Process map explanations (continued) factor

Process Number	Process Name	Explanation
21.	KPI Reports Generated	The KPI reports are generated centrally and sent to the regional P & I offices. These show the performance of each P&I office against the targets.
22.	M MA Report	List of M lines that are currently out of stock at a branch. M Lines should have at least 1 item in stock at each branch.
23.	PO Over Max Report	List of products where the stock level is greater than the max holding value. ▪ Current stock + Raised Purchase Orders > Max
24.	Regional Excess Report	Once a product has been raised it shows on the excess report if there is excess that can be moved from another branch.
25.	Customer Back Order Report	List of customers awaiting stock orders. These are ordered with stock purchase orders.
26.	Stock Charge Calculated	Branches are charged for stock holding.

APPENDIX H: Process map explanations (continued)

Section 3: Regional P & I

Process Number	Process Name	Explanation
27.	Stock Holding P & I Policy	The stock holding policy drives how much and when stock is purchased. The current policy is to manually set the parameters in Movex so there is a max holding of 8 weeks stock.
28.	P & I Team Database	Text file is uploaded daily on to the team database where reports are then generated.
29.	Forecast Updated	Each forecast alarm is looked at and a decision is made whether to keep the unexpected demand or remove it.
30.	Max Week Stock Calculated	Decisions are made based on the KPIs reports on the maximum level of stock to be held. This is mainly done for A lines and based on the depth KPI.
31.	Supplier Diary	A list of suppliers to be ordered on any particular day.
32.	Fill to Max Report	A list of products and the quantity required to be ordered to reach the maximum stock level.
33.	Below Safety Report	A list of products that have fallen below the safety level. These are typically sorted to show A line products that are out of stock.
34.	Deals	Each supplier has a list of suppliers per product where a deal applies. These deals are negotiated with the supplier via reps.
35.	Supplier Database	Data on each supplier is held such as the minimum order and delivery costs.
36.	Branch Below Target	Stock items that are below the target value.
37.	Branch with excess stock	Stock items that have excess stock.

APPENDIX H: Process map explanations (continued)

Process Number	Process Name	Explanation
38.	Stock Cleanse Report	The products that can be moved are collated in a report.
39.	Distribution Order Placed	A distribution order is placed on Movex to send products from one branch to another.
40.	Products on Order Investigated	Purchased orders that have been placed and have not arrived are chased up. If the products are out of stock they become critical.
41.	Purchase Orders Generated in Draft	Purchase orders are collated by supplier and branch from the reports. A number of different strategies are typically used as primary starting point by the buyers. ▪ Products that meet a deal ▪ Products from the purchase plan ▪ Products from the fill to max report
42.	Do Orders Meet Minimum	Once Purchase orders are generated they are checked against the minimum buying quantity.
43.	Supplier Database	The supplier database has a list of all the suppliers and information such as minimum and distribution costs.
44.	Are Orders Critical	If they don’t meet the minimum requirements they are checked to see whether or not they are critical based, on KPI targets.
45.	Enough Stock Held at Another Branch	If the purchase orders don’t meet the minimum and are critical they can be ordered from another branch where there is enough stock.
46.	Pay Distribution Cost	If the purchase order is critical and cannot be sourced from anywhere then the last resort is to pay the distribution cost.
47.	Order Not Raised	If the purchase order is not critical then the order will not be placed until more products require ordering and the minimum quantity can be reached.

APPENDIX H: Process map explanations (continued)

Process Number	Process Name	Explanation
48.	Purchase Order Raised on Movex	Once purchase orders meet the requirements they are raised on Movex.
49.	BGB Calculated	The products are checked to see whether deals exist and applied where necessary.
50.	Is Order Correct	Products over max holding in the PO Over Max report are investigated.
51.	Can Order be Resolved	Products over max can be resolved if there is a sufficient reason and comments are sent back.
52.	Purchase Order Cancelled on Movex	If there isn't sufficient reason then the purchase order will be cancelled.
53.	Is Order for a Customer	If an order is for a customer and has to be cancelled then the branch is notified.
54.	Branch Notified	The branch is notified by a telephone call if a customer order has to be cancelled.
55.	Delivery Charge Not Added and Below Minimum	If a delivery charge is added then the special order can be purchased straight away. If there is no delivery charge then the buyer will try to add the order to a stock order to try and reach the minimum quantity.
56.	Purchase Order Placed	If the Purchase orders meet the requirements then they are placed with the supplier by EDI or Autofax. Purchase orders can be for stock or customers. The customer orders are either customer back orders or specials.

APPENDIX H: Process map explanations (continued)

Section 4: Suppliers

Process Number	**Process Name**	**Explanation**
57.	Rejection Report	Rejection reports are sent from the suppliers by email if there are any problems with the purchase orders. These are typically disagreements with prices for stocked orders and products are obsolete for specials.
58.	Supplier Deal	Suppliers send in one of deals and a decision is made to see whether or not it is worth buying in the stock to produce the BGB.
59.	Orders Delivered to Branch	Purchase orders are delivered to the relevant branch after a duration of time.

APPENDIX H: Process map explanations (continued)

Section 5: Branch

Process Number	Process Name	Explanation
60.	Stock Holding Branch Policy	A branch can decide how much stock for each product they want to hold and they can negotiate this with the buyer and the parameters on Movex can be changed where applicable.
61.	Enough Stock to Meet Order	When a customer order is placed it is checked to see whether there is enough stock to meet the order.
62.	Is Stock Non-Planned	If there isn't enough stock it is checked to see whether it is a product that is not ordinarily stocked in the branch.
63.	Customer Back Order Raised on Movex	If the product is out of stock it is raised as a customer back order.
64.	Special Purchase Order Raised on Movex	If a product is a direct or cannot be added to a stock order then a special purchase order is raised.
65.	Customer Special Purchase Order	Once a branch has raised a special purchase order the order is sent as an email to the regional P&I.
66.	Is Order for a Customer	When purchase orders arrive at the branch they are checked to see whether they are for stock or for a customer.
67.	Order Picked	When there is enough stock to meet a customer order the products are picked. A customer order can be split if some of the products are in stock and some are out of stock.
68.	BGB Claimed	BGB is claimed automatically for purchase orders that are sent directly to the branch. If they are sent through the distribution network then the branch is entitled to claim this back and is done so by negotiating with the relevant branches.
69.	Customer Invoiced	Once the products have been received the customer will be invoiced for the order.
70.	Accounts Updated	At the end of the process the accounts are updated with the relevant payments and charges.

APPENDIX I: Forecast alarms report snapshot

PRODUCT NO	BRANCH	OFFICE	PERIOD	RESPONSIBLE	ENTRY DATE	CHANGE DATE	CHANGED BY	FA1	FC QTY	DEMAND
1050152229	LJE	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	1	4
1050152231	LBP	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	0	2
1050152232	KFZ	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	4	12
1050152232	LHE	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	1	4
1050152233	JBO	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	1	4
1050152234	JBW	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	1	6
1050152234	JIH	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	0	1
1050152236	LEV	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	0	3
1050152236	JIN	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	1	3
1050152237	LHE	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	0	1
1050152238	NGD	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	1	2
1050152238	JIN	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	0	2
1050152273	LEV	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	10	32
1050152273	KFL	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	1	5
1050152693	KHU	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	2	9
1050152723	KFL	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	1	5
1050152724	KHO	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	0	1
1050152724	JID	Warrington	200803	COWLEL	20080308	20080308	XSBATCH	1	1	2

APPENDIX J: Profile summary review

ODE :	AHL	P&I MANAGER :		LAST PROFILE REVIEW DATE	
BR. NAME :	STAFFORD	HEAD OF P&I :		NEXT PLANNED REVIEW DATE	

BRANCH SUMMARY

TOTAL NO. OF LINES	1,823				
		MIN. VALUE	£4,275		
NO. OF PLANNED LINES	1,217	VALUE OF PLANNED LINES	£24,229	% OF TOTAL	60%
		MAX VALUE.	£10,262		
NO. OF NON-PLANNED LINES	606	VALUE OF NON-PLANNED LINES	£16,289	% OF TOTAL	40%
		TOTAL STOCK VALUE	£40,518		

NO. OF PLANNED LINES NOT ACHIEVING 3 LOB CRITERIA LAST 6 MONTHS	592	£15,261

INVENTORY SUMMARY

PLANNED PROFILE	1,213	£23,886
PLANNED NON-PROFILE	4	£343

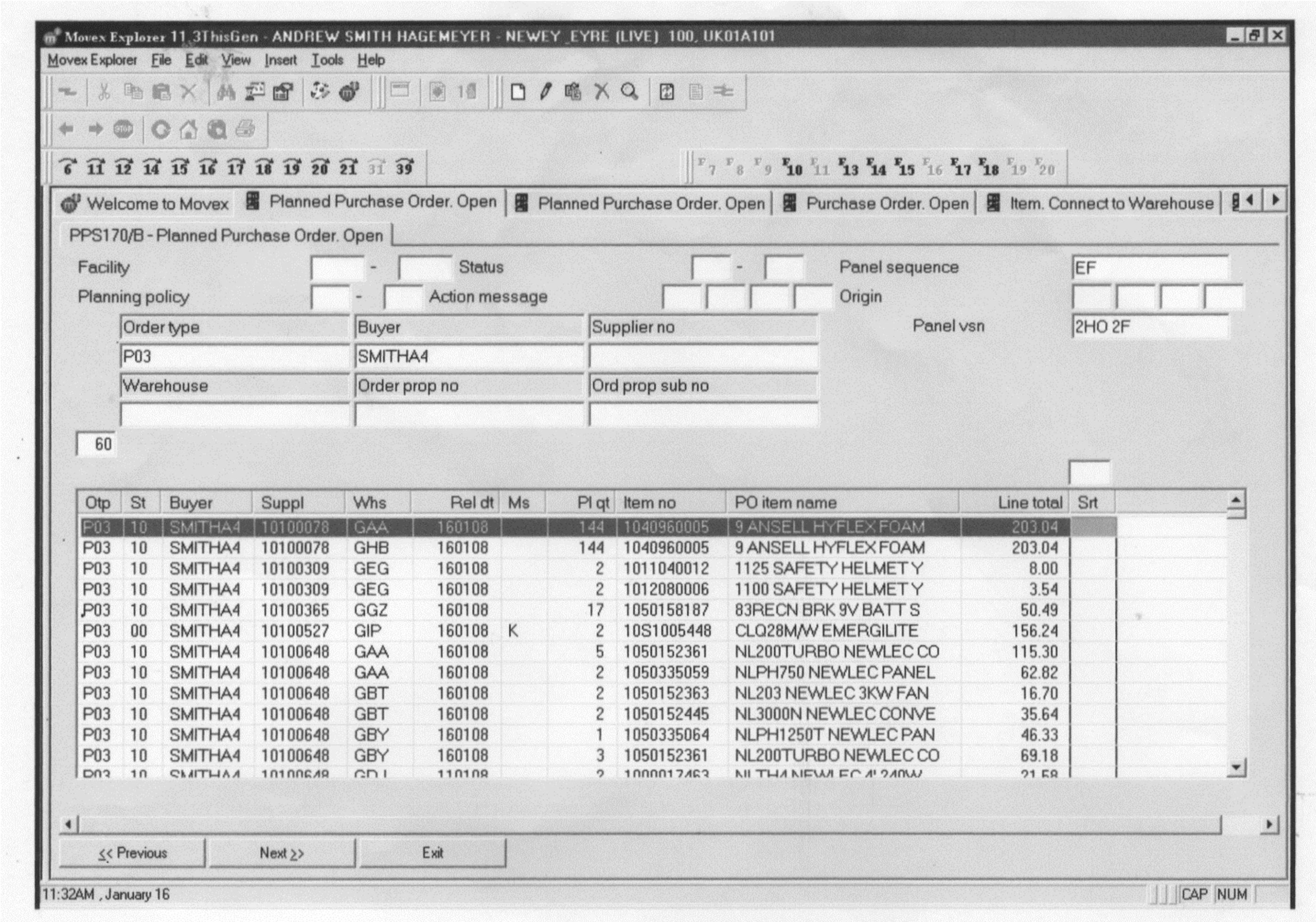
SERVICE LEVELS

	Actual	Target
A	96.27%	98.00%
A ABOVE SAFETY	90.30%	90.00%
ALL PLANNED	93.10%	95.00%

INVENTORY TARGET - PENALTY VALUES

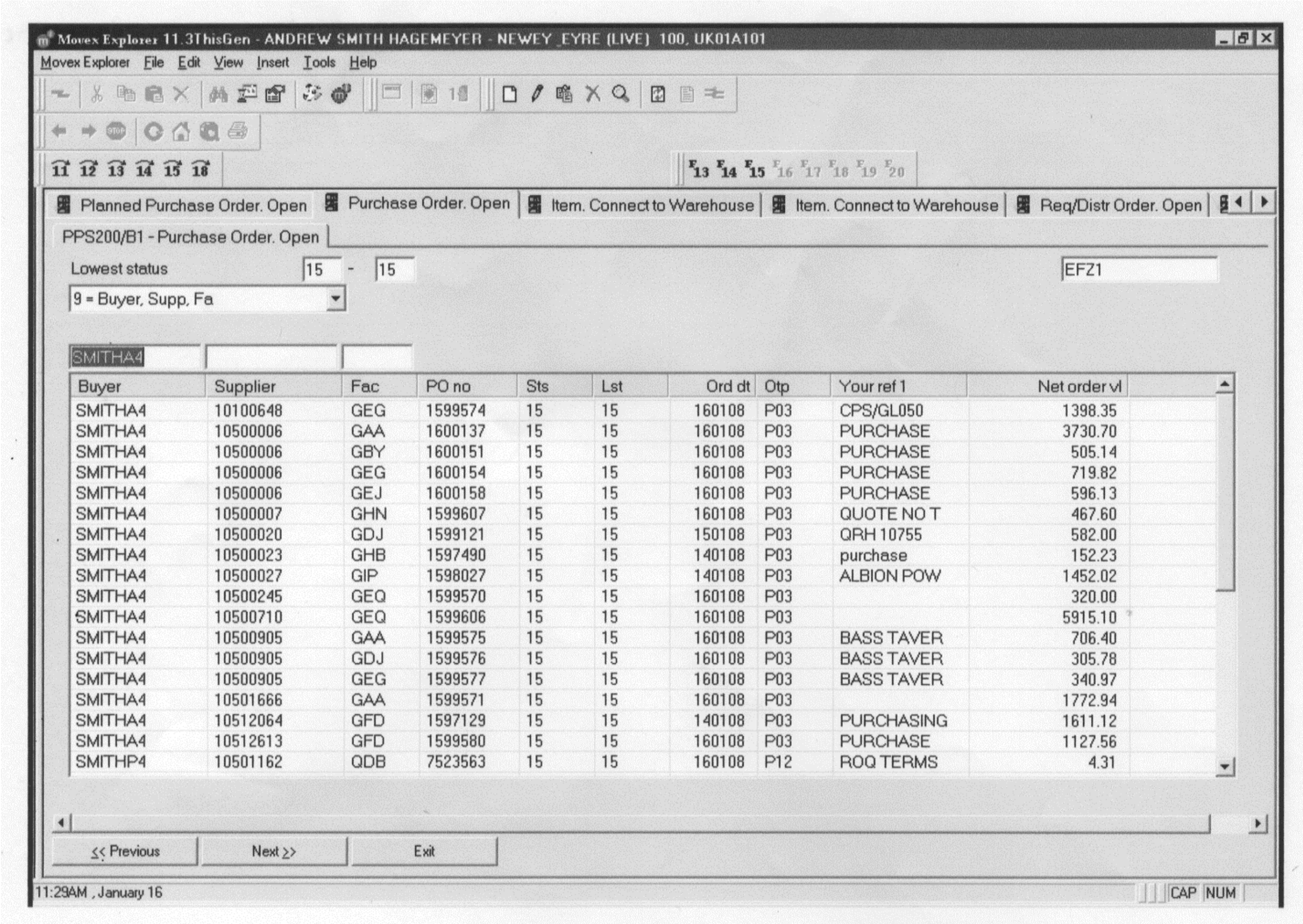
4 - 6 MONTHS	7 - 9 MONTHS	10 - 12 MONTHS	13 - 24 MONTHS	25+ MONTHS		
£699	£554	£122	£293	£179	£1,847	**NPNP TOTAL**
£17	£28	£12	£73	£107	£238	**CHARGE TOTAL**
2.5%	5%	10%	25%	60%		

