MASTER

Optimization in the supply chain of high value reusable containers
a distributor perspective

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Optimization in the Supply Chain of High Value Reusable Containers

A Distributor Perspective

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Univar Ltd.
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Abstract

The Safe-tainer is an expensive reusable container for chlorinated solvents. This project was a research into the supply chain of these containers, aimed at finding opportunities to reduce logistics costs. The main cost trade-off appears to be between the fixed costs of the Safe-tainer pool and the costs of transport. The result of this project is a quantitative model that describes the relationship between pool costs and transport costs. Augmented with a simple Optimization heuristic, the model can be used to determine the optimal pool size and also to determine the optimal allocation of Safe-tainers that are available to the distributor to its sites.

Executive Summary

Univar Ltd is a large distributor of chemicals in the UK. Univar is a reseller. That is, the company buys chemicals from suppliers, possibly repacks them, and sells them to customers. Univar's distribution network consists of 11 sites. There are more than 11 sites but those sites operate independently in another business segment. The network is set up as in a hub & spoke configuration. That is, stock for each product is centralized at one site called the hub. From this site the product is replenished to all other sites that are called spokes when required. Each site serves all products to all customers in its region.

Safe-tainers

Univar operating margins are under pressure and therefore, the company needs to cut its costs of operations. The group of product that is the subject of this research was identified as an important contributor to the operating costs. These products are chlorinated solvents, and more specifically chlorinated solvents in a special type of containers: Safe-tainers.

Safe-tainers are expensive reusable containers for chlorinated solvents. The Safe-tainer is basically a regular drum in a galvanized steel body. The drums are fitted with a pump system that allows solvent to be pumped straight from the Safe-tainer into the user's machine. Because they are double walled and solvent can be pumped out of the drum (instead of having to be poured into the machine), they are safer to handle and during transport than regular drums. This is important because chlorinated solvents are an environmental and health hazard.

All Safe-tainers are property of a subsidiary of Dow Chemicals: Safechem. In the UK, Safechem only sells chlorinated solvents in Safe-tainers to two distributors: Univar and Caldic. Only the solvent is sold. Also no deposit or rent is charged by Safechem for the use of a Safe-tainer.

Assignment

Univar has asked the student to conduct a research into the supply chain of Safe-tainers to identify and implement opportunities to reduce the logistics costs. The project is divided into four phases. In the orientation phase information about the company and the main issues related to the project is collected. This leads to an assignment and to potential improvement opportunities that are investigated in the analysis phase. One of the improvement opportunities is worked out in detail in the design phase. Finally, the implementation issues are dealt with in the implementation phase.

Orientation ——▶ Analysis ——▶ Design ——▶ Implementation

At the end of the orientation phase, the assignment is formulated as follows:

Make an efficient design for the supply chain of chlorinated solvents which comprises both short term 'quick gains' and long term objectives. The short term design will be implemented as soon as possible. The long term design is a feasibility study into a number of supply chain concepts to be defined at a later stage. The design considers inventories, transport, ordering policies, and allocation of operational activities.

In this assignment, short term 'quick gains' refers to two improvement opportunities that were initially proposed by Univar:

1) Transfer the existing process from Grimsby to Middlesbrough, where Middlesbrough is to deliver Safe-tainers via the existing network and Regional Distribution Centres.
2) Negotiate with Dow Chemicals an agreement whereby Univar will store and fill Safe-tainers at Middlesbrough.

These two proposals are very important to Univar and if the would turn out to be profitable, they had to be implemented as soon as possible. We found that the first opportunity would be profitable but suggested a different site to function as the hub: South Kirkby, mainly because expected savings are almost double the expected savings if Middlesbrough is used. Filling of Safe-tainers was found to be not economically viable unless other business can be found to utilize the extra capacity of a filling station.

Issues Identified

The main part of logistic costs for Safe-tainers at Univar is caused by transport. Currently, vehicles of which Safe-tainers are transported are not used efficiently for the following reasons:

1) Safe-tainers are not distributed over the spokes,
2) Special detours need to be made for Safe-tainers,
3) Vehicles need to return to the hub for Safe-tainers only,
4) Vehicles used for trips to and from the filler are poorly utilized.

Essentially, the first three issues mentioned here come down to the same result as issue 4: vehicles are underutilized. The first three issues are solved if the first of the abovementioned proposals is implemented. However, there is one major barrier: the availability of Safe-tainers.

The Safe-tainer is expensive. A lot of capital is tied up in the UK Safe-tainer pool. Safechem therefore limits the size of the Safe-tainer pool. As a result, the number of Safe-tainers that are available to the distributor is also limited and depends on the number of Safe-tainers that are in use by the customer. This sometimes leads to a Safe-tainer shortage at the filler and distributor. Shortages are dealt with by making extra trips on poorly utilized vehicles. An example will clarify this. Suppose 2 Safe-tainers need to be delivered to a customer before the end of the week. Univar is out of stock. Although Univar has placed an order with the Safechem, nothing has been delivered yet because there are only 3 Safe-tainers on stock at the filler (and Univar ordered a batch of say 30 Safe-tainers). Because Univar wants to deliver Safe-tainers to the customer on time, it sends a vehicle to the filler with capacity for at least 40 Safe-tainers to collect the 3 available Safe-tainers. Later in the week, the rest of the Safe-tainers will be collected.

If Safe-tainers are distributed through the spokes, Univar needs to keep a Safe-tainer stock at each spoke in order to meet the delivery lead times. This would increase the amount of stock required at the distributor. In other words, higher availability of Safe-tainers is needed. If the availability is not increased, more frequent trips on poorly utilized vehicles are needed to move Safe-tainers.

Another barrier to the transition to hub & spoke for Safe-tainers is that Safe-tainers are individually tracked. Each Safe-tainer has a uniquely identifying code and with this code, every movement of a Safe-tainer in the supply chain is logged.

Improvement Opportunities

Improvement options other than the first proposal that was mentioned earlier are the following:

3. Supply of bulk solvent by road tankers directly from the production plant in Germany, eliminating current inventories at the Vopak terminal in Teesside
4. Reducing replenishment lead times and perform cross docking at spokes in order to eliminate all inventories at the spokes
5. Differentiated supply chain with two customer lead times aimed at keeping a minimum amount of Safe-tainers at the spokes only to serve customers with the most stringent lead time demands, whereas other customers customer orders are satisfied (over the spokes) from hub stock
6. Determination of the optimal Safe-tainer pool size and optimal allocation of available Safe-tainer to the distributor sites
7. Determination of economic batch sizes
    a. on trips to/from filler
    b. for return of waste Safe-tainers from spokes to hub
    c. on trips to the customer
8. Increasing customer utilization, thereby reducing the number of Safe-tainers at customers and increasing the availability at the distributor
9. Vendor managed inventory (VMI): Univar manages customer inventories
10. An alternative Safe-tainer concept where the outer hull is separated from the drum and the cycle of outer hull is reduced to the spoke and customer

Based on the following criteria, one of these options was selected to be worked out in detail:

- Expected supply chain profits. These also include profits that are incurred by Safechem.
- The risk of failure. This is the product of required investment and the probability that the improvement does not lead to profits.
- Location of profits and investments. The prerequisite is that improvements must yield savings for Univar.
- Added value of the student in working out the improvement option.

A qualitative judgement was made of each option based on these criteria supported by rough quantitative analysis if possible. Option 6 was selected.

The model

A model was developed that has two functions:

- At the tactical level, the model can be used to determine the optimal pool size. The independent control variable is the pool size. The dependent variables are the fixed costs of the Safe-tainer pool and the logistic costs at Univar. The optimum is reached where the marginal increase of these costs are equal.
- At the execution level, the model is used to determine the optimal distribution of available Safe-tainers among the Univar sites. Optimal spoke inventory levels are not fixed but depend on the availability of Safe-tainers. The model determines the cost optimal inventory level for each site given a certain availability.

The model is based on two major assumptions:

- Univar has its own Safe-tainer pool that has a fixed size. In reality the Safe-tainer pool is shared with the another distributor in the UK. Safechem has no policy on the allocation of Safe-tainers in case there are shortages.
- The total logistic costs increase linearly with the average expected system backlog at Univar. The average expected system backlog is the average amount of Safe-tainers backlogs if no special action is taken to avoid a shortage at one of the sites.

The model uses the following input parameters:

- Pool size
- Number of Safe-tainers in use by Univar customers (average and standard deviation)
- Nominal supply lead time, and replenishment lead times
- Parameters of the demand process at each spoke:
  - Average number of orders per week
  - Average size of an order
- The amount of available Safe-tainers at each site

The model output is the expected average backlog. This amount can be translated to expected logistic costs. A simple heuristic is proposed that can be used with the model to determine the allocation of available Safe-tainers to sites that minimizes the system backlog.

The reliability of the model is tested by comparing its results to the results of a discrete simulation. 5 scenarios are based on recent data about 5 products that Univar sells in Safe-tainers. It is shown that the model is reasonably accurate. Average backlog given by the model differs from the simulation by approximately 0.1. There is no bias is the results.

The model is a powerful tool to relate the Safe-tainer pool size costs for the supplier to logistic costs for Univar. Substantial savings can be achieved both at the distributor and at the supplier by choosing the right pool size for each product. The model also provides decision support for stock control of Safe-tainers. This is important because the common DRP approach of fixed target stock levels lead to non-optimality.

If the model is used, availability barriers to further supply chain improvements like the proposed improvements 1 and 7 are reduced.

Preface

Industrial Engineering and Management Science is an MSc. program at the Eindhoven University of technology. This five year program is concluded with the graduation project. During this project that usually takes the form of a placement with a company, the student has to show that (s)he can put the knowledge and skills obtained from the program into practice. A graduation project in this program is always design oriented. An initial problem or assignment is investigated. Using a systematic and scientific approach a solution is developed. Finally, this solution is implemented or a plan for implementation is developed. The project is described and the project results are presented in a final thesis.

This document is the final thesis for the graduation project that I did with Univar Ltd. in the United Kingdom. It is structured chronologically. First, the reader is introduced to the company and the problem. Second, information about the problem that was collected during the orientation phase is presented. Third, alternative solutions are analysed and discussed. Fourth, one option is selected and worked out in detail. Fifth, implementation issues are discussed. The thesis ends with the conclusion and recommendations for the follow-up of the project.

Acknowledgements

First of all I would like to thank the people of Univar Ltd. who made it possible to do this project. These people were always happy to spend time with me providing me the essential information for my research. Special thanks go to Phil Hockaday and Karl Jacobie who were my company supervisors in this project. Also special thanks go to Ken Smart who has spent many hours with me thinking about opportunities and helping me with indispensable knowledge.

I would like to express my gratitude to David Mahon who is the sponsor of this project. I sincerely hope that he will find it interesting to read this thesis and find that it contains useful concepts that may be applied throughout Univar.

I want to thank my University supervisors. My first supervisor, Professor Sharman has travelled to the UK on many occasions to help me with his inexhaustible experience. I want to thank Dr. Ir. Flapper for many critical remarks that led me to spend many a late hour on my thesis. I also greatly value and appreciate his inspired involvement when I built the model.

I want to thank my friends from Adonis for forcing me to stay in contact with the Netherlands and for providing me shelter and distraction whenever I was in Eindhoven.

Foremost, I want to thank my parents who made it possible for me to study and who have supported me throughout.

Michiel Jansen
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1 Introduction

If we had no winter, the spring would not be so pleasant. If we did not sometimes taste of adversity, prosperity would not be so welcome.

Anne Bradstreet

This chapter is an introduction to the project that is the subject of this report. First the company where the project took place is introduced in section 1.1. Then the product that is investigated is described in section 1.2. More specifically, the research focuses on the container in which the product is kept. This container is discussed in section 1.3. Finally, the initial assignment is given in section 1.4. Also presented in section 1.4 is the project approach and the structure of this document.

1.1 Univar Ltd.

History

Univar's history dates back to 1924 when the George Van Waters and Nat Rogers established Van Waters & Rogers. In 1996, Univar was acquired by Royal Pakhoed, making it the world's largest chemical distribution company. After a failed merger attempt in 1998, Royal Van Ommeren (tank storage, deep sea and inland shipping), and Royal Pakhoed merged in 1999 to Royal Vopak. In January 2001. Vopak completed the acquisition of Ellis & Everard, an international distributor of chemicals and the biggest player in the UK. The UK chemical distribution activities of Vopak adopted the brand name 'Ellis & Everard'. At that time Vopak was planning to bring all operations under the Vopak brand name by 2002. Financial results were disappointing in 2001 and the expected synergies of the Van Ommeren – Pakhoed merger stayed out. At the end of 2001, the chairman of the Executive Board of Vopak is replaced by Gary Pruitt, who is asked by the Supervisory Board to develop a plan to address the problems that Vopak faces. This results in the split-up of Vopak in June 2002. The chemical distribution operations are brought into a separate company that is called Univar. The logistics activities go on under the name Vopak. Both companies are listed at the Dutch Stock Exchange. The UK distribution operations face another name change to Univar.

Company

This section provides general information about Univar. Those who are familiar with the company can skip this section and go to section 1.3. We advise those who do not know the company well to read at least the part 'Supply chain' in this section.

Univar Ltd is a distributor of chemicals. Univar does not merely provide a service to its suppliers but actually becomes the owner of the product. For some products, Univar has multiple suppliers. Univar has its own sales and marketing function and performs its own customer acquisition. Although Univar is independent, some suppliers have substantial power over Univar. In order for Univar to tie customers to itself, it needs to have good supplier deals. Suppliers often select only one or two distributors with which they deal. On the other hand, it is also important to have a broad customer base to be attractive to the suppliers.

For a middleman to stay in business, it is very important to have a distinctive added value to the supply chain. Univar owes much to the fact that their suppliers only provide limited flexibility in their service to customers. Univar makes use of this gap. Its added value to the supply chain is fourfold:

- Univar aims to be the single point of supply for its customers. It wants to be able to supply any chemical that the customer requires.
- Univar sells chemicals in many different quantities, and in many different packages. It supplies its products in a way that is tailored to the customer's requirements.
- Univar has extensive knowledge about the applications of chemicals and the processes in which they are used. They are able to provide solutions instead of mere products.
- Univar is highly service oriented, providing short delivery lead times and a high service level.

Univar acts as a middleman that links suppliers of chemicals to customers. The success of the company depends not only on its ability to lock in customers but also on the deals with its suppliers. The company's mission is therefore aimed both at suppliers and customers The mission also points out the importance of society and environment to Univar. Univar's mission is as follows:

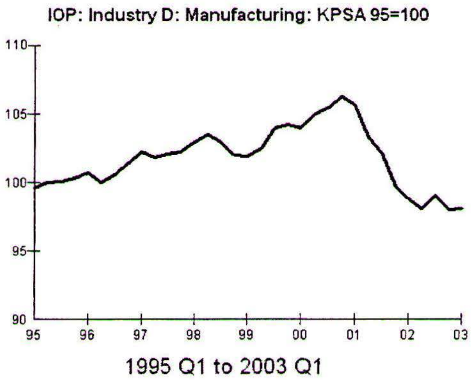
Univar sets out to be the preferred quality partner for the distribution of chemicals and services. We combine economic success with social and environmental responsibility.

Univar Ltd. is a full subsidiary of Univar NV. Univar NV is listed on the Dutch stock exchange but has its head office in Seattle (US). In the annual report amounts are stated in US dollars. Global net sales in 2002 were almost 4.5 billion dollar of which 53% came from the US, 13 % from Canada, and 34% from Europe. Both revenues and sales were less in 2002 than in 2001. Europe faced an 8.9% decline in sales and a 6.8% decline in profits. 2003 seems to become a better year for Univar NV than 2002. In the first half of 2003, sales and gross profit have gone up by 8.8%. However, these improvements mainly take place outside of the UK.

In the UK, Univar is the market leader with a market share of 22%. The biggest competitors of Univar in the UK are Albion and Petrochem. In total, Univar delivers over 440,000 tonnes per annum to more than 10,000 customers across the UK. 2002 sales were EUR407 million.

The events on the 11th of September 2001 have had a serious impact on UK manufacturing. There is also a general feeling among manufacturers that the government is neglecting this industry and favors the tertiary sector. Manufacturing is moving out of the UK to lower wage countries. As a result, production in this industry has fallen to a historical low (see figure 1). The bad economic tide has put the Univar margins under pressure. Suppliers sell at higher prices and customers demand lower prices. Univar is in the middle of this.

Figure 1: GDP
Manufacturing UK



The organization structure of Univar NV is geographically oriented. In Mintzberg's structure configuration theory, Univar NV has a fully divisionalised form. There are three major divisions within Univar NV: the US, Canada, and Europe. Within the division Europe, there 11 country organizations and three organizations that focus on a specific market product market combination. These organizations work completely separately from each other. Within Europe, the largest subsidiary of Univar NV is Univar Ltd (UK).

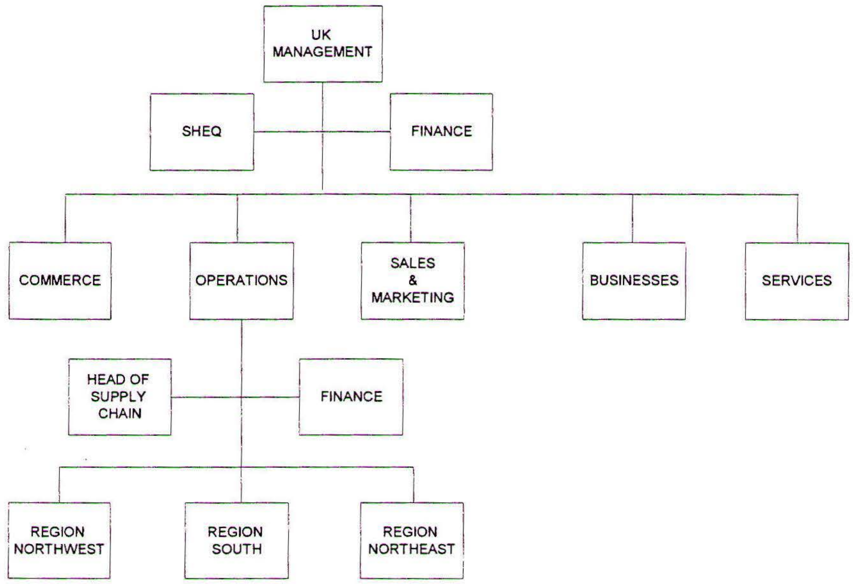
NOTE: *In the rest of this document, Univar refers to Univar Ltd.*

Univar's organizational structure is fairly complex. It is a hybrid structure that is both functionally and market oriented. Currently, the organizational structure is being revisited but the changes to the company structure are not known at the time of writing. Therefore, the structure as it was at the beginning of 2003 is described here.

The top level of the organization has 5 functional departments: Operations, Commerce (responsible for supplier accounts), Sales and Marketing , Finance, and SHEQ (Safety, Health, Environment, and Quality). Besides there are the Business department and Services department. The Services department includes several support functions such as 'Business Analysis', 'Marketing and Development', and 'Operations Logistics'. It includes the company R W Greeff which provides product and process solutions to several manufacturing industries. The department Businesses covers the industry segment Pharmaceuticals & Personal Care.

Operations is divided into 3 regions and has two staff functions: Finance and Supply Chain. Finance covers all site accountants and their managers. It is related to the company staff function Finance. The Head of Supply Chain is responsible for improvements in the distribution network of Univar. The previous head of supply chain is also supervisor of this project. He has now taken on the function of UK Operations Manager.

Figure 2: Organization Chart



Recent developments

Univar has gone through quite a few changes during the last couple of years. There has been a transition from the old Ellis & Everard to the new Univar. Since Ellis & Everard was acquired by Vopak in 2001, change was the order of the day. The main trends since then have been standardization, and centralization.

Ellis & Everard was a company like many others in the chemical distribution industry still are. The sites operated highly independently from each other. Each site had its own way of conducting business. Procedures were different for every site and are historically grown practices. Sites had their own product range and managed inventory completely separate from other sites. The sites depended completely on the experience of their employees. Their independence and lack of formal procedures gave the sites very high flexibility. The customer lead-time was often not more than 2 days.

