Preface

This report is a master thesis written for the Department of design sciences at Lund University. We would like to thank our instructor university lector Mats Johnsson for all help during our work with this rapport and the project in general. We also would like to thank Darrell Harvey and Scott Howitt at IKEA in the UK for their help with data collection and advice.

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SAMMANFATTNING

Titel: Simulating the Supply Chainwith LORD

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Inledning: För att behålla sin konkurrenskraft så måste industriella organisationer hela tiden genomföra förändringar som leder till förbättrad produktkvalité, minskade produktutvecklingstider samt minskade produktionskostnader och ledtider. Vidare så kan dessa förbättringar inte genomföras effektivt om förändringar endast görs på specifika enheter i organisationen.

"The supply chain" (Försörjningskedjan) är ett revolutionerande koncept som är inneslutet i en traditionell utformning. I korthet kan försörjningskedjan sägas vara den väg som fysiskt gods och information tar från leverantören till kunden och alla steg dem emellan. Supply ChainManagement förändrar efterfrågan på materialflödet. Hanteringen av försörjningskedjan har blivit en av de viktigaste uppgifterna för företagsledare de senaste åren.

Användandet av simuleringsverktyg har pågått länge inom tillverkningsindustrin. Eftersom användandet av simuleringar ökade och tillgången på simuleringsverktyg blev större under 1980-talet så ledde detta till att simuleringar fick fler tillämpningsområden och därmed blev också fler människor bekanta med detta.

Den primära uppgiften för en företagsledare är att integrera varje del i organisationen till ett större system Enskilda organisationer på varje nivå sköter fortfarande sina egna tillgångar och försöker nå egna mål men när företagen inom försörjningskedjan arbetar tillsammans som ett företag visar sig den sanna inflytelsekällan.

Simuleringsteknologi framträder idag som ett nytt verktyg inom Supply ChainManagement och dess främsta styrka ligger i att kunna utvärdera variationer i olika system och deras beroendeförhållanden. Dessa nyckelkomponenter underlättar för beslutsfattare att utvärdera förändringar i delar av försörjningskedjan och kan visualisera de genomslag som de förändringarna får på andra komponenter i systemet och i slutändan på hela värdekedjan.

Problemformulering: IKEA expanderar i Storbritannien. Denna situation skapar en rad nya utmaningar. Hur kommer transportkostnaderna att se ut i framtiden? Är det möjligt för IKEA att ha bara ett DC i Storbritannien.

IKEA är i behov av information om Supply Chain. Är LORD ett lämpligt program för IKEA och hur arbetar man med LORD?

Målformulering: Arbetes mål är:

- Simulera den nuvarande situationen samt att använda den som en benchmarking modell mot andra modeller.
- Utvärdera programmet LORD och se om IKEA kan använda det som ett simuleringsverktyg.
- Skapa upp till fyra olika scenarier.
- Finna en lösning som passar IKEAs framtida behov.
- Att identifiera lämpligt antal DCn och deras placering

Slutsatser: Att kunna använda ett simuleringsverktyg som kan arbeta med en modell som inte behöver förenklas i en större grad skulle vara en stor tillgång till IKEA och deras beslutsfattande eftersom de opererar i en komplex omvärld.

LORD är ett program som mycket väl kan lämpa sig för mindre företag som vill simulera olika tidsbegränsade problem som inte kräver allt för mycket indata. Programmet skulle även vara lämpat för IKEA om det blir mer utvecklat men den versionen som finns tillgänglig idag är inte något som vi vill rekommendera. För IKEA:s del skulle det bästa vara ifall programmet hade ett fungerande Excel-gränssnitt och hade förmågan att kunna köra avancerade simuleringar med en snabbare och mer tillförlitlig hastighet.

Kanske kan IKEA gå över till att endast använda ett DC men denna handling kräver en mer genomgående undersökning och simuleringar med mer indata. Simuleringarna som vi har gjort ger en fingervisning om att transportkostnaderna inte skenar iväg, de kan till och med bli lägre än vad de är idag.

ABSTRACT

Title: Simulating the Supply Chainwith LORD

Authors: Rikard Hedenblad
Marcus Ljungdahl

Instructors: Mats Johnsson at the Department of Design Sciences, Packaging Logistics, Lund Institute of Technology.
Darrell Harvey at IKEA in Thrapston, UK

Introduction: To remain competitive, industrial organisations are continually faced with the challenges to improve product quality, reduce product development time, reduce production costs and lead-times. Increasingly, these challenges cannot be effectively met by isolated changes to specific organizational units.

The Supply Chainis a revolutionary concept embedded in a traditional guise. In brief a Supply Chaincan be said to be the way physical goods and virtual information travels from the supplier to the customer and all the steps there between. Supply ChainManagement changes the demands on the material flow. Managing the Supply Chainhas become one of the most important tasks for managers in the recent years.

The use of simulation tools has long been used in manufacturing and assembly operations. As the use of simulations grew in the 1980s and the availability of simulation packages it helped to push the tool into many other application areas and thus exposed new groups of people to simulation.

The primary task for a manager is to integrate each stage into a larger system. Individual organisations at each stage still manage resources, set objectives and pursue individual objectives but when the companies within the Supply Chainwork as one the true source of leverage appear.

Simulation technology is emerging as a new tool in Supply ChainManagement and its basic strength is in evaluating system variation and interdependencies. This key component allows a decision maker to evaluate changes in part of the Supply Chainand visualize the impact those changes have on the other system components and ultimately the performance of the entire supply chain.

Problem Definition: IKEA is expanding in the United Kingdom. Due to this situation a number of problems will arise. How will the transportation costs look like in the future? Is it possible for IKEA to have only one DC in the UK?

IKEA is in need of information about the Supply Chain. Is LORD a suitable program for IKEA and how does it work?

Objectives: The objectives with the project are:

- To simulate the current situation and to build a simulation model which we can use for benchmarking.
- To evaluate the program LORD and see if it would fit for IKEA as a simulation tool.

- Create up to four different scenarios.
- To find a solution that fits the future needs of IKEA.
- The desired output is to identify the optimum number and location of DCs for the network.

Conclusions: To use a simulation tool that can work with a model without making too many simplifications would be a great asset to IKEA and help them in their decision making since they operate in a complex environment.

Lord is program that may be very well suited for a minor company to model problems of limited scope in time and in data. It may also, with more develop, become a suitable tool but the version available today is not one we would recommend. For IKEA's case the best thing would be if it had a working excel-interface and the capability to run advanced simulation at a faster and more reliable rate.

Maybe IKEA can switch to one DC, but this action needs a more thorough investigation and simulation with more correct data. The simulations that we have made gives a hunch that the transportation costs can be kept under control and maybe in fact be a bit lower than they are today.

CONTENTS

1 Introduction

1.1 Background

IKEA currently operate 11 stores, supported by three DCs. The DCs are located in Doncaster, Thrapston and a supportive DC at Dunstable. The majority of the products are imported through Harwich, Immingham and Southampton, either in containers or in palletised form. The Doncaster site has recently been commissioned and has taken over those elements of the Supply Chainpreviously serviced from Belgium. For historical reasons this has meant that Thrapston handles predominantly the furniture article range and Doncaster handles smaller Satellite article range.

As part of IKEA's five-year fiscal plan there is an intention to develop a further eleven stores in the UK. This will also be accompanied by developments in Internet shopping and direct-to-customer deliveries. In order to support this growth the DC infrastructure will need to be developed. Two possible sites at Peterborough and Stanton, near Bury St Edmunds, have already been identified, along with opportunities to extend existing facilities.

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1.3 Objectives

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1.4 Delimitations

Simulations can be very complex. We had to limit our scope of input data to keep the complexity of the model down. Instead of using more than 10,000 different articles, we focused on 6 different product types. In this case, when LORD is not an optimisation tool, one can run hundreds of different scenarios before it is safe to say where the best location is to put a new DC. Therefore, we focused on four different scenarios and compared the transportation costs. These models are based on today's situation, IKEA's planned investments and our own assumptions.

1.5 Methodology

The purpose with this chapter is to describe our research approach and how the work proceeded during this report. This chapter also describes why we chose IKEA and the LORD programme for our master thesis. Further more, this chapter will describe how knowledge through different sciences are built up and tried out. Below we will describe three fundamental traditions that cover the most of today's research. These are the system theory, the positivism and the hermeneutics.

1.5.1 The positivism

The positivism took its form in the beginning of the 20th century in Austria and Germany. Its main thesis tells us that a scientific thesis does not say anything unless it can be empirical verified. The explanations should be given in the form of cause and effect and the knowledge in conformity to law. In the positivism should scientific rationality prevail and the scientist has to be objective i.e. only rely on facts and not let personal feelings and opinions have influence on the results. This research tradition has been criticised for this. The critics mean that people should not be handled as objects without feelings and own opinions. Natural science is the science that practices the positivism the most. It often seeks explanations on the lowest possible level and it often tries to reduce all phenomenons to something measurable[1].

1.5.2 The hermeneutics

Hermeneutics deals with interpretation. This could be in the form of everything from decoding conventions and symbols to understanding a person's situation in life. It is in the areas of psychology and healthcare the main interest for the hermeneutics exists. This is because the positivistic research is considered not to be sufficient. In the research process one alters between the entirety of the system and a part of it and observes any conflicts between them. It is also important that the interpretation is done with the knowledge of how and in what context the text has been made and in what situation the reader is. Hermeneutics can also be used as a method for communication and understanding.[2]

1.5.3 The system theory

The system theory was created in the end of the 1960s. This was partly due to the criticism to the positivism and partly as an attempt to hang on to the development that took place in the branches of technology and biology. The purposes of this theory are to understand and plan the complex connections with many different factors that interact with each other. There are usually two kinds of systems that are discussed; the constructed (devices, organisations etc.) and the natural (ecosystem, organisms etc.). It is of great importance to make a clear definition of the system and to make delimitations against other systems. This is done to avoid unnecessary effort in examine irrelevant factors. It is also important to study the flow of material, energy and information within the system and between the system and its surroundings since a system can be a part of a bigger system. As in the positivism, the system theory has focus on measurement, comparison, rationalism and technology. The main thing that differs from the positivism is that, in the system theory, the overall view of the system is central.[3]

[1] Wallén, G. "Vetenskapsteori och forskningsmetodik" Studentlitteratur, 2000
[2] Wallén, G. "Vetenskapsteori och forskningsmetodik" Studentlitteratur, 2000
[3] Wallén, G. "Vetenskapsteori och forskningsmetodik" Studentlitteratur, 2000

We have in our master thesis used the system theory. The IKEA logistics in the UK involves a lot of different flows and products that influence each other. It was also of great importance to define the system to know what data to be gathered and to avoid building a model that was too complex.

1.5.4 Quantitative and qualitative methods

There are many different research methods, some are more general and other are more specialised for a certain purpose. In the literature there are two dominating methods that often appear: quantitative and qualitative methods. These methods are often used together so it would be wrong to say that one method exclude the other. Below we will describe the principal features of the two methods.

1.5.4.1 Quantitative method

One can say that quantitative methods are based on quantity. Partly one tries to gather so many facts as possible by asking for it so many times as possible, partly one gather data to process and then later on present the conclusions in form of numbers. This method has strong influences from the statistics and its applications on relation analysis.

1.5.4.2 Qualitative methods

Qualitative methods are, on principle, the straight opposite to quantitative methods. This procedure means that instead of getting as many answers as possible, one tries to get less answers but of greater quality. This is done by intensive case studies. The results are often presented in form of verbal descriptions and explanations[4].

If we have to pick one of these two procedures it would be the quantitative method. The work involves the comparison of different parameters.

1.6 Target group

The target group for this master thesis is primary IKEA in the UK. Secondly, of course, for people interested in logistics and simulations. Most important of all is also that this is a master thesis made at the Department of Design Sciences, Division of Packaging Logistics at Lund Institute of Technology, University of Lund, Sweden and that it fulfils the requirements for a MSc Degree in Mechanical Engineering.

1.6.1 Choice of Subject

The subject for this master thesis was predefined by IKEA and announced by the Division of Packaging (Department of Design Sciences). That is also the reason why we used the LORD simulation software. We are both very interested in simulation software so we did not hesitate to choose this project.

1.6.2 Sequence of Work

1.6.2.1 Study of literature

To extend our knowledge base in this area of logistic simulations we began with study of literature. This proceeded during the whole process of the project. Above our own course literature we used literature from our supervisor, different libraries and the Internet.

[4] http://home.swipnet.se/~w-90687/usability 2002-05-03

1.6.2.2 Gathering information

To be able to build up a model in LORD we had to gather a large quantity of data. IKEA in Thrapston, UK, has a large database. Unfortunately, they were not able to give us all the information we needed. It was very difficult to get all the necessary data at one time so we got additional data throughout the project. We also visited the DC's in Thrapston and Doncaster to get an overall idea of the situation today. All data to and from IKEA were sent by e-mail.

1.6.2.3 Building a model

To begin with we had to build a basic model of the present situation. This was the most difficult part of the project. The basic model had to be somewhat near the reality otherwise there was not any point in doing any extended models. Further on we built a couple of extended models with different locations of future DC's.

1.6.2.4 The simulations

We simulated a couple of different scenarios, each with new locations for future DCs and stores. Further more we simulated the scenario with only one DC. Each scenario was simulated a couple of times to make sure that the output were reliable. The time of which the scenarios were simulated was set to 180 days. An average simulation took about thirty minutes to finish.

1.6.2.5 Analyses

The results from the simulations were analysed with focus on the logistics costs. The results are presented in the report.

1.6.3 Modelling Strategy

It was of great importance to have a right modelling strategy from the beginning as this saves resources and time. Doubling the number of details improves the results only a little but may require many times more effort. To be able to get the correct information, it is important that the right persons are involved from the very beginning. A number of people from IKEA helped us with the information needed.

Most logistics planning tasks are finished most efficiently by just modelling a minor part of the operations. This is done, for example, by limiting the model to a restricted modelling period, a small number of certain delivery types and to the most typical products/segments. It is also important not to strive for too accurate data that takes a great deal of time. Complete accurate data aren't, as in this case, necessary to obtain the objectives.

We used a top-down modelling approach. With a top-down approach means developing a very simple and rough model first, for testing. The testing is needed to see if the model works. As next steps, the scope of the model was broadened and more details were included[5].

As the project went along, we had to make many small practical modelling strategy decisions. For example, we had to decide how to convert existing data from available formats to a functional format in the software.

[5] Virtual Supply Chain – Interactive Cases and Exercises, Remix Ltd, 1999

1.7 About IKEA

Ingvar Kamprad created IKEA in 1943 when he was seventeen years old. In the beginning he sold almost anything that filled a need at a low cost. This included everything from pens to wallets and jewellery. Furniture was first introduced in IKEA's product mix in 1947. The decision to include furniture in the product mix turned out to be a success and in 1951 the founder decided to focus wholeheartedly on low-price furniture. In 1955 IKEA started to design its own furniture and in 1956 IKEA began to experiment with flat packages. The opening of the first IKEA department store took place in 1958. During the 1960s and the 1970s IKEA expanded both inside and outside Europe and in 1983 IKEA had 6000 employees. The concept of children's IKEA was developed in 1997 and its goal was to make IKEA and its products more suitable for children. The turn over from the year of 1954 to 2001 is shown in figure 1, every number in million Euros.

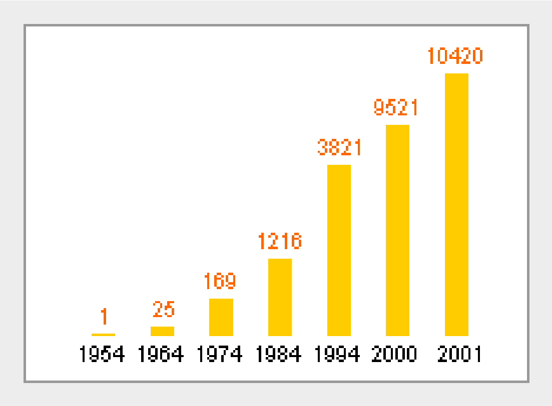

Figure 1 - IKEA's turnover in million euros

The IKEA group had on the 31 august 2001, 143 stores in 22 countries. There are also 20 stores that are owned and managed by franchising companies outside the IKEA group. IKEA has about 2000 suppliers in 55 countries and 40 purchasing offices in 33 countries. The turnover was 10.4 billion Euros. Eighty percent of the sales where made in Europe, as shown in the figure 2, where the big area represents the sales in Europe, the second largest north-America and the smallest Asia.

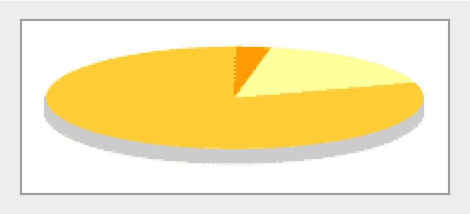

Figure 2 - The size of IKEA's different markets

IKEA has today about 65000 employees, 48000 of them works in the sales department, the rest with procurement[6].

[6] www.ikea.se, 2002-03-18

Part I: THEORETICAL FRAMEWORK

The schematic below represents how we have constructed the theory chapter. We have focused on making the theory as two cone shaped models where one level, when finished, lead to the next. This will bind the theory together and hopefully make it easier for a reader to grasp. Chapter 2.3 will be constructed in the manner of the goods actual physical flow, as it enters the UK and until it is dispatched in the DCs. This chapter will focus mainly on the warehouses since this is the field where IKEA have most influence, and where the biggest potential for changes exists.