APPENDIX K: Purchase plan example



Otp	St	Buyer	Suppl	Whs	Rel dt	Ms	Pl qt	Item no	PO item name	Line total	Srt
P03	10	SMITHA4	10100078	GAA	160108		144	1040960005	9 ANSELL HYFLEX FOAM	203.04	
P03	10	SMITHA4	10100078	GHB	160108		144	1040960005	9 ANSELL HYFLEX FOAM	203.04	
P03	10	SMITHA4	10100309	GEG	160108		2	1011040012	1125 SAFETY HELMET Y	8.00	
P03	10	SMITHA4	10100309	GEG	160108		2	1012080006	1100 SAFETY HELMET Y	3.54	
P03	10	SMITHA4	10100365	GGZ	160108		17	1050158187	83RECN BRK 9V BATT S	50.49	
P03	00	SMITHA4	10100527	GIP	160108	K	2	10S1005448	CLQ28M/W EMERGILITE	156.24	
P03	10	SMITHA4	10100648	GAA	160108		5	1050152361	NL200TURBO NEWLEC CO	115.30	
P03	10	SMITHA4	10100648	GAA	160108		2	1050335059	NLPH750 NEWLEC PANEL	62.82	
P03	10	SMITHA4	10100648	GBT	160108		2	1050152363	NL203 NEWLEC 3KW FAN	16.70	
P03	10	SMITHA4	10100648	GBT	160108		2	1050152445	NL3000N NEWLEC CONVE	35.64	
P03	10	SMITHA4	10100648	GBY	160108		1	1050335064	NLPH1250T NEWLEC PAN	46.33	
P03	10	SMITHA4	10100648	GBY	160108		3	1050152361	NL200TURBO NEWLEC CO	69.18	

APPENDIX L: Raised order example



Buyer	Supplier	Fac	PO no	Sts	Lst	Ord dt	Otp	Your ref 1	Net order vl
SMITHA4	10100648	GEG	1599574	15	15	160108	P03	CPS/GL050	1398.35
SMITHA4	10500006	GAA	1600137	15	15	160108	P03	PURCHASE	3730.70
SMITHA4	10500006	GBY	1600151	15	15	160108	P03	PURCHASE	505.14
SMITHA4	10500006	GEG	1600154	15	15	160108	P03	PURCHASE	719.82
SMITHA4	10500006	GEJ	1600158	15	15	160108	P03	PURCHASE	596.13
SMITHA4	10500007	GHN	1599607	15	15	160108	P03	QUOTE NO T	467.60
SMITHA4	10500020	GDJ	1599121	15	15	150108	P03	QRH 10755	582.00
SMITHA4	10500023	GHB	1597490	15	15	140108	P03	purchase	152.23
SMITHA4	10500027	GIP	1598027	15	15	140108	P03	ALBION POW	1452.02
SMITHA4	10500245	GEQ	1599570	15	15	160108	P03		320.00
SMITHA4	10500710	GEQ	1599606	15	15	160108	P03		5915.10
SMITHA4	10500905	GAA	1599575	15	15	160108	P03	BASS TAVER	706.40
SMITHA4	10500905	GDJ	1599576	15	15	160108	P03	BASS TAVER	305.78
SMITHA4	10500905	GEG	1599577	15	15	160108	P03	BASS TAVER	340.97
SMITHA4	10501666	GAA	1599571	15	15	160108	P03		1772.94
SMITHA4	10512064	GFD	1597129	15	15	140108	P03	PURCHASING	1611.12
SMITHA4	10512613	GFD	1599580	15	15	160108	P03	PURCHASE	1127.56
SMITHP4	10501162	QDB	7523563	15	15	160108	P12	ROQ TERMS	4.31

APPENDIX M: Customer back order rejection report

CUSTOMER BACK ORDER - UPDATE

Please be aware that the following line(s) on your customer's sales order have not been ordered from the supplier for the reason detailed below.

Sales Order Line No or Description	Reason:	Planned order date
	Order will not cover the carriage paid value	
	No stock orders are planning as yet.	

Please advise P&I by return of this email should your customer no longer require the goods.

This is a Hagemeyer internal communication between Branch and P&I Office and is not for external use.

APPENDIX N: Fill to max report snapshot

BUYER	BRANCH	SUPPLIER NO	CLASS	PRODUCT NO	PRODUCT NAME	TO MAX	TO MAX COST
SMITHA4	HAA	10100365	B	1050271893	86RACEN BRK IONIZATION SMOKE A	18	£159.66
SMITHA4	HAA	10100558	C	1050140783	1A 799725 QUICK BLOW FUSE	2	£0.15
SMITHA4	HAA	10100558	C	1050140784	2A 799750 QUICK BLOW FUSE	5	£0.38
SMITHA4	HAA	10100558	C	1050140786	5A 799798 QUICK BLOW FUSE	5	£0.72
SMITHA4	HAA	10100648	B	1000009542	NL202 NEWLEC PORTABLE FAN HEAT	3	£22.52
SMITHA4	HAA	10100648	B	1000015942	NL3AC NEWLEC 3KW CURTAIN	1	£54.00
SMITHA4	HAA	10100648	B	1000017463	NLTH4 NEWLEC 4' 240W TUBULAR H	2	£21.15
SMITHA4	HAA	10100648	B	1050027967	TRC150 DIMP TOWEL RAIL-OIL	1	£77.41
SMITHA4	HAA	10100648	B	1050028030	XLS24N+8 PKS XT8300 BRICKS	2	£476.47
SMITHA4	HAA	10100648	B	1050028122	XLS6N+2 PKS XT8300 BRICKS	2	£196.51
SMITHA4	HAA	10100648	B	1050151357	NLTH6 NEWLEC 6' 360W TUBULAR H	4	£56.57
SMITHA4	HAA	10100648	B	1050152358	NLTROC90 NEWLEC CHR TOWEL RAIL	1	£45.48
SMITHA4	HAA	10100648	B	1050152445	NL3000N NEWLEC CONVECTOR HTR	3	£52.39
SMITHA4	HAA	10100648	B	1050152679	NL200TN NEWLEC CONVECTOR HTR	1	£24.50
SMITHA4	HAA	10100648	B	1050153833	NLSH12AN+4 PKS XT8300 BRICKS	2	£166.31
SMITHA4	HAA	10100648	A	1050153834	NLSH18AN+6 PKS XT8300 BRICKS	1	£104.75
SMITHA4	HAA	10100648	A	1050153835	NLSH24AN+8 PKS XT8300 BRICKS	2	£254.85
SMITHA4	HAA	10100648	A	1050153836	NLSH6MN+2 PKS XT8300 BRICKS	2	£114.46

APPENDIX O: Customer back order report

COMM REGION	BUYER	SUPPLIER NO	BRA NCH	OFFICE	PRODUCT NO	PRODUCT NAME	CLASS	BOH	RES QTY	ORDE R QTY	REM QTY	CUSTOMER NO	CUSTOMER ORDER NO	ENTRY DATE	SALES PRICE
1020	CARSOD	10500454	PEE	KIRK	1050076670	C60HC110 MERLIN SP MCB C 10A	C	113	216	0	108	105041845	KM07250	20071023	9.63
1010	HUGHEL1	10500005	FEZ	KIRK	1050078420	K4857 MK WHI 6A 1G TP FAN SW	B	0	21	20	10	105091058	KW24637	20080208	5.5
1010	HUGHEL1	10500005	FEZ	KIRK	1000007266	K182 WHI MK 1G 2MOD FRONTPLATE	B	0	21	0	21	105091058	KV29265	20080131	0.7
1010	CARSOD	10544678	FFG	KIRK	1050274706	NL18DCVS NEWLEC 18 DC STAT	C	4	23	3	16	105134391	KX54115	20080221	6.61
1010	MIGRATED	10506886	EAA	KIRK	1050301579	GUG10IMW GET INTERMEDIATE MODU	C	0	2	0	1	105055047	KM57143	20071029	22.27
1010	SPECIALS	10500967	VAM	KIRK	10X6081096	BH/PS 10A MITSUBISHI 10AMP TYP	C	0	1	0	1	105086907	KV40233	20080131	15.84

APPENDIX P: MMA report snapshot

BUYER	SUPPLIER NO	BRANCH	CLSS	STKCAT	PRODUCT NO	PRODUCT NAME	MIN	MAX	MAX HOLD	ALLO NETT	ON ORDER
TILLEN	10101598	GDJ	B	M	1000008780	DFBHS51 DEFIANCE HOLESAWS 51MM	5	10	£21.70	0	0
SMITHA4	10500007	GEQ	B	M302	1050091127	2'18W OSRAM LUMILUX COOLWHITE	20	40	£26.23	0	0
MADAMA	10500012	GEG	B	M112	1050285800	6242YH DRAKA 6.0 GREY PVC 50M	84	168	£163.45	0	0
MADAMA	10500012	GEQ	C	M113	1050355461	6243BH 3C 1.5MM WHITE 100M	99	100	£44.70	0	0
MADAMA	10500012	GFT	C	M113	1050355461	6243BH 3C 1.5MM WHITE 100M	99	100	£44.70	0	0
MADAMA	10500012	GHB	C	M113	1050355461	6243BH 3C 1.5MM WHITE 100M	99	100	£44.70	0	0
MADAMA	10500012	GHN	C	M108	1050285788	6242YH DRAKA 2.5 GREY PVC 100M	1000	2000	£768.20	0	0
MADAMA	10500013	GIB	B	M	1000017842	NLPDT1 NEWL DADO TRNK {3MTR}	3	6	£129.02	0	0
TILLEN	10500024	GEP	C	M	1050150563	NLRCD4030A NEWLEC 40A 30MA RCD	1	2	£18.20	0	0
TILLEN	10500024	GIP	B	M	1050150563	NLRCD4030A NEWLEC 40A 30MA RCD	3	6	£54.60	0	0
MADAMA	10500306	GKE	C	M	1000008421	NLBR6 NEWLEC 1.5-2.5MM RING TE	148	296	£5.21	0	0
SMITHA4	10500789	GBY	B	M	1000009598	NLRT NEWLEC ROOM THERMOSTAT 10	2	6	£23.10	0	0
SMITHA4	10500893	GFD	C	M	1050326814	NLTL1N NEWLEC UN-FUSED TEST LE	1	2	£18.00	0	0
TILLEN	10501049	GFT	B	M	1000008820	DFMAS5.5 DEFIANCE MASONRY DRI	1	3	£0.69	0	0

APPENDIX Q: Supplier diary snapshot

SUPLIER	BUYER	SUPPLIER NO	DAY	MIN ORDR
ABB CONTROLS	HAYNEC	10500076	TUESDAY	£100.00
ABB WYLEX	HAYNEC	10500042	MONDAY	£200.00
ABLE	UNDERP	10510526	MONDAY	£200
ADAPTAFLEX	ASTONC	10500118	MONDAY	175.00
ADE	UNDERP	10510587	FRIDAY	£250
AICO	UNDERP	10503739	THURSDAY	£200
AIRFLOW	SUTHEK	10500139	MONDAY	35m
AIRSYS COMMUNICATION TECH LTD	SUTHEK	10535027	WEDNESDAY	1000
ALLIED PAPER (nlppe16 towels)	SUTHEK	10102751	WEDNESDAY	0
ANDA	SUTHEK	10500203	THURSDAY	150.00
ANGLEPOISE	SUTHEK	10500213	MONDAY	0
ANGLO CONTINENTAL CLOCK CO.	SUTHEK	10500215	MONDAY	150.00
ANTIFERENCE	SUTHEK	10500233	FRIDAY	250.00
APEX CABLES	ASTONC	10501609	WEDNESDAY	1000.00
APPLEBY	HAYNEC	10534487	MONDAY	£200.00
APPLIED ENERGY PRODS (REDRING)	SUTHEK	10501113	THURSDAY	250.00
ARC TAP AND DIE	SUTHEK	10500253	MONDAY	85.00
ASD	UNDERP	10500245	FRIDAY	£150
ASHLEY & ROCK	HAYNEC	10500009	MONDAY	£250.00
AVOCET	ASTONC	10513145	TUESDAY	25.00
BACKER	SUTHEK	10500070	MONDAY	100.00
BAHCO TOOLS	SUTHEK	10100130	TUESDAY	0