The current Univar is much different from the old Ellis & Everard. In order to stay in business, Univar recognises that it needs to exploit its economies of scale. Sites now operate in a much more integrated way. The change culminated with the introduction of hub & spoke (see next section) and DRP (Distribution Requirements Planning). Univar also recognises that it runs a high risk by depending solely on the knowledge and experience of individuals for the day to day operations of the company. The transition to Univar involved closing down many sites and people leaving the company. In order to avoid being left in chaos if people leave the company, the company is standardising and formalizing its procedures. Key functions such as stock keeping are now supervised by a newly created management layer that formulates company policies.

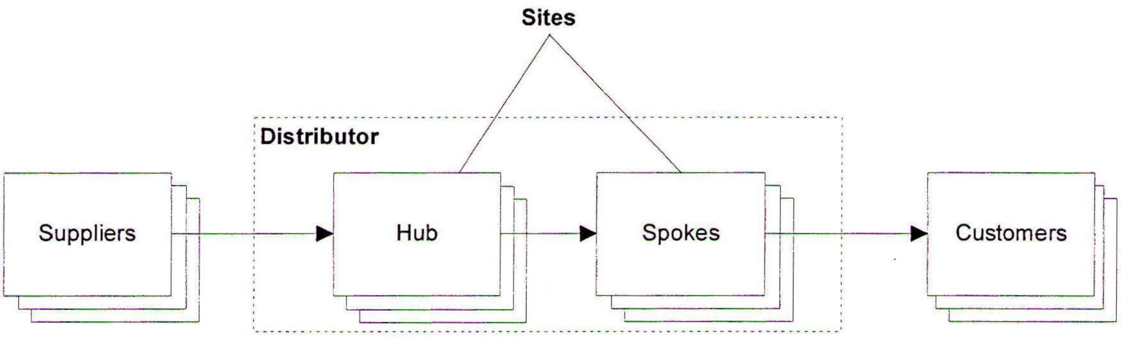
Although fine-tuning is still taking place, Univar believes that the changes have led to a clearer and more efficient distribution network. Univar can now utilize its size and achieve economies of scale. All products can now be delivered from all sites, customers and suppliers have a single point of contact, and inventories have been centralized and reduced.

Univar has made some major changes to its business. However, most of the changes have been imposed upon the organization much in a top-down fashion. The top management of Univar is very change oriented but at a lower level people are not involved. This causes a sort of weariness. Many employees in operations and even in the middle management of Univar do not understand what the benefit of these changes is. The most important example is that the majority of the employees do not understand the purpose of the hub & spoke network. The form of change management at Univar is much in line with Lewin's model [1]. Kanter, Stein, and Jick [2] criticise this approach because it assumes that change can be forced upon the organization. The result is often that change is only apparent because the organizational culture has not changed (see Gagliardi [3]). In the end it is the employee that has to carry out the plan. If the employee can see the sense of the change, or even better, if the employee is actively involved, changes will take place faster, more efficient, and will meet much less resistance. Furthermore, employees have a lot of valuable knowledge that the company can benefit from. An important concept in organizational psychology that recognises the importance of employees during organizational change is 'Organizational Development'. For an overview of this concept see Porras and Robertson [4].

Supply chain

Figure 3 shows the Univar business supply chain. Univar is the distributor. A site is one location of operations. All (Univar) sites together make up the distributor. Sites can be a hub, a spoke or both. The terms hub and spoke are explained below.

Figure 3: Univar business supply chain



The most important change of Univar's logistic setup is, by far, the transition to hub & spoke. Since the end of 2002, Univar has been centralising its inventories at four major sites, called hubs. The bulk of each stock keeping unit (SKU) is kept on stock at one of the four hubs. The hubs replenish product to all other sites when required. These sites are called the spokes. In general, intersite transport is limited to transport between hubs and spokes. Each spoke has its own region and serves all Univar customers in that region.

The hub & spoke network is an attempt to achieve economies of scale. Univar thinks that stock levels have been reduced thanks to the implementation of hub & spoke. There has been a reduction in stock value of 20% since the transition to hub & spoke. But perhaps more important, the hub & spoke network is likely to have led to more efficient use of vehicles. By centralizing the stock keeping function, intersite transport is limited to trips from the hubs to the spokes. Limiting he number of intersite origin-destination pairs leads to higher volume on the intersite transport. Therefore, more frequent deliveries on better utilized vehicles can be made to the spokes. At the same time, spokes are able to make daily deliveries to customers on well utilized vehicles, because they serve all customers in their region.

Figure 4 shows the geographical locations of the hubs and spokes in the Univar distribution network. The large triangles are hubs and the small triangles are spokes. Except for Grimsby, all hubs are also spokes for the products from the other hubs. In total, there are 11 sites: 4 hubs and 7 pure spokes.

Although the largest part of the inventories are kept at the hubs, spokes are not completely deprived of stock. In order to provide delivery lead times of 2 to 3 days, spokes must deliver products directly from their own stock. For this purpose, spokes keep a minimal amount of stock (just enough to cover the replenishment lead time). When a customer order is placed at the spoke, a replenishment order of the same size is placed at the hub immediately. This kind of inventory policy is referred to in literature as an (S-1, S) inventory policy. This means that there is a fixed order-up-to level (S) and whenever the economic inventory position[1] is equal or less than S-1, a replenishment order is placed to get it back at S.

A problem that the company currently faces is its long replenishment lead times. For example, the total lead time for replenishment of an order from the Middlesbrough site to another site is at least 4 days. If replenishment lead times can be reduced, Univar can eliminate stock at the spokes completely (also see the cross-docking concept in section 3.2). Gradually, this problem gets more recognition from within the company and people start believing that it is necessary to reduce lead times.

In general, suppliers deliver products to the hubs only. Stock controllers are responsible for managing the stock in the Univar network. Each product is assigned to exactly one stock controller who places orders with the supplier. The stock controller also confirms every replenishment order. There is no standard inventory policy at the hub. It is up to the stock controller to determine the requirements. Optionally, reorder points can be set in the ERP system that Univar uses. The stock controller sets these reorder points manually based on experience with the product. There are no decision support tools to determine these reorder points, nor for determining order sizes[2].

[1] Economic inventory position is a term that denotes the physical on-hand stock plus any stock that is due in minus any customer backlogs.

[2] Univar is currently working on a simple approach for setting the reorder points of fast moving products.

Historically, Univar has had very high stock levels. It was not uncommon that products were kept on stock for more than a year. Since the end of 2002, Univar has been actively trying to reduce stock levels wherever possible. 'Stock profiling' is the most important tool that Univar uses to achieve this. The stock profile of the company is a set of four percentages that divide total inventory in four categories based on the stocking time[3]. These four categories are:

- <4 months
- 4-6 months
- 7-12 months
- >12 months

Univar tries to have a stock profile with the majority of the stock in the first category. Sometimes however, Univar has no other choice than to place a purchase order that causes the product to move in one of the latter categories. This situation typically occurs if a supplier has a minimum order size for a slow moving product. Any orders placed by stock controllers that would increase the stocking time of the product above four months must be approved by the Product Manager or another senior employee.

[3] Stocking time is the average time that a product is kept on stock before it is sold.

Figure 4: Hubs & Spokes Locations

Univar uses a set of KPIs (Key Performance Indicators) to evaluate the supply chain operations. For spokes, the main performance indicator (from a supply chain point of view) is the OTIF rate. OTIF stands for 'On Time In Full'. This is the percentage of orders that is delivered to the customer within the agreed lead time and in full. Note that the performance depends on the lead time that was agreed upon when the order was placed. Therefore, an order that is delivered to the customer with a lead time of more than a week can still be considered to be a hit. On the other hand, if sales takes on an order for delivery on the next day, the order is considered to be a miss if it is delivered two days later. This sometimes leads to controversy between sales and stock control. (The people in the sales department are evaluated on other KPIs.) For hubs, the main performance indicator is the number of replenishment orders that arrive at the spoke on time and in full. Again here, on times means within the agreed lead time. For most combinations of spokes and products, these lead times are preset. The KPI system is used to guide management decisions. However, this system should be more than a set of individual metrics. Caplice and Sheffi [5] give a useful set of evaluation criteria that can be used to determine the strengths and weaknesses of the KPI system.

1.2 Chlorinated solvents

Product

This project looks into the supply chain of chlorinated solvents. Chlorinated solvents are colourless liquids with a low boiling point They are not flammable or explosive. In the UK, the most popular solvent is Trichloroethylene. In most of Europe, Perchloroethylene is commonly used. Methylene Chloride is much used in the pharmaceutical industry.

Both Perchloroethylene and Trichloroethylene are mainly used for cleaning and degreasing of metal parts and for dry cleaning of clothes. The solvent is heated in a bath under a basket with the metal parts that need to be cleaned. The vapour that arises from the bath condenses on the cold metal and drains back into the bath. Once the metal parts have got the same temperature as the vapour, no condensation takes place anymore and the parts are clean and dry.

There are basically two types of vapour degreasing machines. Most older machines are open top machines. In these machines, the vapour is captured by tubes through which cold water flows. The vapour condenses on these tubes and is fed back to the bath. Because the top of these machines is open, much of the vapour escapes in the process. Newer machines are closed top machines. These machines roughly use ten times less vapour than open machines. A Univar technician estimates that in the UK, only 5% to 10% of the vapour degreasing machines are closed machines.

Chlorinated solvents can have a serious effect on human health. Most of them can affect nervous system, liver, and kidneys. Most will also cause skins and eye, and mouth irritations. Some of them are suspected to cause cancer. Furthermore, chlorinated solvents are environmental hazards. Because of the health and environmental risks that are involved with chlorinated solvents, special precautions need to be taken when handling chlorinated solvents. An example is a special bonded floor that is required where filling takes place. Concrete is permeable to chlorinated solvents and cannot prevent ground water contamination.

Univar sells four types of chlorinated solvents:

- Trichloroethylene (1.971 tonnes)
- Methylene Chloride (1.545 tonnes)
- Perchloroethylene (168 tonnes)
- Chloroform (72 tonnes)

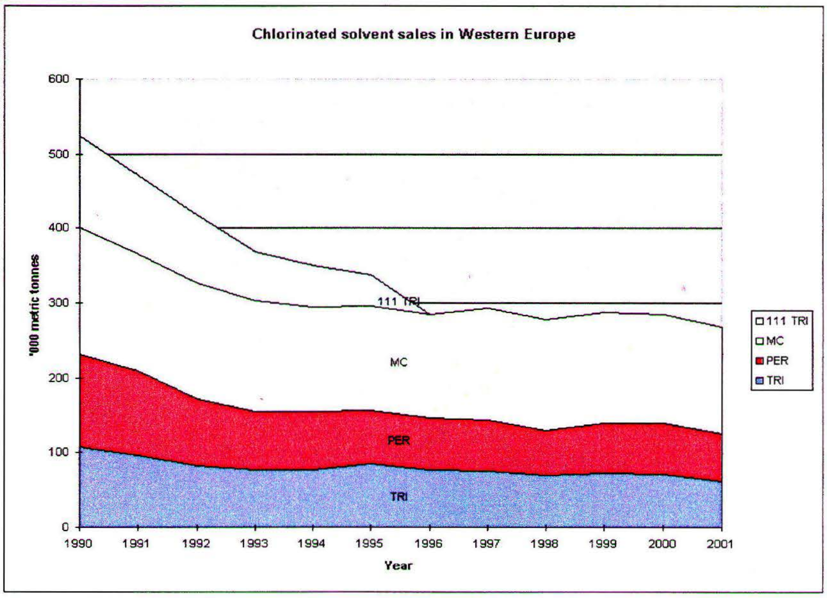
Included between brackets is the 2002 sales volume to give an indication of the proportions. Some of these products have multiple variants. One variant to the technical form of the solvent is often a stabilised form (stabilisers prevent the solvent from acidifying).

Industry

The market for chlorinated solvents is in decline. This decline is generally ascribed to two causes. Firstly, chlorinated solvents are mainly used in manufacturing processes and the manufacturing industry is in decline. Secondly, greater knowledge about the product and higher environmental and safety standards caused many companies to reconsider their cleaning activities. Although there is no qualitatively equal substitute for vapour cleaning and degreasing, some companies move to other forms of cleaning such as aqueous cleaning, or abandon cleaning altogether (which is then compensated for by cleaner manufacturing processes). A minor explanation for the decline may also be that the cleaning machines become more efficient. However, new machines are expensive and the current users are very reluctant to invest in vapour cleaning.

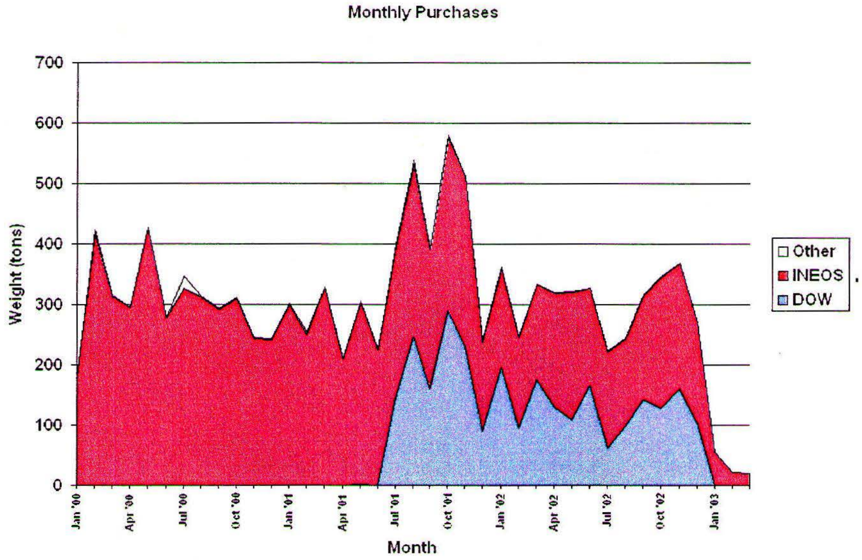
Figure 5 is a chart from the website of Euro-Chlor. It shows the decline in sales of chlorinated solvents since 1990. We can see that only the market for Methylene Chloride has remained stable. This can be explained by the fact that Methylene Chloride is not used for vapour degreasing but in the pharmaceutical industry for coating. 1,1,1 Trichloroethane was phased out because it is an ozone depleting chemical. Today's market for both Perchloroethylene and Trichloroethylene is about 75% of the size that it was in 1990.

Figure 5: Chlorinated Solvent Sales



Univar saw its chlorinated solvent sales hit bottom after the merger in July 2001. This can clearly be seen form figure 6. Before the merger, the graph shows the size of the market for the part of the company that was Ellis & Everard. After the merger, the graph shows the combined volume of Ellis & Everard and Univar. We can see that the combined volume has decreased by almost 50% in the last half of 2001. Part of this is probably explained by the events on September 11th but this cannot explain everything. Lack of management attention may have driven customers into the arms of competitors.

Figure 6: Historical Chlorinated Solvent Purchase Orders for Univar Ltd.



Currently, Univar has two suppliers of chlorinated solvents: Ineos and DOW. Ineos is a UK based company whereas DOW produces in Germany. This situation is the result of the Univar – Ellis & Everard merger. Univar was dealing with DOW and Ellis & Everard was dealing with Ineos. According to Univar, having two suppliers has advantages as well as disadvantages. The advantage is that it gives Univar bargaining power. The disadvantage of having two suppliers is a potential lack of trust in the relationship with the suppliers. If the supplier is not sure whether his product will be sold or the product of its competitor and this will make him less keen to cooperate with the distributor.

In the UK, there are four main suppliers of chlorinated solvents active and 5 distributors that operate nationwide. Ineos is the only UK based supplier and deals with Albion and Univar, DOW deals with Caldic and Univar, Ata Fina deals with SIS, and PPG deals with Samual Benner.

1.3 Safe-tainer

Background

Over the last couple of years, chlorinated solvents have come under a lot of pressure because of the health and environmental risk involved. In reaction to this development, DOW has developed a special reusable container for chlorinated solvents: the Safe-tainer. The Safe-tainer is a double walled container that can be used in a vapour-return system[4]. The main purpose of the Safe-tainer is to reduce the risk involved with transporting and handling of chlorinated solvents.

[4] In a vapour-return system, the air in the vessel that is being filled from the Safe-tainer is led back into the Safe-tainer. It is a closed system.

The costs of a single Safe-tainer are estimated at around a thousand pounds[5]. Safechem is the subsidiary of DOW that manages the Safe-tainer business. DOW has invested a lot of money in Safechem even though the market for chlorinated solvents is in decline. DOW reckons that there will still be a definite need for chlorinated solvents in future. Furthermore, they think that due to stricter regulations and increased safety awareness at companies, the Safe-tainer will be the only alternative for transporting chlorinated solvents other than in bulk containers. It would be very difficult for competitors of DOW to introduce a similar concept. It would require a huge investment and they do not have the infrastructure to support it. Univar agrees with the view of DOW.

In the UK, Safechem sells chlorinated solvents in Safe-tainers via 2 distributors. They do not use more than two distributors because substantial technical knowledge is required to install Safe-tainers at the customers. A new Safe-tainer customer buys equipment that is needed to connect the Safe-tainer to the degreasing machine. The equipment is installed by a distributor technician. The distributor also provides technical support to existing customers.

The Safe-tainer itself remains property of Safechem. No rent or deposit is charged for the use of the Safe-tainer. The price that the distributor pays for chlorinated solvents in Safe-tainers is not linked to the market price for chlorinated solvents (which can fluctuate substantially). DOW hopes to penetrate the market by offering a semi-fixed price that is not much higher than the price of a drum (and sometimes even lower). Safechem employs two full time sales persons that persuade customers of chlorinated solvents in drums to convert to the Safe-tainer.

Products & types

A Safe-tainer is basically a regular drum in a galvanized steel body. Figure 7 shows the top and front of a Safe-tainer. On the left, the top of the inner drum of a fresh Safe-tainer is shown. The drum is fitted with the one-way valve (right) and a vapour return inlet (left). Inside the drum is a pump-tube. An external motor is connected to the pump-tube to pump the solvent out of the Safe-tainer. On the right in figure 7, the Safe-tainer is shown in full. The bottom part of the Safe-tainer is suited for direct forklift truck handling. The outside contains several labels with information about the contents and a safety chart. On three sides, the Safe-tainer is fitted with a metal plate that shows the unique Safe-tainer number.

[5] In a conversation with SAFECHEM, an amount of 1,500 pounds was mentioned. However, from experiences of a (failed) project on similar containers, Univar estimates these costs at 900 to 1,000 pounds.

Figure 7: Safe-tainer

There are two types of Safe-tainers: fresh Safe-tainers and waste Safe-tainers. Fresh Safe-tainers are used for transporting fresh solvent to the customer only and come back empty. The inner drum of the fresh Safe-tainer is fitted with a one-way valve to prevent filling of the drum with waste material. The fresh Safe-tainer is dedicated to one type of product. Therefore, it does not need to be cleaned upon return from the customer and can be filled immediately after a quality check.

The other type of Safe-tainer is the waste Safe-tainer. This Safe-tainer is sent to the customer empty who fills it with its waste material. Waste Safe-tainers are not cleaned upon return to the filler. The complete inner drum is removed from the outer container and is sent to a waste disposal company. A new drum is fitted with the right valves and is placed in the outer container after which it is ready to be used again. Not all customers that use fresh Safe-tainers, also use the waste Safe-tainers. In fact, most customers deal with other disposal and recycle companies.

Univar sells 8 different Safe-tainer products. All of these Safe-tainers have a volume of 200L. Neu-Tri is by far the most sold product in a Safe-tainer. The following is a list of Safe-tainer products. Between brackets is total sales (quantity of Safe-tainers) in the period 1 October 2002 to 30 September 2003.

- ALTWARE GP (223) – General waste Safe-tainer
- ALTWARE MECL GP (4) – Waste Safe-tainer for Methylene Chloride
- DOWPER (110) – DOWPER is the DOW variant of Perchloroethylene
- DOWPER MC (143) – DOWPER with stabilizer
- MECL (7) – Methylene Chloride
- MECL SVG (1) – Methylene Chloride with stabilizer
- MECL SVG-N (21) – Methylene Chloride with stabilizer
- NEU-TRI (1839) – NEU-TRI is the DOW variant of Trichloroethylene

(Note: ALTWARE is the name that Safechem uses for waste Safe-tainers).

Safe-tainers are sometimes referred to based on whether the go to, or come from a customer. Safe-tainers that are filled but are not yet put into use by a customer are unused Safe-tainers. Safe-tainers that are used by the customer (and need to be returned to the filler) are used Safe-tainers. Table 1 summarizes the terminology that is used by Safechem.