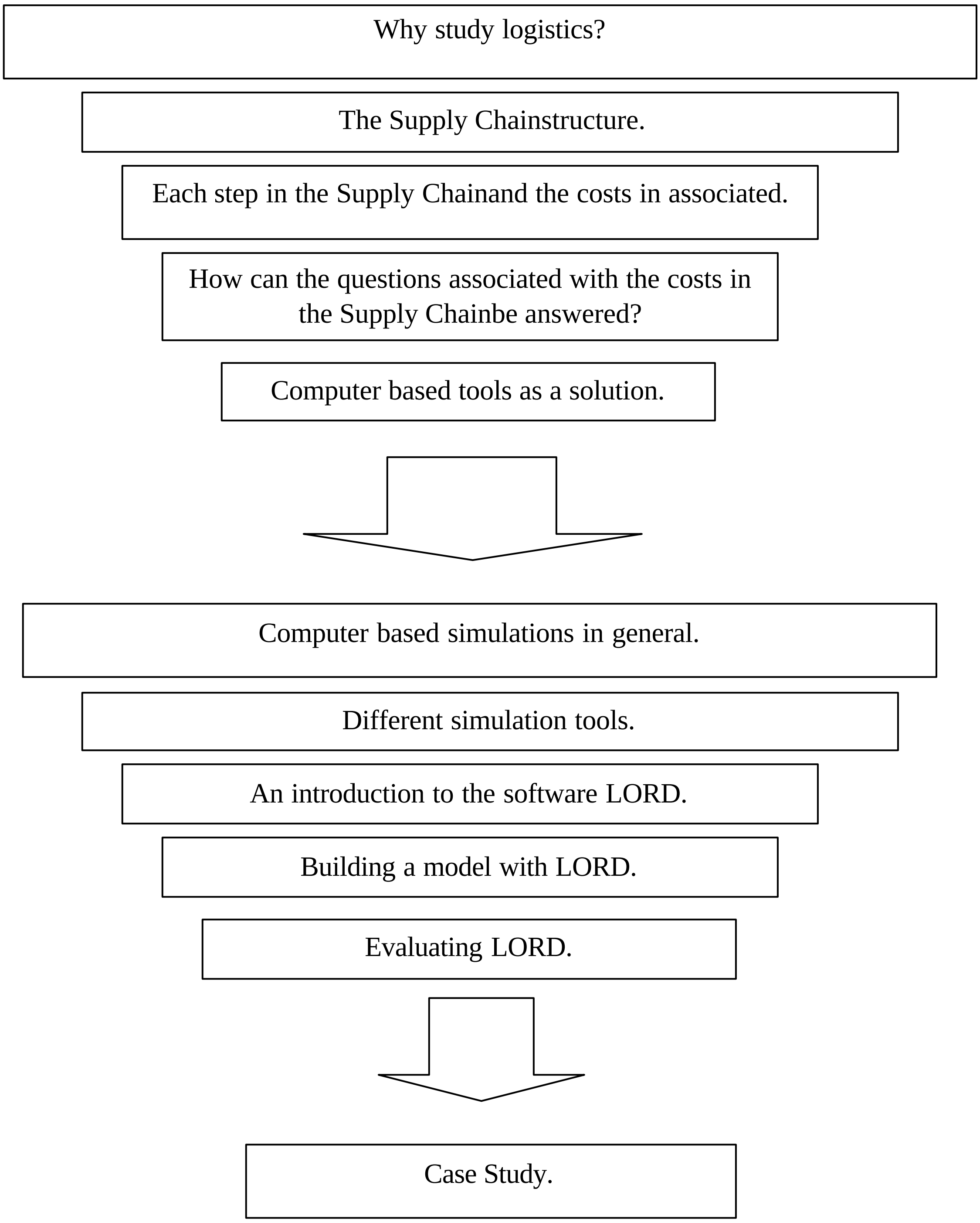

Figure 3 - Disposition of the thesis

2 Why study logistics problem

The definition of logistics is not really consequent. It is uncertain if different activities such as transportation, warehousing or shipping are logistics or if logistics first develops when activities are combined together to a process oriented service. The most common and accepted opinion is that the term logistics refers to the integrated process.[7]

During the last decades logistics have begun to take an important role in almost every company. This is due to the insight that logistics costs stand for a major part of a company's total costs. Logistics should be a core competence for multinational companies with transports over large distances. Depending on how the logistics is defined different results of the total logistics cost are derived. Typical costs are costs for internal and external transportation, warehousing costs, material handling, order processing and administration. The costs for raw material and components are frequently included in the logistics costs. The total logistics cost could be somewhere between 40 and 80 per cent of the total costs depending on which company that is studied.[8]

Since the mid sixties the growth in trade has been greater than the growth of the worlds total GDP.[9] This have led to that most of the markets have become more global in the resent years. This does not only mean increased flow of goods but also that the competition has increased. It is also important to cut costs and create more value for money as competition hardens. In addition, companies may find the need to distinguish themselves from rivals. This is often done by adding features to the product or the package, which of course leads to added logistics costs. Another type of differentiation is that if the supplier can guarantee a short lead-time between the order point and the receiving. Combining this with the demand for low stock levels and cost cuts leads to an increased demand for good logistics solutions.[10]

The trend that has been predominated since the mid sixties is expected to continue. For developed industrial nations the growth in trade will increase further with the creating of large trade areas such as the EU and ASEAN.[11] Companies have to become more focused on the market to survive this situation. Companies also have to realise that even small market changes can effect the company. The market is no longer driven by the producers but by the customers, which in turn leads to shorter product life cycles and products designed especially for a particular group of customers. In reality this may lead to that 50 per cent of the products and components companies now have in stock may be out of date.

The response to these challenges are shorter developing times for products, increased sensitivity to customer demands, shorter lead times in production and a more flexible production apparatus. This should be combined with swiftness and precision in the whole flow of materials. All this leads to a demand for more advanced logistical tools and a focus on the logistical aspects throughout the company.[12]

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[7] www.swedfreight.se, 2002-04-07
[8] Persson G, Virum H "Logistik för konkurrenskraft" Liber Ekonomi, 1999
[9] Dicken P. "Global Shift- Transforming the World Economy" Paul Chapman Publishing Ltd, 1999
[10] Schary P, Skjött-Larsen T "Managing the global Supply Chain" Copenhagen Business School Press, 2001
[11] Dicken P. "Global Shift- Transforming the World Economy" Paul Chapman Publishing Ltd, 1999
[12] Schary P, Skjött-Larsen T "Managing the global Supply Chain" Copenhagen Business School Press, 2001

One of the aspects that are growing most rapidly in the logistical field is the use of IT and computers as a base for business. There are many definitions of electronic business but OECD has stated one that have gained acceptance. They state:

"Business occurring over networks which use non-proprietary protocols that are established through an open standard setting process such as the Internet… the term "business" refers to all activity that generates value both within a firm (internally) and with suppliers and customers (externally). Some of this activity may result in a monetary transaction and some will not" [13]

The statement OECD has made does not limit the electronic businesses to transactions that include purchases and sales but rather all situations where business documents are exchanged. Some examples of this are: placing orders, verifying orders, delivery notes, invoices, contracts etc. The information technology enables companies to reduce stocks and overcapacity in production.

The information technology also threatens old structures as it enables replacement for many manually done routine procedures within a wide range of sectors such as traditional industry, trade and insurance businesses.[14]

[13] Hörndahl R "Den nya ekonomin. Elektroniska affärer I svensk industri" Ekonomi-Print. 2000
[14] Hörndahl R "Den nya ekonomin. Elektroniska affärer I svensk industri" Ekonomi-Print. 2000

3 Definition of a Supply Chain

3.1 Introduction

To remain competitive, industrial organizations are continually faced with the challenges to improve product quality, reduce product development time, reduce production costs and lead-times. Increasingly, these challenges cannot be effectively met by isolated changes to specific organizational units. The need have to be met by the relationships and interdependencies among different organizations. As the markets moves towards a global economy, companies are increasingly inclined toward specific and high-value-adding manufacturing niches. This will lead to new challenges and problems with establishing and maintaining efficient material flows along product Supply Chains. The ongoing competitiveness of an organization is tied to the dynamics of its Supply Chainand the recognition of this fact is leading to considerable change in the way organizations interact with their environment and Supply Chainpartners.[15]

The term Supply ChainManagement was originally introduced by consultants in the early 1980s and has subsequently gained tremendous attention.[16] The Supply Chainis a revolutionary concept embedded in a traditional guise.[17] In brief a Supply Chaincan be said to be the way physical goods and virtual information travels from the supplier to the customer and all the steps there between.[18] Supply ChainManagement changes the demands on the material flow.[19] Managing the Supply Chainhas become one of the most important tasks for managers in the recent years. Managing the Supply Chainis not just the same as the traditional logistics aspect but rather implies a deeper relationship between the different actors in the Supply Chain. The company's position will often strengthen by developing a deeper relationship with its key actors. A company can start a joined research project with a key supplier for example.[20]

The terms "upstream" and "downstream" are often used when the Supply Chainis discussed. "Upstream" describes the actors before the goods or information reaches the company. In the same manner, "downstream" describe the actors after the company. In this perspective the Supply Chainin seen as a river on which goods and information flows between different actors.[21]

3.2 The value chain

The Supply Chain's underlying framework is the Value chain developed by Michael Porter.[22] As the Supply Chaindescribes the company's external relationships the "*Value Chain describes the activities within and around an organization, and relates them to an analysis of the competitive strength of the organization*". The value chain is constructed of a series of primary processes (inbound logistics, operations, outbound logistics, sales and services) that adds value to the output of the firm. These processes are supported by four "support

[15] www.2.cs.cmu.edu, 2002-04-29
[16] Lambert D "Supply ChainManagement: what does it Involve?" The Ohio State University, 1998
[17] Schary P, Skjött-Larsen T "Managing the global Supply Chain" Copenhagen Business School Press, 2001
[18] Persson G, Virum H "Logistik för konkurrenskraft" Liber Ekonomi, 1999
[19] www.adea.se, 2002-04-29
[20] Persson G, Virum H "Logistik för konkurrenskraft" Liber Ekonomi, 1999
[21] Simachi-Levi D, Kaninsky P, Simachi-Levi E "Designing and Managing the Supply Chain" Irwin/McGraw-Hill, 1999.
[22] Schary P, Skjött-Larsen T "Managing the global Supply Chain" Copenhagen Business School Press, 2001

activities" which helps to improve the effectiveness or efficiency of primary activities. The "support activities" are: firm infrastructure, human resource management, technology development and procurement.[23]

3.3 Drivers behind the Supply Chaindevelopment

The reason behind the development of the Supply Chaincan be said to be the comprehension that one firm, or a department, are not sufficient to meet the end customers' needs. The organisations in the Supply Chainmust come together as a coordinated system, the true source of leverage.[24]

Business is rapidly moving towards new perspectives of closely coordinated, cooperative, networks or business ecosystems that are competing with other networks. The focus is on managing processes that engage other firms as partners in managed relationships to perform the activities that are necessary to fulfil the process. This is driven partly by the realisation that one firm alone cannot be good at everything and partly by the expanding ease and reach of communication. The Supply Chainperspective cannot be said to be only for growth, but for the survival in a harsh global competitive environment as well. No firm alone can accomplish the complete process of meeting the demands of the market in the face of intense competition, evolving customer requirements and changing technologies. A more detailed description is necessary to understand the drivers behind the Supply Chain.[25]

There are five fundamental themes that have driven the development of the Supply Chain.

1. *The customer orientation*. The customer requirements in product offerings and response are supreme. This has led to direct ordering, real-time operations and product and service customisation.
2. *Smaller inventories*. The production quantities are smaller, saving inventory holding costs while it increases the flexibility in the production and distribution. The trend to smaller inventories is increased by the concept of lean thinking, which emphasises the reduction of waste and has a philosophy of continuous improvement.
3. *The decline of mass production*. Many industries have moved from mass manufacturing towards craft production. This is a reflection of the marketplace and the market segmentation. Drivers behind this development are the use of computer-assisted production and niche-markets with unique products and short, flexible runs.
4. *Development of electronic commerce*. The results of the Supply Chainare significant. As companies move towards Web-based supply, networks procurement has become more efficient. The distribution between the factory and market has become more direct with fewer inventories. This leads to shorter Supply Chains that are more reactive and responsive and can easily be switched to different products.
5. *Smaller organisations*. Many organizations are being reduced, both by downsizing and outsourcing. One outcome of this trend is the virtual organisation.[26]

[23] Johnson G, Scholes K "Exploring Corporate Strategy Gerry" Prentice Hall, 1999
[24] Schary P, Skjött-Larsen T "Managing the global Supply Chain" Copenhagen Business School Press, 2001
[25] Schary P, Skjött-Larsen T "Managing the global Supply Chain" Copenhagen Business School Press, 2001
[26] Schary P, Skjött-Larsen T "Managing the global Supply Chain" Copenhagen Business School Press, 2001

3.4 Requirements

The concept of the Supply Chainas presented above requires a wide scope. A manager can no longer see his company or department as a single object but must rather view his company as a part of a chain that must be optimised together with the rest of it. In this aspect it is crucial to realise that even if every operation is optimised singly the result may very well be, and in fact almost always is, worse than it would be if a Supply Chainapproach was used. This phenomenon can be explained with the following simple example. A manager calculates, from his perspective, the correct stock-level for the inbound logistics to achieve cost cuts. This is an action that may very well lower his costs. The next step in the Supply Chainon the other hand may have to struggle with higher costs due to shortage of materials and production stops.

To achieve a positive response from people and organisations it is important that everybody involved realises that Supply ChainManagement is not a collaboration that only one of the participants will gain from but instead that everybody involved benefits from having a Supply Chainview.[27]

3.5 Managing challenges

The primary task for a manager is to integrate each stage into a larger system. Individual organisations at each stage still manage resources, set objectives and pursue individual objectives. Even within a larger corporate framework there is a danger from independent decisions. Customers are remote, the lead times are long and markets change rapidly. Organisational independence invites conflicts.

The concept of the Supply Chainis shown in figure 4. As seen, coordination is imperative. It becomes the core of reducing the quantity of physical assets while this in turn leads to reduced costs and improves response to change. In a static sense it can improve the return on investment but it also provides the opportunity for strategy.[28]

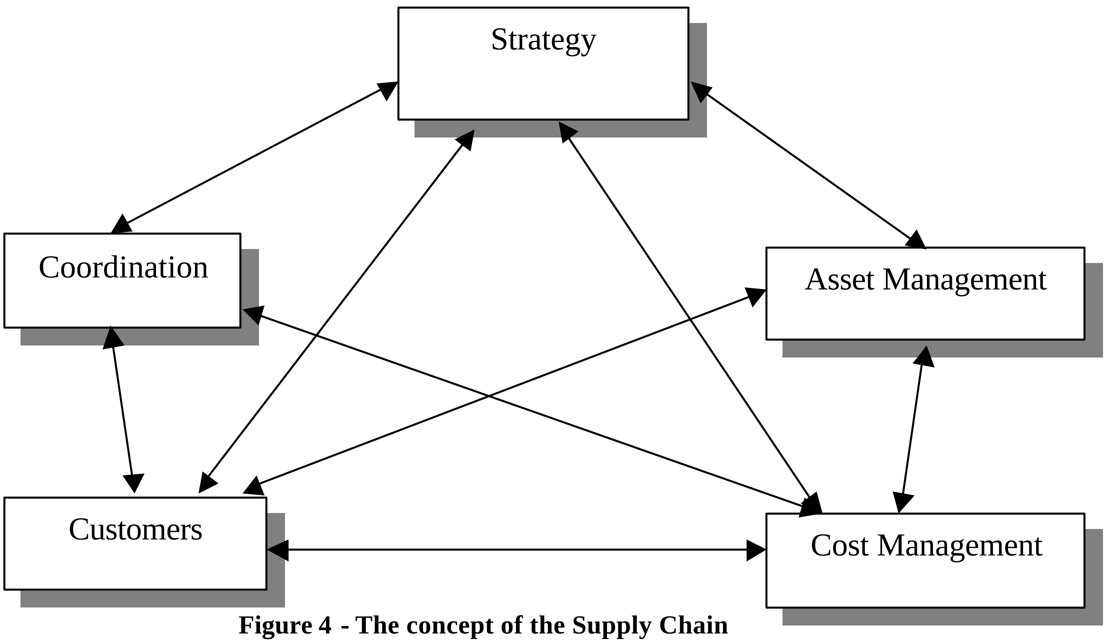

Figure 4 - The concept of the Supply Chain

[27] Persson G, Virum H ”Logistik för konkurrenskraft” Liber Ekonomi, 1999
[28] Schary P, Skjött-Larsen T “Managing the global Supply Chain” Copenhagen Business School Press, 2001

Coordination becomes the first management task. The market demands and the customer orders must be visible throughout the chain and therefore create a concerned effort to supply them. The tools for this task are information systems across normally traditional boundaries.

The Supply Chaintakes on characteristics that in them selves are not unique, but when the Supply Chainis viewed collectively it creates new management challenges. These challenges can be summarized into the following points:

- The Supply Chainis a complete process for providing services and goods to final user.
- Membership includes all parties including their logistical activities form initial material suppliers to final user.
- The scope of Supply Chainoperations includes procurement, production and distribution.
- A common information system that is accessible to all members makes coordination possible between the different organisations.
- Management extends across the organisational boundaries to include planning and control over operations of other organisational units.
- Member organisations achieve their own individual objective through the performance as the Supply Chainas a whole.[29]

3.6 Measuring the Supply Chainand key performance indicators

3.6.1 Introduction

Measuring an integrated Supply Chainis very different than measuring just a single part, mainly because the large number of organisations and companies involved in the Supply Chain.

A meaningful measurement system can be constructed by focusing on the purpose of the system. These measurements then allow you to focus on what is strategically important and to inspire change and action.[30]

3.6.2 Benchmarking

“Benchmarking is about comparing and measuring your performance against others in key business activities, and then using lessons learned from the best to make targeted improvements. It involves answering two questions – who is better, and why is they better? – With the aim of using this information to make changes that will lead to real improvements. The best performance achieved in practice is the benchmark.”[31]

There are two main types of benchmarking:

Competitive benchmarking - this is benchmarking against direct competitors in your own market. This may involve benchmarking of strategic measures such as market share, return on assets or customer satisfaction. It may also focus on functions or processes. It may stimulate improvement in the company if they can get a detailed view of their competitors’ situation. This information is usually hard to get though.