APPENDIX R: Below safety report snapshot

BUYER NAME	ABC	PARENT/SPOKE	SUPPLIER NO	BRANCH	PRODUCT NO	PRODUCT DESCRIPTION	ALLO NETT	BOH	SAFETY STK	ON ORDER
MADAMA	D	S	10500012	GHN	1050285621	6242BH DRAKA 2.5MM 2C WHI 100M	5100	5100	10000	0
TILLEN	A	O	10501049	HCG	1050151289	DFPLRED DEFIANCE WALL PLUG RED	3700	3900	3848	0
TILLEN	A	O	10501049	HET	1050151289	DFPLRED DEFIANCE WALL PLUG RED	1900	1900	3405	0
MADAMA	B	O	10800019	HAA	1050356180	$NL329A NEWLEC 8-CORE ALARM	400	400	739	0
TILLEN	B	O	10506886	GEP	1050152069	DFS4628EN DEFIANCE 8X2 SCREW P	400	400	489	0
MADAMA	A	O	10536794	HCI	1050324653	NLCOND20MMGV NEWLEC CONDUIT	329	329	365	0
MADAMA	D	O	10501792	GHB	1050331580	AX 6491X 1.5 BLUE PVC 100M	300	300	500	0
MADAMA	A	O	10500012	GBY	1050285732	6241YH DRAKA 1.5 GREY/BRN 100M	200	200	400	0
MADAMA	B	O	10500015	HFY	1050152140	DFS4333CN DEFIANCE ROOF NUT+	200	200	840	0
MADAMA	D	O	10501792	GBY	1050331587	AX 6491B 1.5 G/Y LSF 100M	200	200	375	0
TILLEN	B	O	10506886	GEQ	1050152095	DFS4428DN NLS4428DN 8X1.5 SCR	200	200	650	0
TILLEN	B	O	10506886	GFT	1050152086	DFS54AN DEFIANCE 6X.75 SCREW S	200	200	1012	0
MADAMA	A	O	10509319	GFD	1000009225	NLZN101 NEWLEC M10 SPRING NUT	170	170	237	200
MADAMA	B	O	10509319	HFX	1000009263	NLZS1035 NEWLEC SET SCREW M10X	150	150	152	0
TILLEN	A	O	10500042	GHB	1050106563	NH00 WYLEX BLANKING PLATE	140	140	152	0
MADAMA	D	O	10500012	HCI	1050027643	6491X 50 DRAK 16 GRN/YEL 1M	80	130	98	0
TILLEN	A	O	10500605	HET	1000015796	NLF5 NEWL FUSES BS1362 5A	113	113	125	0
MADAMA	A	O	10500012	GKE	1050285797	6242YH DRAKA 1.5 GREY PVC 50M	100	100	138	50

APPENDIX S: Not in stock and none on order report snapshot

SUPPLIER NO	BRANCH	PRODUCT NO	PRODUCT NAME	CLASS	BOH	ALLO NETT	ON ORDER
10500005	NGM	1000007314	K4881 WHI MK 10A 1WA	A	0	0	0
10500042	NGM	1050106035	NSB32 WYLEX SP 32A 1	A	0	0	0
10500005	LEN	1000006989	K4880 WHI MK BLANK IN	B	0	0	0
10500005	MAA	1000007290	K1060 WHI MK SW/SPUR	B	0	0	0
10500005	MCC	1000006659	K983 ALM MK 13A SPUR	B	0	0	0
10500005	NFU	1000007233	K1522 WHI MK LV 2G 250	B	0	0	0
10500005	NGM	1000006889	K3827 WHI MK 1GANG B	B	0	0	0
10500005	NGM	1000006837	K3491 ALM MK 1G META	B	0	0	0
10500005	NGM	1000006839	K3492 ALM MK 2g META	B	0	0	0
10500005	QCH	1050078235	5544S MK MODULE BLA	B	0	0	0
10500005	QCH	1050078392	K4881 WHI MK 10A 1WA	B	0	0	0
10500005	QDP	1000017186	5544S MK MODULE BLA	B	0	0	0
10500005	QDP	1050022023	K370 MK WHI SW/SPUR+	B	0	0	0
10500011	MAA	1000017185	NL8853 NEWLEC 3G GRI	B	0	0	0

APPENDIX T: Days to out of stock report snapshot

DAYS TO OUT OF STOCK	BUYER NAME	CLASS	SUPPLIER NO	PRODUCT NO	PRODUCT NAME	BOH	ALLO NETT	ON ORDER	PO	DO
0	POLLAD	A	10500015	1050134322	ML20SP SMITH M20 M/E S/COL L/R	0	0	300		4363971
0	POLLAD	A	10500017	1050285777	FP200H GLD BASEC 1.5MM 2C WHI	0	0	9200	1623652	
0	POLLAD	A	10500130	1000015831	NL38503 NEWLEC TELCLEAT 15-20M	0	0	525	1625865	
0	POLLAD	A	10500306	1000008214	NL16C10 NEWLEC 16MM CU TUBE LU	0	0	80		4363971
1	POLLA D	A	10501792	1050331596	AX 6491B 6 G/Y LSF 100M	100	100	4000	1625637	
1	POLLA D	A	10500012	1050027106	6491X 100 DRAK 10 GRN/YEL 1M	89	89	4000	1626055	
2	POLLA D	A	10500017	1050299077	6943XLH PIREL 6.0 G/Y LSF 100M	68	68	1250	1609128	
3	POLLA D	A	10501792	1050331584	AX 6242BH 1.5 WHI LSF 100M	100	100	1000		4363073
3	POLLA D	A	10500130	1000009336	NLCB5DP NELWEC 100A DP CONN BL	2	1	10		4339173
4	POLLA D	A	10501792	1050331580	AX 6491X 1.5 BLUE PVC 100M	100	100	700		4361257
4	POLLA D	A	10500012	1050285923	BASEC NEWLEC NLMT2H METER TAIL	1	1	10		4356235
4	POLLA D	A	10500012	1050285797	6242YH DRAKA 1.5 GREY PVC 50M	250	250	3000	1627146	
4	POLLA D	A	10500012	1050285797	6242YH DRAKA 1.5 GREY PVC 50M	250	250	3000	1596991	

APPENDIX U: Open A lines report snapshot

BRANCH	ENTRY DATE	SUPPLIER NUMBER	SUPPLIER NAME	ORDER TYPE	PURCHASE ORDER NUMBER	PRODUCT NO	PRODUCT NAME	ORDER QTY	COMMENT
JAA	20080104	10500013	MK ELECTRIC LTD	P03	1591459	1000017847	NLDTA5 NEWLEC END CAP	100	BELOW SAFETY
JAA	20080125	10500007	OSRAM LTD	P03	1608448	1000009402	NL250M NEWLEC 50W 12V DICH T/H	1180	BELOW SAFETY
JAA	20080125	10500015	SMITH FASTENERS LTD	P03	1608290	1000012858	SC200GP SMITH 2 SOLID COUPLER	150	OUT OF STOCK
JAA	20080128	10500007	OSRAM LTD	P03	1609181	1050161923	NLGU10 NEWLEC GU10 50W	1580	BELOW SAFETY
JAA	20080128	10500017	PRYSMIAN CABLES	P03	1609643	1050092845	6491X 100 PIREL 4.0 GRN/YEL 1M	1700	BELOW SAFETY
JAA	20080129	10533060	WIHA TOOLS LTD	P03	1610083	1000008748	DFVSS8 DEFIANCE 1000V SCREWDRI	81	OUT OF STOCK
JAA	20080130	10500963	MITA UK LTD	P03	1611849	1000009333	NLPG251RED NEWLEC CABLE GLAND	12000	BELOW MINIMUM
JAA	20080130	10500017	PRYSMIAN CABLES	P03	1610957	1050092845	6491X 100 PIREL 4.0 GRN/YEL 1M	1000	BELOW SAFETY
JAA	20080131	10500021	SQUARE D UK LTD	P03	1612174	1000013428	SQODNBP SQ-D 5POLE BLANKING PL	19	BELOW SAFETY
JAA	20080131	10501049	ARTEX RAWPLUG LTD	P03	1612872	1000008837	DFW10 DEFIANCE WEDGE ANCHOR M1	2500	OUT OF STOCK
JAA	20080131	10501792	PX MANUFACTURING	P03	1612998	1050331585	AX 6242BH 2.5 WHI LSF 100M	40000	BELOW MINIMUM
JAA	20080131	10501049	ARTEX RAWPLUG LTD	P03	1612872	1000008848	DFMSD4N NLMSD4 METAL SELF-DR	4000	BELOW SAFETY
JAA	20080205	10500016	EATON ELECTRIC LTD	P03	1615528	1050072798	MS1001N MEM 100A SPSN SW/DISC	54	BELOW SAFETY
JAA	20080205	10500896	LEC REFRIGERATION PLC	P03	1615614	1050334902	R5026W LEC 50CM FRIDGE	19	BELOW SAFETY
JAA	20080206	10508313	S L I LIGHTING LTD	P03	1616903	1050325832	NLUS21W NEWLEC T5 21W CABINET	37	BELOW SAFETY
JAA	20080206	10500963	MITA UK LTD	P03	1616545	1050151466	NLDTG20SRED NEWLEC DOME TOP GL	2500	BELOW MINIMUM
JAA	20080207	10500655	WJ FURSE & CO LTD	P03	1617595	1050317599	(NLCWGN)DFCWGN DEFIANCE CATENA	750	BELOW SAFETY
JAA	20080207	10500789	HORSTMANN CONTROLS	P03	1617597	1000009598	NLRT NEWLEC ROOM THERMOSTAT 10	100	BELOW SAFETY

APPENDIX V: Deals list

SUPLIER	SUPPLIER NO	BRANCH	MIN
BARO	10511445	GFS	TBC
CONSORT	10504845	GEQ	500
COOPER	10500027	GIP	300
ELECTRAK	10500475	GAA	500
EMERGILITE	10100527	GIP	250
GAMM	10511785	GFD	TBC
INVENSYS	10511141	ALL	TBC
MENVIER	10500905	GBY, GFD	300
OSRAM	10500007	GFD	250
PHILIPS	10512613	GFD	250
STEARN	10500028	GEQ	250
APPLIED ENERGY – CREDA	10512064	GED, GHN	NO MIN
CONSOLIDATED TECHNOLOGY	10511651	ALL	1500
GLEN DIMPLEX	10100648	ALL	NO MIN
KEWTECH	10535769	GEQ, GFD	1000
STIEBEL	10501258	GDJ, GEQ	TBC
TRITON	10501435	GEQ, GIP	5 UNITS
VENT-AXIA	10500023	GIP, GFD	200 MIN
XPELAIR	10500020	GBY, GDJ, GFD, GFT, GHB	350
ZIP	10505001	GIP	200

APPENDIX W: Supplier deal example

COOPER Lighting and Security [illegible]

Cooper Lighting and Security Ltd
Wheatley Hall Road
DONCASTER
South Yorkshire
DN2 4NB
UNITED KINGDOM

Page 3 of 10

Consignee
NEWEY & EYRE LTD
17 REDENESS STREET
LAYERTHORPE
YORK
YO3 7UX

Quotation

Quotation Number 20157654
Date: 23.05.2007

Currency GBP

Item	Material No. Description	Quantity	UOM	Price/Qty	Per COST	Amount
10	VSWO28S VIENZA 28W 2D SS WHITE SQ OPAL DIFF LMP	1.00	EA	21.06	20.01	21.06
20	CP41S CROMPACK 5 1.2M 1x36W SS BATTEN C/W LAMP	1.00	EA	6.84	6.50	6.84
30	CP42S CROMPACK 5 1.2M 2x36W SS BATTEN & LAMPS	1.00	EA	12.72	12.08	12.72
40	CP51S CROMPACK 5 1.5M 1x58W SS BATTEN C/W LAMP	1.00	EA	7.82	7.43	7.82
50	CP52S CROMPACK 5 1.5M 2x58W SS BATTEN & LAMPS	1.00	EA	13.34	12.67	13.34
60	CP61S CROMPACK 5 1.8M 1x70W SS BATTEN C/W LAMP	1.00	EA	9.90	9.41	9.90
70	CP62S CROMPACK 5 1.8M 2x70W SS BATTEN & LAMPS	1.00	EA	14.57	13.84	14.57
80	CP42Z CROMPACK 5 1.2M 2x36W HF BATTEN & LAMPS	1.00	EA	22.08	20.98	22.08
90	CP51Z CROMPACK 5 1.5M 1x58W HF BATTEN C/W LAMP	1.00	EA	18.71	17.77	18.71
100	EBCP41S CROMPACK 5 1x36W SS INTEG EMERG & LAMP	1.00	EA	37.43	35.56	37.43
110	EBCP51S CROMPACK 5 1x58W SS INTEG EMERG & LAMP	1.00	EA	43.76	41.57	43.76
120	EBCP52S CROMPACK 5 2x58W SS INTEG EMERG & LAMP	1.00	EA	46.60	44.27	46.60
130	EBCP61S CROMPACK 5 1x70W SS INTEG EMERG & LAMP	1.00	EA	49.16	46.70	49.16
140	EBCP51Z CROMPACK 5 1.5M 1x58W HF INTEG EM & LMP	1.00	EA	54.95	52.20	54.95
150	CPC41 CROMPACK 5 1.2M SINGLE PRIS CONTROLLER	1.00	EA	3.74	3.55	3.74
170	CPC42 CROMPACK 5 1.2M TWIN PRIS CONTROLLER	1.00	EA	5.20	4.94	5.20
190	CPC51	1.00	EA	4.42	4.20	4.42

E&DE Registered Office: 100 New Bridge Street, London, EC4 V6JA. Registered in England No. 3012749. VAT No: GB 651795019

APPENDIX X: BGB gained report snapshot

BRANCH CODE	BRANCH NAME	COMM REGION	PRODUCT NO	PRODUCT NAME	PO No.	BUYER	PO QTY	PO VALUE	COST A	Unit Cost on PO	BGB
PAA	NE PARK ROYALII	1010	1000010121	BM121 MEM 12WAY TPN DIST/BOARD	1646932	LAMONT	32	3192.64	106.04	£99.77	£201
QED	NE GRAVESEND	1060	1050352506	TFW170Z Tufflite TFW 1.8m 1x70	7569024	EMERYL	45	1189.8	30.927	£26.44	£202
NHH	NE SOUTHAMPTON	1060	1050215979	DUO500I+8PACKS DH03024 BRICKS	8357898	EMERYL	7	1507.45	246.204	£215.35	£216
JAA	NE NORTH WEST RDC	1040	1050286586	FP PLUS H 2C 2.5MM 100M RED	1647040	MCGILM	400	684	2.265	£1.71	£222
PAA	NE PARK ROYALII	1010	1050072545	MCH132R30 MEM 32A 30MA RCBO	1646932	LAMONT	100	3549	37.72	£35.49	£223
FDO	NE DUNDEE	1010	1050018810	#MSPFR618 CROM MODUSPEC 600X60	7568343	MCARTB	56	1637.44	33.376	£29.24	£232
NGM	NE PORTSMOUTH	1060	1050128736	MF100HCT VECTAIRE DUCT FAN	7568884	CIEROM	5	239.5	94.696	£47.90	£234
FKN	NE ROSS ELECTRICAL	1010	1050294270	96230345 THORN FQDIZ240MP MP	1646962	KIRKD	8	376	76.8284	£47.00	£239
NGM	NE PORTSMOUTH	1060	1050128735	MF100T VECTAIRE DUCT FAN	7568884	CIEROM	10	245.7	48.608	£24.57	£240
MAA	NE AVONMOUTH (HUB)	1060	1050331585	AX 6242BH 2.5 WHI LSF 100M	1647160	POLLAD	8000	3828	0.5097	£0.48	£250
KFZ	NE NOTTINGHAM	1040	1050338452	HDL600G UNI 600MM HD HDIP GLV	8357954	BIRCHS	200	7000	36.25	£35.00	£250
HCG	NE BURY ST EDMUNDS	1030	1050153334	AXS100SVIT GREENWOOD LV FAN	1647496	CYPRIS	28	1127	49.1865	£40.25	£250