Table 1: Safe-tainer Typology

Location in cycle	Fresh Safe-tainer		Waste Safe-tainer	
	Name	Description	Name	Description
Unused Safe-tainers	Fresh Full (F1)	Full Safe-tainer containing fresh material.	Waste Empty (A1)	Empty Safe-tainer for the purpose of being filled with waste.
Used Safe-tainers	Fresh Empty (F1)	Empty Safe-tainer used for holding fresh material.	Waste Full (A1)	Filled waste Safe-tainer

Note: the code between brackets is the first part of the unique identification code of the Safe-tainer. This is explained in the following section.

Tracking

Safechem wants to keep track of every movement of every individual Safe-tainer. Univar is required to report back to Safechem all daily movements of Safe-tainers to and from the customer. For this purpose, every Safe-tainer has a unique code. This code is a combination of F1 (for fresh Safe-tainers) or A1 (for waste Safe-tainers) and four digits. The code is printed on 3 sides of the Safe-tainer. There are 3 reasons for Safechem track Safe-tainers.

- Safechem wants to know where its assets are. Safe-tainers have a high value and large investments have been made in the Safe-tainer pool. By registering each movement, Safechem can be certain that Safe-tainers do not get lost.
- Safechem uses the information to identify problems with the return of Safe-tainers. Safechem wants to be able to see if a Safe-tainer has been at a location for a long time. If necessary, Safechem can then take action to get the Safe-tainer back. One reason for getting back Safe-tainers is that a full inspection is needed every two years.
- Safechem wants to be able to see whether certain customers are damaging Safe-tainers on a regular basis. There may be faulty equipment that is used with the Safe-tainer.

Availability

Safe-tainers are very expensive containers. Safechem has mentioned before that the manufacturing costs of a Safe-tainer are about £1,500. (Univar thinks this is rather much and reckons that the costs manufacturing are closer to £900.) Currently, there are more than a thousand Safe-tainers in use in the UK[6]. Together, these Safe-tainers represent a capital value of more than £1,5 million. Because of their high value, Safechem tries to minimize the number of Safe-tainers in the network. This can lead to problems with the availability of Safe-tainers at the distributor.

Safechem makes yearly sales forecasts for the entire UK. These sales forecasts are then used to decide whether new Safe-tainers should be issued for the UK. Sales are compared with sales in other countries to see how much should be needed. According to Safechem, the UK has a relatively large Safe-tainer pool considering current sales. This is opposite to Safechem's expectations. A large percentage of the UK manufacturing industry uses open-top systems (see section 1.2). This implies short Safe-tainer cycle times at the customer because more solvent is used in open-top machines than in closed-top machines. Safechem would like to see the cycle times reduced. However, they have little means of achieving this. The only strategy that Safechem can employ to reduce cycle times, is not to increase the number of Safe-tainers in the pool.

Safechem only has two distributors in the UK that share the Safe-tainers in the pool, namely Univar and Caldic. These two distributors have an awkward relationship. Caldic is not only the competitor of Univar, it is also the filler of all Safe-tainers for the UK. For Univar, this is not a pleasant situation to be in. Caldic may be able to influence the supply of Safe-tainers to Univar. Furthermore, the competitor knows exactly how well Univar's Safe-tainer business is running because they know the exact quantities that go to Univar. This situation that Univar is

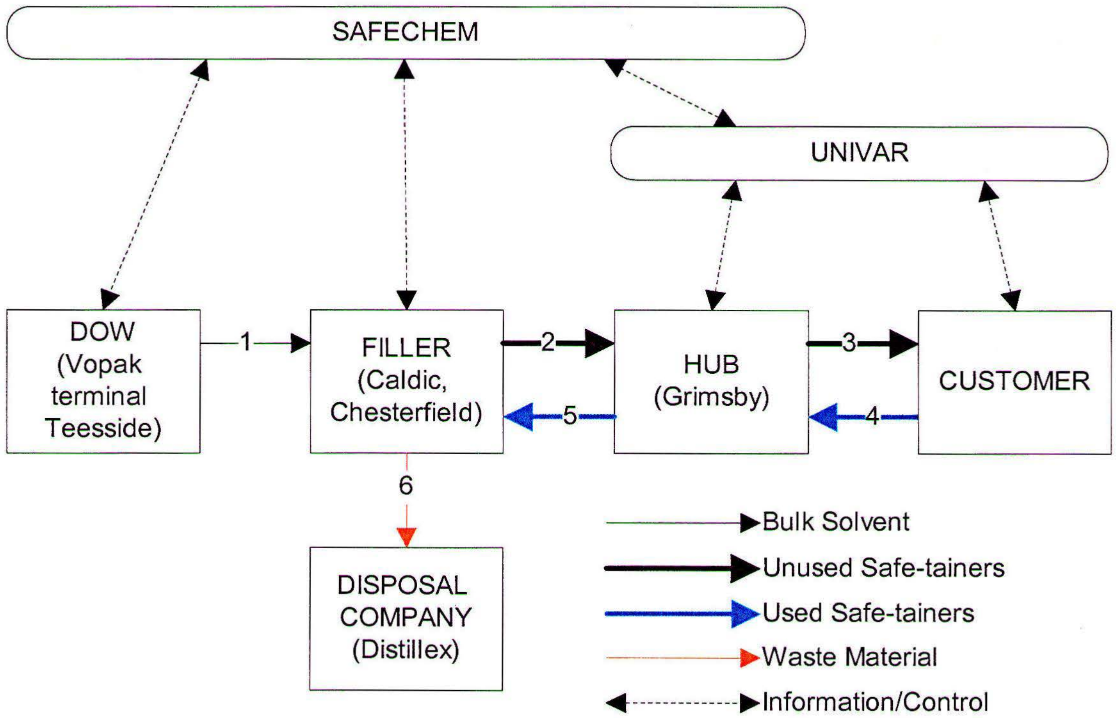
[6] This can be deduced from the number of different Safe-tainer codes that Univar has registered in the past.

in, is worsened by the fact that Safechem has not defined a policy for the allocation of Safe-tainers from the pool to its distributors. It will become clear in the rest of this document that availability of Safe-tainers is a very important limitation to network optimization and an important driver of transport costs. It is Safechem that makes the decision about where every Safe-tainer is going but the idea that Caldic can influence the availability of Safe-tainers directly is an unpleasant thought to Univar.

Supply Chain

Safechem orchestrates the flow of Safe-tainers through the network although the company does not get involved physically. All filling, maintenance, storing, transporting, and handling is outsourced. The first two tasks are performed by the filler and the latter three are done by the distributor. Figure 8 shows the Safe-tainer supply chain.

Figure 8: Safe-tainer Supply Chain



1) Virgin chlorinated solvents are shipped in barges to the Vopak terminal in Teesside. From there, they go to the filler in road tankers. The filler stores the solvent in tanks from which Safe-tainers are filled.
2) Univar orders Safe-tainers from Safechem after which Safechem places a filling order with the filler. When the Safe-tainer is ready to be picked up, the filler informs Safechem who in turn informs Univar. Univar collect the Safe-tainer from the filler. The supply lead time is commonly 1 week.
3) Univar keeps Safe-tainers on stock at one site only: Grimsby. Grimsby also handles all customer orders. Safe-tainers are delivered to customers from stock. Usually, the customer lead time is 2 to 4 days, depending on the region where the customer is located.

4) Normally, used Safe-tainers are collected from customers only when unused Safe-tainer are delivered. Used Safe-tainers are stored at Grimsby for a short while.
5) Usually, used Safe-tainers are returned to the filler twice a week. At the filler, a quality check is done and the inner drums of waste Safe-tainers are removed. Waste Safe-tainers get a new drum and the valves from the waste drum that was removed are placed on the new drum. The necessary Safe-tainer maintenance is also done by the filler.
6) The drums with waste that are removed from the waste Safe-tainers are stored temporarily at the filler and are then sent to a disposal company (Distilex).

1.4 Initial Assignment

The trigger for this project are the exceptionally high transport costs at the Grimsby site. A brief analysis by Univar accountants indicated that these costs could almost completely be ascribed to Safe-tainers. The total Univar transportation costs were roughly estimated at £40 per Safe-tainer, which is approximately the contribution margin of a Safe-tainer. The proposed solution was to move Safe-tainer activities in line with the existing Univar distribution network. The primary goal of the project was to analyse this proposal and implement it. A second suggestion to get more value from the Safe-tainer business was proposed: to fill Safe-tainers at Univar. Two deliverables were formulated in an initial terms of reference document:

1) Transfer the existing process from Grimsby to Middlesbrough, where Middlesbrough is to deliver Safe-tainers via the existing network and Regional Distribution Centres.
2) Negotiate with Dow Chemicals an agreement whereby Univar will store and fill Safe-tainers at Middlesbrough.

During the initial meeting, it was agreed upon that prior to any implementation, a thorough research into the costs in the supply chain of Safe-tainers should be done to identify potential savings. One of these potential savings to be investigated would be the filling of Safe-tainers at Univar. The project deliverables were reformulated as follows:

1a Transfer the distribution process from Grimsby to Middlesbrough*
1b Setup distribution through spokes (RDCs)*
2 Negotiate with Dow an agreement whereby Univar stores and fills Safe-tainers at Middlesbrough*
3 Identify and implement ways to speed up flow of Safe-tainers to decrease the capital invested in the Safe-tainer pool

* It is not likely that the student will be involved in the full implementation. He will only be involved in the first stages.

At the initial meeting in March 2003, the assignment was discussed. It was decided, in order for the assignment to be sufficient for a graduation assignment, to extend the scope of the assignment. The project objective agreed on was as follows:

The main objective of this assignment is to analyse the business supply chain of chlorinated solvents of Univar Ltd., and identify ways to improve the supply chain efficiency and to reduce logistics costs. The service level may not worsen. A secondary objective is to improve service.

Basically the main issue in this project is as follows:

The Safe-tainer business is not profitable enough to Univar because the logistics costs are too high.

This report is structured according to the project approach. In the orientation phase (chapter 2), various information about the company is collected and the main issues related to the initial assignment are identified and made explicit. This results in a (revised) assignment that is presented in section 2.6. Based on this assignment a research plan is developed. This research plan is presented in section 2.7. The research in the orientation phase is used to develop alternative solutions to the main issue. These solutions are evaluated in the analysis phase. The results can be found in chapter 3. One solution is selected to be worked out further in the design phase. The result is presented in chapter 4. Finally, the implementation phase is discussed in chapter 5. Chapter 6 contains the final conclusions from the project and recommendations for the follow up of this project.

2 Results of the orientation phase

It is not sufficient to see and know the beauty of a work. We must feel and be affected by it.

Voltaire

The Safe-tainer business is not profitable enough for Univar because the logistics costs are too high. Costs of transport within the distribution network in particular are high. This was the starting point for the orientation phase of the research. Before anything can be said about the costs of the logistics, we need to know what the Safe-tainers logistics are, and how these are related to the rest of the company. Therefore, the part of the supply chain that is relevant to this project was investigated. The relevant part is determined by the problem and how far back and forward it reaches. The primary focus however, was on the business supply chain of Univar. The business supply chain is Univar, its first tier supplier, and its first tier customer. If it appeared that problems have root causes that lie outside the business supply chain, the scope could be broadened. Once the supply chain was mapped, the important cost drivers could be determined. On the customer side, we required information about the use of solvents, the service requirements, and the flexibility in the service.

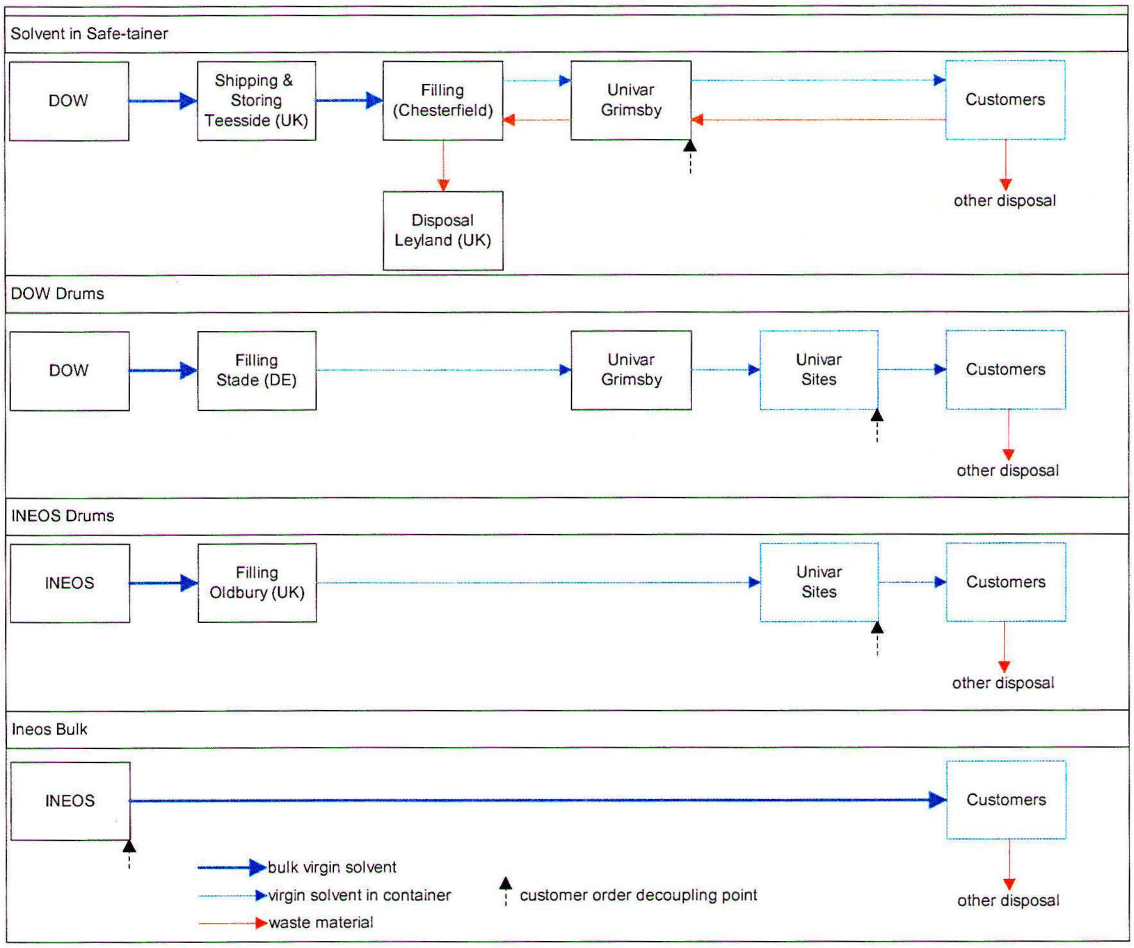
The main method for acquiring information during the orientation phase were interviews with people inside Univar, a visit to the supplier in Germany, a visit to the filler, and a customer survey. A full list of people that have been interviewed can be found in appendix I

In section 2.1 the supply chain of Safe-tainers is described. Because of their importance to this project, transport costs are treated separately in section 2.2. The major factor of influence on transport costs is discussed in section 2.3. Then the customer is discussed in section 2.4. The supply chain costs are summarized in section 2.5. Next, the revised problem description is given in section 2.6. Finally, the research model is discussed in section 2.7.

2.1 Network

Figure 9 shows the current supply chain of chlorinated solvents. Blue lines show the flow of fresh solvent and the red lines show the flow of waste solvent. Four different configurations can be seen that represent the flows of Safe-tainers, DOW chlorinated solvents in drums, Ineos chlorinated solvents in drums, and Ineos bulk chlorinated solvents respectively. Univar also sells Ineos bulk chlorinated solvents but the physical distribution of these is done by Ineos.)

Figure 9: Different Supply Chains of Chlorinated Solvents



After production (DOW/Ineos), the two main activities are filling and distribution. DOW fill their Safe-tainers at a different place than their drums. Drums are filled in Germany and them shipped to the UK whereas Safe-tainers are filled in the UK. The obvious reason for this is that Safe-tainers are returned to the filler and the distance between customer and filler must therefore be minimized. Drums are not returned and can be filled at a central European filling location to achieve economies of scale.

Figure 9 also shows the location of the customer order decoupling point in the supply chain. The customer order decoupling point (CODP) is the point in the supply chain at which unpredictable demand becomes predictable. Production upstream (left) of this point is planned on the basis of forecasts, production downstream (right) of this point is based on firm end-customer orders (see Wouters et. al. [6]). The further upstream the CODP is, the longer the customer lead time is, and the lower total supply chain inventory is, and vice versa. An upstream CODP is particularly useful in cases where the product has a high value and where demand is highly irregular. The downstream CODP is suitable for cheap, fast-moving products. Safe-tainers represent a high value and most products in Safe-tainers have a relatively erratic demand. This would imply that the CODP for Safe-tainers would have to be upstream in the supply chain. However, customer service requirements also play a role in the determination of the CODP location. The next section discusses these customer requirements.

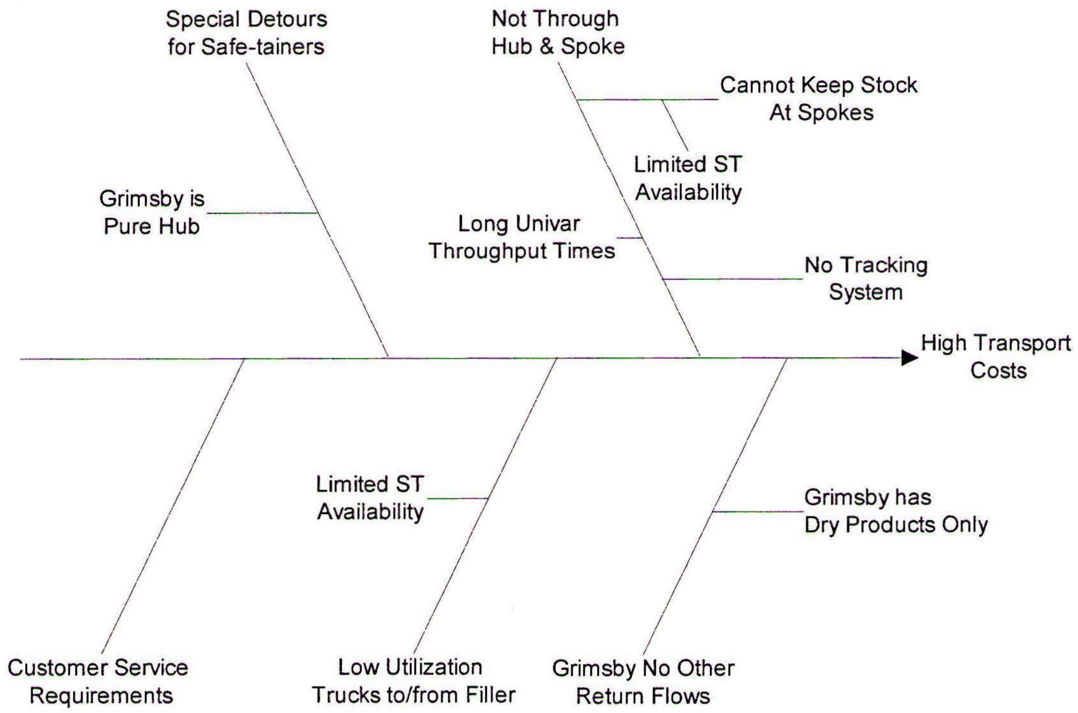
Inventories

Inventories in the UK part of the supply chain of Safe-tainers are kept at four locations. Bulk solvent is stored at the Vopak terminal in Teesside, and at the filler. Unused Safe-tainers are stored at the Grimsby site of Univar. Finally, unused Safe-tainers are also stored at the customer. Because Safe-tainers move in a closed loop supply chain, Safe-tainer inventory levels are subject to both demand and returns. Univar make agreements with Safechem about their maximum stock level but since supply of Safe-tainers is subject to availability, stock is often lower than allowed.

2.2 Transport

Because the costs of transport were the reason to initiate this project, we discuss them separately. Univar is responsible for all transport after the Safe-tainers are filled and until they are returned to the filler. Currently, the Univar hub in Grimsby arranges all transport of Safe-tainers in the supply chain. Many causes for the high transport costs were given in the interviews during the orientation phase. The causes are summarized in the fishbone diagram in figure 10.

Figure 10: Causes high transport costs



The different branches of the fishbone diagram are explained below.