[29] Schary P, Skjött-Larsen T “Managing the global Supply Chain” Copenhagen Business School Press, 2001
[30] Holmberg S “Measurements on an integrated Supply Chain” KF-Sigma, 1997
[31] www.kpizone.com, 2002-04-27

The second type of benchmarking is called non-competitive benchmarking and this type of benchmarking are focused on strategic measures, functions or processes of non-competing companies or of functions/processes within the same organisation. Frequently, there may occur similarities between processes in companies in different industries. Benchmarking companies in other industries may very well lead to innovative approaches to old problems and lead to significant improvements. If a company only benchmarks against other companies in the same industry they are likely to just get as good as their competitors, not better.[32]

The benefits of benchmarking can be summarized into the following points

- Establishing effective business goals and objectives.
- Better performance in meeting customer requirements and needs.
- Help to measure the true productivity.
- Becoming competitive.
- Identifying and implementing best practice in business processes.[33]

A Key Performance Indicator (KPI) is an objective measurement tool for comparing company or project performance in key activities of a business. The key performance indicators provide a benchmark that a project or a company's performance can be measured against.[34] The information provided by a KPI can be used to determine how an organisation work compared with the benchmark, and is therefore a key component in an organisation's move towards best practice.

Key Performance Indicator can be used for a range of activities associated with a business, for example cost and time reduction: cost and time predictability: number of defects: accident records: client satisfaction: productivity and profitability.[35]

3.6.3 The Purpose of Key Performance Indicators

Companies need to objectively compare and benchmark their practices and performance so that they can identify areas of improvement. After the comparison the company needs to implement the changes that will lead to performance improvements. The purpose of a Key Performance Indicator is to provide an objective performance measures in a key activity associated with a company or project. This can then be used to compare and benchmark against the range of performance currently being achieved across other projects, companies or the rest of industry.[36]

3.7 Supply Chainrisks

Supply Chainrisks come in many different forms. First, the financial risk can be huge. Inventory costs due to obsolescence, markdowns and stock-outs, can be significant. Supply Chains that are not managed properly can lead to excessive or mismatched inventory and are thus liable to huge financial risks. Financial risks can come in the form of the risks of reworking stock and penalties for non-delivery of goods.

[32] Mann, R "What is benchmarking" United Business Media, 1996
[33] www.kpizone.com, 2002-04-27
[34] www.dti.gov.uk, 2002-04-19
[35] www.kpizone.com, 2002-04-20
[36] www.kpizone.com, 2002-04-20

Since a Supply Chainis complex it will lead to uncertainty forces that also can drive the "chaos" risks of a Supply Chain. These chaos effects stem from many factors such as: over-reactions, unnecessary interventions, second-guessing, mistrust, and distorted information throughout a Supply Chain. The well-known bullwhip effect, which describes increasing fluctuations of order patterns from downstream to upstream Supply Chains, is an example of such chaos. This increased nervousness will of course lead to higher costs and inefficiencies through over-ordering and "squirreling" inventory.

In the Supply Chainthere is the risk of nervousness and chaos which makes it impossible for every player in the Supply Chainto make the right decisions. The inevitable consequence of this is the making of wrong or ineffective decisions. For example, if there is uncertainty as to when materials or components will be available, it will not be possible to design optimal production schedules.

The Supply Chainis exposed to market risks, i.e. missing presented market opportunities. The responsiveness of a Supply Chaincannot be fit to changing market trends and customer preferences if the right market signals cannot be obtained.

A simple, yet good solution to most of these problems is to nourish relationships and increase the collaboration and confidence between the parts involved in the Supply Chainwork. By this course of action the different organisations feel that their partners "hold up their end of the bargain".[37]

[37] Christopher M, Lee H "Supply Chainconfidence" Cranfield University and Stanford University, 2001

4 The facilities of the Supply Chain

4.1 Introduction

In this chapter we will discuss the operations and facilities that are vital for our case company. This chapter will be heavily influenced by the modelling situation that we are facing in the case study. Chapter 4.2 will discuss properties of the whole Supply Chain, while 4.3 will discuss the individual facilities in the order they occur in the material flow.

4.2 A view of the whole Supply Chain

4.2.1 Logistics costs in general

The most common used figure when measuring the profits in a modern industry is the return on capital. The three factors in logistics that has the biggest impact on the return on capital are:[38]

1. *Supply service* - Supply service is a long term investment, but it is an investment worth making since bad supply service can damage the company's competitive profile. Another aspect is that the rate of the Supply service should not be regarded as just a fixed number on a curve but instead be seen as a mean to increase the company's competitive strength.

2. *Logistics costs* - Typical logistics are costs for intern and extern transportation, costs for running the warehouse, handling, order processing, maintenance and service of equipment and losses due theft and damaged goods. It is not unusual to view the costs for materials and components as a logistics costs and then total logistics costs can end up somewhere between 40 or 80 per cent.

3. *Capital costs* - Logistics have an impact on the capital that is tied down in assets in warehouses and production etc. Among the variable assets it is primarily the goods in warehouses that are mostly affected by how the logistical operations are conducted. This is both in regard to products at work, finished products and raw materials. The way the logistical activities are conducted also affects the capital investments in equipment and buildings.

4.2.2 Push or pull – two different philosophies

These two systems can be said to be each others opposites but both try to arrange the flows through the Supply Chainin a manner that optimises the flow rate and minimises the costs and the lead times. The push-system is based on what is commonly known as the Japanese production philosophy and is "based on demand".[39] This means that when there is a demand for a product at the end of the Supply Chainan order will be generated. This demand will flow backwards through the Supply Chainand therefore products are pulled through the system.

Push is the opposite of this. Instead of creating or delivering a product at an actual demand the push method calculates what the order quantities should be and then delivers the products. This sort of system has many disadvantages. The biggest of those is that the push-system

[38] Persson G, Virum H "Logistik för konkurrenskraft" Liber Ekonomi, 1999
[39] Rundqvist T "Kompendium Tillverkningssytem" LTH, 1999

leads to queues before the operations and thus to long lead and waiting times. The capital is then bound in the production, which leads to higher costs for the company. The only time a push system can be justified is when the demand is fixed for a long time and the variation in the Supply Chainis virtually non-existing, otherwise a pull system is always favourable.[40]

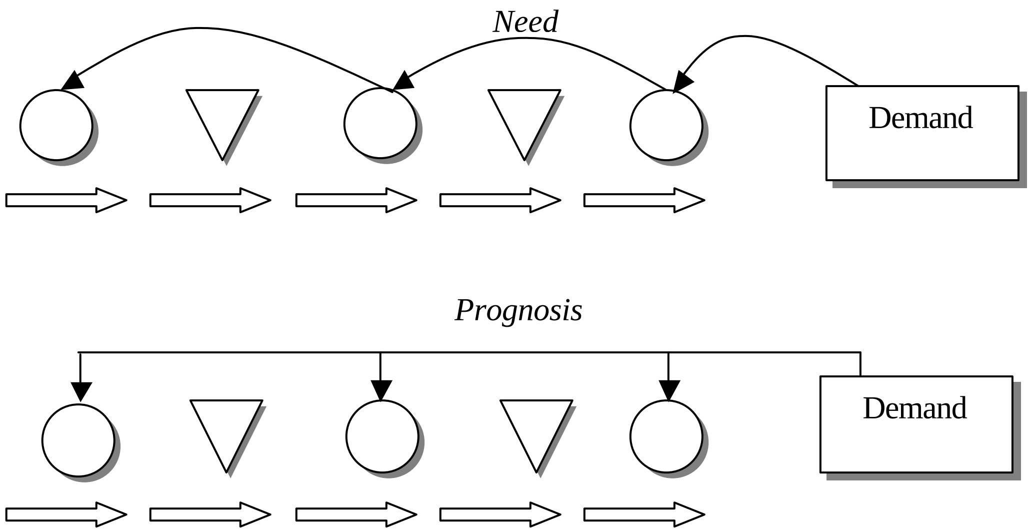

Figure 4 - Pull versus Push

4.2.3 Prognoses

To get an even flow to and from a warehouse and minimizing shortages it is important to know the order quantities. Since the order cannot be delivered instantly, the lead-time must be taken into account. Since the lead-time may change slightly and the demands even more a calculated guess of how much that needs to be ordered is necessary. Such a procedure is called making a prognosis. It is also vital to estimate the prognosis errors so that shortages do not occur.

When studying production and/or warehouses, a shorter span of the prognoses is often sufficient. A typical prognosis perspective is one or two years. There are two types of models that are of interest.

The first prognoses model is called "Extrapolation of historical data". Historical data and statistical models that are based on time series analysis are used when creating this kind of prognosis. Methods of this kind can with good result be implemented in a computer based warehousing control system. With a computer tool prognoses for thousands of articles can easily be created. Extrapolation of historical data is the most common way for making short time prognoses.

Sometimes the prognoses system mentioned above cannot provide a satisfying answer. Situations that do not depend on historical data cannot be analysed in such an easy manner and are often harder to estimate. This way of making prognoses is called "Prognoses which are based on different underlying causes". This problem is often solved with manual estimations of the demand. These demands can be of new products or products that are promoted during a sales campaign.[41]

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[40] Persson G, Virum H ”Logistik för konkurrenskraft” Liber Ekonomi, 1999
[41] Axsäter S ”Lagerstyrning” Studentlitteratur, 1991

4.3 The different facilities and operations in the Supply Chain

4.3.1 Terminals

A terminal is a facility where goods are changed from one vehicle to another. There is often a change in the means of transport, such as a ship unloads to trailers. Another function of the terminals is to gather small dispatches of goods into larger ones that are better suited for shipping. Some terminals also offer other functions such as long term warehousing abilities, direct delivery to customers and service depots for vehicles.

In the near future, with an increased demand for swift deliveries, the size of shipments will be smaller and smaller. This leads to an increased use of terminals as gathering and breaking points of the material flow.

There are many stakeholders in a terminal, especially if the investments are high. This is often the case for airports and harbours.[42]

4.3.2 Transports within the Supply Chain

The global Supply Chaindepends on the effective use of transportation networks. They vary widely depending on the range they are meant to operate in, all from region to continent.
A company can make the choice of having the transports and logistical activities in-house or outsourced. The way a company chooses depends on if it sees the logistical activities as core competences or as process that would be served more favourably by a third party. In this chapter we will mainly focus on the latter of the alternatives since this course of action best suits our overall work.[43]

4.3.2.1 Third party logistics

Since the beginning of the 1990s there has been a noticeable change in arrangements between shippers and logistical providers.[44] Outsourcing of logistics services has increased rapidly during the last few years.[45] Cooperation between parties has become long term in nature, mutually binding and there have also been changes in both organisations and information systems on both sides. The solutions offered by third party logistics companies are often tailored for a specific requirement. Value added activities such as packing, labelling and assembling are often included in the operations. This broader and more flexible agreement is titled Third Party Logistics (TPL).

A precise definition of what is entailed in the term Third Party Logistics is not possible because the term in still evolving. Lieb and Randall suggested this explanation to the TPL:
".. involves outsourcing logistics activities that have traditionally been performed within an organization. The functions performed by the third-party can encompass the entire logistics process, or more commonly, selected activities within that process."[46]

[42] "Kompendium Internationell distributionsteknik" LTH, 2002
[43] Schary P, Skjött-Larsen T "Managing the global Supply Chain" Copenhagen Business School Press, 2001
[44] Schary P, Skjött-Larsen T "Managing the global Supply Chain" Copenhagen Business School Press, 2001
[45] Bask A "Relationships among TPL providers and members of supply chains - a strategic perspective" The Journal of Business and Industrial Marketing; Volume 16 No. 6, 2001
[46] Schary P, Skjött-Larsen T "Managing the global Supply Chain" Copenhagen Business School Press, 2001

Supply Chainand logistics management, inbound and outbound transportations management, warehouse location planning, rate negotiations and transportations are examples of operations that can be carried out by a TPL.[47]

There are several forces behind the development of third party logistics. In a global environment, logistics and other Supply Chainactivities become more expensive, complex and capital intensive. By outsourcing these activities companies can reduce the capital tied in logistics and their overall logistics costs. The company may furthermore get the expertise that is missing. They can then focus on activities that they consider being their core activities instead.

The benefits of using a third-party logistics company can be:

- *The conversion of fixed costs to variable costs*. By outsourcing warehousing and logistical activities a company can free capital and transform costs that once were fixed so they become variable and can thereby transfer the financial risk to a third party.
- *Economics of scale and scope*. The third-party logistics company can use its assets to serve multiple clients. By doing so they can use their size to sink costs for each action carried out.
- *Creation of leaner and more flexible organizations*. The shipper may be able to simplify his processes and streamline routine logistics operations such as documentation, distribution planning and personnel administration. Dealing with one third party logistics company is more efficient than working with a number of haulers.
- *Faster access to new markets and distribution channels*. Here the company that outsourcers its logistics can use the network and the market knowledge of the third party logistics company. This gives the company that is set on expanding on a new market a fast and swift access to the new environment.[48]

Still there are some drawbacks to outsourcing or reasons why people do not outsource. These can be summarized as:

- The company may loose control over the process. It is imperative to choose the correct outsourcing partner and to form contractual arrangements to ensure appropriate delivery and lead times.
- Afraid of outsourcing competitive advantage.
- Partnering with wrong supplier.
- Company wants to integrate vertically.
- The outsourcing costs are not justified.
- Does not understand the benefits of outsourcing.[49]

[47] www.buslog.com, 2002-03-05
[48] Schary P, Skjött-Larsen T “Managing the global Supply Chain” Copenhagen Business School Press, 2001
[49] www.supplychaintoday.com, 2002-03-05

4.3.3 Warehouses

4.3.3.1 Background to warehouse control

In today's modern business world it is important to minimize every cost possible. One area that has been under scrutiny during the last years is the warehousing operations. It is necessary to have a good "stock control" to be able to reduce the stock level and the products in work while maintaining a good customer service.[50]

The awareness that a great deal of capital was bound in warehoused products was first conceived in Japan in the middle of the 20th century. In the mid seventies Japanese companies could offer cheaper products with higher quality than their western competitors. This was partly due to that the Japanese industries managed to reduce their warehousing costs.[51]

4.3.3.2 Economical theory for warehouses

The following costs are associated with warehousing:[52]

1. *Stock-keeping costs*. These costs are primarily costs for the capital bound in warehoused products. The capital tied up in goods in warehouses could instead be invested or used to pay back loans and thereby increase the company's financial situation.

2. *Order specific costs or production costs*. When an order is processed there will be costs for administration and sometimes costs for transport and handling.

3. *Shortage costs or service agreement*. If a product is ordered but cannot be delivered certain costs will occur. These costs are often very hard to estimate. If a customer does not mind waiting the order can be back ordered. If the customer chooses another supplier then the company have missed the profit contribution for that certain delivery. Every shortage will also lead to losses in goodwill, losses that are especially hard to calculate the costs for. Sometimes shortage costs can be accurately calculated, for example when a company chooses to buy the product from a competitor and then delivers it. The shortage cost is simply the additional cost that appears when purchasing the product instead of producing it.

When studying warehouses and when gathering data it is important to understand that the theoretical capacity, e.g. the volume the warehouse can hold, cannot be used in practical situations. A warehouse running at nearly 100 % fill rate is not nearly as efficient as one operating at a lower percentage. The results stem from that in a near full warehouse there will appear a lot of congestions, double handling and overtime work. Furthermore, there will be goods stacked in the aisles, delays on unloading, refusals, storage of goods waiting on the trailers and problems with despatch due to difficulty in locating and retrieving items.[53]

[50] Persson G, Virum H "Logistik för konkurrenskraft" Liber Ekonomi, 1999
[51] Rundqvist T "Kompendium Tillverkningssytem" LTH, 1999
[52] Persson G, Virum H "Logistik för konkurrenskraft" Liber Ekonomi, 1999
[53] Sussams J "Logistics Modelling" Trans-Atlantic Publications, 1992

4.3.3.3 Future trends

We have discussed the managing of a single warehouse, but we will now see what happens when we have more than one linked. Warehouses can be linked in three different types of systems. The first is called distribution system and it has the structure shown in figure 6.

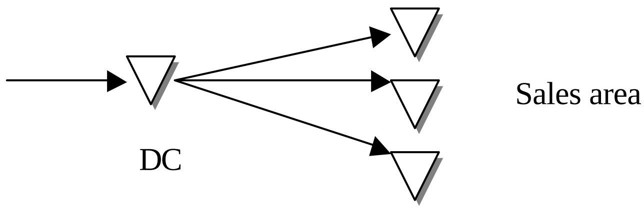

Figure 4 - Distribution system

The special feature for this system is that every warehouse only has one predecessor.

The second system is called a production system, a system quite common in the processing industry. Figure 7 shows a production system titled an assembly system since it allows only one warehouse to be next in line.

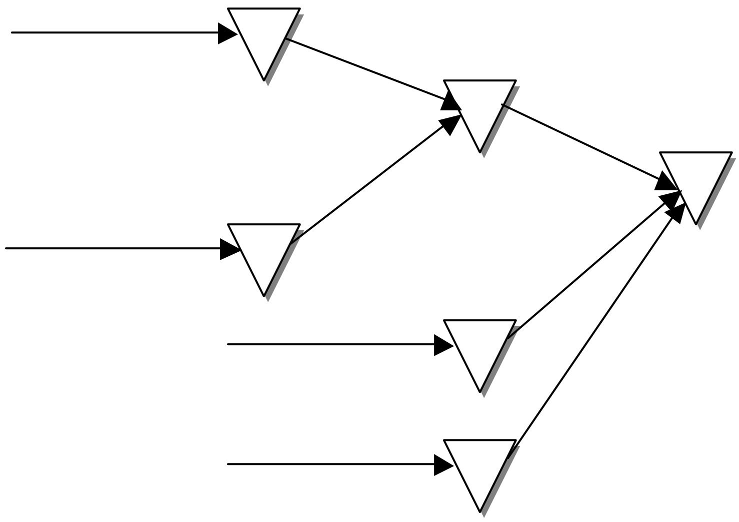

Figure 4 - Production system

The third system is called a general system and as the name implies it allows warehouses in various combinations.[54]

The future trends in modern logistics centre show that logistics are becoming more centralised in more than one aspect. The most important change is that warehousing is centralised, for example only one warehouse or DC serves a country or a region which formerly have been supplied by several smaller and local warehouses. This of course leads to more transportation but as long as the benefits from having a single DC exceed the disadvantages of more transports, a centralised DC is often favourable. Another trend in logistics is that instead of just having storage capacity in a DC or warehouse, the facility is complemented with value added activities such as packaging or some final stage of assembling.