APPENDIX Y: Cable best buy

Type	Size	Prysmian	IDH	Copper	Draka
6491X	1.5	**106.70**	**n/a**	**98.77**	**105.75**
	2.5	**161.70**	**n/a**	**162.37**	**150.17**
	4	**247.50**	**n/a**	**299.60**	**240.42**
	6	**363.00**	**n/a**	**414.20**	**371.75**
	10	**599.50**	**n/a**	**647.74**	**589.66**
	16	**951.50**	**n/a**	**1,049.30**	**942.64**
6491B	1.5	**122.10**	**104.00**	**113.23**	**109.99**
	2.5	**187.00**	**167.50**	**183.62**	**171.04**
	4	**286.00**	**257.00**	**284.43**	**269.50**
	6	**408.10**	**379.50**	**421.10**	**396.03**
	10	**819.50**	**637.00**	**688.95**	**690.80**
	16	**1,061.50**	**1,015.00**	**1,093.48**	**1,053.33**
6242Y	1	**218.90**	**n/a**	**209.03**	**200.24**
	1.5	**273.90**	**n/a**	**255.48**	**260.16**
	2.5	**401.50**	**n/a**	**369.03**	**415.97**
	4	**654.50**	**715.30**	**728.98**	**669.78**
	6	**929.50**	**1,006.20**	**1,001.29**	**1,000.12**
	10	**1,600.50**	**1,836.30**	**1,739.35**	**1,609.31**
	16	**2,530.00**	**n/a**	**2,761.30**	**2,570.71**
6243Y	1	**291.50**	**311.30**	**310.97**	**296.11**
	1.5	**385.00**	**417.10**	**428.00**	**415.97**

Key	Best buy supplier
	First
	Second
	Third
	Fourth

APPENDIX Y: Cable best buy (continued)

Type	Size	Prysmian	IDH	Copper	Draka
6242B	1	**308.00**	**258.50**	**n/a**	**n/a**
	1.5	**324.50**	**292.00**	**n/a**	**331.37**
	2.5	**478.50**	**457.00**	**n/a**	**467.89**
	4	**709.50**	**681.00**	**n/a**	**720.42**
	6	**1,045.00**	**992.00**	**n/a**	**1,076.79**
	10	**1,738.00**	**1,902.00**	**n/a**	**1,794.64**
	16	**2,640.00**	**2,700.00**	**n/a**	**2,897.06**
6243B	1	**462.00**	**n/a**	**416.95**	**n/a**
	1.5	**484.00**	**426.00**	**483.22**	**461.48**
	2.5	**n/a**	**689.00**	**n/a**	**n/a**
6181Y	16	**n/a**	**1,073.90**	**1147.33**	**982.82**
	25	**n/a**	**1,697.00**	**1523.87**	**1,539.80**
	35	**n/a**	**n/a**	**2585.95**	**2,813.10**

APPENDIX Z: PO over max report snapshot

WHS	BRANCH	PRODUCT NO	PRODUCT NAME	PO No.	PO QTY	PO LINE VALUE	BUYER	EOQ	MAX + 2 MONTHS DEMAND	BOH	ALLOC NET	% of Max + 2 months	Total Excess	Comment / approved by
QDP	NE EASTBOURNE	1050355457	9083P DILOG MULTIFUNCTION 17TH	1647421	10	2800	SUTHEK	1	4	1	1	275%	£1,960	
MCL	NE CARDIFF	1050332389	96202579 THORN DLUX2CCZ158 DIF	1646996	30	1469.84	HAYNEC	5	12	10	10	333%	£1,372	
KAA	HUKL DERBY HUB	1050071633	30KXTNC2F MEM 32A TPN SW/FUSE	1646999	24	1955.76	SIMISM	3	12	2	2	217%	£1,141	
MCL	NE CARDIFF	1050332395	96202580 THORN DLUX2CCZ258 DIF	1646996	20	1204.16	HAYNEC	3	7	5	5	357%	£1,084	
KAA	HUKL DERBY HUB	1000009972	MCH332 MEM 32A MCB TYPE-C TP	1646999	60	1307.4	SIMISM	4	19	4	4	337%	£981	
HFX	NE NORTHAMPTON	1050331576	AX 6242YH 2.5 GREY PVC 100M	1591485	1000	352.25	MADAMA	8000	16000	17500	17500	116%	£881	
MCL	NE CARDIFF	1050332580	96202610 THORN E3DLUX2CCZ258	1646996	10	1028.49	HAYNEC	3	7	5	5	214%	£823	
YCY	EE CORK	1000015984	NL8310/22 NEWLEC WHI 2GANG SWI	1646976	1500	885	OTOOLL	102	358	0	0	419%	£674	
EAA	NE GLASGOW	1050338953	VP187 WHI MK FLAT TEE	1629630	42	1442.86	HUGHEL1	13	60	43	40	132%	£653	
EAA	NE GLASGOW	1050335348	96232640 THORN OTX70 SONPAK	1647471	6	165.84	KIRKD	8	59	74	74	136%	£580	
EAA	NE GLASGOW	1050335356	96232648 THORN OTX400 SONPAK	1647471	3	210.89	KIRKD	4	34	37	37	118%	£422	
YJZ	EE PORTLAOISE	1000015259	P10003 UNIST 41X41X2.5T PLAIN	1647432	50	397.5	KELLYJ	1	3	0	0	1667%	£374	
MGJ	NE PLYMOUTH	1050299090	6944XLH PIREL 10 XLPE/SWA	1647424	250	825	POLLAD	50	164	14	14	161%	£330	
LDL	NE DUDLEY	1050020874	61/B06 CRAB S/BREAK MCB 6A	1647520	200	360	HALLO	10	54	20	20	407%	£299	
MCL	NE CARDIFF	1050332575	96202609 THORN E3DLUX2CCZ158	1646996	15	1489.92	HAYNEC	5	22	10	10	114%	£298	
NFU	I.O.W	1050299091	6944XLH PIREL 2.5/7 XLPE/SWA	1647425	500	548.5	POLLAD	40	310	78	78	186%	£294	

APPENDIX AA: Purchase order transmission confirmation

Successful Purchase Order Transmissions
2008-01-16 01:00:00 - 2008-01-16 11:59:59

Buyer ID : smitha4   Branch : VAE

Vendor No : 10501162   **Vendor Name : SCHNEIDER LTD**

Order Number	Order Date	Buyer Name	Order Value	Selected Transmittion Method	Actual Transmittion Method	Supplier Fax Number	OrderType
1599227	2008-01-16 01:11:21	ANDREW SMITH	338.7	FAX	FAX	08706088606	P03

APPENDIX AB: Purchase order confirmation

Order Confirmation

Honeywell

Page 1 of 2

Date	18/03/2008
Our Reference Order No	1109700
Order Date	17/03/2008
Your Sold To Acct No	7101936
Your Pay To Acct No	7101917
Your Purchase Order No	EAA1648337

Address:
Ross Electrical Limited
17/25 Devon Place
St Andrews Industrial Estate
Glasgow
GLASGOW CITY
G41 1RB

Thank you for your order. Please take this as our confirmation of your instructions to proceed. If you have any queries please contact Customer Services on the number below. Please note that if we receive orders which are deemed "Exceptional Demand" we will confirm an availability date within 48 hours of order.

Terms of payment: -
Within 28 days 2.800 % cash discount
Baseline date on day 31 of month

Terms of delivery — Currency GBP

Item	Material	Description	Qty Ord / Qty Due	Price Per UoM / Est Del Date	Net Value
10	VP180 WHI	MAIN CARRIER	60	19.58 M	238.20
		Discount		**59.00- %**	**693.13-**
		Project Discount		**50.57- %**	**243.58-**
			60	19/03/2008	
20	VP100 WHI	STRAIGHT COVER	90	4.53 M	82.80
		Discount		**59.00- %**	**240.54-**
		Project Discount		**50.43- %**	**84.30-**
			90	19/03/2008	
30	VP110 WHI	CURVED COVER	30	4.53 M	27.60
		Discount		**59.00- %**	**80.18-**
		Project Discount		**50.43- %**	**28.10-**
			30	19/03/2008	

Novar ED&S Limited

The Arnold Centre Paycocke Road Basildon Essex SS14 3EA United Kingdom | Telephone +44 (0)1268 563000
E-mail ed&s.salesteam@honeywell.com | Website www.novar-eds.com | Fax +44 (0)1268 563563
Registered office Honeywell House Arlington Business Park Bracknell Berkshire RG12 1EB | Registered No. 189291
Novar ED&S Limited incorporates | VAT Registered GB223472878

APPENDIX AB: Purchase order confirmation (continued)

Order Confirmation

Honeywell

Page 2 of 2

Date	18/03/2008
Our Reference Order No	1109700
Order Date	17/03/2008
Your Sold To Acct No	7101936
Your Pay To Acct No	7101917
Your Purchase Order No	EAA1648337

Item	Material	Description	Qty Ord / Qty Due	Price Per UoM / Est Del Date	Net Value
40	VP185 WHI	FLAT ANGLE	24	66.92 EA	465.36
		Discount		**59.00- %**	**947.59-**
		Project Discount		**29.34- %**	**193.20-**
			24	02/04/2008	

Number Of Items	4		
Total Net Value			813.96
Vat		17.5 %	138.45
Final Amount			952.41

Sales are made in accordance with our conditions of sale which are available on request.

The 'Estimated Delivery Date' is the advised delivery date at the time of order being processed and may be subject to change.

Novar ED&S Limited

The Arnold Centre Paycocke Road Basildon Essex SS14 3EA United Kingdom | Telephone +44 (0)1268 563000

E-mail ed&s.salesteam@honeywell.com | Website www.novar-eds.com | Fax +44 (0)1268 563563

Registered office Honeywell House Arlington Business Park Bracknell Berkshire RG12 1EB | Registered No. 189291

Novar ED&S Limited Incorporates | VAT Registered GB223472876

ACKERMANN™ Friedland MK

APPENDIX AC: Purchase order rejection

Schneider Purchase Order Pricing Error Notification 16/01/2008

Schneider Order Number	Hagemeyer Order Number	Line Number	Part Number	EAN Code	Quantity	Schneider Net Price	Hagemeyer Net Price	Price Difference	Order Date
0002656914	VAE1599227	000020	CA3KN40BD3	3389110484663	9	£101.98	£105.57	£3.59	20080115

APPENDIX AD: Special purchase order example

Melvyn Robinson1
21/01/2008 10:53

To: P&I Leeds@Hagemeyer
cc:
Subject: Order : CO- XCO REF KU15406

PURCHASE ORDER REQUEST - P05 / P13 / P15

FOR URGENT OR SPECIAL INSTRUCTIONS ORDERS ONLY

Branch Name :	INDUSTRIAL LEEDS	Branch Code:	BAEI
Raised by:	MELVYN ROBINSON	Contact phone number	0113-3895010

Only the fields marked with (✸) are mandatory, unless additional Supplier information required.

Purchase Order Information:	Supplier 1	Supplier 2	Supplier 3
Supplier Name or Number ✸	THOMAS & BETTS		
Contact Name:	SALES DEPT		
Contact Phone:	0115-9643820		
Contact Fax :	0115-9860071		
Supplier Quote Ref :			
Faxed Quote sent to P&I ?			
Text to appear on PO			
Number of lines to Release ✸	1		
Ship from Whs and/or Direct ✸	WHS		
Carriage limit achieved? ✸	NO	YES / NO (add Text)	YES / NO (add Text)
Special Instructions for P&I			

Provide details below of any special prices or discounts agreed with the supplier and not entered on sales order:

Line Description	Special Price £ or Discount %	UOM

This is an internal communication between Branch and P&I Office and not for external use.
EMail to:P&I Leeds@Hagemeyer.co.uk
The subject header format must be - "Order: CO-XXnnnnnnnn : DD: Cut off hh:mm : P&I Name"
IT IS A BRANCH RESPONSIBILITY TO PROGRESS URGENT/SPECIAL PURCHASE ORDERS!

P&I REPLY - SECTION	Supplier 1	Supplier 2	Supplier 3
Purchase Order No.			
P&I Lines placed			

PO Order - Leeds - form version 2.0

APPENDIX AE: Special purchase order cancellation example

Carl Green2

21/01/2008 10:23

To: P&i Leeds@Hagemeyer
cc:
Subject: HET7330745

PURCHASE / CUSTOMER ORDER CANCELLATION

Branch Name :	IPSWICH	Branch Code:	HET
Raised by:	CARL GREEN	Contact phone number	01473 230404

Supplier Name or Number	10100369 - COMBINED PRECISION COMPONENTS PLC
Contact Name:	
Contact Phone:	
Supplier has agreed to cancel?	YES
Are there any charges?	NO
Supplier Confirmation faxed to P&I?	NO
Purchase Order Number(s):	HET7330745
Reason for cancellation:	NO STOCK, CANT WAIT FOR THEIR DELIVERY TIMES
CANCEL ACTION NEEDED BY P&I (Delete not applicable)	ALL ITEMS ON ORDER

Line item	Order Qty:	Cancel Qty:

P&I USE ONLY	Actioned
Purchase order (lines) cancelled / amended:	
Sales order (lines) cancelled / amended:	

The "Subject" of this Email must be in the format heading "Cancel : CO- XX12345678"
Please Email to your respective P&I office mailbox.