Special Detours for Safe-tainers

Grimsby is a pure hub. That is, there is essentially only transport between Grimsby and other sites and not to customers (see figure 3). Safe-tainers are an exception (see figure 8). A delivery of a Safe-tainer means that the haulier needs to make a detour on its trip to another site, or make a special trip for Safe-tainers only. The latter trips are often highly underutilized. Appendix II gives an overview of vehicle utilization that confirms this. Vehicles from Grimsby that go to customers have an average weight that is about one third of the average weight on trips to sites.

Not Through Hub & Spoke

A question that follows from the problem branch mentioned above is: "Why are Safe-tainers not distributed through the hub & spoke network, like all other products from Grimsby?" An answer to this question is: "There are not enough Safe-tainers available to keep stock at the spokes, like we do for all other products."

The subsequent question is: "So why is stock required at the spokes? Is it not possible to cross-dock Safe-tainers at the spokes?" (see section 3.2). The answer to that question is that the replenishment lead-times of Univar are too long. The replenishment lead time and delivery lead time together exceed the maximum order lead time that the customer allows (also see section 2.4).

Another problem with Safe-tainers is that they need to be tracked individually. Until recently, there was no system to support this tracking if Safe-tainers were distributed through the hub & spoke network.

Customer Service Requirements

If customers would allow for a lead-time of 2 weeks, Univar could send its Safe-tainers through the spokes without having to hold stock at the spokes. Unfortunately, most customers request a lead-time of 3 days and accept no longer lead-time than 1 week. Univar currently cannot meet these requirements without delivering directly from stock.

Low Utilization Vehicles to/from Filler

Because there is only a limited number of Safe-tainers available, frequent trips need to be made to the filler to collect new ones. Because the frequency of trips to and from the filler is high, they are underutilized[7].

Grimsby No Other Return Flows

There is a reverse flow of used Safe-tainers. For Grimsby, the Safe-tainer is the only container that is returned. Grimsby is a so called 'dry hub'. This means that Grimsby does not keep any fluids except for chlorinated solvents. Dry products such as powders, come in non-returnable packages. Hauliers therefore need to make trips back to the hub for Safe-tainers only. Because Grimsby only uses third party hauliers, these are extra trips that are charged for. Other sites can use own fleet vehicles that always return to the site.

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[7] Analysis showed that in the period August 2002 to July 2003, on average 24 Safe-tainers were collected and 20 were returned on trip to and from the filler. The capacity of a vehicle is 40 full Safe-tainers and 60 empty Safe-tainers.

2.3 Availability

Many of the causes for the high transportation costs can be solved if there would be sufficient Safe-tainers available. More Safe-tainers could be kept on stock and therefore batch sizes could be larger. As a result, vehicles would be better utilized because less frequent trips would be required. Distributing Safe-tainers through the hub & spoke network would not be a problem because Safe-tainers could be kept on stock at the spokes. Univar would be much helped by an increase of the Safe-tainer pool. However, Safechem is already concerned with the size of the pool. They say that compared to other countries the size of the pool in relation to the sales is very high. This is awkward because the UK has a high percentage of open-top degreasers. These use much more solvent than closed-top degreasers and therefore, Safechem would expect shorter customer dwell times in the UK and thus a higher throughput than in countries with a high percentage closed-top machines (like Germany).

2.4 Customer

It appeared from interviews in the orientation phase that low availability of Safe-tainers in the Univar distribution network is a major cause for high transport costs. Since Safechem is very reluctant to issue new Safe-tainers, other means of increasing the availability in the distribution network must be found. The alternative to issuing new Safe-tainers to increase availability, is to reduce the cycle-time[8] of the Safe-tainer. It may be possible to reduce the dwell time at the filler and distributor but the largest part of the Safe-tainer cycle time is spent at the customer (see appendix XI). Reason to take a closer look at the customer, to see if Safe-tainers can be turned around more quickly by increasing customer utilization. We will define customer utilization here as the percentage of Safe-tainers at the customer that is minimally in use. For example, a customer with two machines that wants to be able to top up its machines at any time may require a Safe-tainers to be connected to the machine continuously. In this case, the minimum number of Safe-tainers in use is two. Usually. the Safe-tainer is disconnected from the machine after it has been topped up. In that can one Safe-tainer can be used to top up both machines and the minimum number of Safe-tainers in use is one.

The customer survey was meant as and explorative study into the possibilities to increase Safe-tainer turnover at the customer. There were three questions that needed to be answered:

- Is there potential for an increase in Safe-tainer utilization at the customer?
- What are the reasons for holding Safe-tainers on site?
- Can any service adjustments be made by Univar such that the customer can reduce the number of Safe-tainers in use?

Besides, the survey was also meant to determine customer service requirements. The results from the survey can be found in appendix III. In the rest of this section, a summary of the results is presented. The following list summarizes important conclusions from the survey.

[8] Total time between filler dispatch of the Safe-tainer and return to the filler plus the time used for filling and maintenance at the filler.

- Large customers do not necessarily have more ST in use but do have more ST on site.
- Customers claim not to be able to determine solvent remnant, hence forecasting requirements is difficult.
- The configuration of the machine park is of no significant influence on Safe-tainer utilization.
- Lead time is important for customers but current lead time is satisfactory. However, to reduce the customer Safe-tainer stock, next day delivery by Univar is required.

The survey points out that it is difficult to decrease the number of Safe-tainers that are on site at small customers. The major improvement potential is at the large customers. Large customers keep many Safe-tainers on stock.

One option to reduce the number of Safe-tainers on site would be reducing the order quantities of Safe-tainers. It seems in some cases that customers order in quantities more than one simply because this is more convenient to order lees frequently.

Less can be achieved by making use of the ability of the customer to forecast their demand. Most customers have difficulties doing this because they do not know how much will be needed and how much is left in the Safe-tainer. Improvement may be achieved if Univar can find a way to do the forecasting for them.

The survey points out that customers that have many Safe-tainers on site, have a poor utilization rate[9]. This is an argument for starting to charge a rent or deposit for Safe-tainers. Customers currently lack an incentive to turn Safe-tainers around. A rent or deposit can provide this incentive and will affect customers that have many Safe-tainers on site most, which are the customers that perform badly and can improve on their use.

Current customer service is satisfactory but it is important that service does not deteriorates. Customers are sensitive to customer service. Therefore it is not an option to allow delivery lead time to increase. A reduction of lead time on the other hand, may result in higher customer satisfaction but it will not change the utilization rate of Safe-tainers at the customer. Only if Univar is able to make next day deliveries can customer stock be eliminated. (Some customers would appreciate it if Univar could tell them at what day an order will be delivered.) The overall idea from the survey and conversations with customers is that they are not monitoring supplier performance consciously.

A theoretical upper bound to the improvement of utilization is 100% minus the current utilization. This potential is 61% for the fresh Safe-tainers. Improvement must come, both from faster return of used Safe-tainers and reduction of customer stock.

2.5 Supply chain costs

This paragraph discusses the costs in the supply chain of Safe-tainers. These costs are upper bounds on the savings that can achieved in different areas. Unfortunately, not all costs are available. Especially those costs that are not incurred by Univar, are difficult to estimate. The most important player other than Univar in this research is Safechem. Safechem is unwilling to

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[9] The customer utilization rate of Safe-tainers is defined as the percentage of Safe-tainers at the customer that is in use.

share information about the fixed costs of the Safe-tainer. Rough estimates of Univar experts are used here.

Fixed Costs

No information is available about the fixed cost of a Safe-tainer. The following figures are estimates.

Safechem overhead

Safechem is a large organization with many employees. No reasonable estimate of the overhead costs can be made.

Depreciation/new containers

The price of a new container is approximately £900. This information is based on experience with similar containers at another supplier. The pump hose in particular is very expensive. The technical lifespan of the outer container is thought to be 15 years. We assume an opportunity cost (of capital) of 9%, so that the annual costs for a Safe-tainer are about £104 per year. This is £20.08 per cycle for a fresh Safe-tainer and £29.71 for a waste Safe-tainer (2003) See appendix XI for information about cycle times.

New Drum

About once every two years, the inner drum of a fresh Safe-tainer needs to be replaced (source: Caldic). For a waste Safe-tainer, the drum is replaced every cycle. The cost of a new drum are about £18. For a fresh Safe-tainer, this is £1.80 per cycle.

Costs of damage (not recovered)

It is not possible to make an estimate of this cost because no information is available about the number of repairs or repair costs.

Costs of loss

Last year, two Safe-tainers got lost and were invoiced to Univar by Safechem. This is an extraordinary occasion since every movement of every Safe-tainer is tracked. On the whole, it can be assumed that the costs of true loss are close to nought.

Cost of processing waste

There is no information about the costs (or revenues) of processing waste.

At filler

Costs of filling and maintenance

Safechem pays about £20 per Safe-tainer per cycle for filling and maintenance. This estimate is based on exploratory talks with Safechem about filling in-house at Univar. We assume that Safechem pays the same amount for filling and maintenance of waste Safe-tainers. Although these are not filled, substantial extra labour is required to replace an inner-drum filled with waste by a new drum and change the valves.

At Distributor

Inventory Costs

Univar does not keep track of stock holding costs. The following is an estimate of the true costs. Inventory costs can be split up into three categories:

1) costs of obsolescence and write-offs
2) costs of damage, loss, and theft
3) opportunity costs of capital invested
4) costs of physical storage

Ad. 1) Safe-tainer customers are not one-time users. They invest in Safe-tainer equipment and work with only one supplier with who they agree on a purchase price that is fixed for a longer period. For these reasons, Safe-tainers are never written off. Neither do they become obsolescent because only those products are ordered from the supplier for which there are existing customers.

Ad. 2) Safe-tainers are individually tracked and are very sturdy. Damages to Safe-tainers are usually repaired during normal maintenance and are paid for by the supplier (remember that the Safe-tainer remains property of the Safechem). For these reasons, no costs of this type have ever been registered and we have no reason to assume that there will be relevant costs of this type in future.

Ad. 3) Until recently, for administrative reasons Safe-tainers were not invoiced to the distributor before they were actually sold to a customer. Therefore no costs of this type were incurred by Univar. The company pays 6% to 7% interest on bank loans. Therefore we will assume an opportunity cost of working capital of 6.5%.

Ad. 4) Univar keeps track of total warehouse costs per net tonne. These include everything from site depreciation and maintenance to handling. No separate physical storage costs are identified. Univar argues that there are no costs at all for physical storage of Safe-tainers because there are no marginal costs of storing Safe-tainers. Keeping in mind that they are included in the costs of handling no cost are specified here.

Inventory costs are thus estimated at 6.5% of stock purchase price. With the current average stock of 98 fresh and 12 waste Safe-tainers at the average purchase price of £169 for a fresh and £45 for a waste Safe-tainer, inventory costs amount up to £1,077 (fresh) plus £35 (waste) per annum. With sales of 2,251 fresh and 235 waste Safe-tainers in 2003, this is £0.48 per fresh Safe-tainer per cycle and £0.15 per waste Safe-tainer per cycle (see appendix XIII.4).

Handling & Warehouse costs

The best estimation for the costs of handling and the warehouse is the key performance indicator 'Warehouse Cost per Tonne' that Univar calculates monthly. This is the total of all warehouse costs divided by the total net product weight that flow to the customer (note that return flows are not included). This ratio may be overestimated because Safe-tainers can be stored outside, therefore need less handling, and do not need to be placed on a pallet. On the other hand, it may be an underestimate because Safe-tainers also have return flows. We assume that both factors level each other out. Another difficulty is that the warehouse costs are measured per net tonne. This would imply that waste Safe-tainers have no warehouse costs at all. However, waste Safe-tainers are filled upon return. Assuming that both type of Safe-tainers require the same amount of handling, we will take the average net weight of a fresh Safe-tainer as the basis for warehouse costs. The KPI master of March 2003 shows a warehouse cost/net tonne is £6.22. At the average net weight of 283 kg per Safe-tainer, handling costs amount up to £1.76 per Safe-tainer per cycle.

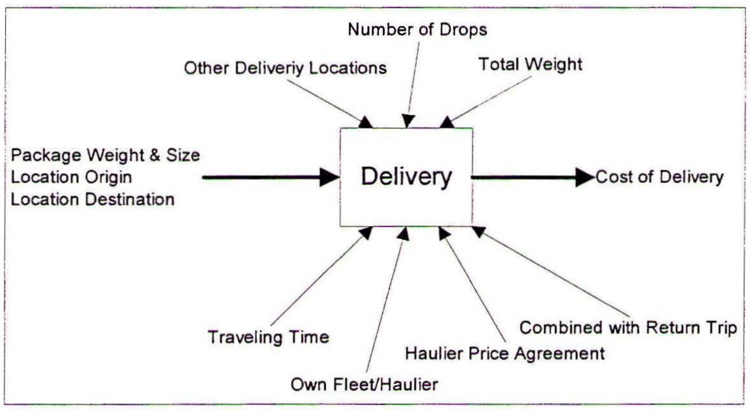
Administration/Support/Purchasing

At least three people at Univar spend part or most of their time on the Safe-tainer business. Firstly, there is an employee that provides support to customers for the Safe-tainer system and assist new customers on implementing the system. This is a full-time job. Next, there is an employee that is responsible for the administration of Safe-tainers, and sales and purchase order processing. At least half an FTE is spent on Safe-tainers by this employee. Finally, there is the Product Manager of chlorinated solvents who also spends at least half an FTE on the Safe-tainers. A lower limit on the costs in this category is therefore 2 FTEs, or £45k per annum. Based on 2003 sales, this is £18.10 per Safe-tainer.

Transport Costs

There are many factors that influence the cost of moving product from one location to the other. Therefore it is impossible to determine the cost of a single delivery until it is actually planned. Figure 11 shows the factors that influence the cost of a delivery.

Figure 11: Cost of transport: factors of influence



The most important factors are:

- Own fleet versus 3rd party hauliers
  Univar uses both own fleet as well as 3rd party hauliers. The own fleet has a fixed operating cost. With 3rd party hauliers, Univar has many different agreements about pricing. Pricing also depends on the time that the haulier is contacted in advance.
- One way versus return trips
  Univar vehicles always return to the site but 3rd party vehicles do not. Return trips with 3rd party hauliers are more expensive.
- Multiple stops on a trip
  Hauliers invoice Univar for a complete trip, not for a single delivery. Most trips consist of multiple deliveries. Some trips combine replenishments to other sites with deliveries to customers. The number of drops, and the locations of the stops affect the price.
- Composition of the load
  Some loads use all of the vehicle capacity whereas other loads leave the vehicle half empty. Loads may consist of many small drops and others may only have one large drop. These factors seriously influence the costs of a delivery.

Although it is nearly impossible to make an estimate of the transport cost for a single delivery, transport costs can be estimated based on historical data. However, the main argument is that estimates of future transport costs based on historical data should be used with much caution,, especially if one of the factors mentioned above changes.

The following is an overview of the transport costs in the Safe-tainer supply chain. Four different transport legs are distinguished.

Leg 1: transport to filler

The chlorinated solvents of DOW are shipped to the UK in barges after which they are stored at the Vopak terminal in Teesside. From that point, the solvents are sent to the filler in Chesterfield by road tanker. Transport costs for the road tanker are an estimate of an expert in the transport department of Univar. We assume here that the road tankers are utilized 100% so the figure is probably underestimated.

		Source:
Cost per road tanker	£359	*Univar expert*
Capacity of road tanker	25 tonnes	*Univar expert*
2003 sales	2,251 fresh ST	*Safechem WebInfo*
2003 net weight (283 kg/ST)	637 tonnes	*Univar ERP system*
2003 estimated costs	£9,148	

Per fresh Safe-tainer, this is £4,06.

Leg 2: transport between filler and distributor

Univar arranges the transport between filler and distributor for Safechem. Safechem pay Univar for this transport. However, from a supply chain perspective this is merely a transfer of funds and no real cost. The figures were drawn from Safechem WebInfo. We assume that the number of trips to the filler will only decrease in future because vehicles on this leg are currently highly underutilized[10]. The costs on this leg are:

		Source:
40 collections @ £120/trip	£4,800	*WebInfo / Haulier invoices*
50 returns @ £120/trip	£6,000	*WebInfo / Haulier invoices*
57 combined collections & returns @ £160/trip	£9,120	*WebInfo / Haulier invoices*
Annual costs at current utilization	**£19,920**	
Univar invoices Safechem @ £250 / return	*£26,750*	

Based on 2003 sales, the costs per Safe-tainer on this leg are £8,01. Univar receives £10.76 of Safechem for transport per Safe-tainer.

Leg 3: distributor intersite transport

There is currently no intersite transport.

Leg 4: distributor to customer

On this leg, deliveries and returns are considered separately. The cost of deliveries is best estimated by taking the total amount for 3rd party haulage out to customers from Grimsby and dividing it by the total gross weight of goods dispatched from Grimsby. Since the capacity of vehicles going out is almost always limited by weight, gross weight is a good unit for cost allocation. Secondly, there are the collections of used Safe-tainers from customers. There is no separate account for these costs at Univar. Furthermore, weight is almost never the limiting constraint on capacity for collections of used containers. If there is any constraint, it is space on the vehicle. Fortunately, collections of Safe-tainers are included on invoices from the haulier separately. The best estimate of the costs for collections of empty Safe-tainers from customers is therefore the average invoiced amount per Safe-tainer collected.

The resulting cost per Safe-tainer on this leg is the sum of the cost of a delivery plus the cost of a collection. Together, this amount is £24.69 per Safe-tainer (also see appendix V).

Total Costs

The total known costs are summarized in appendix IV. The results are shown in table 2. It can be seen that fresh Safe-tainers are profitable to Univar at the moment. However, it can also be read from this table that waste Safe-tainers is unprofitable business to Univar at the moment. Here, it should be noted however, that costs in distribution can never be separated from each other. One type of business may seem unprofitable if costs are duly divided on the basis of weight. If however, Univar would choose not to sell the product, costs of another product are likely to rise. Furthermore, waste Safe-tainers are also a service to the customer.

[10] Vehicles have a capacity of 20 tonnes or 60 Safe-tainers. With the current ratio of 8.5 fresh Safe-tainers (500kg) per waste Safe-tainer (200 kg), the capacity is 41 Safe-tainers on a collection and 60 Safe-tainers on a return trip. In reality there are only 17 Safe-tainers on average each trip.

Table 2: Summary of Supply Chain Costs

Costs Per Cycle	*Fresh*				*Waste*			
	Safechem	Caldic	Univar	Supply Chain	Safechem	Caldic	Univar	Supply Chain
Average Selling Price	£169.00		£238.00		£45.00		£70.00	
Average Buying Price	?		£169.00				£45.00	
Total Costs	£33.17	£15.67	£50.33	**£99.17**	£70.00	£4.02	£50.14	**£124.16**
Margin	?		**£18.67**		-£25.00		-£25.14	

2.6 Revised assignment

Two deliverables were given in the initial assignment:

1) Transfer the existing process from Grimsby to Middlesbrough, where Middlesbrough is to deliver Safe-tainers via the existing network and Regional Distribution Centres.
2) Negotiate with Dow Chemicals an agreement whereby Univar will store and fill Safe-tainers at Middlesbrough.

The second deliverable seems to be completely unrelated to the first deliverable. However both deliverables share the same goal: to make the Safe-tainer business more profitable. The first deliverable is aimed at reducing the main cost driver: transport. The second deliverable is aimed at both reducing transport costs and increasing the revenues.

A revised assignment was proposed after a general project meeting on the 16th of July 2003. At that point, initial calculations had shown that implementation of the first deliverable (hub & spoke), would be profitable to Univar. It was not clear yet whether this would be the best solution possible. However, it was decided that this deliverable should be implemented as soon as possible. Univar adopts a sort of trial-and-error strategy. This strategy was strikingly phrased by a senior manager: "Ready, fire, aim!". Basically the idea is that the risk that a chosen option needs to be rolled back or changed is offset by the earlier profits from immediate implementation.

Initial calculations also showed that in-house filling can be profitable although it was not clear yet whether the internal rate of return of building a filling station would be sufficient. Besides, the actual building of a new filling station falls outside the scope of the project. It involves areas like chemical engineering and SHE (safety, health, and environment). It is an area that requires the management of experienced people in the work field. It is also a change that is part of the normal course of business within Univar. The profitability of filling Safe-tainer is investigated further in the next phase of the project. However, for the reasons mentioned above, the implementation of in-house filling will not be part of this project.