[54] Axsäter S "Lagerstyrning" Studentlitteratur, 1991

What are the advantages of having a logistical strategy as mentioned above? The most important ones are reduced costs, better control over goods flows, and an increased distribution and delivery service. If a value added activity is added in the end chain the flexibility towards the market increases and it becomes easier to meet changes in customer demands.[55]

The disadvantages are mainly that it requires a warehouse closer to the market and that the implementation may require changes in the company.[56]

4.3.4 Materials handling

The cost associated with a warehouse depends on the outlay. To comprehend these it is vital to understand the internal and outbound flows of the warehouse. In short these flows can be summarized by figure 8.

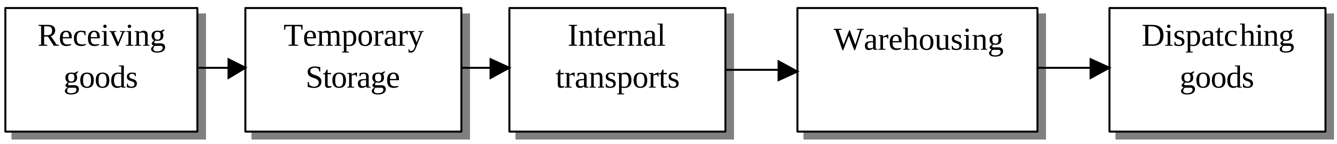

Figure 4 - Warehouse operations

Each of these processes can be divided into sub processes that now will be discussed.

4.3.4.1 Receiving goods

The process of receiving goods consists of a number of activities. Some of these need a bit more explaining than others.

1. The first sub process takes place when the goods arrive at the warehouse or DC. The process consists of unloading external vehicles. The unloading capacity has to be dimensioned according to the number of arriving vehicles. The goods that are placed on pallets can be handled with a forklift and are therefore easier to unload than other types of goods.

2. The received goods are inspected. Things that have to be verified are the number of pallets, that the goods have not been damaged during the transport and in some cases that the numbers of articles are correct on each pallet.

3. When the goods are approved and possibly corrected, the flow has to be converted from external to internal flow. If the products arrive un-palletised or on a different form then the one internally used, the warehouse needs to unpack or repack the goods. This activity is done to make the internal handling easier.

4. After the conversion into an internal flow the goods undergo a quality inspection. This process is often directly combined with the previous activity. The activity of quality inspection is associated with the risk of prolonged flow-time. Therefore it is

[55] Persson G, Virum H ”Logistik för konkurrenskraft” Liber Ekonomi, 1999
[56] Schary P, Skjött-Larsen T “Managing the global Supply Chain” Copenhagen Business School Press, 2001

favourable if most of the quality check has been done earlier, preferably before the goods were dispatched to the warehouse.

5. When the quality of the goods is approved they have to be marked so they can easily be traced in future operations.

6. The next step is internal transports between the receiving area and the storage area. The internal transports should be as short as possible and with straight flows.

4.3.4.2 Temporary Storage

Temporary storage is an area where the goods can be placed while they wait to be transported into the warehouse.[57]

4.3.4.3 Internal transports

The following activity can be done in numerous ways and by many different tools. By describing these tools it is easy to get an understanding for the shape of the internal transports. The selection of tools in material handlings depends on the number of articles and what type of articles that is stored, but a frequent used tool is the forklift truck. This tool comes in many shapes, depending on what kind of warehouse they are operating in. One of the forklift truck's biggest advantages is that it is very flexible and can handle many different types of situations. The capital cost for investing in this transport system is also quite low. On the downside are the costs for personnel operating the equipment. If the routs are more fixed an AGV system can be implemented. AGV stands for Auto Guided Vehicle[58] and operates mainly in the same fashion as an ordinary forklift truck but, as the name implies, is guided by some sort of automation. This could be by a computer, by magnetic strips laid down in the floor or with laser beams.

A conveyer system can be used if the goods always travel in fixed routes. The advantages are that it is easy to plan flow-times and volumes, reliable and fast. The disadvantages are mainly the high purchasing costs and the low flexibility.

4.3.4.4 Warehousing for DCs

The factors that determine the size of warehouse vary from company to company but some factors can be said to be more or less common for all types of warehouses. The size of the warehouse can then be said to depend on the following:

1. The quantities that are delivered to the warehouse and the quantities that are shipped.
2. Different types of insecurity, for example insecurity in demand, prices etc.
3. The ability to meet bigger disruptions in the supply structure.

4.3.4.5 Dispatching goods

The dispatching of goods resembles in many ways the activities that characterised receiving goods just that the processes are done in a reverse order.

4.3.4.6 Warehouse designs – different types of storage

There are many types of warehouses and their design has an impact on how effectively the logistics activities are carried out. The choice of warehouse is foremost decided by what kind of goods it should contain and how the ordering system works. Mainly two kinds of goods are

[57] Johnsson M ”Kompendium i materialhantering” LTH, 1998
[58] Seminars in the Course ”Materialhantering” LTH, 2000

predominant, minor goods and palletised goods, where the palletised are the most usual. There are many different types of warehousing for palletised goods but we will only discuss those that are the most common and that have importance for the case study.

The conventional rack is the most used type. In this type of storage every pallet is easily accessible and the storage layout is easily changed.

A storage type that allows a high number of pallets per m^2 is the crane storage. It must be adapted well to the operations if automated and therefore this type of storage has a low flexibility. It also requires a well functioning administrative guiding system. Since the investment level is very high the best course of action is to let the warehouse operate around the clock. A typical height for this kind of system is ten meters or higher.[59]

[59] Johnsson M "Kompendium i materialhantering" LTH, 1998

5 Computer based simulations

5.1 Introduction

"Simulation technology is emerging as a new tool in Supply ChainManagement and its basic strength is in evaluating system variation and interdependencies. This key component allows a decision maker to evaluate changes in part of the Supply Chainand visualize the impact those changes have on the other system components and ultimately the performance of the entire Supply Chain."[60]

Simulation tools have long been used in manufacturing and assembling operations. The use of simulations grew in the 1980s and the availability of simulation packages increased. It helped to push the tool into many other application areas and thus exposed new groups of people to simulation. Companies began to expand the use of simulation beyond manufacturing and assembly operations, looking at the start and finish of these processes. Once financial reward was demonstrated in main-line operations it opened up the door for the investigation of new areas such as warehousing projects, projects that focused on tightening up delivery of raw materials and shipment of finished goods.

In the 1990s there was an increased focus on competition and market survival. Many companies were pressed to improve their shipping systems so they could deliver finished goods to customers in a shorter amount of time. This was to be done without an increase in the products overhead costs since otherwise they would loose ground to competitors.

Many tools began to surface that dealt with the logistics surrounding shipping. In the mid 1990s a focus on Supply ChainManagement led to a market for simulation tools that could simulate basic issues, surrounding the flow of products from vendor to customer.[61]
"These tools are able to gather all the valid information regarding the four basic processes involved in a Supply Chain: plan, source, make and deliver. These systems attempt to use algorithms to determine the configuration of raw material supply and resource constraints to fill customer demand. Similar to the success of the simulation market, the Supply ChainManagement software market has been able to provide a tool that can assist in what had been a time-consuming task of scheduling the entire supply process from order to delivery."[62]

5.2 Wanted Features of Simulation Software

When you simulate there are some features that are desirable. Simulation software should be capable of being used interactively. It should allow a variety of data analysis alternatives for both input and output data but under all circumstances it should be user-friendly and easy to understand.[63] Another thing that is important for the simulation software is to have animation capabilities, to graphically display the product flow through the system. The software should also output standard statistics such as wait times, cycle times and utilisation. A preferable

[60] Wyland B, Buxton K, Fuqua B. "SIMULATING THE SUPPLY CHAIN" Magazine: IIE Solutions, January 2000
[61] Wyland B, Buxton K, Fuqua B. "SIMULATING THE SUPPLY CHAIN" Magazine: IIE Solutions, January 2000
[62] Wyland B, Buxton K, Fuqua B. "SIMULATING THE SUPPLY CHAIN" Magazine: IIE Solutions, January 2000
[63] Sussams J "Logistics Modelling" Trans-Atlantic Publications, 1992

advantage the software could have is to allow users to write and incorporate their own routines because no simulation program can provide for all needs.

The features that are mentioned above are only some of many different desirable functions. Depending of the task for the simulation many other features are most certainly wanted.[64]

5.3 Modelling approach in general

5.3.1 Getting started with modelling

When it is desired to start a simulation it has to be realised that if the person responsible for the simulation does not understand the underlying problem and what it entails he cannot simulate it. In this aspect simulation is no different than an ordinary algebraic solution to a problem. Simulation just allows the user to handle problems with a wider scope and complexity.

We have earlier discussed the Supply Chainbut we will now discus which activities that are commonly associated with logistics and what we mean with the word logistics. One definition of the word logistics is as follows "Logistics is the process of planning, implementing and controlling the efficient, effective flow and storage of raw materials, in-process inventory, finished goods, services and related information from point to origin to point of consumption (including inbound, outbound, internal and external movements) for the purpose of conforming to customer requirements".[65]

Building a simulation model is only a small portion of a simulation project. It is important for a project team to understand all logistical aspects of a system in order to build a comprehensive model and thus complete the project. Pinpointing this information and involving the right people in the project will undoubtedly provide new insights into the processes involved.[66]

We will now discuss areas that are associated with logistics. We have discussed some of these points earlier, but a short reminder of what one must consider when building a model might be necessary.

The list below is not complete because a myriad of things can be connected to the term logistics. It rather gives a hint of which areas are connected to the term.

- Transportation.
- Warehousing and control of the warehouse levels.
- Materials handling and packages.
- Prognoses.
- Production Planning.
- Procurement and the material supply.
- Customer service and order treatment.

[64] Virtual Supply Cain. Interactive cases and exercises. Remix Group 1999.
[65] Persson G, Virum H "Logistik för konkurrenskraft" Liber Ekonomi, 1999
[66] Wyland B, Buxton K, Fuqua B. "SIMULATING THE SUPPLY CHAIN" Magazine: IIE Solutions, January 2000

It is important that the right modelling strategy is used as it saves resources and time and it keeps up the motivation of the people involved. The first one must do when it is desired to simulate a problem is to formulate the problem in such a way that a quantitative approach is possible. This step should not be taken lightly because a badly formulated problem will lead to difficulties later on. Doubling the number of details can improve the result but maybe only a fraction of it and may require four times more work, which will direct attention from the major issues.[67]

The next step is to create a suitable model. The process of model development is shown in figure 9 below. Once this is done it is necessary to take the following approach:

- Collect or synthesise relevant data.
- Input data to the appropriate model.
- Run the model.
- Interpret the results.
- Take appropriate action.[68]

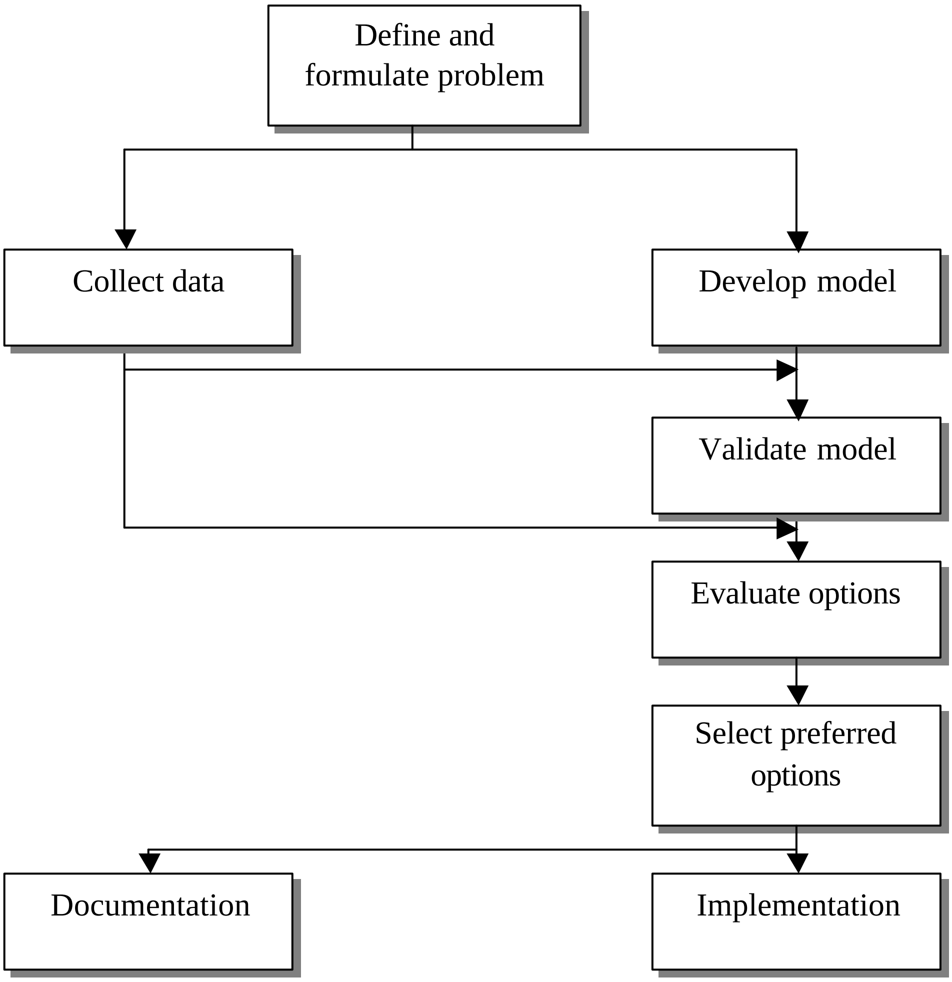

Figure 4 - Simulation approach

[67] Sussams J "Logistics Modelling" Trans-Atlantic Publications, 1992
[68] Sussams J "Logistics Modelling" Trans-Atlantic Publications, 1992

A top-down method is an excellent way to overcome many risks related to a non-optimum original goal, organisational problems and several modelling mistakes. The method consists of the developing of a rough and simple model as a first step for testing the model approach. In the next step, the scope of the model may be broadened; more details included, new innovations considered and more analysis perspective included.[69]

The opposite of a top-down method is the bottom-up approach. With a bottom-up project, modelling components are finished before actual models and scenarios are created. The components include customer prototypes, cost structures analyses views, alternative logistic control etc. The method is justified if the final goal has not yet been defined, the actual project cannot start yet or the components are to be reused. The risks are that components are done in a way that does not meet the analyses needs, or that unnecessary resources will be spent making the components.[70]

5.3.2 Collecting data

In many simulation situations one has to decide which data that is relevant. The extent of data is usually too vast. It is impossible to include all of it. Some data may also be more relevant than other. It might be especially so for a company that has a wide variety of products and customers. It is possible that a company may have thousands of different products in stock.

The ABC-rule can be used to distinguish those products that are important for the simulation from those that are not. Many companies apply this rule and it is focused on the volume times the value, e.g. the more expensive and the higher volume a product has the higher it is classified. The articles with the highest value are called A- products, those with middling values B-products and the ones with low values are termed C-products. Now the products are placed into three different-sized categories. The rates for these categories may differ but usually they are around these approximate sizes: 10 % are A-products, 30% are B-products and 60% are C-products.

An even simpler rule, but which often is true, is that 20 per cent of the articles are worth 80% volume-value. This rule is called the 80/20-rule. Note that the numbers can change in the rule, but what is common is that the distribution is often very uneven.[71]

5.3.3 Validating the model

The validity of most logistics models is dependant on the correct understanding of the underlying cost structures.

If the simulation scenario is built on an existing scenario one can use historical data when validating the model. The base model may deviate from the expectations. To correct this, one approach is to take iterative steps until the model corresponds with reality.

It becomes slightly harder when one wish to compare the model to future events. The best way of doing this is to validate the results from the simulation against already made prognoses. The prognoses may be flawed and thus one can mistake a corrupt model for a right one.[72]

[69] Virtual Supply Chain – Interactive Cases and Exercises, Remix Ltd, 1999
[70] Virtual Supply Chain – Interactive Cases and Exercises, Remix Ltd, 1999
[71] Axsäter S ”Lagerstyrning” Studentlitteratur, 1991
[72] Enshoff J, Sisson R “Design and use of computer simulations models” McKinsey & Co, 1970

5.3.4 Documentation

During the work the steps taken to create a model should be recorded. It makes it easier for someone else to duplicate the model and it also allows the constructor of the model to check for errors and validate assumptions that he or she has made earlier.[73]

5.4 Advantages and Disadvantages of Simulation

The following advantages and disadvantages are generalised for all simulation software i.e. not just for LORD.

5.4.1 Advantages

Simulations have many advantages. One of the most obvious advantage is that time can be compressed in a simulation. Years in the real system can be compressed into minutes. At the same time the simulation does not disrupt ongoing activities of the real system. Simulation is also a great tool for answering “what if” questions. This means that it can be used to see what happens when trying out different scenarios. These scenarios could be all from the outlay of a factory or a warehouse to how a human organ will react when exposed to a certain treatment.[74] It allows managers and other people with interest in the results to get a good opinion before they make a decision. Using a simulation tool, decisions are made more easily.

Furthermore, it can be used where the conditions are not suitable for standard mathematical analysis, though simulation is far more general. The computer software may be able to simulate events that are too complex to analyse in other manners. Besides, it provides a more realistic imitation of a system than mathematical analysis and it can be used to analyse short-lived conditions and while statistical analysis are often time consuming and expensive simulations are often not.[75].

Most humans base their understanding of the world on their vision. The centre of the brain where visual images are processed is therefore the largest in the brain. When using simulations people can communicate data in a swift and easy manner. The data on the other hand may have taken years to collect. Unfortunately not all people consider the use of graphics really necessary for modelling and simulating. Their opinion is that graphics and visual display is a non-value added activity.[76]

Finally, there is also a great chance for a user to think that it is fun to simulate, which is why simulations often can be used as a game for training experience

5.4.2 Disadvantages

Unfortunately, simulation as a tool is not perfect. A great deal of time and effort may be spent on developing a model for simulation and there is no guarantee that the model will provide good answers. Complicated systems can take a long time to model and very much computer time could be needed which makes the simulation an expensive solution. Simulation involves

[73] Banks J, Carsson II J, Nelson S “Discrete event simulations” Prentice Hall, 1996.
[74] Jinbäck A, Vranjes S ”Simulering och analys av MCT på Stockholm – Arlanda” KF-Sigma, 2001
[75] Bekker J, Sayman S ”Drawing conclusions from deterministic logistic simulation models” MCB University Press, 1999
[76] Jinbäck A, Vranjes S ”Simulering och analys av MCT på Stockholm – Arlanda” KF-Sigma, 2001

numerous repetitions of sequences that are based on randomly generated occurrences, so there is no way of telling if a simulation model's performance is completely reliable. Since it is randomly based, it may be less accurate than a mathematical analysis. The technique of simulation, while making progress, still lacks a standardized approach. Consequently, models of the same system but built by different individuals may differ widely.