APPENDIX AF: Excess moves report snapshot

BUYER	SUPPLIER	WHS	PRODUCT NO	PRODUCT NAME	EXCESS	TO WHS	ABC	TO MOVE	VALUE	P & I 1	P & I 2	COST
MCGILM	10501792	LKG	1050331586	AX 6243BH 1.5 WHI LSF 100M	10700	JAA	A	10700	5153.12	NW & WALES	SW & MID	£0.48
MCGILM	10501792	LKG	1050331586	AX 6243BH 1.5 WHI LSF 100M	10700	KAA	A	6717	3234.9072	NE & MID	SW & MID	£0.48
COWLEL	10503739	JGB	1050132570	EI156TLH AICO OPTICAL SMOKE AL	100	JAA	A	100	2310	NW & WALES	NW & WALES	£23.10
WELSBJ	10500018	JGX	1000002639	ETB1 MARSH BASE 3M	136	JAA	A	115	2245.881	NW & WALES	NW & WALES	£19.53
THOMPK	10512064	LBP	1050014881	TSR12AW+4 PKS 79140 BRICKS	17	JAA	B	14	2183.503	NW & WALES	SW & MID	£155.96
WELSBJ	10500789	LBP	1050150437	NLE7 NEWLEC W/HTG CONTROLLER	52	JAA	A	52	2022.8	NW & WALES	SW & MID	£38.90
MCGILM	10500017	LBP	1050286308	6242BH PIREL 4MM 2C WHI 100M	6100	KAA	C	2165	1883.55	NE & MID	SW & MID	£0.87
WELSBJ	10500018	JGX	1000002643	ETL1 WHI MARSH LID 3M	399	JAA	A	399	1776.1086	NW & WALES	NW & WALES	£4.45
SIMISM	10500035	JAA	1000008264	NL3101 NEWLEC 75X75 TRUNKING	235	KAA	A	185	1732.118	NE & MID	NW & WALES	£9.36
MCGILM	10500831	JFK	1050341825	CAT5E UTP PVC IN GREY (305M BO	51	KAA	D	45	1489.05	NE & MID	NW & WALES	£33.09
SIMISM	10500898	KAA	1050088714	ALB321H30 MEM 250V 32A SP MCB/	80	JAA	B	66	1431.144	NW & WALES	NE & MID	£21.68
HITCHJ1	10500011	LBP	1050022278	410/2563B CRAB S/L CONS UNIT	219	LIC	A	48	1385.856	SW & MID	SW & MID	£28.87
SIMISM	10500898	JGX	1050155615	M522 MEM250V 13A 2G DP SW SKT	1696	KHO	A	773	1349.2715	NE & MID	NW & WALES	£1.75
MCGILM	10501792	LIJ	1050331586	AX 6243BH 1.5 WHI LSF 100M	2695	JAA	A	2695	1297.912	NW & WALES	SW MID	£0.48
MCGILM	10501792	LIJ	1050331586	AX 6243BH 1.5 WHI LSF 100M	2695	KAA	A	2695	1297.912	NE & MID	SW & MID	£0.48
MCGILM	10501792	LIJ	1050331586	AX 6243BH 1.5 WHI LSF 100M	2695	KFZ	A	2617	1260.3472	NE & MID	SW & MID	£0.48
MCGILM	10501792	LKG	1050331586	AX 6243BH 1.5 WHI LSF 100M	10700	KFZ	A	2617	1260.3472	NE & MID	SW & MID	£0.48

APPENDIX AG: National warehouse moves

AREA	SUPPLIER	WHS	LOCATION	PRODUCT NO	PRODUCT NAME	EXCESS	TO WHS	TO MOVE	VALUE
West & South Wales	10500169	MAA	AVONMOUTH RDC	1050009668	RACK-A-TIER BOW CABLE STAND	3	AGY	3	£87.26
West & South Wales	10530427	MAA	AVONMOUTH RDC	1050318089	NLLVCK1 NEWLEC LOW VOLTAGE	3	AGY	1	£24.72
South West	10509768	MBI	BARNSTAPLE	1000009602	NL750/1 NEWLEC PORT TRANS 1X16	1	KMK	1	£28.25
South West	10501666	MFW	NEWTON ABBOT	1050334945	NL3823N NEWLEC 150W SON LOWBAY	1	KMK	1	£29.33
South West	10501751	MFW	NEWTON ABBOT	1050344197	NLS522 NEWLEC 4X75W GU10 4 BAR	1	KMK	1	£27.28
South West	10500005	MGJ	Plymouth	1000006593	741 MCO MK 13A 1G FLOOR SOCKET	6	KMK	6	£117.50
South West	10500025	MGJ	Plymouth	1050047944	STREAMLINE-182 HEATRAE 3KW	1	KMK	1	£103.29
South West	10500018	MGJ	Plymouth	1050074114	MCMR20 MARSH WHI DBL ENTRY BOX	25	KMK	16	£79.12
South West	10500027	MGJ	Plymouth	1050150863	NL3548HF NEWLEC 2X58W HF LUMIN	1	KMK	1	£62.67
South West	10500027	MGJ	Plymouth	1050334970	NL3813N NEWLEC HIGHBAY BODY &	1	AAV	1	£48.08
South West	10500007	MGJ	Plymouth	1000015734	NAVE OSRAM SONE 400W INT.IGNIT	3	AAV	3	£38.50
South West	10500042	MGJ	Plymouth	1050162371	NHRS17SL WYLEX CONSUMER UNI	1	AAV	1	£32.57
South West	10100648	MGJ	Plymouth	1050329017	PLX1000TI DIMP 1.0KW PNL HTR C	8	AAV	1	£30.38
South West	10500006	MGJ	Plymouth	1050108940	AS450 THORN FTG WITH TUBE	5	AAV	3	£29.89
South West	10500042	MGJ	Plymouth	1050106291	WRM100/4 WYLEX 100A 4POLE RCD	1	AAV	1	£27.30

APPENDIX AH: Weekly scoreboard report

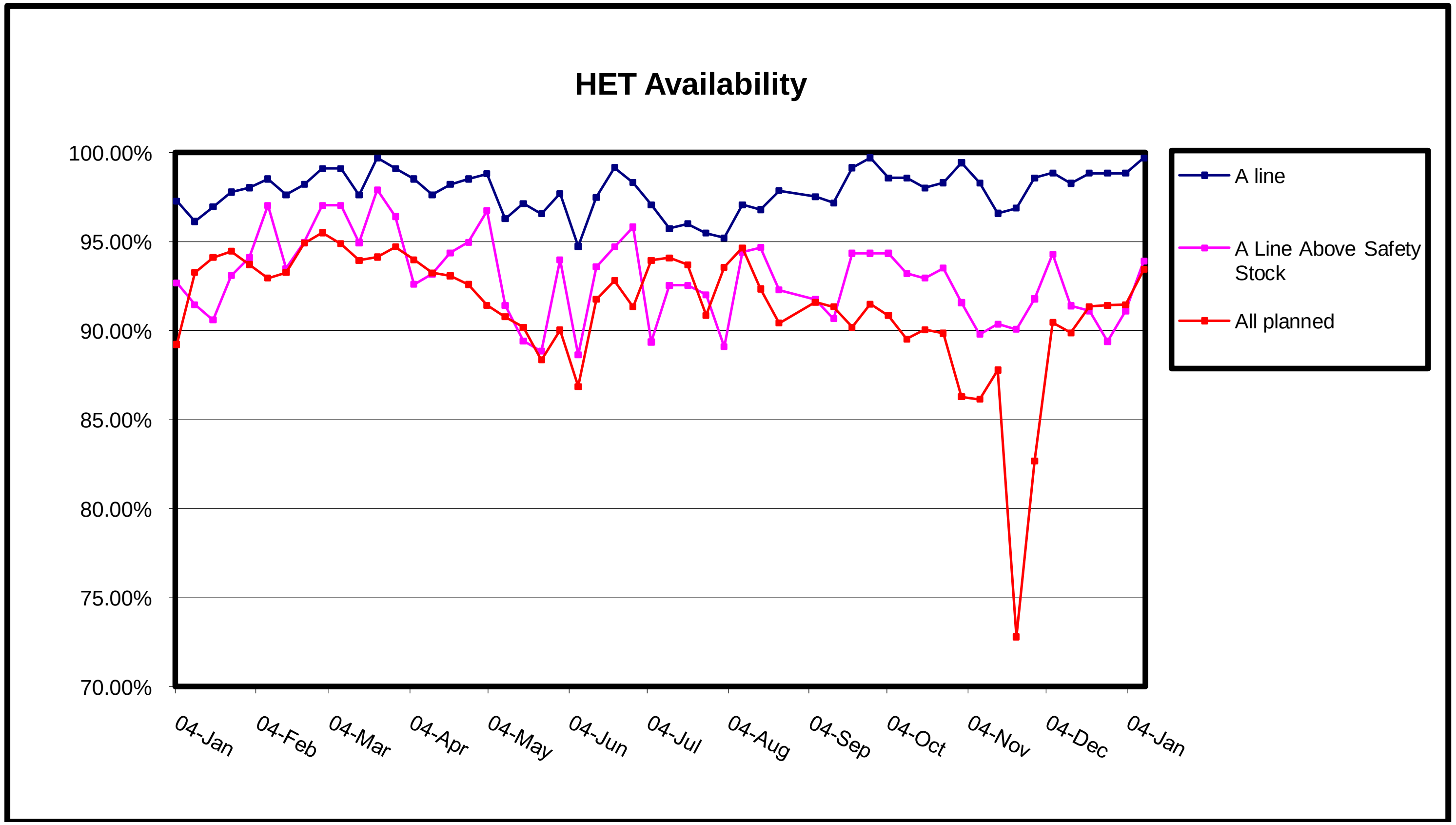
Week Commencing: 13-Mar	**Kirkcaldy**		**Leeds**		**Warrington**		**Avonmouth**	
Topic	**Actual**	**Points**	**Actual**	**Points**	**Actual**	**Points**	**Actual**	**Points**
A Line Availability (98%)	98.33%	0	98.66%	0	98.47%	0	98.45%	0
A Line Depth (92%)	95.98%	0	93.98%	0	94.14%	0	95.30%	0
ABC Line Availability (94%)	95.65%	0	93.53%	1	94.98%	0	96.46%	0
M & MA Line Availability (98%)	98.31%	0	97.29%	1	98.37%	0	98.21%	0
Stock PO's > 3 Months (NIL) - Entry Date	0	0	0	0	16	2	4	1
DO's > 10 Days (NIL) - Entry Date	0	0	3	2	1	1	0	0
CBO Lines > 10 Days (NIL) - Entry Date	6	2	4	1	27	4	10	3
Forecast Alarms	5632	0	3127	0	2	0	2945	0
NE Current Stock Value (10 Mar)	£6,003,951		£11,488,018		£12,001,262		£8,087,412	
NE Current Stock Target (Not Yet Finalised)	£7,159,251		£12,059,624		£13,230,444		£9,131,890	
% Under Target	-16.14%	1	-4.74%	4	-9.29%	3	-11.44%	2
Total Points		3		7		10		4
Rank		**1**		**3**		**4**		**2**

APPENDIX AI: Branch availability report

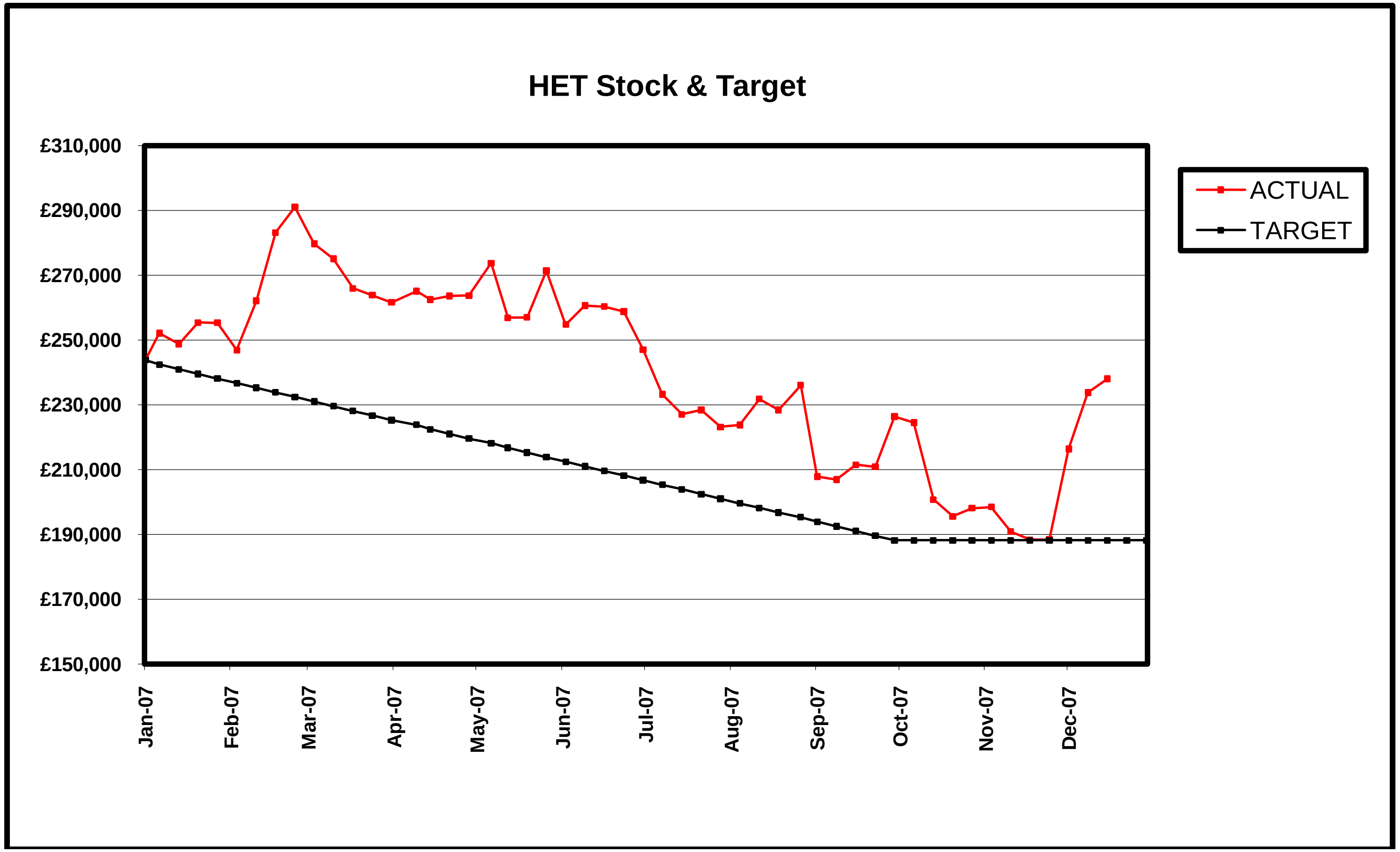
TEAM AVAILABILITY

		A LINES			B LINES			C LINES			D LINES		
SALES AREA	***WHS***	***TOTAL***	***OUT***	***%***	***TOTAL***	***OUT***	***%***	***TOTAL***	***OUT***	***%***	***TOTAL***	***OUT***	***%***
NORTH & EAST MI	KAA	608	18	97.04%	1412	100	92.92%	3582	415	88.41%	324	44	86.42%
	KDD	160	2	98.75%	333	8	97.60%	366	10	97.27%	118	9	92.37%
	KDG	0	0		0	0		0	0		1	1	0.00%
	KEO	151	5	96.69%	335	9	97.31%	388	8	97.94%	94	17	81.91%
	KER	162	0	100.00%	327	1	99.69%	262	4	98.47%	137	6	95.62%
	KFE	331	6	98.19%	774	31	95.99%	1136	67	94.10%	198	24	87.88%
	KFH	140	1	99.29%	344	6	98.26%	373	8	97.86%	130	15	88.46%
	KFL	221	3	98.64%	461	9	98.05%	426	8	98.12%	136	10	92.65%
	KFO	192	1	99.48%	356	9	97.47%	390	4	98.97%	127	12	90.55%
	KFZ	451	14	96.90%	1201	77	93.59%	1238	68	94.51%	303	27	91.09%
	KHL	178	1	99.44%	299	5	98.33%	277	2	99.28%	189	17	91.01%
	KHO	332	0	100.00%	867	40	95.39%	1085	38	96.50%	221	20	90.95%
	KHU	399	6	98.50%	880	36	95.91%	818	30	96.33%	202	12	94.06%
	KIX	196	1	99.49%	423	7	98.35%	548	13	97.63%	96	11	88.54%
	KJD	150	0	100.00%	356	2	99.44%	320	4	98.75%	176	11	93.75%
Summary for NORTH & EAST MIDLANDS (15 detail records)													
Sum		*3671*	*58*	98.42%	*8368*	*340*	95.94%	*11209*	*679*	93.94%	*2452*	*236*	*90.38%*