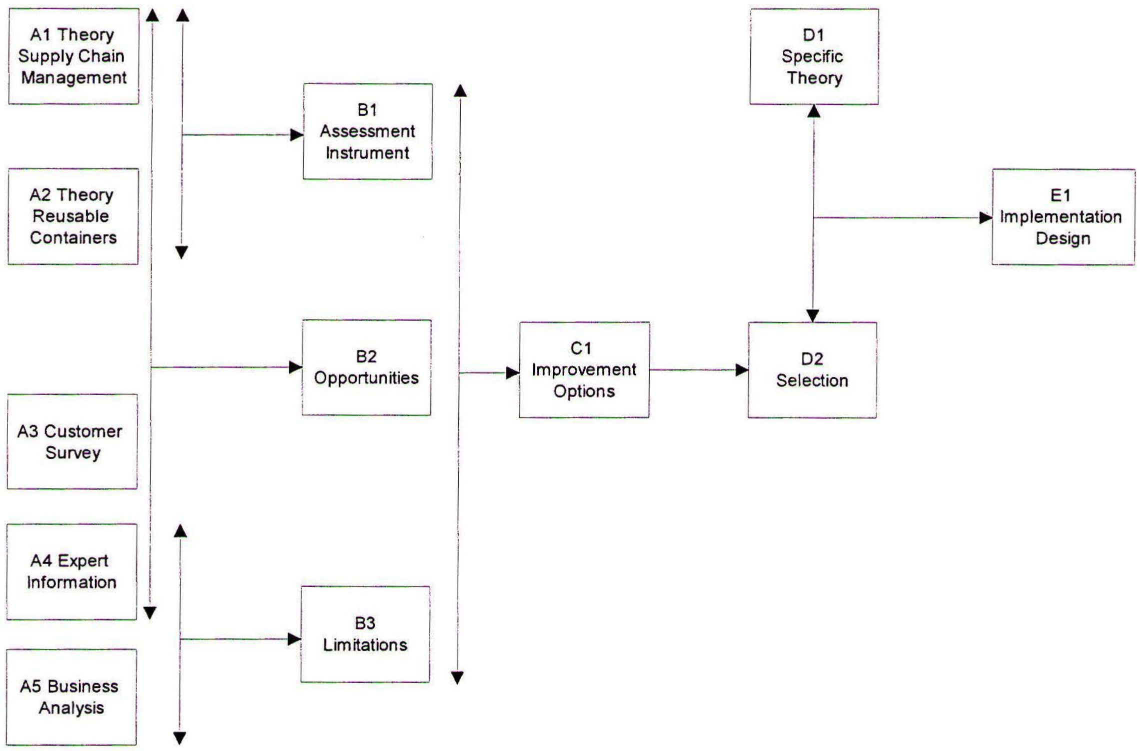
Two potential solutions were presented by Univar to a problem that was not described explicitly: the business supply chain of Safe-tainers is not profitable enough for Univar, if it is profitable at all. The revised assignment deals with this more general issue. However, it is of great importance to Univar that the two deliverables in the initial assignment are implemented as soon as possible if they are profitable and viable. To differentiate between the two initial deliverables, and the general goal to increase profitability by improving the logistics process, the revised assignment includes the terms 'short term goals' and 'long term goals'. Short term goals refer to the two initial deliverables and the long term goals are a general analysis of potential improvements in the supply chain.

Make an efficient design for the supply chain of chlorinated solvents which comprises both short term 'quick gains' and long term objectives. The short term design will be implemented as soon as possible. The long term design is a feasibility study into a number of supply chain concepts to be defined at a later stage. The design considers inventories, transport, ordering policies, and allocation of operational activities.

2.7 Research Model

The following figure shows the research model for the project phases after the orientation phase. The boxes are explained in this section. Also, an overview is given about the related sections in this report.

Figure 12: Research Model



A1, A2, D1 Theory

Two areas of theoretical research will be considered in this project. The first area is theory of supply chain management and supply chain improvement. Literature about supply chain management and improvement gives a vast list of supply chain improvement options and their criteria for successful implementation. It also is a source for tools that can help analyzing the supply chain and framing improvement alternatives.

An important characteristic of Safe-tainers is that they are reusable. Theory about reusable containers should provide specific insights in the consequences of this characteristic.

At the end of the analysis phase, one improvement option is selected to be worked out to a design. Specific theory will serve as input to the design phase.

A3, A4, A5 Analysis

Interviews with different people inside and outside of Univar, as well as extensive data analysis has lead to a comprehensive picture of Univar Ltd and the business supply chain of Safe-tainers. It also shows the limitations of supply chain improvements at Univar. The customer survey provides insight into the limitations from the customer perspective.

B1, B2, B3 Opportunities, limitations, and assessment

The business analysis, and customer service lead to a description of the business supply chain of Safe-tainers, opportunities for improvement of the logistics, and also to the limitations to improvements. Opportunities can also follow from the theory about supply chain management and reusable containers. To ensure that we get a comprehensive picture, that opportunities can be tested for viability and profitability, and also to be able to compare different options, an assessment instrument is used.

C1 Evaluation of opportunities

The opportunities will be tested using the assessment tool and taking into account the limitations of the network. The result is an overview of opportunities with evaluation criteria.

D1, D2, E1 Selection, design, implementation

After the evaluation of all opportunities, one option is selected that is worked out to a design. A literature study into the topic of the selected option serves as input for the design. Finally, the implementation of the design is discussed.

3 Analysis

Not everything that can be counted counts, and not everything that counts can be counted.

Albert Einstein

In this chapter, several improvement options are presented and evaluated. The framework is used for this purpose is presented in section 3.1. One option is selected will be worked out in detail in the next phase of the project. The selection criteria used for this purpose are also given in section 3.1. The results of the analysis phase are presented in section 3.2. The selection of an option is discussed in section 3.3 and the requirements for the design phase can be found in section 3.4.

3.1 Framework and evaluation criteria

In this section, a framework is described that we use for categorising supply chain improvement options. We will use the framework that was presented by Otto & Kotzab [7]. Otto & Kotzab have collected research in Supply Chain Management and categorised it into 9 major categories. These categories are described in table 3. In the next sections, supply chain management concepts that may be relevant for this project are described and discussed.

Table 3: Otto & Kotzab SCM Principles

SCM-Principle	Principle's Framework
Compress	Means for improving a supply chain by (1) reducing the number of nodes, members, or actors in the chain, (2) or by reducing the physical distance between any two nodes. Compression primarily applies to structure and aims at costs.
Speed up	Means for reducing the amount of time necessary to move between any two nodes in a chain or network or between any two stages in a process. Speed up primarily applies to processes and aims at time.
Collaborate, cooperate	Means for improving a supply chain by increasing the intensity and scope of cooperative behaviour between two or more independent decision making units. Collaboration primarily applies to relationships, planning, scheduling and executing. It aims at cost and service.
Integrate	Means for improving a supply chain by reducing the penalty in time, effort, cost or performance to move between any two activities in a process or between processes. Integration can be applied sequentially (activity A to activity B), vertically (generic process A to generic process B) or horizontally (activity A is pooled for products X and Y). Integration primarily applies to processes and aims at time and cost.
Optimize	Means for improving a supply chain by maximizing the value of a target function through the use of quantitative models. Optimization primarily applies to planning and scheduling and aims at time and cost.
Differentiate, customize	Means for improving a supply chain by increasing the specificity and thus the effectiveness of a subject towards a given purpose. Differentiation primarily applies to structure, processes, and planning and aims at cost and service.
Modularize	Means for improving a supply chain by reducing the penalty in time, effort, cost or performance to replace a particular segment of the chain. Modularization primarily applies to products and processes and aims at

	cost and time.
Level	Means for improving a supply chain by reducing the magnitude of variation of a certain parameter of an object over time. Levelling may apply to material flows and order flows. Levelling primarily applies to goods and order flows and aims at cost.
Postpone	Means for improving a supply chain by moving the product differentiation closer to the time and locus of consumption.

In this project we select only one concept to be worked out to a complete design. There are four criteria that we find most important to base the selection on:

1) Expected supply chain profits;
2) The risk of failure;
3) Location of profits and investments;
4) Added value of the student.

Ad. 1) This is an obvious criterion. Note that expected revenues is no criterion.

Ad. 2) The risk of failure is the chance that an improvement will not lead to the expected profits multiplied by the expected loss in case of failure.

Ad. 3) This is an important criterion to Univar. From a supply chain perspective, a certain improvement option may be very profitable but in order to qualify, at least part of the profits must fall to Univar. Furthermore, if a substantial investment must be made, also a substantial part of the revenues must go to Univar.

Ad. 4) Added value of the student is an important criterion from the point of view of Univar. Options that are profitable but do not require specific skills of the student can better be worked out by the company so that the student can work on an option where he has the most added value.

Besides these criteria the options that can be selected are restricted to those that fall completely inside the scope of the project. The company has explicitly requested not to do any research into issues that involve products other than chlorinated solvents.

Ideally, criteria are quantified for each improvement option. However, the effort required to quantify these criteria for every improvement option does not offset the added value in our opinion. Furthermore, some of these criteria like added value of the student are very difficult to quantify. Therefore the students makes a qualitative judgement of these criteria for each option in cooperation with the company. Every criterion can be valued in five steps from '- -' (worst), to '++' (best), if possible based on a (rough) quantitative estimate. The framework is discussed at a project meeting that is attended by the first university supervisor and the first company supervisor. It is agreed upon that one option (selected during that meeting) will be worked out in detail.

3.2 Improvement options

Some of the categories from the Otto & Kotzab framework are discussed together because the options in the category can be put into both.

Compress/Integrate

The aim of first deliverable of the initial assignment (see section 1.4) was to reduce transport costs by utilizing the existing Univar hub & spoke network. This is an example of horizontal integration where transport of Safe-tainers is combined with transport of other products in the Univar network

The second deliverable of the initial assignment was a proposal to start filling at the Univar site in Middlesbrough. This is a good example of compression. Further compression can possibly be achieved by eliminating the Vopak inventories at Teesside.

Hub & Spoke

For calculating the savings that can be expected from the transition to hub & spoke, those costs are taken into account that are different from the current situation where customers are delivered straight from the hub. These are the following costs:

- Current transport costs for trips to and from the customer;
- Current transport costs for trips to and from the filler;
- Estimated costs for intersite transport in the hub & spoke situation;
- Estimated costs for handling of Safe-tainers at the spokes;
- Estimated costs for deliveries to (and collections from) customers.

These costs are calculated for four scenarios. These scenarios differ in the choice for the site to function as a hub for Safe-tainers: Middlesbrough, Wellingborough, South Kirkby and the current hub: Grimsby. Initially South Kirkby was considered not to be an option because there is no administrative capacity to support Safe-tainers. It was included as an option on the condition that the administrative processes would remain at Grimsby.

Only the results are given here. The complete analysis can be found in appendix V. An important assumption is that all costs are linearly proportional to sales. It was already argued in section 2.2 that transport costs are probably not proportional to sales. Still, it is our best estimate.

Hub & Spoke Score	
Savings	++
Risk	++
Location profits	++/0
Added value	+

Table 4: Expected Savings 2004 from Hub & Spoke

Scenario	Estimated Savings
Middlesbrough Hub	£24,400
Wellingborough Hub	£41,591
Grimsby Hub	£22,436
South Kirkby	£40,607

Filling of Safe-tainers

In-house filling was a proposal by the Regional Operations Controller and the Product Manager of chlorinated solvents. They see two main advantages of in-house filling:

1) Transport costs are reduced because the transport leg between filler and distributor is eliminated;
2) Extra revenues are generated by taking on this new activity (Univar would seek to be paid for the filling by Safechem).

Ad. 1) Bulk solvent is shipped over a distance of more than 100 miles from a Vopak terminal in Teesside to the filler in Sheffield. After have been filled, Safe-tainers are shipped to Grimsby, approximately 75 miles from Sheffield. If the Univar site in Middlesbrough (Teesside) would fill Safe-tainers, the total distance over which solvent is moved from the Vopak terminal to the distributor, is reduced from 185 miles in two trips to a few miles in 1 trip. Savings on transport can be substantial. However, currently this transport is paid for by Safechem. It is not clear what Univar's share would be in the savings.

Ad. 2) Filling would lead to extra revenues. However, the question is whether it leads to extra profits.

On top of the two arguments for filling that were mentioned above, Univar would also be less dependent on the current filler: Caldic. Caldic is not only the filler of Safe-tainers in the UK, they are also a distributor of Safe-tainers in the UK and thus a competitor of Univar. Some people within Univar are uncomfortable with the fact that Caldic knows exactly what is being sold by Univar, and the idea that Caldic may influence the supply of Safe-tainers (and thus availability).

It became clear from the conversations with site managers and people in the SHEQ department that there is much resistance within the company to fill Safe-tainers with chlorinated solvents. Sites and people do not want the environmental and safety risk involved with filling chlorinated solvents.

A new filling station would have to be built for filling chlorinated solvents. According to senior managers, currently there would be only the Univar site in Middlesbrough has the space, tank capacity, and skills required to do the filling. Special environmental and safety precautions are needed and these would make a new filling station for chlorinated solvents expensive. The question is whether besides extra revenues, in-house filling would also lead to a higher profit.

Experts within Univar have made an estimate of the costs of a filling station. From previous conversations with Safechem, Univar can also make a good estimate of the filling fee that Safechem would pay. Expected savings on transport are based on current transport costs for Safe-tainers[11]. According to the second company supervisor of this project and the Product Manager of chlorinated solvents, Univar would want at least half of the savings on transport. Based on these figures, a net present value (NPV) analysis

Filling Score	
Savings	-
Risk	-
Location profits	+/+
Added value	-

[11] Univar makes two filler collections and two filler returns per week. The capacity of this transport is approximately twice the capacity that is needed.

approximately £36,500 (increasing). For Univar, this pay-back time is too long. Univar would prefer a pay-back period not longer than 3 years. However, the capacity of the filling station that must be built is far greater than the required capacity. Univar engineers estimate the capacity that is required to fill 50 Safe-tainers per week is approximately 1 day per week. If the remaining capacity can be utilized, the investment costs can be split and building the filling station may become profitable.

Eliminating Vopak Safe-tainer inventory

The other potential for compressing the supply chain is the storage of solvents at the Vopak terminal (see figure 8). Elimination of this inventory may result both in a lower supply chain inventory and reduced handling costs. Solvents could be delivered to the Middlesbrough site directly from the DOW production facilities in Germany by road tankers. However, it is not known at this point whether DOW uses Vopak to deliver chlorinated solvent directly to (large) customers. If they do, it is unlikely that savings on inventory costs can be achieved here. Savings can be achieved if the amount of handling is reduced. Currently there is no information available about the costs of handling at Teesside. Investments needed are likely to be high since tankers need to be available to store the individual products.

Vopak Inventory Score	
Savings	-
Risk	-
Location profits	**DOW**
Added value	-

Acceleration

There is a potential for acceleration within Univar. The replenishment order lead time is currently 4 to 5 days. The process consists of 4 activities that each take a full day. At Univar there are people that recognize this problem. If the replenishment lead-time can be reduced to one or two days, spokes may start cross-docking[12] products. This would lead to a substantial reduction of stock (all spoke stock could be eliminated) and even handling could be reduced because the products need not be put into the warehouse and be picked from the warehouse. For more information about the concept of cross-docking see Kinnear [8].

The replenishment process consist of five activities:

1) Order generation– the ERP system generates replenishment orders once a day;
2) Stock control – all new replenishment orders are checked against availability of stock at the hub manually once a day;
3) Transport planning – once replenishment orders have been confirmed by stock control, transport planning can plan it on a load. Only replenishment orders that have been confirmed before a specific time (usually around 12 am) are included in the planning process;
4) Loading – vehicles are usually loaded the day after they are planned. Loading takes place in the afternoon;

[12] Cross-docking is a concept where a site does not store products but has a consolidation and break-bulk function. Goods come in from the hubs, are unloaded and reloaded again in a very short time span. In this scenario, the CODP lies at the hub. That is, only firm customer orders are received by the site. Also see figure 9.

5) Dispatch – vehicles are usually dispatched the day after they are loaded.
6) Delivery and unloading – most transport takes no more than one day

Each of these activities is performed for all daily replenishment orders together and at fixed times on the day. Each daily batch of replenishment orders must be processed completely at each step before the next step can start. The replenishment lead time is the sum of the batch processing time of the activities.

The replenishment lead time can be reduced by processing orders dynamically. By dynamic processing we simply mean that replenishment order batch sizes are reduced to 1. Essentially, no start-up cost or time is involved with these activities. Therefore, each replenishment order can be processed separately and immediately be forwarded to the next step. The replenishment lead time would still be the sum of the processing times at each step but the individual processing times are reduced to the time for processing one order. Obviously, steps like load planning and loading are difficult to perform for individual replenishment orders, but the daily batch can still be split up into batches per load. Furthermore, the current DRP system does not support real time processing of orders. Much research is available about dynamic vehicle dispatching and dynamic vehicle routing. See for example Chwen-Tzeng [9] and Noah & Garrett [10].

Safe-tainers have relatively low inventory and handling costs (less than 5% of the total logistic costs), although the costs may be higher if Safe-tainers are distributed through the spokes. If these costs can be reduced by 30% to 40% then savings could amount up to £700 to £900 per year. These savings solely may not justify changes in the operational process but reducing the lead time of a replenishment provides opportunities for inventory cuts for all products. Besides, if Safe-tainers are distributed through the hub and spoke network, limited availability may prevent Univar from keeping Safe-tainer stock at the spokes. In that case, cross-docking may be required from a customer service perspective.

Acceleration Score	
Savings	0
Risk	0
Location profits	++/0
Added value	+

Differentiation

In table 4, it was shown that major savings can be achieved on transport costs if Safe-tainers are distributed through the spokes. Usually, hub & spoke products are kept on stock at the spokes. However, a major concern is that Safe-tainers cannot be kept on stock at the spokes due to limited availability. On the other hand, if Safe-tainers are not kept on stock at the spokes, delivery lead times exceed the maximum accepted lead time for many customers. Here differentiation may provide a solution.

The customer survey shows that there are two types of customers: those that require delivery lead-times of 2 to 3 days, and those that are satisfied with delivery lead-times of a week or longer. In the hub & spoke scenario, the former type of customers must be supplied from spoke stock. However, it is possible to supply the latter type of customers from hub stock by cross-docking it at the spoke (see acceleration). An option in the category differentiation is to do both. In that case, spokes have to keep stock only for part of the customers.

Differentiation Score	
Savings	0
Risk	0
Location profits	++/0
Added value	+

However, it is doubtful whether this type of differentiation leads to a lower system stock level (than in the hub & spoke scenario without differentiation). If the demand that is satisfied from spoke stock is low, this probably leads to a relatively high safety stock (because the remaining demand is relatively more erratic). Besides, it would require a lot of extra administrative effort from the spokes to distinguish between customers that are not delivered from stock, and customers that are for the same product. Altogether, it is highly likely that extra costs will be incurred if this option is implemented. Yuzeng et. al. [11] study lead time differentiation in an inventory system with returns.

Optimization

Optimization of the size of the Safe-tainer pool and allocation of stock

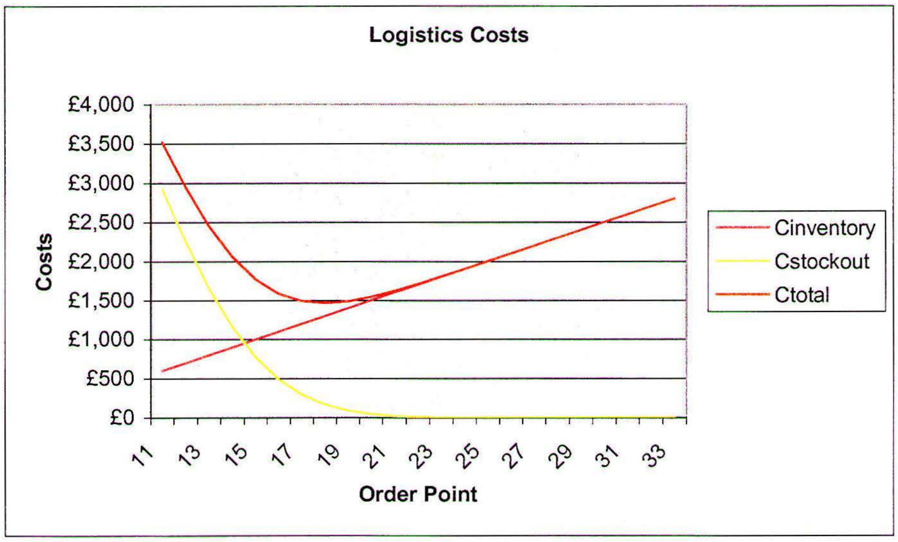
An area that would benefit from Optimization is that of the availability of Safe-tainers. It was already argued in section 2.3 that the availability of Safe-tainers strongly influences transport costs. It is therefore of great importance to Univar that the number of Safe-tainers that is allocated to Univar is increased. Safechem on the other hand is anxious to limit the number of Safe-tainers in the network because of the high capital investment. Currently, there is no true understanding of the relation between these two major cost drivers. There is no method to make an objective choice for the size of the Safe-tainer pool. To give a rough estimate of the savings that may be achieved by optimizing the number of Safe-tainers that is allocated to Univar, consider the following.