If the input-data to the simulation model is wrong the model will in all likelihood also be incorrect. The result can be corrupted even if the amount of data that is flawed is only a small fraction of the main bulk. The correct data is a necessity for getting good results since even the best of models cannot compensate for faulty in-data. Even if the output from the simulation is inaccurate it can provide a sense of where the result is headed and with further study of the in-parameters lead to a satisfying model.

Most systems that are appropriate for simulations are often very complex, this may in turn lead to the scenario that the user cannot grasp the problem in it is whole and therefore is unable to simulate it.[77]

5.5 Errors that can occur

When simulating there can occur numerous problems and errors. These errors can be divided into three categories into which each error can be placed. The errors are named Type I, Type II and Type III. Type I errors are when the model is correctly build but the results are stated as invalid and the model rejected or reworked. Type II errors are of the opposite character and they occur when an invalid model that delivers the wrong output is considered valid. Type III is when the makers of the model are aiming at the wrong problem. Most efforts are aimed at solving and correcting the first two types of errors but the third one is of equal importance. This should be taken into consideration already at the very first activity, the project planning.[78]

Although these three types describe the errors themselves a bit more explaining is needed on what causes them. There can be ten errors, or 'sins', that a maker of a simulation can do:[79]

1. To run a simulation without a clear definition of the goals.
2. Believe that the model can compensate for errors in the in-data.
3. Ignore the effects of randomness, which is present in almost every situation.
4. Input randomness at the wrong places.
5. An inadequate understanding for stochastically processes. Only using averages may render the model useless.
6. Ignore the question of what is really asked. One will then end up simulating the wrong things.
7. Not take the down-time of operations into account.
8. Make illogical assumptions. Instead the maker of a simulation model should gather data from persons that are familiar with the situation that is going to be simulated.
9. To not view the simulation as a mean for analysis.

[77] Jinbäck A, Vranjes S ”Simulering och analys av MCT på Stockholm – Arlanda” KF-Sigma, 2001
[78] Persson F, Olhager J “Performance simulation of Supply Chaindesigns” International Journal of Production Economics. June 2000
[79] Jinbäck A, Vranjes S ”Simulering och analys av MCT på Stockholm – Arlanda” KF-Sigma, 2001

10. To not question the result. Just because the result where delivered by a computer does not make it right. One always has to take into consideration if the model and therefore the results are correct.

5.6 Different Simulation tools

5.6.1 Introduction

There is a wide range of simulation tools, some more used than others. We will discuss three of these tools and then focus on the one we have chosen for the project. First we will discuss two products that are not downright used for simulation. They are used for many other purposes such as monitoring, alerting and giving visibility over the total Supply Chain. One author states: "Companies like i2 and Manugistics have created Supply ChainManagement applications that incorporate all the logistics behind the Supply Chainand attempt to create methods that will find optimal balances between costs and customer satisfaction"[80].

5.6.2 i2

i2 is not just a simulation tool; it uses the DVCM (Dynamic Value Chain Management) methodology. It is a business methodology that helps companies manage marketplace variability and complexity and align company strategies with execution processes. i2 solutions span the value chain interactions, including customer relationship management, Supply ChainManagement and supplier relationship management. In Supply Chaindesign, i2 SCM allows analysts to run simulations to test different global network scenarios, to determine where to place facilities and where to manufacture. Strategic planning goes down to one node in the Supply Chain, such as an individual plant, to determine optimal assembly, production and stocking for that plant, as well as the transportation links between plants. i2 Supply ChainPlanner helps companies to optimise production, distribution, inventory and transportation simultaneously across multiple enterprises.[81]

5.6.3 The Manugistics Manufacturing Planning & Scheduling Solution

The Manugistics Manufacturing Planning & Scheduling Solution is a tool provided by Manugistics. It has five different key components; buffer management, constraint management, realistic business modelling, synchronization and event management & analysis. Buffer management provides protection from anticipated but unforeseen disruptive events by calculating and allocating proper inventory buffers across the manufacturing facilities and stages. Constraint management gives the ability to identify business constraints and optimise and manage these constraints by matching demand. Realistic business modelling is a tool to effectively model the interaction between capacity and material flow so that both can be considered simultaneously by the optimisation engines. Synchronisation helps ensure that the material flow is balanced across the enterprise so resource utilisation is effectively utilised and inventories and material waiting times are minimised. Event management & analysis has simulation capabilities that allow for rapid and optimal correction of business exceptions.[82]

[80] Wyland B, Buxton K, Fuqua B. "SIMULATING THE SUPPLY CHAIN" Magazine: IIE Solutions, January 2000
[81] www.i2.com, 2002-02-10
[82] www.manugistics.com, 2002-02-10

5.6.4 LORD

Lord is a program that simulates the Supply Chain. It is vital to understand that LORD is not a program that gives an optimised answer but instead allows you to run different scenarios. This makes it an excellent tool when you need to evaluate complex situations that are next to impossible to calculate by hand. It is necessary to have a deeper understanding for logistics problem than would be required with a program that optimised the result from the start when running LORD.

LORD is built around a geographical map in which the user places different facilities, for example factories, DCs and customers. An example of this map is shown in the figure 10. Every facility can be edited and suited for the task at hand. Creating relations between facilities are also feasible. The results received from LORD are presented both in numbers and in charts. Among the outputs that are obtainable are “Company Service Level” and “Company Logistics Costs”. ABC-calculated costs can also be derived. This feature makes the program suitable for calculating individual costs. The routes between the different facilities are drawn straight but a database containing geographical data makes the distance a vehicle must travel more plausible.

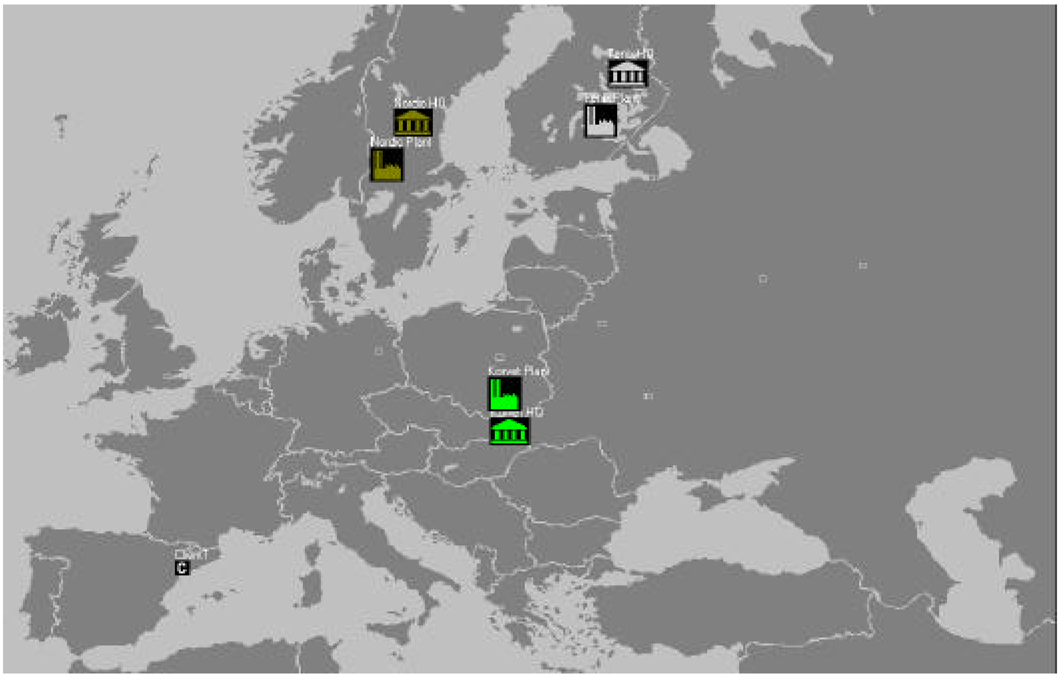

Figure 5 - The view of Europe in LORD

5.6.4.1 LORD’s disadvantages

LORD’s disadvantages can be either intentional or unintentional. With the intentional we mean that the designers did not make the program suitable for certain types of logistics planning. In short these are:

- *Facility planning*. Since LORD studies the entire Supply Chainit has quite a low level of detail. A disadvantage that can be seen when one wishes to study the outlay of a single facility.

- Solving everyday operative problems. A typical simulation period is between 50 and 100 days.
- Optimising very small or local operations.

The unintentional disadvantages will be discussed in the case chapter since this information is more closely linked to our own experiences.

5.6.4.2 LORD's advantages

Probably LORD's most important feature is that it is easy to work with and the results are displayed in a manner that makes them easy to understand and present.

LORD is best used when it is employed to problem regarding strategic/structural planning, but it can also be used to support tactical decision-making. There are many examples where LORD is an excellent tool but we will only discuss the most important of them here:

- Decision-making, regarding not only cost but also time, capital, or customer service.
- A Supply Chainincluding several company functions or more than one company.
- Where it is a question of complete redesign of the Supply Chain.
- When it is needed to improve the logistics management and new control parameters are being searched.
- To visualise problems and solutions in a good manner.
- Where an optimum balance has to be found between somewhat contradictory objectives, like production cost and distribution cost. [83]

5.6.5 How to make a model

When working with simulations, the construction of the model is of great importance. The reliability of formal data and statistics are very significant and are often more useful than information described in text. There will be no use of the statistics gathered if the input data is incorrect and if the case that should be simulated is wrongly described in the model.
Before starting to make a model it is reasonable to find answers to the following questions:

- What is the geographical region of the company logistics network?
- What are the company facilities (plants, terminals, distribution centres) and their location (geographical places)?
- What are the company products?
- Where are the company's customers located? In most cases, few customers or customer groups can represent a high number of customers in a model.
- How are goods delivered between facilities, and then finally to customers?
- How much do the products cost?[84]

[83] Virtual Supply Chain– Interactive Cases and Exercises, Remix Ltd, 1999
[84] Virtual Supply Chain– Interactive Cases and Exercises, Remix Ltd, 1999

Part II Case Study

6 Supply Chainat IKEA

6.1 Different parts in the IKEA Supply Chain

Here is a short presentation of the different parts in the IKEA Supply Chain:[85]

- *Service Office:* In the countries where IKEA operates there are service offices. The purposes of those are to coordinate the stores in the current country. In matters concerning commercial activities and the product range, the service office provides the coordinating function for the mail order outlet. Each store is a separate business unit and the stores are responsible for their own financial results.

- *Warehousing:* The Company does not exercise the principle of Just-in-Time. IKEA needs big warehouses to be able to meet the changes of demand. Because of the product catalogue and the products that all stores have, the demand increases very much when all the customers wants the same products. Physical and administration handling are typical activities for a DC. Goods that arrive from suppliers are received, stored and then delivered to stores. The goods are shipped as half pallets, full pallets or picked pallets. The suppliers do not care for the major part of the storage, IKEA does. Each store has storage of its own. Stock turnover rate is three months in the DCs and three days in the stores. Twice a year they do an inventory so they can identify which products that have a low turnover.

- *IKEA of Sweden (IKS):* IKS is located in Älmhult, Sweden. IKS is responsible for all product development in IKEA. The defined role for IKS is to take full responsibility for the effectiveness and the efficiency of the product range. IKS has a long list of different functions, such as development of administration support, quality, product development, design and environmental considerations. The business area managers that work within IKEA of Sweden can be described as Supply Chainmanagers.

- *Distribution organisation* manages all logistics including the transport of over 10,000 articles from 2,000 suppliers to about 160 stores in 30 countries. This global organisation constantly works to make the route from supplier to the customer as short as possible.

- *Trading office:* These offices are in those countries where IKEA has a purchaser. Trading office manage the daily purchase activity that consist of transportation and contacts with other companies and authorities.

[85] Holmberg S "Supply ChainIntergration through Performance Measurement" KF-Sigma, 2000

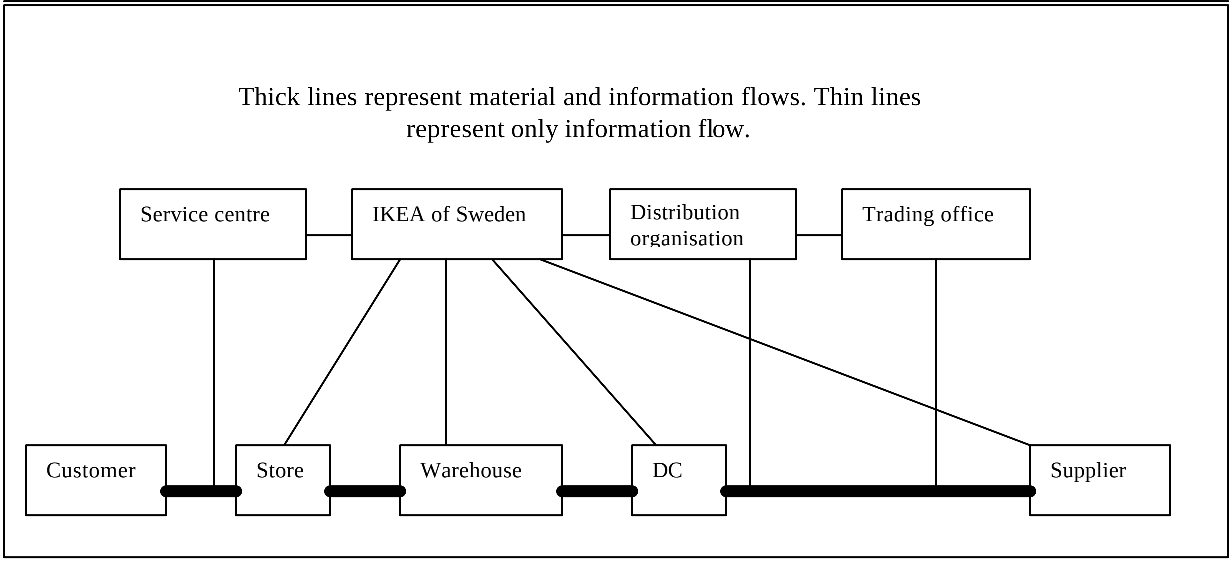

Figure 6 - The Supply Chainof IKEA

6.2 A comparison between the two existing DCs

There is a remarkable difference between the two main DCs that operates today, even though they have been built around the same time. One of the facilities is placed in Thrapston and the other in Doncaster.

The DC in Doncaster is almost a model of a modern warehouse. With crane-storage and with conveyers that transport the goods to the area where the crane picks up the pallets it is very efficient. The crane puts the pallets in the nearest available spot and thereby avoiding the extra distance a fixed storage position requires. Due to the advanced warehousing, Doncaster is in need of a computer system that keeps track on where the goods are in the facility. Each pallet is equipped with a bar code that identifies the goods and allows it to be handled swiftly. The driver of the forklift truck has a computer at his disposal on the vehicle and is therefore always updated on the work that must be done. Doncaster also has a high number of loading and unloading areas and therefore can handle high volumes each day.

The facility at Thrapston is smaller than the one at Doncaster and is less efficient. It has a conventional racket fitted for different sorts of pallets. When goods at Thrapston are ordered for outbound delivery it needs to be picked up the by a truck driver who has a manual order list from which he operates. This leads to inflexibility, because if an order is changed, the driver of the forklift truck will not be aware of it. The Thrapston facility also has relatively few loading and unloading areas. Therefore, if the flows and the efficiency within the warehouse would increase, a rebuild of the warehouse could be necessary.

Both the warehouses operate today at their practical maximum capacity. This leads to the need for either expansion of the existing DCs or the introduction of a new one.[86]

[86] Interview with Scott Howitt, 2002-04-11

7 Building a model with LORD

The first step in building a model is to define a geographical map where the Supply Chainis studied. There are several different areas predefined in the software. In our case, we picked the United Kingdom shown in figure 12. It is rather easy to build a model in Lord. It is build around a geographical map that is used to place facilities, customers, terminals and other logistics model components to right locations. This could be done simply by a few clicks on the mouse or by typing in the facility's coordinates. Further, drawing on the map can create delivery and ordering links. Editing parameters of objects located on the map are done through pop-up menus. Clicking right mouse button when the cursor is placed on the map or an object icon opens these pop-up menus.

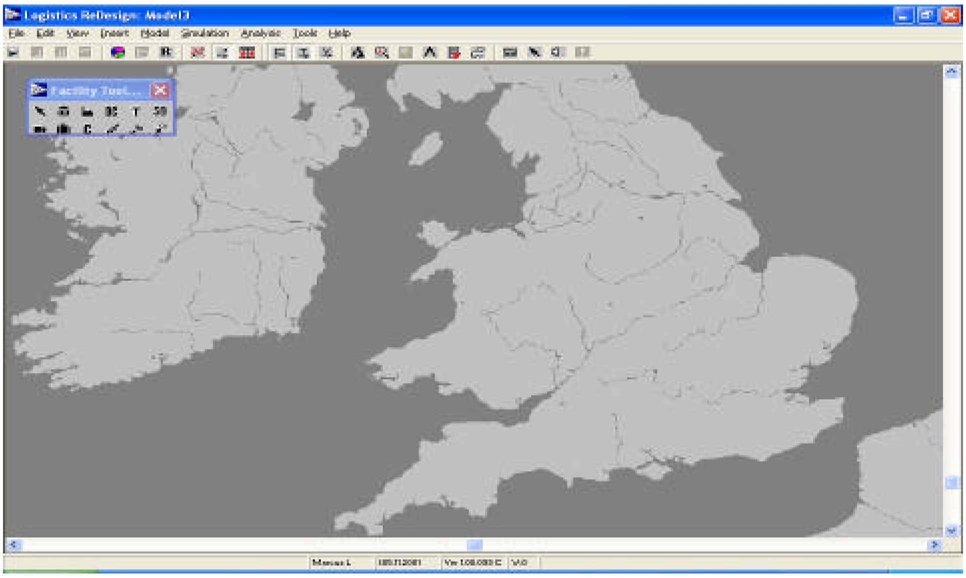

Figure 7 - Start-up map of the UK

The company is defined in connection with this. In the definition of the company there are a few parameters to define. It is here the company's finances such as rate for inventory costs are defined. The second step is to define the products that are transported in the Supply Chain. It is recommended by the creators of Lord that the products are divided into product areas or segments if the numbers of products are high. This is done to keep the simplicity of the model. Examples of product parameters are; weight, volume, length and area per storage unit etc. (see figure 13).