APPENDIX AJ: Branch availability graph



APPENDIX AK: Branch stock target graph

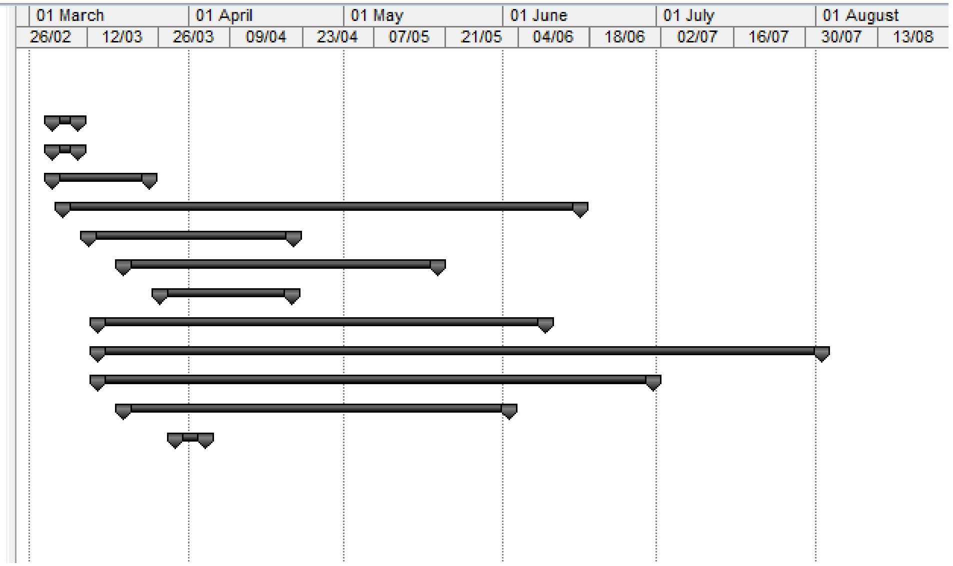


APPENDIX AL: Weekly checklist report

P&I CHECKLIST – Kirkcaldy		**P&I Office**			A	K	L	W
W/C 10/03/08		**League**			2	1	3	4
TOPIC	**TARGET**	**ACTUAL**		**TOPIC**		**ACTUAL**		
"A" Line Availability	98%	98.33%	▲	Forecast Alarms		5632		▼
"A" Line Depth	92%	95.98%	▲	Current Stock value		£11,020,303		▲
ABC Lines Availability	94%	95.65%	▲					
M / MA Line Availability	98%	98.31%	▲					
Stock PO's > 3 Months	NIL	0	▲					
DO's > 10 Days	NIL	0	▲					
CBO lines > 10 Days	NIL	6	▲					

APPENDIX AM: Project Gantt chart

	Task Name	Duration	Start	Finish
1	*Avonmouth Pilot Solution*	0 days	Mon 05/03/07	Mon 05/03/07
2				
3	Initial MK Visit to assess the facility	5 days	Mon 05/03/07	Fri 09/03/07
15	Initial Data collection and review	5 days	Mon 05/03/07	Fri 09/03/07
23	Review Whse set up / config / IT infrastructure for MK	16 days	Mon 05/03/07	Fri 23/03/07
31	Full Service Solutioning Phase 1	77 days	Wed 07/03/07	Fri 15/06/07
66	MK Prep plan phase 1	33 days	Mon 12/03/07	Fri 20/04/07
97	Avonmouth Media Re-modelling / Physical build programme	48 days	Mon 19/03/07	Fri 18/05/07
136	Avonmouth C2 Line transfer phase 1	20.9 days	Mon 26/03/07	Fri 20/04/07
166	Transfer of C2 from AAV to CMK	67 days	Wed 14/03/07	Fri 08/06/07
175	Suppliers	105 days	Wed 14/03/07	Wed 01/08/07
201	Processes & Procedure	82 days	Wed 14/03/07	Fri 29/06/07
219	P&I Changes	58 days	Mon 19/03/07	Fri 01/06/07
226	OTHERS	5 days	Thu 29/03/07	Tue 03/04/07



Source: Tony Elkin, Newey & Eyre Project Manager.

APPENDIX AN: Meeting actions

Actions from meeting of 21/02/2007
Project title - Avonmouth Pilot Project.

HAGEMEYER

Activity	*Owner*	*Required Date*
Request to John Hogan for £150,000 for development of a Canopy and provision for other work to be completed within the warehouse. This requires a CAPEX	AS, TE, MO	22/02
Request to John Hogan for £100,000 for provision of write-offs. Already in budget AS to discuss with TH.	AS	22/02
Request for extra person for cycle stock counting. MS to provide.	AS	22/02
Complete a list of SKU(s) with more than 6 weeks stock holding and the value of the excess stock	JB	22/02
Forward the cycle count paper to DM	TE	23/02
Provide a list of Parkers stock that is held at Avonmouth and also in Portbury Parkers facility – to advise stock to move out ASAP	TE	23/02
Complete a list of damaged products at Avonmouth	PC	28/02
Define a stock disposal route and document details for obsolete lines	GT	
Provide examples of franchise stock held in Avonmouth on behalf of individual branches	GT	28/02
Advise opportunities and process for stock protection against Branches ordering projects from Avonmouth cycle stock.	DM, GT	28/02
Complete a list of C line SKU(s) that are part of a range extension within their respective A & B lines	DM, GT	28/02
Complete 6 data sets that provide the maximum stock holding for SKU(s) over 3 options for both Avonmouth and Avonmouth with Branches	JB	28/02
Recommend which of the data sets provided by JB are feasible to fit within the constraints of the Avonmouth warehouse	PC	28/02
Evaluate quantity of cardboard media type required for use in the Mezzanine zone of Avonmouth then order and set-up	PC	
Data analysis pack	WM	28/02
Develop a spreadsheet solution for management of call-off of product against confirmed PO(s) for use in P&I office	DM	28/02
Review what industrial stock will be moved from Milton Keynes into Avonmouth – NONE as per LL	AS	28/02
Request a formal project cost code from Head Office	TE	28/02
Validate the list of supplier despatch point addresses provided by Colin	GT	
Identify out of the top 20 suppliers which can provide a realistic cost benefit from collection rather than the current process of supplier delivery	DM, GT	01/03
Recommendations upon rationalisation and de-duplication of brands	DM, GT	

APPENDIX AN: Meeting actions (continued)

Activity	***Owner***	***Required Date***
Develop plan for Wave Transport system	AS, MO	
Determine Totes / Boxes required for C line stock exit to Milton Keynes	PC	07/03
Movement of C Lines SKU(s) and NPNP from Avonmouth to Milton Keynes (as of agreed Avonmouth stock profile)	TE, PC	
encement of plan for initial relaying of Avonmouth Warehouse	PC, MO	
Develop a procedure that deals with new products introductions	DM, GT	
Branch profile analysis is required at some point	JB, AS	
Analysis of current delivery service offered for all customers	JB, AS	
Adjust and update the current project brief	TE	
Formalise draft outline plan Gannt for project	TE, DM	TBC
Discuss points regarding the inclusion of HR and other external elements into the project. After discussion with SW AD and DOB	TE, AS	TBS

APPENDIX AN: Meeting actions (continued)

Actions from meeting of 28/02/2007
Avonmouth Pilot Project.

HAGEMEYER

Activity	*Owner*	*Required Date*
Project Team (Eg roles & responsibilities, changes in availability, plans for coming weeks)		
Overall project (Eg Communication, Model clarification, project scope, risks & issues, policy development, overall data sets, ABC definition & AAV profile)		
Define the standard operating polices Carry over	AS	
Complete data set for proposed model which includes LOB greater than 250, 100 – 250 and 26 - 100 for A, B and C lines. - Done	JB	07/03
Provide a list of A,B and C Lines that will be held at Avonmouth in the proposed model for DM to be used to find range completion SKUs - Update	JB	07/03
Complete a list of C line SKU(s) that are part of a range extension within their respective A & B lines – Carry over	DM, GT	07/03
Define the stock profile for Avonmouth	TE, PC	
Update proposed area map and send to JB - Done	TE	01/03
Create list of area postcodes – Done	MO	07/03
Chase project code and organise meeting with TH to explain Capex - Done	TE	
Branch profile analysis is required at some point – Carry Over	JB, AS	
Adjust and update the current project brief – Carry Over	TE	
Formalise draft outline plan Gannt for project – Carry Over	TE, DM	TBC
Discuss points regarding the inclusion of HR and other external elements into the project. After discussion with SW AD and DOB	TE, AS	TBC
Stock levels (Eg Current stock levels, obsolete stock, damaged etc & Changes to levels and practices)		

APPENDIX AN: Meeting actions (continued)

Activity	***Owner***	***Required Date***
Define obsolete stock as one of the four categories; return to supplier, sell to other branches, scrap or hold. Send list to PC. – Carry Over (End of next week)	GT	07/03
Identify scrap stock value then either give to staff, charity or skip it - Carry Over	PC	
Document the plan for the movement of stock from Avonmouth to MK Carry over (end of next week)	TE	07/03
Send the list of products that are stored at both Avonmouth and Portbury (Parkers) – Done	TE	01/03
Arrange Parkers stock to be returned with Larry Patterson – Carry over	AS	
Arrange for franchise stock GE Power Distribution to be sent to Cardiff Branch – Carry over	GT	
Provide a list of Franchise SKUs which have more than 50% of sales at one Branch – Supplier level Carry over 50% at one branch or 75% at two over last 6 months. 21/03/07	JB	
Speak to DOB about a way to protect from Branches ordering projects from cycle stock and Satellites from replenishing from Avonmouth instead of ordering from suppliers - Done (Haddies go to Bristol)	AS	
Communicate with Richard Green with regards to Andover Branch moving over to Park Royal – Done	TE	
Organise switch over of Andover to Park Royal - Update Nigel		26/03
CMK warehouse (Eg Preparation & transfer of items)		
Determine physical media required at MK for C2 Lines – Done – Provide output of this.	PC	01/03
Determine Totes / Boxes required for C line stock exit to Milton Keynes - Done	PC	07/03
AAV warehouse (Eg Plans, permissions, Capex, re-layout)		
Raise Capex for £150,000 for Canopy and related warehouse costs Carry Over waiting for updated quote from MO 09/03/07	TE	07/03
Check feasibility of new data set to fit within the constraints of the Avonmouth warehouse – Carry Over	PC	07/03
Evaluate quantity of cardboard media type required for use in the Mezzanine zone of Avonmouth then order and set-up – Done	PC	07/03

APPENDIX AN: Meeting actions (continued)

Activity	***Owner***	***Required Date***
Commencement of plan for initial relaying of Avonmouth Warehouse Done	PC, MO	14/03
Formulate strategy for isolating of Avonmouth Branch from the Avonmouth Depot – Done	PC, MO	07/03
Transport (Eg taking over responsibilities, waves of transport)		
Develop plan for Wave Transport system - Ongoing	AS, MO	
Movement of deliveries from branches to ANC Avonmouth Ongoing	AS, TE, MS	
Organise movement of vehicle from Truro to Bristol and de-hire vehicle at Bristol	MO	
Talk to DOB about movement of drivers from Branches to Avonmouth - Done	MO	
Suppliers (Eg selection, meetings and action)		
Complete analysis for DM for supplier lead times – Carry on	JB	07/03
Develop a spreadsheet solution for management of call-off of product against confirmed PO(s) for use in P&I office	DM	
Validate the list of supplier despatch point addresses provided by Colin	GT	07/03
Organise meeting with LL and appropriate central buyer to discuss which suppliers are going to be visited to discuss lead times and possible collections	DM	07/03
Create PowerPoint presentation supplier visits	GT, DM	07/03
Provide AS with name of first supplier to be visited - Done	DM	07/03
Discuss pack sizes with LL - Moved off	AS	
Processes & Procedures (Eg list, format & development)		
Define a list of standard operating procedures then agree with team To be obtained from Park Royal	AS	
Document the procedure for cycle stock counting at Avonmouth	DM	12/03
Develop a procedure that deals with new products introductions Carry over	DM, GT	

APPENDIX AN: Meeting actions (continued)

Activity	*Owner*	*Required Date*
Customer review (Eg performance to competitors)		
Analysis of current delivery service offered for all customers – Carry over	JB, AS	
AOB		
Discuss with TH provision for write-offs Carry over	AS	

Actions from meeting of 07/03/2007
Avonmouth Pilot Project.