Consider one spoke with the stock level as its independent control variable. Let's assume that there is a fixed quantity of Safe-tainers at customers. Furthermore, assume that:

- Fixed costs of a Safe-tainer are £100 pa (see appendix XIII.2);
- Spokes are replenished 2 times per week on average (source: transport department Univar);
- There are no shortages at the hub;
- Demand is normal distributed with an average of 10 Safe-tainers per week per spoke and a standard deviation of 4 (based on pilot project figures, see chapter 5) for all sites;
- Costs of a stock-out are £70 (rough estimate of a Univar expert).

Based on these figures simple probability analysis (see appendix XIII.3) result in the following graph.

Figure 13: Logistics Costs



The graph shows the inventory costs at a spoke for different order points. It also shows the annual costs for stock-outs per spoke. The graph shows that the total logistics costs vary considerably around the optimal order point. Within the order point range of 14 to 19, there is £1,000 difference in costs. If all spokes are equal and have 5 Safe-tainers short, the supply chain opportunity costs are £8k. If half of the sites have 5 Safe-tainers more than the optimal number (opportunity costs are £340 per site), and the other half has 5 Safe-tainers less than the optimal number, total opportunity costs are 5*£1,000 + 5*£340 = £6,7k.

Pool Size Optimization Score	
Savings	+
Risk	++
Location profits	+/+
Added value	+

Optimal batch sizes

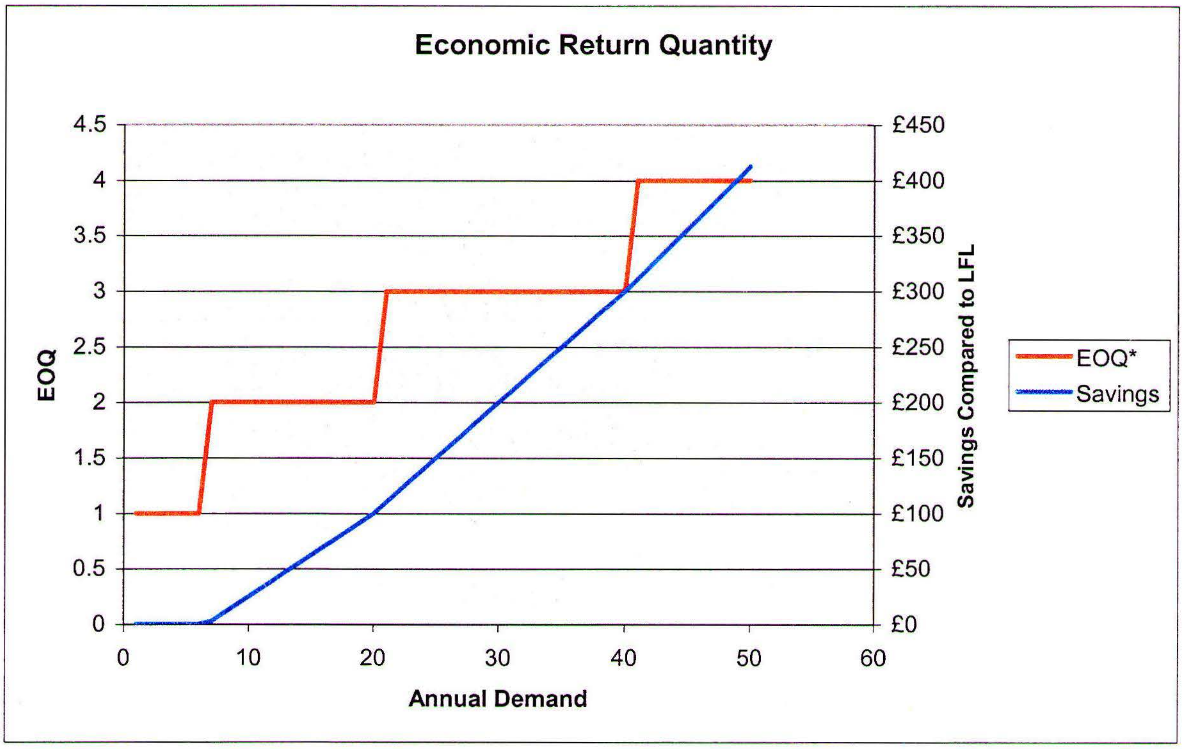
Waste Safe-tainers also pose a challenge. Waste Safe-tainers need to be turned around quickly because of their limited availability. On the other hand, through batching Safe-tainers, high costs for waste registration can be avoided. An rough estimate of the savings is determined by using a simple EOQ approach (see appendix XIII.1). For an introduction on lot sizing methods, see Silver, Pyke, and Peterson [12].

We use the following figures:

- All sites have equal and constant return flows of 29 Safe-tainers per annum (based on 2003 sales).
- The costs per batch returned to the hub are £15 for waste registration
- The fixed costs per Safe-tainer are £100 pa.

Based on these figures, the optimal batch size for waste Safe-tainer return to the hub is 2. Compared to batch size 1, savings are £3.53 With 2003 sales of 229 waste Safe-tainers, potential savings are £808 pa. For spokes with larger demand, savings can be even higher. figure 14 shows the optimal return batch size (red line) for different annual return quantities at the spoke. Also the supply chain savings of the choice for the optimal batch size instead of lot-for-lot returns is shown (blue line).

Figure 14: Savings per Safe-tainer for EOQ versus lot-for-lot



Similar to determining the optimal return batch sizes of waste Safe-tainers to the hub, the optimal batch sizes for collection of Safe-tainers from the filler can be determined. Currently, many trips to the filler are underutilized. If the availability of the Safe-tainers would be less of a problem, trips to and from the filler could be limited to minimize the total costs. To show this, we make the following assumptions:

- The fixed cost of a Safe-tainer are approximately £100 pa;
- Annual demand is 2486 Safe-tainers;
- The fixed costs per order are £120
- Currently, two trips per week are made

The optimal collection quantity with these figures is 77 Safe-tainers. The maximum number of Safe-tainers that can be fitted on a vehicle is 42[13]. Therefore, vehicle should always be fully utilized to minimize the supply chain costs. The factor with the highest uncertainty here is the annual fixed costs of a Safe-tainer. Figure 15 shows what happens to the optimal batch size if these costs are higher than £100. The optimal batch size is shown in red. The corresponding

[13] The number of full Safe-tainers is limited by weight to a maximum of 40. The number of waste Safe-tainers is limited by volume to a maximum of 60. At current ratio fresh/empty Safe-tainers, on average 42 Safe-tainers can be fitted on a vehicle.

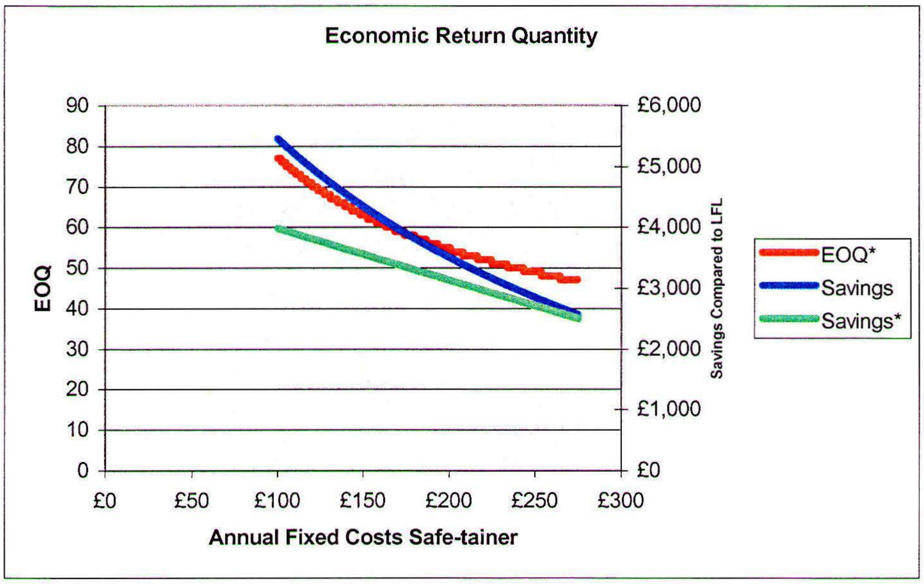
maximum savings are shown in green (the blue line shows savings at EOQ batch size). Not even if the fixed costs are twice as high as assumed here is it profitable to use underutilized vehicles.

The savings that can be expected from fully utilizing vehicles from the filler £4k maximum. Similarly by fully utilizing vehicles going to the filler, another £4k maximum can be saved. However, also here, the availability of Safe-tainers is the limiting factor. Unfortunately, Univar needs to make more frequent trips to get Safe-tainers to the customer on time. (Also see section 2.3).

Batch Size Optimization	
Savings	+
Risk	+
Location profits	+/+
Added value	+

The EOQ approach used in this section is a very simple approach. A more elaborate procedure to determine the right order size is presented by Swenseth & Godfrey [13].

Figure 15: EOQ versus weekly demand



Collaboration/Cooperation

Forecasting of customer demand

Most Safe-tainer customers have a reasonably stable demand for chlorinated solvents. Sometimes however, there are special situations in which customers have a higher demand than usual. If occurrences of special demand can be filtered out through close contact with the customer, it becomes possible to have forecast based replenishments to the spokes, keeping the number of Safe-tainers in the network at a minimum. However, customers claim that they are not able to forecast demand because there is no way of determining the solvent remnant in a Safe-tainer. Even if the customer would be able to determine the solvent remnant, it is unlikely that they would put in the effort to make a forecast.

Increasing customer utilization

Much can be achieved if customer utilization is increased. Every unit reduction of the average number of Safe-tainers at the customer results in £100 lower costs (estimated annual fixed costs of a Safe-tainer). However, customers have no incentive to reduce the number of Safe-tainers that they have in use. To give customers an incentive to improve their utilization of Safe-tainers, Univar can charge a rent or deposit for Safe-tainers.

On the other hand, Safechem can also start to charge Univar rent for he use of Safe-tainers. This rent should represent true Safe-tainer costs per day. In return, Safechem can then provide excellent customer service (with Univar as the customer). That is, they should have ample Safe-tainers to satisfy demand and no limitations on numbers should be imposed on the distributor. This makes it more easy to focus on minimizing supply chain costs because each party can optimize their use individually. Univar can then make the trade-off between rent paid and transport costs and Safechem asset costs are covered by the rent.

An alternative to rent and deposit systems are switch pool systems (See Kroon & Vrijens [14].) In switch pool systems, each customer has its own allotment of containers. Full containers are exchanged with empty containers one-for-one. The disadvantage of this system is clearly the lack of flexibility.

Yet another opportunity to increase customer utilization is tot limit batch sizes. The best approach here is to determine an optimal order size in a way similar to the one described in the previous category. However, for reasons mentioned in section 2.5, transport costs are very difficult to determine (and differ substantially from site to site). Figure 16 shows histograms of customer order sizes for Neu-Tri Safe-tainer and waste Safe-tainers (source: Safechem WebInfo). We noticed that some customers have especially high average order sizes. Figure 17 shows the economic order sizes at annual fixed Safe-tainer costs of £100. The economic order size is given for fixed costs per delivery of 5, 10, 15, 20, and 25 pounds.

Figure 16: Customer order size

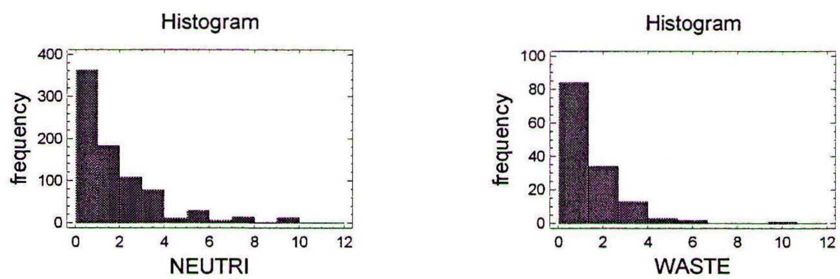
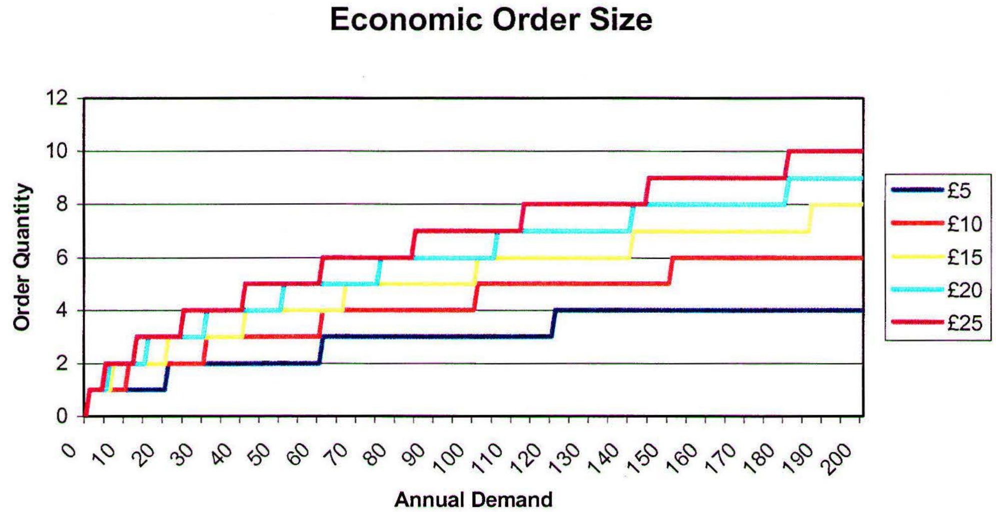


Figure 17: Economic customer order size



One customer with annual demand of 110 Safe-tainers has an average Neu-Tri order size of more than 9. It can be shown that if the fixed ordering costs (such as transport costs per drop) are around £25 then, annual savings that can be achieved for this customer are no more than £12,70. However, if the fixed ordering costs are closer to £10, annual savings for this customer are approximately £102.22. Here, the annual fixed costs for a Safe-tainer are again assumed to be £100. If the Safe-tainer pool size is smaller than the optimal size, extra costs of high batch sizes are incurred,

Safe-tainers cost about £100 per year (see appendix XIII.2). They are turned around approximately 5 times per year (waste Safe-tainers only 4 times per year). (See appendix XI.) This is £20 to £25 per Safe-tainer sold. If the customer dwell time of a Safe-tainer is reduced by 20% (6 full cycles per year), savings of £3.33 to £5 per Safe-tainer per cycle. At 2003 sales of 2,486 Safe-tainers annual savings are expected to be £10k.

Customer Utilization	
Savings	+
Risk	+
Location profits	+/+
Added value	+

Vendor Managed Inventory

VMI or vendor managed inventory is a concept in which the supplier monitors and manages the inventory at the customer. In its most simplest form, Univar would ask the customer at fixed times (based on their demand pattern and their last reported stock level) to read the current inventory and report it back to Univar. Univar then determines when a new Safe-tainer must be delivered.

Currently, about 40% of the Safe-tainers at the customer is unused. If it is possible through VMI to decrease customer stock by half, the number of Safe-tainers at customers could be reduced by 20%. With annual fixed Safe-tainer costs of £100, and almost 600 Safe-tainers currently at customers, VMI could result in savings of £12k pa. There are risks involved with VMI. The major risk is that customers do not report special situations of

Vendor Managed Inventory	
Savings	+
Risk	-
Location profits	+/+
Added value	+

high demand. Also, the prerequisite for VMI is that customers must be able to read solvent remnant from the Safe-tainer for which extra equipment is required. Furthermore, extra effort from Univar sales people or stock managers is needed to get the required information from the customer. For more information about VMI see Williams [15].

Postponement/Modularization

Improvement of the supply chain through postponement and modularization is possible though it would mean a significant change in the Safe-tainer concept. An alternative concept is described in appendix XII. The basic idea of this concept is that the supply chain can be substantially compressed for the outer hull of the Safe-tainer.

Also, outer hulls can be generic. Currently, each individual Safe-tainer is dedicated to one product. There are special containers for holding waste. In other words, there are six different types of fresh Safe-tainers and one waste Safe-tainer, causing seven different types of stock. If it would be possible to design Safe-tainers so that they can be used for any product or as waste Safe-tainer until they are actually filled, the Safe-tainer can be used much more efficiently.

The result would be that fewer outer hulls are required and therefore capital invested can be reduced. Furthermore, transport costs could be reduced because drum require less space and have a lower weight than Safe-tainers. No expensive new equipment is needed to implement this option but the success depends on the willingness of Safechem.

Postponement/Modularization	
Savings	+
Risk	-
Location profits	+/+
Added value	+

3.3 Selection

Each of the improvement options in the previous section was evaluated on the criteria in section 3.1. The results are shown in table 5.

Table 5: Evaluation improvement options

	Improvement Option	Savings	Risk (-- is high risk)	Location of Profits (Univar/ Safechem)	Academic Relevance
	Compression/Integration				
1+	Hub & Spoke	++	++	++/0	+
2	Filling of Safe-tainers in Middlesbrough	- +*	-	+/+	-
3	Storage of raw material at Middlesbrough site instead of Vopak terminal	-	-	DOW	-
	Acceleration				
4+	One day replenishment cycle with cross-docking	0 ++**	0	++/0	+
	Differentiation				
5	Differentiated delivery lead-times for customers	-	--	+/+	+
	Optimization				
6+	Pool size and allocation of stock	+	++	+/+	++
7+	Batch size optimization	+	+	+/+	+
	Collaboration/Cooperation				
8+	Increase customer utilization	+	+	+/+	+
9+	VMI	+	-	+/+	+
	Postponement/Modularization				
10+	Universal Safe-tainers & separation drum and outer hull	+	-	+/+	+

* if extra capacity filling station is used)

** if replenishment lead times are reduced company wide

Those options that result in no or limited savings do not qualify (3, 4, 5). Option 2 is a special case. If the costs of building a new filling station can be shared by using the remaining filling capacity, this option becomes profitable. However, for reasons already mentioned in section 2.6, this option will not be worked out any further. Furthermore, options that are thought to have a relatively high risk are not included. These are options 9 and 10. Option 10 is not worked out because the potential savings from this options can be achieved with less risk through option 8. Option 10 is likely to fail because it reinterprets the Safe-tainer concept. This option can only become a success if Safechem is the leading party in working it out.[14].

The other options all score well on each criterion. Also because of its great importance to Univar, option 1 was already selected. The major barrier to implementation of option 8 is the availability of Safe-tainers. (Also see section 2.3.)

Low availability of Safe-tainers is an important restriction to improvement in the network. Many of the improvement options in the previous section are influenced by availability of Safe-tainers. These options are marked with a + in table 5. Option 8 aims at improving the availability but does not lead to insight about the way different parameters influence

[14] The option was not completely abandoned. Together with the Univar Product Manager for Safe-tainers, some work was done on an alternative Safe-tainer concept that was also briefly introduced to Safechem. The concept is presented in appendix XII. Safechem has said to be happy with the initiative.

availability. Also it does not give insight in what the most profitable level of availability is. Improvement option 6 considers the issue of availability of Safe-tainers. It is aimed at achieving a level of availability that maximises profits. Although option 8 will be given some attention during the implementation, option 6 is selected to be worked out further.