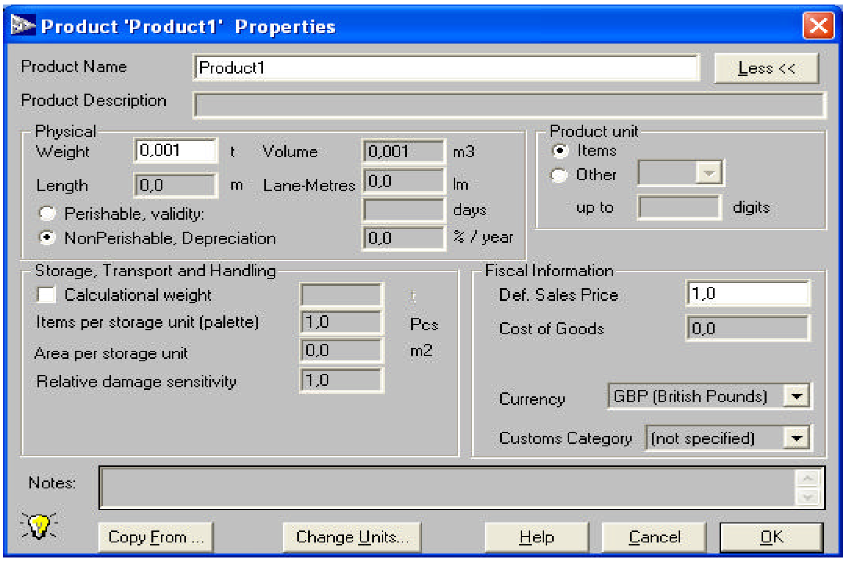

Figure 8 - Defining the product(s)

The next step is to create the facilities such as DC's, terminals and plants. A facility is created with help from a special facility pane (see figure 14) by just clicking on the desired location on the map.

Figure 9 - "Facility properties" pane

When creating a facility, a "Facility properties" pane pops up. The different parameters for DCs and Terminals are listed below:

- *Place* - change location by choosing from a list or by entering coordinates.
- *Operating hours* – defines the operating hours for the facility.
- *Inventory Review (DC only)* – scheduling for inventory review.
- *Suppliers (DC only)* – defines where the facility orders its products. Facility suppliers can be other facilities of the same company (plants or distribution centres) or facilities of other companies where the products are bought.
- *Warehousing* – defines the storage capacity, extra capacity with higher inventory costs, damages on goods and dispatch and receiving capacity.
- *Cost & Time Structure Dialog* – this dialog is used to edit the values of different cost drivers and its cost pools (see figure 15). Operational logistics costs are calculated using activity based cost calculation. A cost-time structure is a definition that can be used by several facilities. A complete cost-time structure defines all costs and time delays related to logistics events.

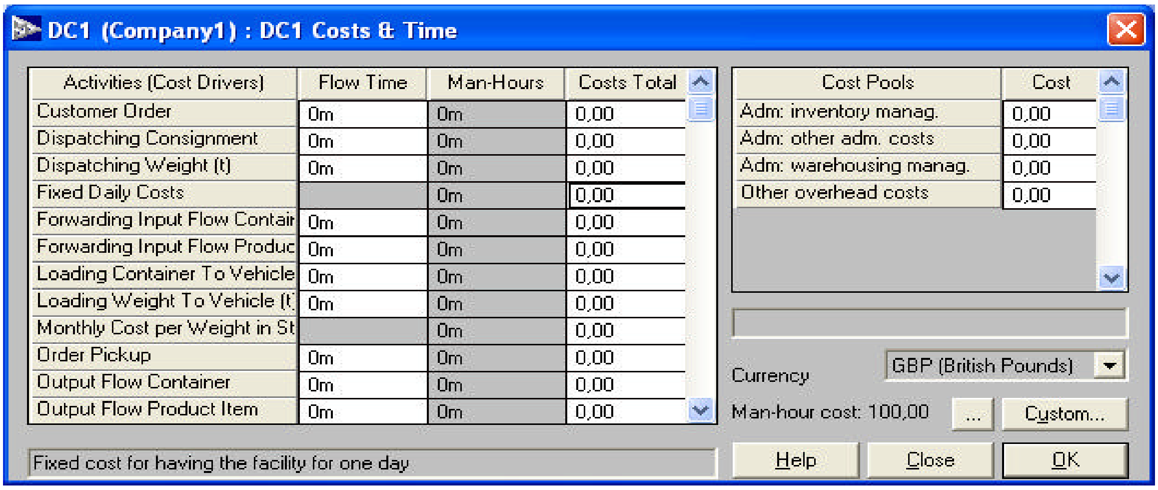

Figure 10 - Cost and time structure

- *Inventory Control Dialog (DC only)* - this dialog is used to edit Inventory Control parameters of the facility (see figure 16). Each product has its own Inventory Control parameters. There are several main control systems which can be used for product's inventory control: Reactive, MRP (DRP), MTO (PTO). The dialog has several pages for editing parameters of the control systems. Each page has a table pane where one can define different parameters.

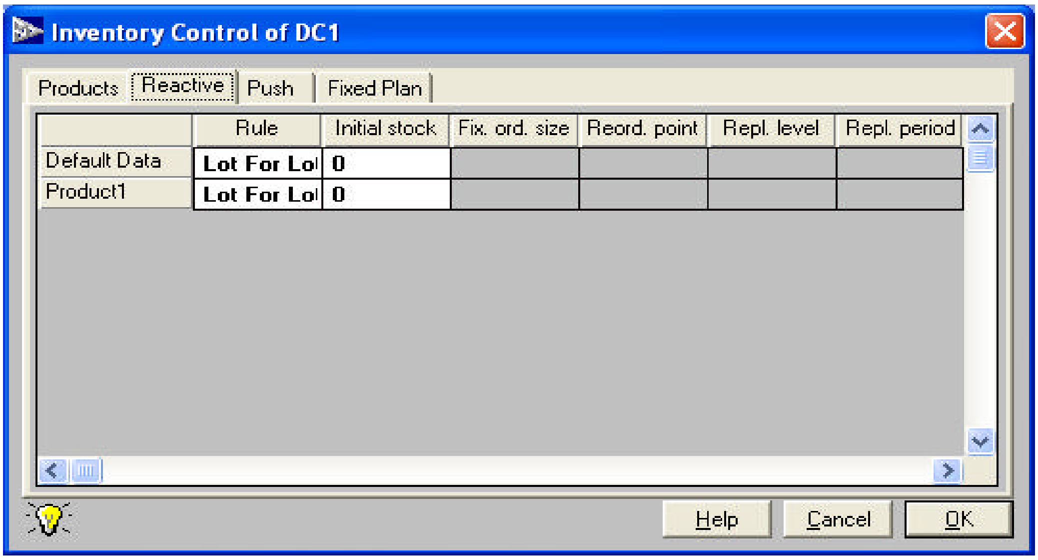

Figure 11 - Inventory control

- *Delivery Policy Dialog* – used to create and edit delivery policies. A policy contains delivery options (estimated delivery time, safety marginal etc), delivery routes and consolidation rules for different delivery segments.

After placing the facilities the customers are placed. This could be done before the facilities, if wanted. It is done just as same as the facilities but here a customer properties dialog appears (see figure 17). The Customer Properties dialog is used to edit the customers demand and suppliers. The same dialog is used for all customers. Some parameters can be edited for several customers at the same time, but some of them (like name) should be edited individually for each customer. Customer's demand could be defined by any two of the three parameters: annual consumption, order size and frequency. It is enough to have only two parameters as they depend on each other. The suppliers are defined in the same manner as for the DCs.

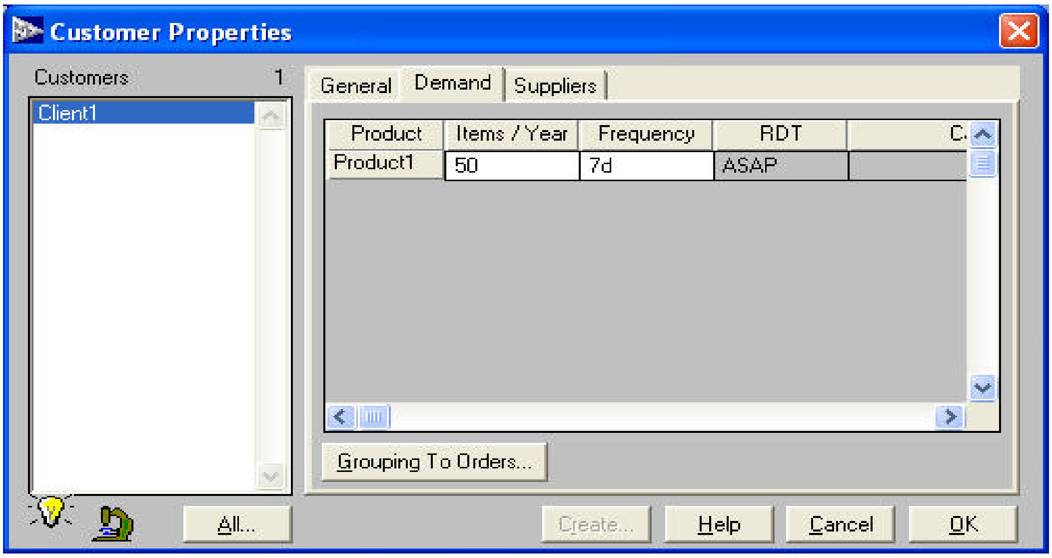

Figure 12 - Customer properties

The last step after placing all the physical objects on the map is the defining of the delivery links and transport links. This is done just as simple as placing facilities, just click and drag with the mouse. The links could be edited just by clicking on them. Delivery links defines which route to use for deliveries. For example, certain transport service companies can deliver a consignment from a plant to the customer through a terminal. A transport link simulates a simple transport between two places. It is not a single vehicle, but a virtual transport, which can deliver goods with certain time delays and costs. Transport links have enough parameters to simulate most transportation cases. They can have daily capacity, different types of costs (see figure 18), random delivery time and even schedules. Each transport link belongs to some transport service company.

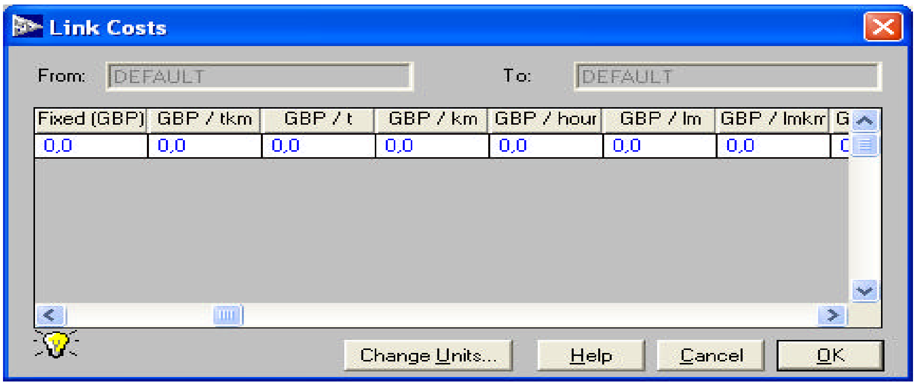

Figure 13 - Link costs

Now, after these steps, the model is built (see figure 19) and a simulation run can be performed. Note that this is only a short summary of how a model is built. The software has additional functions that we do not mention here since we only described how one makes a basic model.

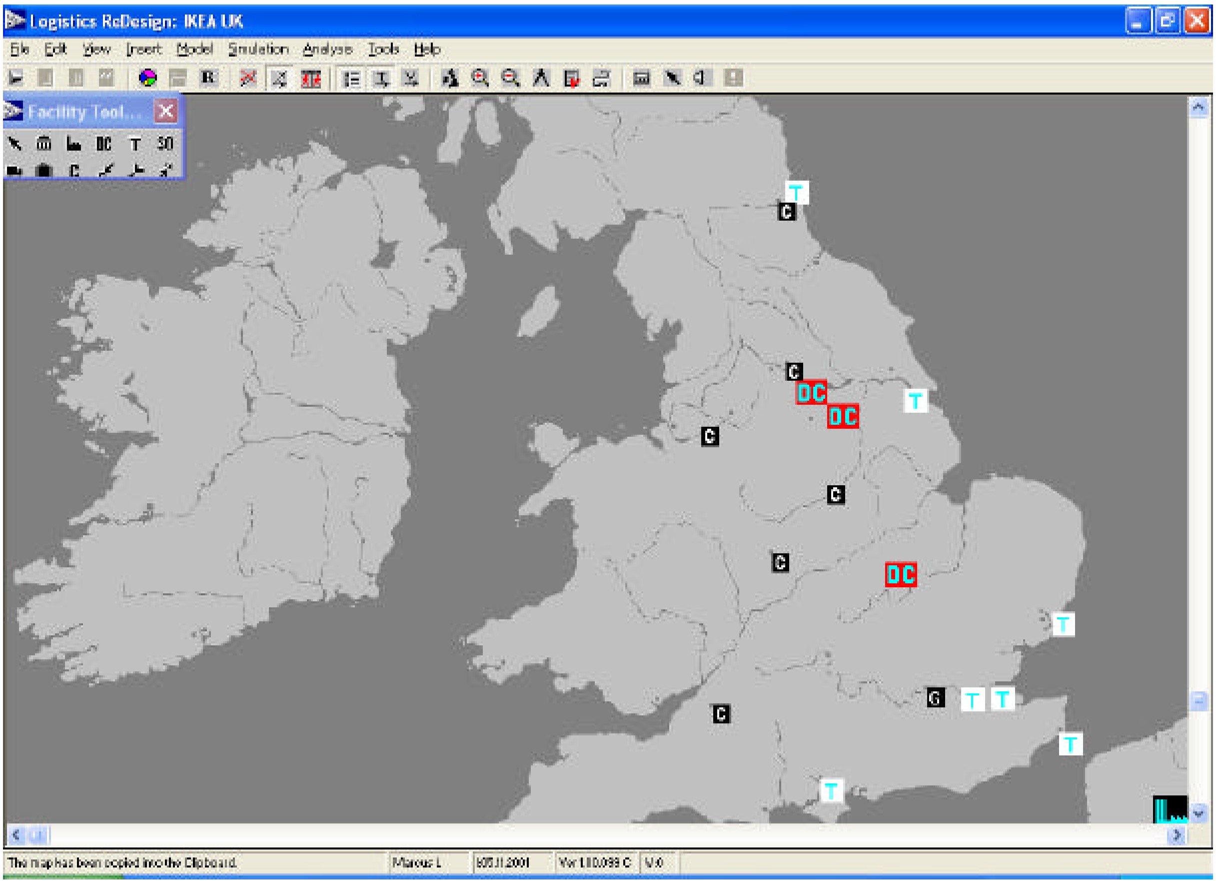

Figure 14 - An example of a model

8 Simulated Scenarios

As we mentioned in the background we have simulated the present situation and a given future scenario, but we have also added a scenario of our own device. Among the scenarios we discussed and finally decided to model is the case when we only have one DC serving the entire UK. We will now discuss the reasons why we chose this particular scenario.

As discussed in the theory chapter, great advantages can be made when the goods that need be stored are concentrated to one DC. These benefits stem mainly from the fact that if a company has more than one DC or warehouse they may store one type of article in many places and therefore creating a situation where the amount of capital that is tied up in warehouses exceeds the scenario with only one DC. On the other hand, as also discussed in the theory chapter, the costs for transportation increases but this can be accepted as long as the increase does not exceed the savings connected to the concentrations of the warehouses. There are also some features that are distinct for the UK market that we now will clarify.

The features that indicate that IKEA could use a single DC at the UK market are the following:

- UK has a rather limited geographical extension and is densely populated. This suggests that the distance a vehicle must travel could be said to be fairly limited. Due to the high population the turnover should also be quite large. This implies that the vehicle fill should be high. To have an adequate service level, a satisfying amount of goods needs to be kept in warehouses.
- IKEA also has a wide product range ~ 10,000 different articles. This suggests that in the case with multiple warehouses, many types of products will be stored at more than one DC and therefore increasing the costs for bound capital and the administration.
- The DC at Thrapston does not have the same efficiency as the one in Doncaster.[87] This indicates that in the long run that Thrapston would have to be modified or to be shut down.

The factors that speak against having just one DC can be summarized into the points below:[88]

- The land is very sought-after in the UK and therefore is the prices on land very high. It is also difficult to get a building permit. IKEA like other companies feel that they have to, more or less, accept an offer if it is presented and thus not always taking the best course of action from a purely logistical point of view.
- IKEA in the UK already have two big DCs and they have bought land and building permit for a third DC. A switch to just one DC can be hard to justify when there is a fully operational system in use.
- Many companies place their DCs in what could be best described as a "belt" that runs through the middle of the UK from west to east and this gives them the opportunity to serve both northern and southern stores. This leads to even harder competition for the most sought-after land.

[87] Interview with Scott Howitt, 2002-04-12
[88] Interview with Darrell Harvey, 2002-05-01

9 Evaluation of LORD

9.1 The case-model

We will discuss the scenario that represents IKEA in the UK at their present state. This will lead to a greater understanding for the reader of the complexity one can be faced with when simulating.

IKEA currently operate 11 stores that are supported by three DCs: Doncaster, Thrapston and a supporting DC at Dunstable. The majority of the products are imported through Harwich, Immingham and Southampton, either in containers or in palletised form. The Doncaster site has recently been commissioned and has taken over those elements of the Supply Chainpreviously serviced from Belgium. For historical reasons this has meant that Thrapston handles predominantly the furniture article range and Doncaster handles smaller Satellite article range. This means that the total transport increases for the Supply Chain. Although the DCs only handle products from IKEA, the warehouses are owned by a third-party that manages them in a long-term relationship.