HAGEMEYER

Activity	*Owner*	*Required Date*
Project Team (Eg roles & responsibilities, changes in availability, plans for coming weeks)		
Overall project (Eg Communication, Model clarification, project scope, risks & issues, policy development, overall data sets, ABC definition & AAV profile)		
Define the standard operating polices Carry over	AS	
Complete data set for proposed model which includes LOB greater than 250, 100 – 250 and 26 -100 for A, B and C lines. - Done	JB	07/03
Provide a list of A,B and C Lines that will be held at Avonmouth in the proposed model for DM to be used to find range completion SKUs - Update	JB	07/03
Complete a list of C line SKU(s) that are part of a range extension within their respective A & B lines – Carry over	DM, GT	07/03
Define the stock profile for Avonmouth	TE, PC	
Update proposed area map and send to JB - Done	TE	01/03
Create list of area postcodes – Done	MO	07/03

APPENDIX AN: Meeting actions (continued)

Activity	***Owner***	***Required Date***
Chase project code and organise meeting with TH to explain Capex - Done	TE	
Branch profile analysis is required at some point – Carry Over	JB, AS	
Adjust and update the current project brief – Carry Over	TE	
Formalise draft outline plan Gannt for project – Carry Over	TE, DM	TBC
Discuss points regarding the inclusion of HR and other external elements into the project. After discussion with SW AD and DOB	TE, AS	TBC
Stock levels (Eg Current stock levels, obsolete stock, damaged etc & Changes to levels and practices)		
Define obsolete stock as one of the four categories; return to supplier, sell to other branches, scrap or hold. Send list to PC. – Carry Over (End of next week)	GT	07/03
Identify scrap stock value then either give to staff, charity or skip it - Carry Over	PC	
Document the plan for the movement of stock from Avonmouth to MK Carry over (end of next week)	TE	07/03
Send the list of products that are stored at both Avonmouth and Portbury (Parkers) – Done	TE	01/03
Arrange Parkers stock to be returned with Larry Patterson – Carry over	AS	
Arrange for franchise stock GE Power Distribution to be sent to Cardiff Branch – Carry over	GT	
Provide a list of Franchise SKUs which have more than 50% of sales at one Branch – Supplier level Carry over 50% at one branch or 75% at two over last 6 months. 21/03/07	JB	

APPENDIX AN: Meeting actions (continued)

Activity	***Owner***	***Required Date***
Speak to DOB about a way to protect from Branches ordering projects from cycle stock and Satellites from replenishing from Avonmouth instead of ordering from suppliers - Done (Haddies go to Bristol)	AS	
Communicate with Richard Green with regards to Andover Branch moving over to Park Royal – Done	TE	
Organise switch over of Andover to Park Royal - Update Nigel		26/03
CMK warehouse (Eg Preparation & transfer of items)		
Determine physical media required at MK for C2 Lines – Done – Provide output of this.	PC	01/03
Determine Totes / Boxes required for C line stock exit to Milton Keynes - Done	PC	07/03
AAV warehouse (Eg Plans, permissions, capex, re-layout)		
Raise Capex for £150,000 for Canopy and related warehouse costs Carry Over waiting for updated quote from MO 09/03/07	TE	07/03
Check feasibility of new data set to fit within the constraints of the Avonmouth warehouse – Carry Over	PC	07/03
Evaluate quantity of cardboard media type required for use in the Mezzanine zone of Avonmouth then order and set-up - Done	PC	07/03
Commencement of plan for initial relaying of Avonmouth Warehouse Done	PC, MO	14/03
Formulate strategy for isolating of Avonmouth Branch from the Avonmouth Depot – Done	PC, MO	07/03
Transport (Eg taking over responsibilities, waves of transport)		
Develop plan for Wave Transport system - Ongoing	AS, MO	

APPENDIX AN: Meeting actions (continued)

Activity	***Owner***	***Required Date***
Movement of deliveries from branches to ANC Avonmouth Ongoing	AS, TE, MS	
Organise movement of vehicle from Truro to Bristol and de-hire vehicle at Bristol	MO	
Talk to DOB about movement of drivers from Branches to Avonmouth - Done	MO	
Suppliers (Eg selection, meetings and action)		
Complete analysis for DM for supplier lead times – Carry on	JB	07/03
Develop a spreadsheet solution for management of call-off of product against confirmed PO(s) for use in P&I office	DM	
Validate the list of supplier despatch point addresses provided by Colin	GT	07/03
Organise meeting with LL and appropriate central buyer to discuss which suppliers are going to be visited to discuss lead times and possible collections	DM	07/03
Create PowerPoint presentation supplier visits	GT, DM	07/03
Provide AS with name of first supplier to be visited - Done	DM	07/03
Discuss pack sizes with LL - Moved off	AS	
Processes & Procedures (Eg list, format & development)		
Define a list of standard operating procedures then agree with team To be obtained from Park Royal	AS	
Document the procedure for cycle stock counting at Avonmouth	DM	12/03
Develop a procedure that deals with new products introductions Carry over	DM, GT	

APPENDIX AN: Meeting actions (continued)

Activity	*Owner*	*Required Date*
Customer review (Eg performance to competitors)		
Analysis of current delivery service offered for all customers – Carry over	JB, AS	
AOB		
Discuss with TH provision for write-offs Carry over	AS	

Actions from meeting of 21/03/2007
Avonmouth Pilot Project.

HAGEMEYER

Meeting	Avonmouth Project		
Venue	Avonmouth RDC	**Date**	21/03/2007
Attendees	Alan Slater, John Burgess, David Morgan, Tony Elkin, David O'Byrne, Nigel Savage, Michael Dunphy, Gary Tromans, Martin Owram, John Fox		
Apologies			

Topic	**Action / comment**	**Who**	**When**	**Open / Closed**
Service Offering	C2 lines to move from AAV to CMK	TE	02/04/2007	Open
Service Offering	Parkers lines to move from AAV to CMK	TE	02/04/2007	Open
Service Offering	No restriction of C2 lines at CMK. 30 branches restricted to ordering from CMK			Comment
Service Offering	48 Hour service for C2 lines with a surcharge for next day delivery of £5.00. 6pm cut-off for ordering			Comment
Product Profile	Product profile list to be finalised	GT	23/03/2007	Open
Product Profile	MD to take ownership of product profile and hold master list	MD	23/03/2007	Comment
Product Profile	Removal of re-order point on Movex for D lines to create a buy for sell policy. Date to be confirmed by NS	MD		Open
Product Profile	Create a list of O lines that are currently sold and planned out of the other RDC's	MD		Open

APPENDIX AN: Meeting actions (continued)

Topic	Action / comment	Who	When	Open / Closed
Product Profile	No more than 6,000 lines to be held at AAV. Any items over this will be on a 1 in 1 out basis unless authorised			Comment
Product Profile	Documentation of obsolete procedures	GT		Open
Product Profile	Determine which O lines are going to be returned to suppliers	GT	30/03/2007	Open
Product Profile	Provide a list of residue obsolete lines for NS	GT	30/03/2007	Open
Product Profile	NS to discuss with Robert and draw up an action plan for the residue obsolete items	NS		Open
Communications	Create a communications brief for the meetings with business managers	AS		Open
Communications	Meeting to discuss Project Avonmouth with Branch and P&I Managers	DM / GT	30/03/2007	Open
Communications	Meeting to discuss Project Avonmouth with Business Managers	AS / NS	30/03/2007	Open
Customer Service Rules	Draw up customer service proposals	DM		Open
Project Stock	Project stock to be moved from AAV to Bristol			Open
Project Stock	Action plan for non-planned non profilled stock at Bristol to be discussed with Robert	NS		Open
Capex for AAV changes	Awaiting property planning			Comment

APPENDIX AO: Branch network

BRANCH CODE	BRANCH NAME	P&I OFFICE	RDC	SALES AREA
ABD	ANDOVER	Avonmouth	Avonmouth	SOUTH EAST
AFU	NEWPORT (I.O.W)	Avonmouth	Avonmouth	SOUTH EAST
AGM	PORTSMOUTH	Avonmouth	Avonmouth	SOUTH EAST
AHH	SOUTHAMPTON	Avonmouth	Avonmouth	SOUTH EAST
AAV	AVONMOUTH (HUB)	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
ABI	BARNSTAPLE	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
ABK	BATH	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AJC	BRIDGEND	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
ACC	BRISTOL	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
ACL	CARDIFF	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AJF	CARMARTHEN	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
ADW	EXETER	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AEH	GUERNSEY	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AFV	NEWPORT (GWENT)	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AFW	NEWTON ABBOT	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AGF	PEMBROKE DOCK	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AGJ	PLYMOUTH	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AGK	POOLE	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AGY	SALISBURY	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AHS	SWANSEA	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AHT	SWINDON	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AHV	TAUNTON	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AHY	TRURO	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AIE	WESTON SUPER MARE	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AIO	YATE	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
AJX	YEOVIL	Avonmouth	Avonmouth	SOUTH WEST & SOUTH WALES
ABF	BANBURY	Avonmouth	Park Royal	SOUTH & WEST MIDLANDS
AGD	OXFORD	Avonmouth	Park Royal	SOUTH & WEST MIDLANDS
ABE	ASHFORD	Avonmouth	Park Royal	SOUTH EAST
ABJ	BASINGSTOKE	Avonmouth	Park Royal	SOUTH EAST
ACB	BRIGHTON	Avonmouth	Park Royal	SOUTH EAST
ACH	CAMBERLEY	Avonmouth	Park Royal	SOUTH EAST
ACK	CANTERBURY	Avonmouth	Park Royal	SOUTH EAST
ADB	CRAWLEY	Avonmouth	Park Royal	SOUTH EAST
ADC	DARTFORD	Avonmouth	Park Royal	SOUTH EAST
AED	GRAVESEND	Avonmouth	Park Royal	SOUTH EAST
AEI	GUILDFORD	Avonmouth	Park Royal	SOUTH EAST
AEL	HASTINGS	Avonmouth	Park Royal	SOUTH EAST
AFJ	LITTLEHAMPTON	Avonmouth	Park Royal	SOUTH EAST
AFN	MAIDSTONE	Avonmouth	Park Royal	SOUTH EAST
AGS	ROCHESTER	Avonmouth	Park Royal	SOUTH EAST
AHA	SEVENOAKS	Avonmouth	Park Royal	SOUTH EAST
AHF	SITTINGBOURNE	Avonmouth	Park Royal	SOUTH EAST
AHZ	TUNBRIDGE WELLS	Avonmouth	Park Royal	SOUTH EAST
AFS	NEWBURY	Avonmouth	Park Royal	SOUTH WEST & SOUTH WALES
AYB	BERMONDSEY HUB	Avonmouth	Park Royal	LONDON & ESSEX
ABZ	BRAINTREE	Avonmouth	Park Royal	LONDON & ESSEX

APPENDIX AO: Branch network (continued)

BRANCH CODE	BRANCH NAME	P&I OFFICE	RDC	SALES AREA
ACP	CHELMSFORD	Avonmouth	Park Royal	LONDON & ESSEX
ACT	CITY	Avonmouth	Park Royal	LONDON & ESSEX
ADE	CROYDON	Avonmouth	Park Royal	LONDON & ESSEX
ADI	DOCKLANDS	Avonmouth	Park Royal	LONDON & ESSEX
ADY	FELTHAM	Avonmouth	Park Royal	LONDON & ESSEX
AEE	GRAYS	Avonmouth	Park Royal	LONDON & ESSEX
BSK	PARK ROYAL II	Avonmouth	Park Royal	LONDON & ESSEX
AGO	READING	Avonmouth	Park Royal	LONDON & ESSEX
AGT	ROMFORD	Avonmouth	Park Royal	LONDON & ESSEX
AHG	SLOUGH	Avonmouth	Park Royal	LONDON & ESSEX
AHI	SOUTHEND ON SEA	Avonmouth	Park Royal	LONDON & ESSEX
AEU	TOTTENHAM	Avonmouth	Park Royal	LONDON & ESSEX
ABA	ABERDEEN (NORTH)	Kirkcaldy	Glasgow	SCOTLAND EAST
ACO	ABERDEEN SOUTH	Kirkcaldy	Glasgow	SCOTLAND EAST
AIU	ARBROATH	Kirkcaldy	Glasgow	SCOTLAND EAST
ADO	DUNDEE	Kirkcaldy	Glasgow	SCOTLAND EAST
AJV	DUNFERMLINE	Kirkcaldy	Glasgow	SCOTLAND EAST
ADT	EDINBURGH	Kirkcaldy	Glasgow	SCOTLAND EAST
AKB	EDINBURGH WEST	Kirkcaldy	Glasgow	SCOTLAND EAST
AES	INVERNESS	Kirkcaldy	Glasgow	SCOTLAND EAST
AIT	KELSO	Kirkcaldy	Glasgow	SCOTLAND EAST
AEZ	KIRKCALDY	Kirkcaldy	Glasgow	SCOTLAND EAST
AFG	LERWICK	Kirkcaldy	Glasgow	SCOTLAND EAST
AJI	LIVINGSTON	Kirkcaldy	Glasgow	SCOTLAND EAST
AIZ	ORKNEY	Kirkcaldy	Glasgow	SCOTLAND EAST
AGH	PERTH	Kirkcaldy	Glasgow	SCOTLAND EAST
AEW	AYR	Kirkcaldy	Glasgow	SCOTLAND WEST
ACM	CARLISLE	Kirkcaldy	Glasgow	SCOTLAND WEST
ADM	DUMFRIES	Kirkcaldy	Glasgow	SCOTLAND WEST
ADX	FALKIRK	Kirkcaldy	Glasgow	SCOTLAND WEST
ADZ	FORT WILLIAM	Kirkcaldy	Glasgow	SCOTLAND WEST
AEA	GLASGOW	Kirkcaldy	Glasgow	SCOTLAND WEST
BQZ	GLASGOW NORTH	Kirkcaldy	Glasgow	SCOTLAND WEST
AKD	HAMILTON	Kirkcaldy	Glasgow	SCOTLAND WEST
AFQ	MOTHERWELL	Kirkcaldy	Glasgow	SCOTLAND WEST
AIQ	OBAN	Kirkcaldy	Glasgow	SCOTLAND WEST
AGC	PAISLEY	Kirkcaldy	Glasgow	SCOTLAND WEST
AJH	STIRLING	Kirkcaldy	Glasgow	SCOTLAND WEST
ABL	BEDFORD	Leeds	Peterborough	ANGLIA
ABQ	BISHOPS STORTFORD	Leeds	Peterborough	ANGLIA
ABX	BOSTON	Leeds	Peterborough	ANGLIA
ACG	BURY ST EDMUNDS	Leeds	Peterborough	ANGLIA
ACI	CAMBRIDGE	Leeds	Peterborough	ANGLIA
AEF	GREAT YARMOUTH	Leeds	Peterborough	ANGLIA
AET	IPSWICH	Leeds	Peterborough	ANGLIA
AJK	KETTERING	Leeds	Peterborough	ANGLIA
AEX	KINGS LYNN	Leeds	Peterborough	ANGLIA
AFM	LUTON	Leeds	Peterborough	ANGLIA

APPENDIX AO: Branch network (continued)