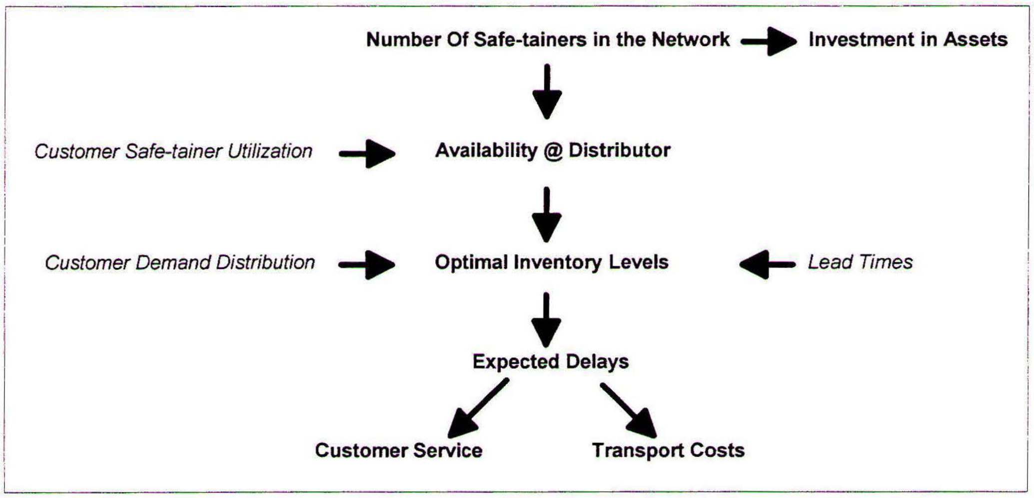
3.4 Design requirements

The main objective of the design phase of the project is twofold. The first objective is one at the tactical level. We want to find a good trade-off between transport costs and the fixed costs of the Safe-tainer pool. Basically the relationship is as follows. If there were an unlimited number of Safe-tainers available in the network, transport costs could be minimized by moving Safe-tainers only in large batches. On the other hand, when the number of Safe-tainers in the pool would be reduced to an absolute minimum, Safe-tainers would have to be moved lot-for-lot. No inventories could be kept at any spoke. The network would be characterized by poor performance and high transport costs.

At the execution level, the second objective is to determine how the Safe-tainer stock that is available to Univar at a specific time should be divided over the hub and spokes to optimise performance.

Furthermore, the design should give insight into how several parameters influence the network costs. This is graphically shown in figure 18.

Figure 18: Abstract Cause-and-Effect Model



There is one important problem in the objectives mentioned above. It was already argued in section 2.2 that it is impossible to determine the exact costs of transport for a specific network setup. It is also shown at different points that limited availability is the main cause for high transport costs and also the main barrier for some of the improvement options in section 3.2. What is then the appropriate availability of Safe-tainers? We will use the average customer backlog as a measure for availability and thus as an indicator of extra transport costs. This can be justified as follows. Consider a network that is optimal from the perspective of Safe-tainer availability. In this network transport costs would be minimized because vehicles are fully utilized and no express shipments are needed. This type of network is characterised by zero customer backlogs. Now we start reducing Safe-tainer availability. Costs increase because somewhere in the network, a shortage exists that prevents Safe-tainers to be delivered to customers immediately. Extra efforts will be made to get the Safe-tainers to the customer in time. Short delays can be solved by ‘pushing’ a replenishment order. The efforts are limited to some extra attention like bypassing normal replenishment procedures to get the Safe-tainer loaded the same day. If the delay is longer, or if more customers are affected by the delay, the measures that need to be taken become more costly. The shortage may be solved by making an express delivery to a customer, or by making a dedicated collection to get Safe-tainers back from customers quickly. In other words, the higher the backlog would be, the higher the extra effort and costs to get the Safe-tainers to customers on time. The expected backlog is thus a good indication of the extra costs.

4 Design

Common-sense: the reason so many people can be wrong at the same time.

The Thinking Man's Dictionary, Kevin Solway

In this chapter, a model is presented for analysing the performance of the Univar hub & spoke network for Safe-tainers. The model has two main purposes. Firstly, the model gives a good allocation of stock to the distributor sites. Secondly, the model gives an estimate of the average backlog taking into account several important parameters. Section 4.1 is an introduction to the model. The model itself is presented in the section 4.2. The results of a simulation study are compared with the results of the model in section4.3. Finally, implementation issues are discussed together with the model outcomes in section 4.4.

4.1 Introduction

The problem of the allocation of Safe-tainers adds an extra dimension to regular inventory management. There are two aspects to Safe-tainers that make them different. The first aspect is that Safe-tainers are returnable. This is not an uncommon problem. Much research has been published about reusable and returnable items such as pallets. A good overview of research about systems with reverse flows in given by Fleishman [16].

A less common aspect of Safe-tainers is that the container has a relatively high value (the container costs more than four time the price of the product). Most literature about reusable containers concerns finding a suitable purchasing policy. See for example Inderfurth & van der Laan [17], and Kelle and Silver [18]. This is not sufficient here. Firstly, Safe-tainers are always returned and have a relatively long technical lifespan. Furthermore, we also want to get insight into factors other than pool size that influence availability. Every time a new container is purchased, this can be seen as an investment. Although we will not look into the mechanism of this investment and its returns (see Rosenau et. al. [19]), a result of the high value of these containers is very important. The number of Safe-tainers is limited. The system that we consider is a continuous review system. Axsäter [20] gives a good overview of these inventory systems.

Besides determining the right allocation of stock, the model should also give insight into the effect of certain important parameters on availability. The most important one being the size of the Safe-tainer pool. There is pressing need for objective information in discussions between Univar and Safechem about the size of the Safe-tainer pool. Too small a Safe-tainer pool leads to high transportation costs at the distributor and dissatisfied customers. Too large a Safe-tainer pool leads to excessive investment and maintenance costs for the supplier. The other tow effects that may be investigated with this model are the effect of an increase in customer utilization of Safe-tainers and the effect of shorter lead times.

The two main cost drivers are investment costs and transportation costs. It is clear that the size of the Safe-tainer pool determines the first type of costs. It was explained in section 3.4 that shortages lead to high transportation costs and that the average number of backlogs is the main cost driver for these extra transport costs. The output of the model is therefore annual average backlog. Furthermore, in combination with a simple heuristic, the model also gives a allocation scheme for the use of stock that minimizes total average backlog.

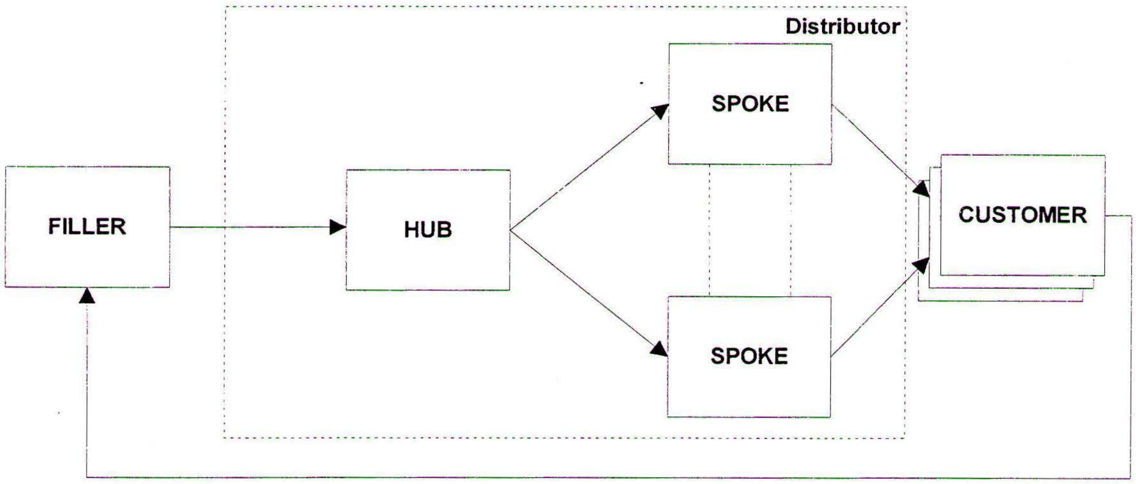
Assumptions

We make the following assumptions in the model:

1) Univar has its own Safe-tainer pool that has a fixed size.
2) There are no stock outs of chlorinated-solvents at the filler.
3) Demand has a shuttering Poisson distribution (see appendix VII).
4) Customer requirements are not influenced by backlogs and no demand is lost due to stock outs.
5) Supply lead time and replenishment lead times are both independently and identically distributed.
6) Replenishment orders are processed FIFO.

Furthermore, we make one important simplification. The status 'at the customer' begins immediately after dispatch at the spoke and ends not until the Safe-tainer is returned to the filler. This is depicted in figure 19.

Figure 19: Simplified network



4.2 Model

Parameters and variables

λ_j	Arrival rate of customer orders at spoke j
δ_j	Throughput at spoke j (j=1..J)
ρ_j	Parameter of the geometric distribution of customer order sizes (see appendix VII)
s_j	Target stock level for spoke j (j=1..J) or hub (j=0)
O_j	Total number of outstanding replenishment orders at spoke j
B_j	Total number of customer backlogs at spoke j
$B(s_j)$	Expected quantity of backlogs at spoke j as a function of the stock level s_j

I_j	On hand stock at spoke j
J	Number of spokes in the model
T_j	Nominal replenishment lead time to spokes (j=1..J) or the nominal supply lead time to the hub (j=0)
L_j	Actual replenishment or supply lead time when waiting time due to backlogs is taken into account
M	Pool size
S	Distributor economic inventory position
K	Total number of containers required by customers
I_D	Total physical stock at distributor
I_K	Physical quantity of containers at customers
I_F	Physical filler stock
O_F	Net filler stock
B_S	Total system backlogs (sum of backlogs at the spokes)
B_F	Supply backlogs at the filler

Model

The system that we examine is a two echelon inventory system with spokes at the lowest echelon and one hub at the higher echelon. Demand occurs at the spokes only. Customer orders arrive according to a Poisson process with arrival rates $\lambda_1,...,\lambda_J$. Customer order sizes follow a geometric distribution f with parameters ρ_j. The probability that a customer order placed at spoke j has size i is:

Equation 1

$$f_i(\rho_j) = (1-\rho_j)\rho_j^{i-1}$$

The demand process described here is an instance of a compound Poisson process called the shuttering Poisson distribution.

The spokes use a (s-1, s) inventory policy. That is, for every item that is ordered at the spoke, immediately a replenishment order is placed at the hub so that the economic inventory position is always equal to S. A special property of these inventory systems is:

Equation 2

$$s_j = I_j + O_j + B_j,$$

where I is the stock on hand at the spoke, O is the total number of items that are due in from the hub, and B is the number of items that are backordered at the spoke. I, O, and B are non-negative.

We want to determine the system backlogs as a function of the stock levels in the system $s_0,...,s_J$. The system backlogs are only the backlogs at the spokes ($B_1,...,B_j$). The backlogs at the hub are only important for as far as they influence the number of outstanding orders at the spoke. In order to estimate the number of system backlogs, we need to determine the steady-state probabilities of the number of outstanding orders at spokes. We use an approach from the field of repairable item control called METRIC. The METRIC method was first developed by Sherbrooke [21] for the RAND Corporation. Since then, many authors have extended the model.

The METRIC method is built on Palm's theorem. Palm's theorem states that an $M/G/\infty$ queue with arrival rate λ and a service time that is independently and identically distributed with mean T, has a steady-state probability distribution that is Poisson with parameter λT. Later, this theorem was extended by Feeney and Sherbrooke [22] to compound Poisson situations. It is easy to see how this theorem can be applied here. The number of outstanding orders at a spoke can be seen as the length of an $M/G/\infty$ queue. Because equation 2 holds, the arrival process at this queue is the same as the customer order process. The service time is the time before an item is removed from the queue. This event takes place when a replenishment arrives at the spoke. The service time for the queue is therefore equal to the replenishment lead time.

Before we can say anything about the steady-state distributions at the spokes, we need to estimate the replenishment lead time. The replenishment lead time consists of two parts. Firstly, there is the nominal replenishment lead time from hub to spoke. Secondly, there is the lead time that is due to backlogs at the hub. When there are backlogs at the hub, there is an extra waiting time for Safe-tainers to be replenished to the hub. The expected lead time for a replenishment to spoke j becomes:

Equation 3

$$L_j = T_j + E(W_0)$$

where T_j is the nominal replenishment lead time from the hub to spoke j, and W_0 is the waiting time due to backlogs at the hub.

We need to determine the average waiting time at the hub due to backlogs. We start with specifying the replenishment requests process at the hub. One implication of equation 2 is that the replenishment requests process at the hub is simply the sum of demand processes at the spokes. The throughput (δ_0) at the hub is:

$$\delta_0 = \lambda_0 / (1-\rho_0) = \sum_{j=1}^{J} \delta_j$$

The arrival rate at the hub is:

$$\lambda_0 = \sum_{j=1}^{J} \lambda_j ,$$

and the parameter of the order size distribution at the hub becomes:

$$\rho_0 = 1 - \lambda_0 / \delta_0 .$$

The average waiting time at the hub can be calculated from the average backlog by Littles formula:

Equation 4

$$E(W_0) = {E(B_0)}/{\delta_0}$$

Now we need to determine the expected amount of backlogs at the hub. Feeney and Sherbrooke give the formula for a queue with compound Poisson arrivals and unit service time. The steady-state probability of x items in the queue is:

Equation 5

$$p(x \mid \lambda) = \sum_{y=0}^{x} \left[\left({(\lambda^{y} e^{-\lambda})}/{y!} \right) f^{y}(x) \right]$$

Here $f^{y}(x)$, is the y-fold convolution of $\{f_i\}$. Feeney and Sherbrooke also present a recursive procedure for calculating $p(x \mid \lambda)$ for the shuttering Poisson distribution (compound Poisson distribution where order sizes are geometrically distributed). See appendix VII. The expected number of backlogs is:

Equation 6

$$E(B_0) = \sum_{x=s+1}^{\infty} p(x \mid \lambda_0 L_0)$$

Here, L_0 is the supply time from the filler.

The METRIC method uses equation 5 and the average lead time calculated from equation 3 to calculate the expected amount of backlogs at the spoke (B_j). Graves [23] suggests an alternative approach for the simple Poisson situation and shows that the results from this approach are better. However, this approach was initially used and the results were highly disappointing (see section 4.3). Therefore, the METRIC approach is also used to determine the expected number of spoke backlogs.

Equation 7

$$E(B_j) = \sum_{x=s_j+1}^{\infty} p(x \mid \lambda_j L_j)$$

so the total number of system backlogs (B_S) becomes:

$$B_S = \sum_{j=1}^{J} B_j \text{, and } E(B_S) = \sum_{j=1}^{J} E(B_j)$$

Until now, we have not addressed how we will determine L_0. Exact determination of L_0 is very difficult. To simplify the situation, we assume that throughput depends on customer demand only, and furthermore, that demand is not influenced by backlogs.

As was the case for the replenishment lead time, the expected supply lead time consists of two parts. The first part is the nominal ordering time T_0. This is the time that it takes after an order has been placed at the filler until that item is actually supplied to the hub, given that the item is available at the filler. If the item is not available, it is backordered at the filler.

Let I_D bet the total number of containers that is physically at the distributor or in transit to the distributor. In other words:

$$I_D = \sum_{j=0}^{J}\left(I_j + Q_j\right)$$

where Q_j is the number of containers in transit to the hub (j=0) or in transit from the hub to a spoke (j=1..J). Let I_K be the total number of containers that is physically at the customer. (Remember that the status 'at the customer' was defined as the part of the supply chain between spoke dispatch and filler return.) Finally let O_F be the net filler stock (physical filler stock minus any backlogs (B_F)). In other words:

$$O_F = I_F - B_F$$

Now, because we assume a closed loop system, using a fixed number of Safe-tainers (M), we know that the physical stock at the filler is equal to that part of the Safe-tainer pool that is neither at the distributor, nor at the customer.

Equation 8

$$I_F = M - I_D - I_K,$$

Let K be the number of Safe-tainers that customers require. That is $K = I_K + B_S$. Furthermore, we know that the total economic inventory position at the distributor (S) is equal to the physical stock at the distributor (including transit stock) plus backlogs at the filler, minus customer backlogs:

$$I_D = S - B_F + B_S,$$

where $S = \sum_{j=0}^{J} s_j$. Now we know:

Equation 9

$$O_F = M - S - K.$$

Since M and S are both constants, O_F can easily be determined from the probability distribution of K. The average filler backlog becomes:

$$E(B_F) = \sum_{x=M-S+1}^{\infty} x\Pr(K = x),$$

and the average waiting time becomes:

$$E(L_0) = {E(B_F)}/{\delta_0} + T_0 .$$

Optimization

We will use the procedure that was proposed by Sherbrooke. The procedure is very straight forward and therefore easy to understand. Furthermore, it can be solved using a non mathematical package such as Excel in reasonable time. Time is important because we want to be able to generate stock keeping advise based on most recent data. The result of the procedure is a table that shows the optimal allocation of stock given a total number of containers that are available to the distributor.

Sherbrooke starts with setting all stock levels to zero and allocates units of stock to sites one by one such that the decrease in system backlog is maximal for every allocation. It is clear that this procedure is only optimal when system backlogs as a function of stock levels is convex. Convexity means here that for any stock level that is increased, the marginal decrease of system backlogs must always be equal or less than the decrease of system backlogs for any previous increase of that same stock level. Convexity is guaranteed for increases of the stock levels of the spokes, but not for increases of the stock level of the hub. Using the proposed procedure may lead to situations where the hub stock level is not increased because the marginal decrease in system backlogs is too small, but if the stock level was increased by two, the decrease in backlogs would have been enough to justify the increase. Sherbrooke proposes to calculate marginal decrease of system backlogs for more than unit increases of stock levels. However, this takes substantial more calculation time and it still does not guarantee that non-convexity is always detected.

Now we will briefly describe the procedure. Let Δ_j be the marginal decrease in system backlogs:

$\Delta_j(s_j) = B_j(s_j) - B_j(s_j + 1)$ for j = 1..J, and

$\Delta_0(s_0) = B_S(s_0) - B_S(s_0 - 1)$

Step 1: set all stock levels to 0

Step 2: calculate all backlogs $B_j(s_j)$, and $B_S(s_0)$

Step 4: calculate $B_j(s_j + 1)$ and Δ_j for all j, and $B_S(s_0 + 1)$ and Δ_0

Step 5: increase s_j for one j such that $\Delta_j = \max(\Delta_j, j = 0..J)$

Step 6: repeat (go to step 2) until maximum stock level is reached

4.3 Simulation Study

The model described in the foregoing section is not exact. Therefore we need to verify the model. The hub & spoke setup of the network for Safe-tainers was only introduced recently and therefore no information about backlogs is available. Since no validation data is available from practice an alternative method is used to get an estimate of the accuracy of the model. A simulation study was done to get a sense of the accuracy of the model.

The simulation model is described and the results are given in appendix VIII. Backlogs from the simulation were compared to the backlog estimates from the model. 5 scenarios were evaluated. The scenarios represent five different products that are sold in the Safe-tainer.

The simulation study revealed that the initial model that was used was not accurate at all. Differences in backlogs were in the range of 60% to 200%. were found. The METRIC approach appeared to have much better performance. Differences in backlogs for this approach range from 1% to 10%. The large differences are probably caused by the fact that the steady state distribution of outstanding orders at the spokes do not follow the negative binomial distribution that was proposed by Graves for the simple Poisson case. We lack time to find the right expression for the variance of outstanding orders at the spoke so for now, we revert to the METRIC approach.

4.4 Implementation & Results

Implementation

The model was implemented in Microsoft Excel. The heuristic described in the previous section was implemented using Visual Basic. The following information was retrieved from WebInfo (Safechem database).

Information about the number of Safe-tainers required by customers

There is no historical information about system backlog. Therefore it is not possible to determine true customer requirements. However, Univar always tries to avoid backorders ant therefore we assume that the number of containers that is physically at the customer is a good approximation of customer requirements. The distribution that best fits the number of containers in use is the lognormal distribution (see appendix IX). A three month average of the logarithm of daily use, and the variance of the logarithm of daily use is calculated and used as the input for the distribution of K.

The aggregated customer order arrival rate

Only the aggregated customer order arrival rate (λ_0) is needed for the model. For the spokes, only throughputs are needed. The arrival rate is an 3 month average of weekly arrivals (see appendix IX).

Throughputs

Throughputs are also 3 month averages of weekly throughputs (number of Safe-tainers sold).