In addition to foreign suppliers IKEA also has thirteen suppliers in the UK. The majority of these suppliers are located around the Manchester – London area in the middle of England.

All transports within Great Britain are handled by external hauling companies that have a fixed rate per route. Lorries transports most of the goods but train transports a small part. The goods that are transported by train are mainly the ones arriving from harbours and goes directly to a DC.

The wide range of articles are stored and handled on different types of storage units. The physical properties of the products vary widely in terms of weight, length, height and price. IKEA is forced to have different types of storage units due to these different product aspects. Although the EUR-pallet is the most common they also have half-pallets, IKEA-pallets, picked pallets and goods that are handled individually.

9.2 Simplifications of the case model and LORD limitations

As described above, the reality is quite complex and to simulate it with every parameter is not possible. A model running with that high amount of data would be very slow and almost impossible to run. When gathering data for the simulation an obstacle is to decide which data that are relevant. In LORD you have the ability to define a great number of costs and other information. As we only have had limited experience of the software and creating models of this scope we had to figure out what data that were needed for the project. For example is the best course of action to define a fixed cost for running the warehouse instead of use the costs for labour, management, rent etc?

We soon found out that the biggest challenge lay in simplifying the product-range and that we had to find a way to narrow down the number of products without compromising the result from the program too much. The solution that we used was to run the simulations with six product groups: palletised, unpalletised, unit load, full pallet, half pallet and picked pallet. The three first mentioned product groups are the ones that arrive at the DCs and the rest are the ones that are delivered to the stores from the DCs.

When building the model we had to input data from the last fiscal year, which runs from September to August. By using this data we did not get a correct view of the present situation rather how it looked like for a year ago. During this period the DC in Doncaster was started up and therefore building up its warehouse levels. This resulted in an inflow that is not representative for a normal fiscal year, therefore we had to approximate a satisfying level of inflows and outflows.

The warehouses have a fixed theoretical limit on how much they can store in m^3. As discussed in the theory chapter a warehouse cannot operate at their maximum capacity without having escalating costs. So in order to take this into account in the model we used a lower volume as a fixed max limit in the DCs. This simplification is not entirely correct because the warehouse capacity has not been optimised and therefore might our approximation be incorrect.

We assumed that the thirteen domestic suppliers had an equal share of one percentage each of the total flow when constructing the material flow to the DCs. The rest of the goods went through the three ports we used in the model. The ports delivered the same amount of goods in cubic meters. These rough assumptions may have an impact on the transport costs in the model but since we did not have the true values, these assumptions seemed logical.

A limitation within the software is the predefinition of a DC. A DC is not able to assemble products in LORD. For example, in our case, an unpalletised product cannot be changed to a picked pallet. To solve this problem we had to create a factory with warehouse capacity that assembled the products.

When simulating the transport costs we had to have the fill rate for the transport vehicles. We had an approximate fill rate for the Supply Chainin IKEA UK but the number probably varies for different types of goods, different locations and distances.

The version of LORD that we worked with, that was a training version, did not have an Excel interface. An interface of this kind would have been most useful since IKEA had the ability to deliver data in this format. LORD also skewed the graphics when the data exceeded a certain level, the location of the facilities moved on the map. This is however only a graphical error which did not affect the results from the simulations.

When a model is finished and ready for simulating, the program asks the user if he or she wants to optimise the road distances so it corresponds to the actual road network. This of course is a good and valuable tool. However, if the program does not find the route between the locations, it sets the distance to zero without alerting the user. This, of course, could cause some very strange results since the transport of goods between two locations can incorrectly be free of charge.

9.3 LORD benefits

As we have been working with the software LORD we have learned its characteristics. There are some features that make LORD a good program to work with and in some aspects compensates for its drawbacks. First of all we appreciate the graphical interface, the interactive features that can be used to edit various model parameters and the simplicity to create a physical model. Moving the facilities on the screen by simple dragging and clicking can easily change the model. When a model is created it is easy to expand the model and therefore allowing the user to build a base model and enhance it as the work progresses. It is also easy to modify the model if the conditions change; this makes it a very flexible tool. The model can be made very simple but the program also has the ability to take numerous amounts of data in to consideration and the input limit is more or less determined only by the user. For example, the user can often switch from simple to advanced mode when defining a process or a facility. The advanced mode has a lot more variables that can be defined. In a production plant the user can, when switched to advanced mode, define such parameters as batch size, hazards and waste etc.

There are many analyse panes predefined in the program that may not always coincide with the one the user needs. To solve this, the program is constructed in such a manner that it also allows the user to define wanted data outputs for analyses.

Most of the time the program is easy to use but when the user is faced with a situation that he or she does not know how to handle, the software has a good built-in help function that most of the time answers the user's questions. If this is not the case and the user still has questions, the manufacture of the program has a good support group. During our work we have consulted the support group via e-mail, and their answers have often been swiftly delivered and of good quality.

9.4 Evaluation of the simulations

9.4.1 Introduction

In this chapter we will discuss the different models that we have simulated. We have focused on four alternate scenarios: a basic model based on the present situation, a future model, a model with only one DC in Doncaster and a model with only one DC in Thrapston.

The basic model is also used as a benchmarking model for the other scenarios. With this approach we were able to add some certainty into the other three models that we were not able to validate.

When we compare the scenarios with each other, we focus on the transportation costs. The time period that the simulations were set to was 180 days. It may be considered to be a short period of time but we think that this was sufficient for our objectives.

Some of the input data that we have used in building the models will be presented in appendix.

9.4.2 Evaluation of the basic model

The basic model is primarily based on data presented by IKEA. It was not possible to use that amount of data that we originally thought due to software limitation i.e. too much time consuming. Anyway, we produced a model that was as close to reality as possible with the data that we had access to.

We restricted the products to six different categories. This was necessary to keep the model simple and made it possible for us to use. We defined the different product segments together with IKEA. They and we thought that using six product types in the model was the best solution.

IKEA gave us the fixed transport rates for the transports between the DCs and the customers. Unfortunately they did not present the delivery costs from the domestic suppliers and the terminals to the DCs. We defined these costs by using the fixed rates (DC to customer). We took the total costs from the fixed rates and divided them with the distance. By this method we got an approximate rate for transportation cost per kilometre.

The customers' demands were presented to us as a percentage of the total outbound delivery from the DCs (see appendix 2). By using the weekly outflow from the DCs we managed to confirm and validate that the model parameters were correct. This led us to believe that LORD is capable of simulating smaller, yet complex models.

9.4.3 Evaluation of the scenario with only one DC in Thrapston

Using the base model as a reference we modified it by removing the DC in Doncaster and the one in Dunstable and rerouting all the transportations to the one in Thrapston. When doing so we also had to increase the warehouse capacity in Thrapston so it would be able to handle all the goods that flowed through it.

This model produced some oddities from what we expected from the theoretical study. The transportation costs did not deviate so much from the base model as would be expected and instead of increasing, they decreased slightly. This may be possible though since UK is a rather small country and having two DCs may very well increase the transportations. The fill rate of the vehicles must also be taken into account. One of the benefits of having only one DC is that the fill rate of the vehicle will likely increase. This does not have to be true in IKEAs case since they transport huge amount of goods and every vehicle that enters or leaves a warehouse almost always has the same fill-rate.

9.4.4 Evaluation of the scenario with only one DC in Doncaster

This model was constructed in the same manner as the model with only one DC in Thrapston. The results from this simulation did not differ very much from the other with only one DC. The transportation costs did sink a bit compared to the scenario with only one DC in Thrapston. Compared to the base model though the transportation costs sunk with around twenty per cent. If this is correct, relocating all the transportations through Doncaster could do enormous gains. This is more or less expected since the geographical distance from Thrapston to Doncaster is not very great and they are both placed in almost the middle of England.

9.4.5 Evaluation of the future model

The future model, as mentioned earlier, consists of additional 11 stores and one extra DC in Peterborough. These stores were to be implemented in the next few years. Since we did not have the location of the eleven new stores we made an educated guess of where they could be placed. The assumption was based on placing the stores in areas where there were none in the general vicinity or where an additional store may be needed, such as in the London-area.

Since we lack prognoses of how much these stores will sell we made the crude assumption that they will have the same average demand as the existing stores in the basic model. These assumptions may have led to a result that is not very valid, but at least it gives a hunch of the future transportation costs. It also allows us to evaluate the program when it is running with additional data. The results that the model presented were that the transportation costs were more than doubled.

9.5 Recommendations to IKEA

9.5.1 General recommendations

The first step when one wishes to use a computer-based tool is to decide what to simulate and if it is necessary to use simulation software. The second question should be if it is worth the cost in program licenses and work-time. It is vital to understand that working with a simulation tool may require a lot of time and effort to collect the correct data. If the company decides that it is needed to simulate the problem, one has to choose what kind of computer tool to use. There may be many types of software that satisfies the company's needs. One must find a balance between the investment needed and the result wanted. A cheaper, simpler program may give an adequate view of the situation and therefore a more expensive type may not be needed.

A way to overcome the problem of selecting software is to have a program that is custom-made for the company. This could be expensive, but the results from the program will likely be very good since the software is tailor-made for that specific company. In IKEA's case a custom-made program could be a solution that could be acceptable. This point of view is based on the size of IKEA in the UK and that the funds that are connected to investments in new facilities are very large. A faulty decision may lead to huge additional costs for IKEA. A simulation may avoid this situation. Another fact that speaks for custom-made software is that the software can be made to gather data directly from IKEA's ERP (Enterprise Resource Planning). It may also, since it is created solely for IKEA, have the wanted features and therefore be fast, reliable and able to run with a wide article range.

If IKEA only has one scenario to simulate, the best course of action would probably be to use the services of a consultant firm since it seems unnecessary to invest in simulation software for a single scenario. If so, it is important that the firm has a clear objective from the beginning and have access to all relevant information needed.

9.5.2 Recommendations regarding LORD

LORD has many advantages. We think that it is a tool that is very easy to get started with. The graphical interface makes the software to a tool that gives a good visibility over the model and its Supply Chain. LORD is therefore a good tool to use when presenting an existing scenario. The predefined analyse panes are good and relevant. The possibility to define own analyse panes also makes the program helpful when making presentations. Since IKEA is in a state of growth in the UK and there are strategic choices to be made, the use for a simulation tool should be great. LORD makes it easy to simulate different scenarios but it does not present any optimal solution. As IKEA already has a pretty good idea of the different scenarios that are available to them, this should present no real problem. LORD is a simulation tool that has a low price[89] compared to other similar programs in the market. Although is the software still in the state of development. There are some features that have not yet been developed as we have mentioned before.

The version of the software that we used was for training. The manufacture of the software has not yet released a commercial product that has all the interfaces that are planned to be included in LORD. As of this date, when the program misses some of the functions that would help us in our work, such as an Excel interface, we would not like to recommend LORD to IKEA in the UK. Although if IKEA could get a free training version for evaluation,

[89] Interview with Mats Johnsson, 2002-02-04

as we did, we strongly recommend it. This would give the employees at IKEA an indication of the problems that occur when simulating and what data that is needed. The training on building a model also gives an insight of how the structure of the Supply Chainlooks like at IKEA. If a commercial version of the program is released that is able to accept Excel-files and have got rid of some of its “baby-diseases” then we certainly would not hesitate to recommend it.

10 Conclusions

The warehouse in Thrapston has a productivity that is much lower than the one in Doncaster. This implies that a switch to only having one warehouse, an extension of the one in Doncaster or that an upgrade of the DC in Thrapston along with the Doncaster facility is of vital importance.

Maybe IKEA can switch to one DC, but this action needs a more thorough investigation and simulation with more correct data. The simulations we have made gives a hunch that the transportation costs can be kept under control and maybe in fact be a bit lower than they are today.

To use a simulation tool that can work with a model without making too many simplifications would be a great asset to IKEA and help them in their decision making since they operate in a complex environment.

It is also vital when building a model of this scope and magnitude not to ignore the difficulties of data collection. Furthermore, it is required to have a clear objective at the beginning so it is easier to know what data is relevant.

LORD is a program that may be very well suited for a minor company to model problems of limited scope in time and in data. It may also, when further developed, become a suitable tool but the version available today is not one we would recommend. For IKEA, the best thing would be if it had a working excel-interface and the capability to run advanced simulation at a faster and more reliable rate.

In the near future when IKEA operates with twice the number of stores as they do today, they can expect a huge increase in the transportation costs.

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APPENDIX

Appendix 1 - Our defined products and its components

Components	**Volume m3**
Palletised	1
Unpalletised	1
Unit load	1

Product consist of:	Palletised	Unpalletised	Unit load
Full Pallet (FP)	2	2	
Half Pallet (HP)	1	1	
Picked pallet (PP)	1	1	1

Appendix 2 – The stores demand and transport prices

The percenatage of flow from DC to store

		% Participation		
Location	**Store No.**	**DC007**	**DC390**	**HSE 3**
Warrington	140	9,5%	10,8%	9,9%
Brent	141	14,4%	14,2%	14,5%
Birmingham	142	7,9%	7,8%	7,9%
Gateshead	143	5,8%	5,6%	4,8%
Croydon	144	11,6%	11,5%	11,4%
Leeds	261	7,9%	7,9%	7,9%
Thurrock	262	10,7%	10,3%	11,2%
Nottingham	263	8,0%	8,3%	8,6%
Bristol	264	9,9%	10,0%	9,3%
Edinburgh	265	6,6%	6,3%	6,8%
Glasgow	266	7,7%	7,4%	7,7%
		100,0%	100,0%	100,0%

Transport prices in British pound

Store No	THRAPSTON	DUNSTABLE	DONCASTER
140	294	276	172
141	210	194	370
142	175	175	200
143	307	307	250
144	244	223	330
261	243	266	162
262	191	190	302
263	174	295	162
264	305	222	307
265	460	475	330
266	460	475	330

Appendix 3 – DC Flow

Thrapston

	unit	Period 1				Period 2			
		September (4)		October (5)		November (4)		December (4)	
	unit	WS FC	Result	WS FC	Result	WS FC	Result	WS FC	Result
In Flow									
Palletised	m3	27 034	29 290	27 256	35 916	23 939	30 209	23 322	24 604
unpalletised	m3	4 621	5 575	9 611	5 619	4 615	3 339	3 743	3 063
unit loads	m3	1 353	-	1 576	805	288	2 291	1 728	2 311
Total New Inflow	m3	33 009	34 865	38 444	42 340	28 842	35 839	28 793	29 978
Internal Flow	m3	4 932	1 644	4 751	2 242	7 211	1 889	1 515	1 463
Tot Inflow	m3	37 941	36 509	43 195	44 582	36 053	37 728	30 308	31 440
variance			*4%*		*-3%*		*-5%*		*-4%*
Out Flow									
Outflow Store/DC/LSC FP	m3	26 322	29 194	33 414	36 785	24 538	26 784	22 602	21 816
Outflow Store/DC PLOCK	m3	7 107	8 152	7 950	10 415	7 222	7 984	7 709	6 570
Outflow LSC PLOCK	m3	3 977	1 762	2 803	2 191	2 633	2 192	1 809	1 271
Total Production Outflow	m3	37 406	38 975	44 167	49 048	34 392	36 594	32 120	29 327
Internal Outflow	m3	378	133	446	343	347	366	324	330
Total Out Flow	m3	37 784	39 108	44 613	49 391	34 740	36 960	32 444	29 657
variance			*-4%*		*-11%*		*-6%*		*9%*
Full Pallet Store	ol	29 247	34 890	37 126	43 991	27 264	33 173	25 114	26 434
Plock Store	ol	37 406	45 277	53 000	58 149	38 013	43 850	42 827	35 747
Plock LSC	ol	49 706	21 783	35 037	28 724	32 906	26 821	22 899	17 179
Total Plock Orders	ol	87 112	67 060	88 036	86 873	70 919	70 671	65 725	52 926
variance			*23%*		*1%*		*0%*		*19%*
Stockholding		72618	69 126	67 708	63 561	69 021	63 960	61 824	63 826
Weekly Inflow		9 485	9 127	8 639	8 916	9 013	9 432	7 577	7 860
Weekly Outflow		9 446	9 777	8 923	9 878	8 685	9 240	8 111	7 414

Store FP m3/ol	0,900	0,848	0,900	0,847	0,900	0,819	0,900	0,836
Store Pick Share M3 %	19%	23%	18%	23%	21%	24%	24%	24%
Store Pick m3/ol	0,190	0,180	0,150	0,179	0,190	0,182	0,180	0,184
CD Share m3	6,5%		6,5%		6,5%		6,5%	
Pick CD Share % m3	75%	78%	79%	79%	78%	77%	78%	76%
CD Pick m3/ol	0,0800	0,0809	0,0800	0,0763	0,0800	0,0817	0,0790	0,0740
Unpall	14%	16%	25%	13%	16%	9%	13%	10%
Unit Loads	4,10%	0,00%	4,10%	1,81%	1,00%	6,07%	6,00%	7,35%
% Internal Inflow	13,00%	4,50%	11,00%	5,03%	20,00%	5,01%	5,00%	4,65%
% Internal Outflow	1,00%	2,73%	1,00%	2,82%	1,00%	1,72%	1,00%	1,07%

Weeks in period	4	4	5	5	4	4	4	4

Thrapston cont.