BRANCH CODE	BRANCH NAME	P&I OFFICE	RDC	SALES AREA
AFP	MILTON KEYNES	Leeds	Peterborough	ANGLIA
AFX	NORTHAMPTON	Leeds	Peterborough	ANGLIA
AFY	NORWICH	Leeds	Peterborough	ANGLIA
AGI	PETERBOROUGH	Leeds	Peterborough	ANGLIA
AHJ	SPALDING	Leeds	Peterborough	ANGLIA
AHX	THETFORD	Leeds	Peterborough	ANGLIA
AII	WISBECH	Leeds	Peterborough	ANGLIA
ABT	BLYTH	Leeds	Stockton	NORTH EAST
ADF	DARLINGTON	Leeds	Stockton	NORTH EAST
ADQ	DURHAM	Leeds	Stockton	NORTH EAST
AEG	GRIMSBY	Leeds	Stockton	NORTH EAST
AEJ	HARROGATE	Leeds	Stockton	NORTH EAST
AEQ	HULL	Leeds	Stockton	NORTH EAST
AFT	NEWCASTLE UPON TYNE (GATESHEAD	Leeds	Stockton	NORTH EAST
AKE	NEWCASTLE UPON TYNE (HEATON)	Leeds	Stockton	NORTH EAST
AGZ	SCUNTHORPE	Leeds	Stockton	NORTH EAST
AXX	STOCKTON HUB	Leeds	Stockton	NORTH EAST
AHQ	SUNDERLAND	Leeds	Stockton	NORTH EAST
AIP	YORK	Leeds	Stockton	NORTH EAST
ABH	BARNSLEY	Leeds	Stockton	NORTH EAST
ABY	BRADFORD	Leeds	Stockton	NORTH EAST
ADJ	DONCASTER	Leeds	Stockton	NORTH EAST
AJW	HALIFAX	Leeds	Stockton	NORTH EAST
AEP	HUDDERSFIELD	Leeds	Stockton	NORTH EAST
AFD	LEEDS	Leeds	Stockton	NORTH EAST
AHB	SHEFFIELD	Leeds	Stockton	NORTH EAST
AIB	WAKEFIELD	Leeds	Stockton	NORTH EAST
AJD	BURTON ON TRENT	Warrington	Derby	NORTH & EAST MIDLANDS
AIX	CHESTERFIELD	Warrington	Derby	NORTH & EAST MIDLANDS
ADD	CREWE	Warrington	Derby	NORTH & EAST MIDLANDS
BVA	DERBY HUB	Warrington	Derby	NORTH & EAST MIDLANDS
AEO	HINCKLEY	Warrington	Derby	NORTH & EAST MIDLANDS
AER	ILKESTON	Warrington	Derby	NORTH & EAST MIDLANDS
AFE	LEICESTER	Warrington	Derby	NORTH & EAST MIDLANDS
AFH	LICHFIELD	Warrington	Derby	NORTH & EAST MIDLANDS
AFL	LOUGHBOROUGH	Warrington	Derby	NORTH & EAST MIDLANDS
AFO	MANSFIELD	Warrington	Derby	NORTH & EAST MIDLANDS
AFZ	NOTTINGHAM	Warrington	Derby	NORTH & EAST MIDLANDS
AHL	STAFFORD	Warrington	Derby	NORTH & EAST MIDLANDS
AHO	STOKE ON TRENT	Warrington	Derby	NORTH & EAST MIDLANDS
AHU	TAMWORTH	Warrington	Derby	NORTH & EAST MIDLANDS
ABG	BANGOR	Warrington	Warrington	NORTH WEST & NORTH WALES
ABO	BIRKENHEAD	Warrington	Warrington	NORTH WEST & NORTH WALES
ABR	BLACKBURN	Warrington	Warrington	NORTH WEST & NORTH WALES
ABV	BOLTON	Warrington	Warrington	NORTH WEST & NORTH WALES
ABW	BOOTLE	Warrington	Warrington	NORTH WEST & NORTH WALES
ACE	BURNLEY	Warrington	Warrington	NORTH WEST & NORTH WALES

APPENDIX AO: Branch network (continued)

BRANCH CODE	BRANCH NAME	P&I OFFICE	RDC	SALES AREA
ACR	CHESTER	Warrington	Warrington	NORTH WEST & NORTH WALES
ADU	ELLESMERE PORT	Warrington	Warrington	NORTH WEST & NORTH WALES
AFB	LANCASTER	Warrington	Warrington	NORTH WEST & NORTH WALES
AFK	LIVERPOOL	Warrington	Warrington	NORTH WEST & NORTH WALES
AGB	OLDHAM	Warrington	Warrington	NORTH WEST & NORTH WALES
AGN	PRESTON	Warrington	Warrington	NORTH WEST & NORTH WALES
AGQ	ROCHDALE	Warrington	Warrington	NORTH WEST & NORTH WALES
AGW	RUNCORN	Warrington	Warrington	NORTH WEST & NORTH WALES
AGX	SALFORD	Warrington	Warrington	NORTH WEST & NORTH WALES
AHM	STOCKPORT	Warrington	Warrington	NORTH WEST & NORTH WALES
BRA	WARRINGTON	Warrington	Warrington	NORTH WEST & NORTH WALES
AIH	WIGAN	Warrington	Warrington	NORTH WEST & NORTH WALES
AIN	WREXHAM	Warrington	Warrington	NORTH WEST & NORTH WALES
ABP	BIRMINGHAM	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AJE	CANNOCK	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
ACQ	CHELTENHAM	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
ADA	COVENTRY	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
ADL	DUDLEY	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AEN	HEREFORD	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AEV	KIDDERMINSTER	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AEY	KINGS NORTON	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AFC	LEAMINGTON SPA	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AGV	RUGBY	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AHD	SHIRLEY (SOLIHULL)	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AHE	SHREWSBURY	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AHW	TELFORD	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AIC	WALSALL	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AIJ	WOLVERHAMPTON	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS
AIK	WORCESTER	Warrington	Wolverhampton	SOUTH & WEST MIDLANDS

APPENDIX AP: Purchasing and inventory presentation

University of HUDDERSFIELD

Key Purchasing and Inventory Process Issues and Solutions

Transport & Logistics Division

Objectives

1. Gain an understanding of the current Newey & Eyre P&I system
2. Produce process mapping flows for each regional P&I office
3. Identify areas where there is differing operational procedures and processes
4. Identify and list current issues
5. Recommend possible solutions

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Methodology

- 2 days spent at each regional P&I office:
  - Leeds
  - Avonmouth
  - Warrington
  - Kirkcaldy
- Informal interviews with key staff – Supervisors, stock & special buyers
- Collection of relevant material

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Explanations, Findings, Issues & Proposed Solutions

1. Profile Review
2. Specials
3. Order Generation
4. Key Performance Indicators (KPI's)
5. Productivity
6. Organisational Dysfunctionality

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Profile Review

- Explanation
  - P & I managers should visit branches every 6 months to review profiles
  - Product data used to compile branch profiles
  - Stock profile decisions:
    1. Increase quantities
    2. Decrease quantities
    3. Add lines
    4. Remove lines
  - Decisions made inline with model inventory system
- Findings
  - Lack of confidence in Movex (perceived to cause stock-outs)
  - Not all branches visited within 6 months
  - Branch priorities are with service levels

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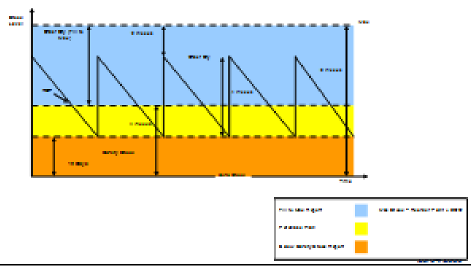
Profile Review

Example inventory model (P&I Leeds Feb 08)



APPENDIX AP: Purchasing and inventory presentation (continued)

Profile Review

- Issues
  - Increased levels of stock holding
  - Demand rising can lead to understocking
  - Demand falling can lead to overstocking
  - One size fits all approach:
    1. Across all classifications
    2. Small inexpensive items & large expensive products
    3. Varying demand patterns

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Profile Review

- Proposed Solutions
  - Revert back to continuous review ordering system for A & B lines
  - Seasonal adjusted forecasting
  - Review inventory system, max stock holding etc
  - Review key formulas
    1. 6 Months moving average
    2. EOQ (£2.50 Acquisition cost, 20% inventory carrying cost)
    3. Lead time demand (static 10/13 days)
    4. Safety stock (static 13 days)

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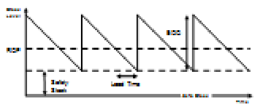
Profile Review

Continuous Review Ordering System



Reorder Point (ROP)

ROP = Lead Time Demand + Safety Stock

Moving Average

$$\frac{\sum Y_{t-1}}{n}$$

Y_{t-1} = Actual demand in period t - 1

n = Forecasted demand for period

Economic Order Quantity (EOQ)

$$EOQ = \sqrt{\frac{2CR}{H}}$$

C = Ordering cost per order

R = Annual demand in units

H = Holding cost per unit per year

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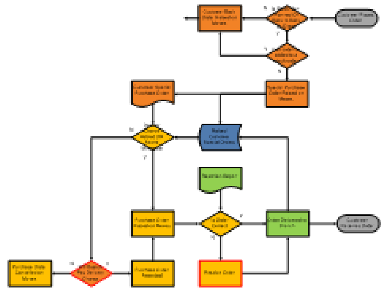
Specials (See handout)



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Specials

- Explanation
  - Non-stocked items and directs
  - Cannot be added to stock purchase orders
  - P&I place the orders with the suppliers
- Findings
  - Orders are raised by branches on Movex & purchase orders sent by email
  - The main queries that are dealt with are:
    1. Delivery charges
    2. Individual product pricing

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Specials

- Issues
  - Same amount of staff as stock buyers doing less orders
  - Excessive time spent on queries
  - Orders raised by branches without the correct information
- Proposed Solutions
  1. Move responsibility to a central location
  2. Move responsibility to projects department
  3. Move responsibility to branches and maintain centrally
  4. Improve current processes

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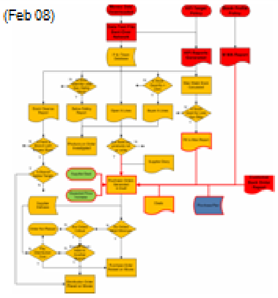
APPENDIX AP: Purchasing and inventory presentation (continued)

Order Generation

Example – Leeds (Feb 08)
(See handout)



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Order Generation

- Explanation
  - Generated through combination of reports & system generation
  - Proposals on Movex are made when stock level reaches reorder point
  - Purchases placed using supplier diary
  - Customer back orders (purchases to fill outstanding customer orders) and MSIB added
- Findings
  - Different strategies used at each regional P&I office
  - Fill to max used to reach minimum
  - Some orders are created to meet deals
    - One off's, existing deals, expected price increases

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Order Generation

- Issues
  - No consistent approach
  - Stock purchased before it is required
  - Stock purchased to create BGB
- Proposed Solutions
  - Consistent model across the regions
  - Order from purchase plan
  - Don't create extra orders that aren't required to obtain BGB (not strategic stock)

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Key Performance Indicators (KPI's)

- Explanation
  - Manage stock and service levels
  - Key driver for management decisions and the evolution of purchasing processes
- Findings
  - Availability & depth targets maintain sufficient stock levels to meet customer demand
  - Order durations targets maintain customer service levels
  - Regional stock value target used to maintain stock holding costs

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Key Performance Indicators (KPI's)

- Targets
  - **A Line Availability (98%)** – Targets A Line stock to be above zero
  - **A Line Depth (92%)** – Targets A Line stock to be above safety stock.
  - **ABC Line Availability (94%)** – Targets ABC line stock to be above zero
  - **Stock PO's > 3 Months** – Purchase orders once ordered have to be delivered within 3 months.
  - **DO's > 10 Days** – Distribution orders have to be delivered within 10 days
  - **CBO's > 10 Days** – Customer back orders have to be delivered within 10 days
  - **Forecast Alarms** – All forecast alarms have to be cancelled by the end of the next month
  - **Stock Value Under Target** – The value of stock has to be below the target value by the end of the year.

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Key Performance Indicators (KPI's)

- Issues
  - There are more targets for service levels which increases stock
  - Depth target creates minimum level of 12 days stock
  - Falls in KPI's creates unnecessary stock buying
  - Some targets maybe outside of the control of P&I (CBO & DO)
  - Less than stringent target for excess stock
  - Scoring methods gives weighting to less important targets

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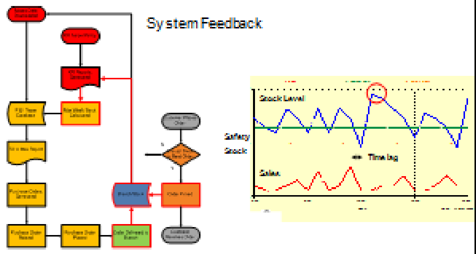
APPENDIX AP: Purchasing and inventory presentation (continued)

Key Performance Indicators (KPI's)



Key Performance Indicators (KPI's)

- Proposed Solutions
  - Explore current business priorities
  - Set and establish new set of business P&I driven KPI's
  - Set challenging stock targets
  - Targets that are in the control of P&I
  - Empowerment and accountability

Productivity

- Explanation
  - Technical ability to use functionalities within Movex
  - Technical ability to minimise the time taken for each process
- Findings
  - Each regional P&I office has different capabilities
- Issues
  - Excessive use of spreadsheets
  - Movex is underused
  - Lack of technical capabilities at some P&I offices
  - Processes such as forecast alarms can be significantly improved

Productivity

- Proposed Solutions
  - Use Movex functions where possible
  - Consolidate spreadsheets and only use applicable data
  - Find optimum solutions for task completion
  - Create best practice across regional P&I offices
  - Manager meetings to discuss improved business practices

Organisational Dysfunctionality

- Issues
  - Mismatch between the P&I regions in the way products are purchased and delivered
  - Some branches aren't using the best strategy for replenishment from the RDC's
  - Organisational conflict between regional P&I offices and Park Royal RDC

Conclusions

- Comprehensive detailed review of P&I policies required
- Many areas for improvement for processes and system functionality
- Improvements can lead to:
  - Staff reductions
  - Reduced stock holding
  - Reduced purchasing
  - Improved customer service

APPENDIX AQ: North-East region branches

Branch no	Branch code	Branch name	No of products
1	GAA	Stockton RDC	4052
2	GFD	Leeds	2927
3	GHB	Sheffield	2737
4	GBY	Bradford	1907
5	GIP	York	2000
6	GEQ	Hull	2095
7	GEJ	Harrogate	1265
8	GDQ	Durham	985
9	GDF	Darlington	941
10	GGZ	Scunthorpe	1023
11	GDJ	Doncaster	1600
12	GEG	Grimsby	1823
13	GEP	Huddersfield	1209
14	GFT	Newcastle	1606
15	GBT	Blyth	1026
16	GKE	Heaton	1106
17	GBH	Barnsley	883
18	GIB	Wakefield	818

APPENDIX AR: South-West region branches

Branch no	Branch code	Branch name	No of products
1	HAA	Peterborough	4205
2	HFY	Norwich	2271
3	HCI	Cambridge	2710
4	HEX	Kings Lynn	1727
5	HFX	Northampton	2003
6	HEF	Great Yarmouth	1837
7	HII	Wisbech	1073
8	HCG	Bury St Edmunds	1703
9	HET	Ipswich	1849
10	HFM	Luton	1453
11	HHJ	Spalding	1284
12	HBX	Boston	1006
13	HBQ	Bishops Stortford	1012
14	HFP	Milton Keynes	962
15	HJK	Kettering	905

APPENDIX AS: Anglia region branches

Branch no	Branch code	Branch name	No of products
1	MAA	Avonmouth	3341
2	MBK	Bath	748
3	MCC	Bristol	1255
4	MCL	Cardiff	1507
5	MDW	Exeter	823
6	MEH	Guernsey	971
7	MFV	Newport	642
8	MFW	Newton Abbot	505
9	MGF	Pembroke Dock	935
10	MGJ	Plymouth	1276
11	MHS	Swansea	1258
12	MHT	Swindon	800
13	MHY	Truro	918
14	MIE	Weston Super Mare	498
15	MIO	Yate	623
16	MJC	Bridgend	652
17	MJF	Carmarthen	723
18	MJX	Yeovil	835