Period 3				Period 4				Period 5			
January (5)		February (4)		March (4)		April (4)		May (5)		June (4)	
WS FC	Result	WS FC	Result	WS FC	Result	WS FC	Result	L/E	Result	L/E	Result
28 906	33 725	27 913	33 433	26 187	32 311	28 710	23 064	34 494	-	31 027	-
3 483	3 642	3 533	1 985	2 209	2 462	2 421	1 326	2 808	-	2 496	-
2 438	4 575	3 887	3 328	3 155	3 874	3 459	2 004	2 808	-	2 140	-
34 827	41 942	35 333	38 746	31 551	38 647	34 590	26 394	40 109	-	35 663	-
1 833	1 616	1 281	1 148	976	1 064	1 070	862	3 019	-	2 276	-
36 660	43 558	36 614	39 894	32 527	39 711	35 660	27 256	43 128	-	37 939	-
	-19%		*-9%*		*-22%*		*24%*				
28 333	32 744	23 189	26 458	19 030	25 862	24 807	18 083	29 873	-	25 863	-
9 447	8 978	7 065	6 354	5 317	6 152	6 693	4 349	7 087	-	5 692	-
1 584	2 084	1 860	2 038	2 240	2 087	1 966	1 527	2 411	-	1 928	-
39 364	43 413	32 114	34 655	26 587	33 665	33 465	23 392	39 370	-	33 484	-
398	394	489	195	405	435	1 394	567	2 072	-	2 137	-
39 762	43 807	32 603	34 851	26 992	34 101	34 860	23 959	41 443	-	35 621	-
	-10%		*-7%*		*-26%*		*31%*		-		-
31 481	38 935	27 281	32 545	22 388	31 903	31 008	21 900	37 342		32 329	
52 486	47 977	37 781	35 299	28 743	34 689	35 227	23 713	37 298	-	29 959	-
21 408	26 559	23 843	25 184	30 269	24 742	23 126	18 227	28 359	-	22 685	-
73 894	74 536	61 624	60 483	59 012	59 431	58 353	41 940	65 657	-	52 645	-
	-1%		*2%*		*-1%*		*28%*		*0%*		*0%*
60 724	64 629	68 640	69 203	74 738	73 447	74 247	78 446	75 933		78 250	

7 332	8 712	9 154	9 974	8 132	9 928	8 915	6 814	8 626	-	9 485	-
7 952	8 761	8 151	8 713	6 748	8 525	8 715	5 990	8 289	-	8 905	-

0,900	0,849	0,850	0,823	0,850	0,820	0,800		0,800		0,800	
24%	22%	22%	20%	20%	20%	20%		18%		17%	
0,180	0,187	0,187	0,180	0,185	0,177	0,190		0,190		0,190	
6,5%		6,5%		6,5%		7,0%		7,0%		7,5%	
76%	76%	70%	73%	75%	74%	75%		75%		75%	
0,0740	0,0785	0,0780	0,0809	0,0740	0,0843	0,0850		0,0850		0,0850	
10%	9%	10%	5%	7%	6%	7%		7%		7%	
7,00%	10,50%	11,00%	8,34%	10,00%	9,76%	10,00%		7,00%		6,00%	
5,00%	3,71%	3,50%	2,88%	3,00%	2,68%	3,00%		7,00%		6,00%	
1,00%	1,56%	1,50%	1,33%	1,50%	0,82%	4,00%		5,00%		6,00%	

5	5	4	4	4	4	4	4	5	5	4	4

Thrapston cont.

Period 6						
July (5)		August (4)		Total		
L/E	Result	L/E	Result	Original FC	Latest Estimate	Result
33 813	-	28 370	-	335 593	340 971	242 552
2 733	-	2 295	-	44 117	44 567	27 011
2 492	-	2 115	-	26 835	27 438	
39 037	-	32 779	-	406 544	412 976	288 751
2 492	-	2 467	-	34 508	33 824	11 929
41 529	-	35 246	-	441 052	446 800	300 679
32 094	-	27 308	-	318 320	317 372	217 726
6 089	-	4 369	-	75 243	81 748	58 955
2 411	-	1 928	-	28 884	27 549	15 152
40 594	-	33 605	-	422 447	426 669	289 069
3 055	-	3 734	-	10 788	15 180	2 764
43 649	-	37 339	-	433 235	441 849	291 833
	-		-			
40 117		34 135		365 657	374 832	263 771
32 048	-	22 993	-	407 223	447 780	324 701
28 368	-	2 269	-	348 242	320 875	189 219
60 415	-	25 261	-	755 465	768 654	513 920
	0%		*0%*			
76 130		74 038				

8 306	-	8 812	-
8 730	-	9 335	-

0,800		0,800	
15%		13%	
0,190		0,190	
7,5%		8,0%	
75%		75%	
0,0850		0,8500	
7%		7%	
6,00%		6,00%	
6,00%		7,00%	
7,00%		10,00%	

5	5	4	4

Doncaster

	unit	Period 1				Period 2			
		September (4)		October (5)		November (4)		December (4)	
	unit	WS FC	Result	WS FC	Result	WS FC	Result	WS FC	Result
In Flow									
Palletised	m3	23 333	15 106	14 300	12 958	12 681	13 047	13 485	12 722
unpalletised	m3	10 769	7 865	15 889	8 687	10 793	8 860	14 113	8 444
unit loads	m3	1 795	2 877	1 589	5 018	3 508	3 702	3 763	3 638
Total New Inflow	m3	35 897	25 848	31 778	26 663	26 981	25 609	31 361	24 804
Internal Flow DC-DC	m3	3 989	5 855	10 593	8 004	6 745	7 217	6 884	3 654
Tot Inflow	m3	39 885	31 703	42 371	34 666	33 727	32 826	38 245	28 458
variance			*21%*		*18%*		*3%*		*26%*
Out Flow									
Outflow Store/DC	m3	23 510	19 354	24 409	25 276	23 241	22 459	20 911	19 708
Outflow Store/DC PLOCK	m3	5 898	5 228	6 115	6 720	5 113	5 304	5 568	4 891
Outflow LSC	m3	80	401	53	619	51	460	35	498
Total Production Outflow	m3	29 488	24 983	30 577	32 615	28 405	28 223	26 514	25 097
Internal Outflow	m3	-	-	-	-	-	-	-	-
Total Out Flow	m3	29 488	24 983	30 577	32 615	28 405	28 223	26 514	25 097
variance			*15%*		*-7%*		*1%*		*5%*
Full Pallet	ol	26 123	24 369	30 511	31 162	29 051	27 317	26 139	23 837
Plock store	ol	34 691	32 047	38 222	41 043	31 955	32 120	32 752	28 770
Plock LSC Replenishment	ol	80	430	53	797	51	550	35	607
Total Plock Orders	ol	34 771	32 477	38 275	41 840	32 006	32 670	32 787	29 377
variance			*7%*		*-9%*		*-2%*		*10%*
Stockholding		60 863	55 912	67 705	62 902	73 028	67 171	78 903	69 890

Weekly Inflow	**M3**	9 971	7 926	8 474	6 933	8 432	8 206	9 561	7 115
Weekly Outflow	**M3**	7 372	6 246	6 115	6 523	7 101	7 056	6 628	6 274
Weekly Outflow	**OL**	8 673	8 012	7 644	8 209	7 989	8 030	8 188	7 193

Store/DC M3/OL	0,80	0,79	0,80	0,81	0,80	0,82	0,80	0,83
Plock Share Store M3	20%	21%	20%	21%	18%	19%	21%	20%
Size per store plock ol	0,17	0,16	0,16	0,16	0,16	0,17	0,170	0,170
CD Share	1,5%		1,5%		1,5%		1,5%	
Plock Share CD M3							0%	
Size per CD plock ol	1,00		1,00		1,00		1,00	
Unpall	30%	25%	50%	23%	40%	27%	45%	30%
Unit Loads	5%	9,1%	5%	13,0%	13%	11%	12%	13%
% Internal Inflow	10%	0%	25%	0%	20%	0%	18%	0%
% Internal Outflow	0%	2%	0%	2%	0%	2%	0%	2%
Weeks in period	4	4	5	5	4	4	4	4

Doncaster cont.

Period 3				Period 4				Period 5			
January (5)		February (4)		March (4)		April (4)		May (5)		June (4)	
WS FC	Result	WS FC	Result	WS FC	Result	WS FC	Result	L/E	Result	L/E	Result
16 411	15 393	12 834	14 313	13 540	17 311	16 796	13 465	18 230		17 940	
13 966	12 941	9 557	7 111	10 083	8 357	7 798	6 647	12 039		11 847	
4 539	6 818	4 915	3 411	5 186	5 761	5 399	4 476	4 128		4 062	
34 916	35 152	27 307	24 835	28 809	31 429	29 992	24 588	34 396		33 849	
6 162	3 654	3 034	2 394	3 201	589	1 250	608	1 433		1 410	
41 078	38 806	30 341	27 228	32 010	32 018	31 242	25 196	35 829		35 259	
	6%		*10%*		*0%*		*19%*				
28 343	25 860	23 074	20 117	23 214	20 018	23 461	15 220	28 911		22 972	
7 094	6 681	6 144	5 387	6 950	5 447	6 248	4 328	7 696		6 119	
31	595	40	712	55	555	44	311	39		48	
35 468	33 136	29 258	26 216	30 219	26 021	29 753	19 858	36 646		29 140	
-	-	-	-	-	-	-	-	-		-	
35 468	33 136	29 258	26 216	30 219	26 021	29 753	19 858	36 646		29 140	
	7%		*10%*		*14%*		*33%*				
35 429	31 354	28 842	23 797	29 017	22 975	26 067	17 836	32 124		25 525	
41 727	39 563	36 356	31 660	40 884	31 774	33 773	24 916	41 598		33 077	
31	728	40	784	55	639	44	398	39		48	
41 759	40 291	36 396	32 444	40 939	32 413	33 817	25 314	41 638		33 126	
	4%		*11%*		*21%*		*25%*				
75 500	76 339	77 422	77 083	78 874	83 117	84 606	88 731	83 789		89 909	

8 216	7 761	7 585	6 807	8 003	8 004	7 810	6 299	7 166	-	8 815	-
7 094	6 627	7 315	6 554	7 555	6 505	7 438	4 965	7 329	-	7 285	-
8 345	7 913	9 089	7 915	10 221	7 944	8 443	6 229	8 320	-	8 269	-

0,80	0,82	0,80	0,85	0,80	0,87	0,90		0,90		0,90	
20%	21%	21%	21%	23%	21%	21%		21%		21%	
0,170	0,169	0,169	0,170	0,170	0,171	0,185		0,185		0,185	
1,5%		1,5%		1,5%		1,5%		1,5%		1,5%	
0%		0%		0%		0%		0%		0%	
1,00		1,00		1,00		1,00		1,00		1,00	
40%	33%	35%	26%	35%	26%	26%		35%		35%	
13%	18%	18%	13%	18%	18%	18%		12%		12%	
15%	0,00%	10%	0%	10%	0%	4%		4%		4%	
0%	2%	0%	3%	0%	2%	0%		0%		0%	

5	5	4	4	4	4	4	4	5	5	4	4

Doncaster cont.

Period 6				Total		
July (5)		August (4)				
L/E	Result	L/E	Result	Original FC	Latest Estimate	Result
19 701		16 704		**192 150**	**195 956**	**114 314**
13 010		11 031		**141 676**	**140 896**	**68 912**
4 461		3 782		**44 668**	**47 125**	**35 701**
37 172		31 518		**378 494**	**383 977**	**218 927**
1 549		1 313		**58 546**	**47 563**	**31 975**
38 721		32 831		**437 040**	**431 540**	**250 902**
27 793		25 163		**290 613**	**295 003**	**168 012**
7 398		7 531		**81 242**	**77 874**	**43 984**
39		48		**585**	**562**	**4 151**
35 230		32 742		**372 439**	**373 439**	**216 147**
-		-		**-**	**-**	**-**
35 230		32 742		**372 439**	**373 439**	**216 147**
30 881		27 959		**360 001**	**347 669**	**202 647**
39 991		40 706		**485 363**	**445 735**	**261 893**
39		48		**585**	**562**	**4 933**
40 030		40 755		**485 948**	**446 297**	**266 826**
93 400		93 489				

7 744	-	8 208	-
7 046	-	8 186	-
7 998	-	10 177	-

0,90		0,90	
21%		23%	
0,185		0,185	
1,5%		1,5%	
0%		0%	
1,00		1,00	
35%		35%	
12%		12%	
4%		4%	
0%		0%	

5	5	4	4

Dunstable

		Period 1				Period 2			
		September (4)		October (5)		November (4)		December (4)	
	unit	WS FC	Result	WS FC	Result	WS FC	Result	WS FC	Result
In Flow									
Palletised	m3	6 380	1 791	10 208	11 695	6 582	8 346	5 101	5 077
unpalletised	m3	3 435	7 576	3 403	2 891	2 821	2 072	2 747	1 495
unit loads	m3	-	-	-	-	-	-	-	-
Total New Inflow	m3	9 815	9 367	13 611	14 586	9 403	10 418	7 848	6 572
Internal Flow	m3	99	112	137	323	95	961	1 385	2 340
Tot Inflow	m3	9 914	9 479	13 748	14 909	9 498	11 380	9 233	8 912
variance			*4%*		*-8%*		*-20%*		*3%*
Out Flow									
Outflow Store/DC	m3	7 703	8 513	9 687	11 294	6 779	10 559	9 367	8 530
Outflow Store/DC PLOCK	m3	-	-	-	-	-	-	-	-
Outflow LSC	m3	-	-	-	-	-	-	-	-
Total Production Outflow	m3	7 703	8 513	9 687	11 294	6 779	10 559	9 367	8 530
Internal Outflow	m3	1 359	971	1 984	1 179	1 389	1 047	1 653	790
Total Out Flow	m3	9 062	9 484	11 671	12 473	8 168	11 606	11 021	9 320
variance			*-5%*		*-7%*		*-42%*		*15%*
Full Pallet	ol	7 703	9 137	10 196	12 685	7 136	11 532	9 860	9 515
Plock store	ol	-	-	-	-	-	-	-	-
Plock LSC	ol	-	-	-	-	-	-	-	-
Total Plock Orders	ol	-	-	-	-	-	-	-	-
variance									
Stockholding		42 582	42 066	44 144	44 396	45 474	43 881	42 094	43 344
Weekly Inflow		2 479	2 370	3 437	3 727	1 900	2 276	2 308	2 228
Weekly Outflow		2 266	2 371	2 918	3 118	1 634	2 321	2 755	2 330
Store FP m3/ol		1,00	-	0,95	-	0,95	-	0,95	-
Store Pick Share M3 %		-	-	-	-	-	-	-	-
Store Pick m3/ol		-	-	-	-	-	-	-	-
CD Share m3		-	-	-	-	-	-	-	-
Pick CD Share % m3		-	-	-	-	-	-	-	-
CD Pick m3/ol		-	-	-	-	-	-	-	-
Unpalletised		35%	0%	25%	0%	30%	0%	35%	0%
Unit Loads		0%	0%	0%	0%	0%	0%	0%	0%
% Internal Inflow		1,0%	0,0%	1,0%	0,0%	1,0%	0,0%	15,0%	0,0%
% Internal Outflow		15,0%	0,0%	17,0%	0,0%	17,0%	0,0%	15,0%	0,0%
Weeks in period		4	4	4	4	5	5	4	4

Dunstable cont.

Period 3				Period 4				Period 5			
January (5)		February (4)		March (4)		April (4)		May (5)		June (4)	
WS FC	Result	WS FC	Result	WS FC	Result	WS FC	Result	WS FC	Result	WS FC	Result
7 553	6 795	4 592	3 287	4 696	5 219	4 612	2 864	4 940	-	6 974	-
2 518	2 302	2 473	1 746	2 528	1 425	2 484	1 823	2 660	-	3 755	-
-	-	-	-	-	-	-	-	-	-	-	-
10 070	9 097	7 065	5 033	7 224	6 644	7 096	4 687	7 600	-	10 729	-
6 714	3 780	4 710	2 701	2 408	466	1 774	444	1 900	-	2 682	-
16 784	12 876	11 775	7 734	9 632	7 110	8 870	5 130	9 500	-	13 412	-
	23%		*34%*		*26%*		*42%*				
8 038	12 148	8 392	7 663	6 592	6 345	6 982	4 963	7 449	-	7 184	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
8 038	12 148	8 392	7 663	6 592	6 345	6 982	4 963	7 449	-	7 184	-
2 009	1 400	1 481	1 089	1 648	866	1 232	804	1 315	-	1 268	-
10 047	13 548	9 874	8 751	8 240	7 212	8 214	5 767	8 764	-	8 452	-
	-35%		*11%*		*12%*		*30%*				
8 461	12 732	8 797	8 075	6 910	6 975	7 319	5 325	7 809	-	7 184	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
50 081	43 141	45 043	41 790	43 182	41 899	42 555	42 033	43 291		48 251	

3 357	2 575	2 944	1 933	2 408	1 777	2 218		1 900		3 353	
2 009	2 710	2 468	2 188	2 060	1 803	2 054		1 753		2 113	

0,95	0,95	0,95	-	0,95	-	0,95	-	0,95	-	1,00	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
25%	25%	35%	0%	35%	0%	35%	0%	35%	0%	35%	0%
0%	0,0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
40,0%	29,4%	40,0%	0,0%	25,0%	0,0%	20,0%	0,0%	20,0%	0,0%	20,0%	0,0%
20,0%	0,5%	15,0%	0,0%	20,0%	0,0%	15,0%	0,0%	15,0%	0,0%	15,0%	0,0%

5	5	4	4	4	4	4		5		4	

Dunstable continue

Period 6				Total		
July (5)		August (4)				
WS FC	Result	WS FC	Result	Original FC	Latest Estimate	Result
8 112	-	5 416	-	**77 185**	**75 166**	**45 072**
4 368	-	2 916	-	**37 195**	**36 107**	**21 330**
-	-	-	-	**-**	-	-
12 480	-	8 332	-	**114 380**	**111 273**	**66 402**
3 120	-	2 083	-	**28 626**	**27 107**	**11 126**
15 600	-	10 415	-	**143 006**	**138 380**	**77 529**
7 911	-	8 660	-	**98 569**	**94 744**	**70 015**
-	-	-	-	**-**	**-**	**-**
-	-	-	-	**-**	**-**	**-**
7 911	-	8 660	-	**98 569**	**94 744**	**70 015**
1 396	-	1 528	-	**18 937**	**18 262**	**8 146**
9 307	-	10 188	-	**117 506**	**113 006**	**78 161**
7 911	-	8 660	-	**101 954**	**97 945**	**75 976**
-	-	-	-	**-**	**-**	**-**
-	-	-	-	**-**	**-**	**-**
-	-	-	-	**-**	**-**	**-**
54 544		54 771				

3 120	2 604
1 861	2 547

1,00	-	1,00	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
35%	0%	35%	0%
0%	0%	0%	0%
20,0%	0,0%	20,0%	0,0%
15,0%	0,0%	15,0%	0,0%

5		4