The following information cannot be calculated from directly from historical data:

Pool size

For each product, the size of the Safe-tainer pool is required as input to the model. One difficulty here is that the assumption that each distributor has its own pool size, is not true in reality. Furthermore, Safechem says not have a specific policy concerning the allocation of Safe-tainers. Finally, Safechem does not seem very willing to share information about the size of the Safe-tainer pool. Our best estimate of the size of the pool is therefore based on the visible quantity in the network. Visible Safe-tainers are those Safe-tainers the are either at Univar or at Univar customers The information about these Safe-tainers can be drawn from WebInfo. See appendix XIII.5 for the exact procedure that was used to estimate the pool size.

Nominal lead times

There is an agreed supply lead time of one week. Often however, the supply lead time is shorter that one week. Furthermore, the supply lead time varies because collections do not take place every day. There is no historical information about average lead times. We will use the agreed lead time of one week as our estimate.

Results

The main result of the model is a schedule that gives an estimate of the average system backlog that can be expected and a good allocation of stock. Table 6 shows part of the results for Neu-Tri based on data from the last 14 weeks of 2003. For the full schedules see appendix X.

Table 6: Model results for Neu-Tri

Stock	EBO	HUB	CA	CV	EX	GL	LO	MD	WD	WL
80	5.26	33	1	16	5	0	10	0	9	6
81	5.05	33	1	17	5	0	10	0	9	6
82	4.86	33	1	17	5	0	10	0	10	6
83	4.67	33	1	17	5	0	10	0	10	7
84	4.48	33	2	17	5	0	10	0	10	7
85	4.30	33	2	17	5	0	11	0	10	7
86	4.12	33	2	18	5	0	11	0	10	7
87	3.97	34	2	18	5	0	11	0	10	7
88	3.84	35	2	18	5	0	11	0	10	7
89	3.69	35	2	18	5	0	11	0	10	8
90	3.55	35	2	18	5	0	11	0	11	8

The first column of table 6 gives the total amount of stock in the network for Neu-Tri. The second column gives the average backlog (EBO) as a result of the allocation of stock that follows in the subsequent columns of the schedule. For example, if there are 85 fresh full Neu-Tri Safe-tainers available at Univar, then the expected system backlog is 4.30 if Safe-tainers are allocated to the sites as is specified in the schedule.

Now we know the expected backlogs but the question is how these should be interpreted. Imagine a simple world in which Safe-tainers are delivered to customers on time or are late by exactly one week (orders are unit size). In this world, a fraction p of the orders is late. Another way of saying this is that an order is p weeks late on average. If every year D Safe-tainers are delivered to customers, all orders together would be $p \cdot D$ weeks late. So we have $p \cdot M$ weeks lateness per year. This means that the number of orders that is late at any time (the backlog) is on average $EBO = \frac{p \cdot D}{52}$. Now suppose that we deliver orders that would be late on time against an extra cost of £20. The total annual costs would be £20 $p \cdot D$ or $£20 \cdot 52 \cdot EBO$. In general, if C is the cost per average expected backorder, annual costs are $52 \cdot C \cdot EBO$. If the costs per Safe-tainer per week (would be) late are £10, the total annual cost that is incurred by Univar is £520 per average backorder.

We propose the following procedure to determine the cost per average expected backorder:

1) Every time special effort[15] is required to deliver a Safe-tainer to a customer, make an estimate of all extra costs incurred.
2) Tally up these costs over a long period of time. Pool size, lead times, the customer demand process, and customer use distribution must not change during this period.
3) Extrapolate the total costs to a period of a year. (Multiply by 52/T where T is the length of the period in weeks.)
4) Determine average distributor stock in the selected period.
5) Find the average expected backorder in the schedule for the average distributor stock
6) Divide the extrapolated costs from step 3 by the average expected backorder

The other objective of model is to determine the optimal pool size for Safe-tainers. To illustrate how the optimal size of the Safe-tainer pool can be determined we consider the product Neu-Tri. We have taken data from the last 14 weeks of 2003 as input for the model. The optimal allocation is chosen. Suppose now that the Univar incurs a costs of £10 per expected Safe-tainer backorder per week. Furthermore suppose the annual fixed costs per Safe-tainer are £100. Figure 19 shows the annual fixed Safe-tainer costs (pool costs, blue line) and the costs incurred by Univar for shortages (network costs, red line) for different pool sizes. Total supply chain costs (green line) are minimal where the marginal network costs equal the marginal pool costs.

Figure 19: Pool costs - network costs trade-off

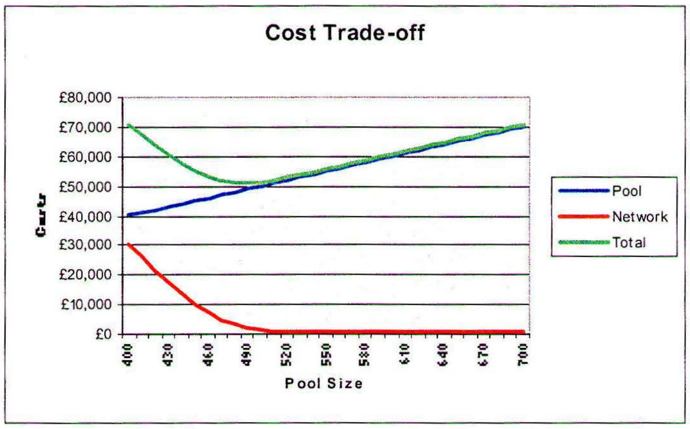
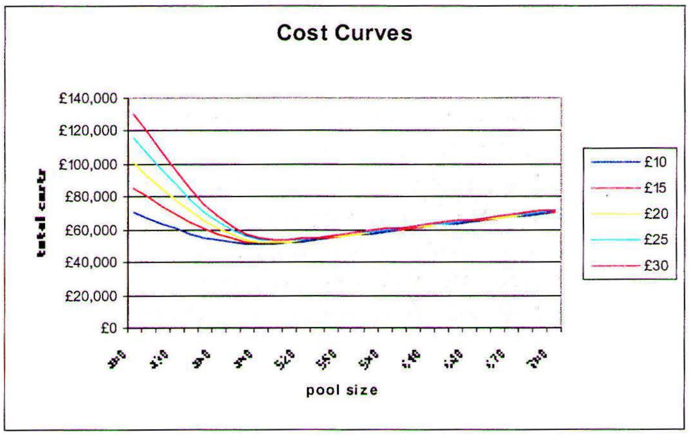


Figure 20 shows the total cost curves (pool costs + network costs) for different backorder costs (of £10, £15, £20, £25, and £30 per expected average backorder per week respectively). We can see that the exact backorder costs have no strong influence on the optimal pool size.

[15] Special efforts are all actions that deviate from the standard procedure. These include extra trips to the filler, special customer deliveries, but also efforts to 'rush' an order (e.g. bypass the standard replenishment procedure to put a Safe-tainer on a replenishment load the same day as the customer order was placed).

Figure 20: Pool size cost curves



5 Implementation

All mankind is divided into three classes: those that are immovable, those that are moveable, and those that move.

Benjamin Franklin

Implementation started already after the orientation phase. This chapter discusses the progress and what remains to be done. The pilot project on hub and spoke is described in section 5.1. An important issue is the tracking requirement for Safe-tainers that is discussed in section 5.2. The use of the model for stock control is discussed in section 5.3. Finally, some issues with the determination of the optimal pool size are considered in section 5.4.

5.1 The Pilot

Already after the orientation phase of this project it was decided by Univar that the transition to the hub and spoke network had to be implemented as soon as possible. We took a growing pilot project approach for the implementation. The pilot project started at a very small scale and will be rolled out to Univar as a whole in a few steps. This approach has several advantages:

- Initial problems are limited to the scope of the pilot. They can get all attention and are therefore solved quickly.
- Operational procedures can be developed and improved gradually.
- Problems with inventories are detected quickly. The initial group of customers get assigned a relatively large amount of stock. The relative amount of stock is reduced gradually by including more customers.
- People in operations get the time to get used to Safe-tainers which need to be treated differently from other products. (They need to be tracked.).

Disadvantage of this approach is:

- Part of the Safe-tainer volume is taken out of the current operations. This results in lower utilization of the vehicles for the remaining products

The pilot project is coordinated by a workgroup consisting of the following people:

Phil Hockaday	North East Operations Manager
David Ball	Coventry Operations Manager
Paul McGuinness	Stock Controller
Gary Smith	Grimsby Operations Manager
Paul Kirk	Technical Support Safe-tainers
Michiel Jansen	Safe-tainer Supply Chain Project

The first phase of the pilot project involves serving a selected group of customers from one of the spokes. An important criterion is that overall demand at the spoke should be relatively stable. Erratic demand would be more difficult to manage. The first objective is to deal with any operational problems at the sites so the pilot is kept as simple as possible. The following setup is chosen:

- Only one spoke: Coventry;
- Only one type of product: Neu-Tri;
- 10 customers that:
  - have a reasonably stable demand (that is, fixed size, at least every month)
  - do not return waste

In the second phase of the project, the scope will be broadened to all customers the selected site. In the third phase, other spokes are included. During the fourth phase of the project, the scope of the project will be broadened to include other products and waste Safe-tainers.

The last phase involves the transfer of the hub activities for Safe-tainers from Grimsby to South Kirkby. Initially, administration is done by someone at Grimsby because there is not enough personnel capacity at South Kirkby. The last phase may take place parallel to the other phases if it turns out to be possible and beneficial at an earlier stage.

Unfortunately, at some sites there appears to be a high resistance towards unconventional procedures. Coventry is a good example. The local manager in charge was fully involved in the early stages of the pilot project. Explicit procedures were developed and only one product and a small set of customers were included. Problems at this site include wrong product deliveries, late deliveries, deliveries to the wrong customers, and even complete cancellation of orders without cause. Other sites (e.g. Widnes) seem to have no problems at all. Typically, during the meetings, those managers of sites where problems occur, already showed much resistance against having to handle Safe-tainers, whereas the managers that took a positive approach have no problems. It seems therefore that staff need an incentive to avoid problems. It is thus advisable to include delivery performance in the KPI calculations for the sites. Another option is to give responsibility to someone who shows less resistance to change.

5.2 Tracking

Safe-tainers are the only containers at Univar that need to be tracked on an individual basis. Previously, no information system was in use at Univar that can provide this functionality. One person was keeping an Microsoft Excel based administration of all incoming and outgoing Safe-tainers. This was possible because only one site dealt with Safe-tainers and all administration could be done centrally. In the hub and spoke network, movements need to be logged by different people at different sites. The Excel administration will not suffice anymore.

Coincidently, Univar is working on implementing an Electronic Proof of Delivery System. From conversations with the coordinator of this project, it became clear that this system would be perfectly suited for tracking Safe-tainers. However, this system will not be implemented until the end of the first half of 2004. An alternative is needed till then.

Thus there is a need for a temporary tracking system. Because of the temporary nature, the system must be inexpensive and easy to use. Three alternatives were considered:

- Using Inform, the existing Univar web based information system;
- Create an Microsoft Access database to be shared over the Univar LAN;
- Using Safechem WebInfo. A web based information system managed by Safechem for tracking Safe-tainers.

A workgroup was formed that determined the requirements for the information system. Next the three options were assessed based on the requirements. It immediately became clear that the

Univar Inform system is not suitable. Advantages and disadvantages the other two options were considered and the second option was selected. The database was developed but not implemented. Even after pressure of senior management, the IT department refused to make the database available over the network on the ground that it could not be supported, and that it would generate to much network traffic.

The third option was considered again. Although not optimal, a combination of Safechem WebInfo (to track movement between Univar, Customers, and the filler) and Excel (to track internal Univar movements) was selected. One major disadvantage of this alternative is that it only logs data but does not generate useful information such as customer utilization information. A second disadvantage is that separate administrations are used for external tracking (movements between the filler, Univar, and the customers), and internal tracking (movements between hub and spokes).

5.3 Stock Control

The model presented in chapter 4 provides decision support on the allocation of stock in the Univar network. The advice is based on the total number of unused Safe-tainer that Univar has on stock. There are no fixed stock levels. This approach requires central stock control. One person must determine the right site (hub or one of the spokes) for each Safe-tainer delivered by the supplier. Because there are no fixed stock levels, Safe-tainers can be no DRP item. The DRP system works with fixed target stock at the spokes.

The schedule that is generated by the model is based on historical data. More valuable (future) information can be obtained from the customer. A customer may decide that the solvent in the degreasing machine must be changed. Such a change is often planned long time in advance. Univar should try to build a relationship with the customer will lead to immediate sharing of this kind of information. If extra (known) demand occurs at a spoke, extra Safe-tainers can be sent to that spoke. The Safe-tainers that cover the extra demand should be deducted from total available stock to get the advice for the rest of the stock. It would be best to also exclude this extra demand from the historical data used for estimation of the model parameters. However, in practise this is difficult to maintain.

The model is implemented as an Excel sheet. An Access database is used to manipulate data from the Safechem database to get the model parameters. These two tools will be combined so that the model can be run periodically by a Univar employee to generate new schedules based on new information. Generation of the schedules can best be done on a fast computer or overnight.

5.4 Pool Size

We have shown in section 4.4 that the network costs of shortages do not need to be known exactly. A good way to make a reasonable estimate of the costs of shortages is to keep track of 'extra' costs. The average expected backlog can be read from the model (use average total stock as input). See also section 4.4. More important is it to get a good figure for the fixed Safe-tainer costs per year.

A major assumption in the model is that there is a fixed pool size. However, the Safe-tainer pool is shared with another distributor. Temporary shortages in the Univar network can therefore be offset by surpluses at the other distributor. Safechem could not give insight in the level of overlap of the Safe-tainer pools of both distributors. In order to get most value from the model more insight is needed in this aspect.

The model provides support in discussions between Safechem and Univar about the size of the Safe-tainer pool. It can also be used to study the effect of other supply chain improvements:

- Reducing lead times
- Increasing customer utilization
- Reducing customer order sizes

6 Conclusion & Recommendations

Work is the greatest thing in the world, so save some for tomorrow.

Author unknown

This chapter reflects on the project and discusses to what extend the assignment has been fulfilled. It also presents recommendations for the follow-up of the project.

6.1 Conclusion

The assignment that was stated in section 2.6 differentiated between a short term objective and a long term objective. The short term objective was to investigate two proposals by Univar to reduce supply chain costs. The results of analysis of these proposals were presented in section 3.2. The first proposal was to bring Safe-tainer distribution activities inline with the hub & spoke network. This proposal was found to be profitable, and the best suited hub was found to be South Kirkby. The second proposal was to fill Safe-tainers in-house. Although positive returns can be expected from filling in-house, it was shown in section 3.2 that these returns are to small to justify the investment. Only if the overcapacity of a filling station for Safe-tainers can be utilized, this option may become profitable.

The long term objective was to find solutions other than those mentioned in the previous paragraph to the main issue in this research. This issue was stated in section 1.4 and is repeated here:

The Safe-tainer business is not profitable enough to Univar because the logistics costs are too high.

Initial research in the orientation phase showed that transport is the main cost driver (see section 2.5). The costs are caused by underutilized vehicles. Various reasons for this underutilization are summarized in figure 10. Part of the problem is that the distribution channel used for Safe-tainers was not the best suited one. The best suited distribution channel was determined in section 3.2 (Hub & Spoke).

However, this is only part of the problem. Just as important is that Safe-tainer batch sizes are smaller than is economically desirable. This was shown in section 3.2 (Optimal batch sizes). It was argued in 2.3 and 3.3 that the major limitation to setting economic batch sizes is the availability of Safe-tainers. The Hub & Spoke option mentioned in the previous paragraph is likely to lead to even lower availability. Several options aimed at increasing availability were considered in section 3.2. Increasing customer utilization was mentioned as an important option to increase availability without requiring new Safe-tainer issues. Optimization of the distribution among sites of available Safe-tainers at the distributor aims at using available Safe-tainers most efficiently.

After opportunities like those mentioned in the previous paragraph have been fully exploited, the only control variable in setting Safe-tainer availability is the size of the Safe-tainer pool. However, increasing the size of the Safe-tainer pool comes with a cost. An optimum can be found between the fixed cost of the Safe-tainer pool and the logistic costs. For this purpose the model was developed.

The model is a decision support tool for setting the optimal size of the Safe-tainer pool. In order for the model to be used to compare costs, annual fixed costs per Safe-tainer, and the annual increase of logistics costs per average backlog need to be determined. A method for determining the latter cost was given in section 4.4. The model also gives the optimal distribution of available Safe-tainers among sites. Furthermore, the model can also be used to explore relationships between lead times, customer utilization, and customer demand patterns, and the logistic costs.

6.2 Recommendations

Roll-out hub & spoke network

The pilot project for the transition to hub and spoke is well on its way. There are some sites that seem to have problems with the unconventional procedures (e.g. Coventry) but this seems to be mostly unwillingness of the staff involved. It is therefore highly advisable to take delivery performance for Safe-tainers into account when calculating key performance indicators. Change of responsibilities is another option to take away the barrier to change.

Although problems exist, Univar should not accept any further delays in the roll-out of hub & spoke for Safe-tainers. Grimsby incurs costs a smaller part of the Safe-tainers is delivered directly from Grimsby resulting in even lower utilization of vehicles.

In cooperation with Safechem, determine the annual fixed costs per Safe-tainer

The model gives the relationship between pool size and average expected backlogs. To make cost trade-offs, the costs of increasing the pool need to be clear. Therefore, the fixed cost per Safe-tainer per year is needed (only variable costs of the pool). These should be obtained from Safechem.

Keep track of logistic costs caused by network shortages and relate them to the average expected backlog

Besides the fixed cost of a Safe-tainer, the logistics costs of shortages need to be determined. The procedure for determining the annual cost per average expected backlog was described in section 4.4 (Results).

In cooperation with Safechem, agree on a size of the Univar Safe-tainer pool per product and agree on an explicit policy on how the pools of Univar and Caldic are shared

Once the costs that are mentioned above have been determined or estimated, the model can be used to determine the size of the Safe-tainer pool for each product. However, one assumption was that the Univar Safe-tainer pool is fixed. In reality, the pool is shared with Caldic. A clear and explicit agreement is needed to be certain of the Safe-tainer availability that the model predicts.

Study the effect of flexibility of a shared pool on availability at Univar

After an explicit policy is formulated on how Safe-tainers in the pool are shared by Caldic and Univar, it is advisable to investigate the effect on the availability and shortages.

Determine waste return batch sizes

Economic return quantities can be determined using the economic order quantity approach presented in section 3.2. A quantity can be determined per site using figure 14.

Central stock control and no DRP

Safe-tainers have two very typical properties: they are reusable and they are expensive. As a consequence, there is a fixed Safe-tainer pool and the decision to increase the size of this pool is one at the tactical level. The availability of Safe-tainers at the distributor is therefore variable. The model shows that for this type of containers, also variable stock levels are required.

At Univar, a DRP system is used that generates replenishment orders in order to keep stock at the spokes at a preset fixed level. In the case of Safe-tainers, this would imply that only the stock level at the hub varies with the availability of Safe-tainers. This would result in stock situation that is suboptimal.

All Safe-tainer stock should be controlled centrally and the stock at the spokes should not be controlled by the DRP system. Instead, the stock controller for Safe-tainers should use the model in combination with information about future demand and supply to determine the right stock levels of Safe-tainers.

In cooperation with Safechem, study an alternative Safe-tainer concept whereby the outer container and inner drum follow separate cycles

An alternative Safe-tainer concept was briefly discussed in section 3.2 and appendix XII. This preliminary concept may lead to substantial cost savings but it reinterprets the Safe-tainer concept. If this option is developed further, in should be done in close cooperation with Safechem. Preferably, Safechem should be the leading party in this.

Charge customers a deposit for the use of a Safe-tainer

In sections 2.4 and 3.2 (Increasing customer utilization) it is argued that charging a deposit is likely to lead to higher customer utilization. This is a 'free' increase of Safe-tainer utilization. A rent that represents the value of a Safe-tainer throughout the supply chain is theoretically better than a deposit because it allows each individual party to determine the optimal quantity. However, it was decided by Univar that a rent is impracticable.

Estimate the fixed costs of a customer delivery and limit order sizes to the economic order quantity

Reduction of order sizes leads to increased availability of Safe-tainers. See section 3.2 (Optimal batch sizes). However, too small order sizes may lead to unnecessary high delivery costs. Economic order sizes should be determined for each customer. If there are no other limitations to delivery frequencies these should be used.

Look into the possibilities of filling other containers at a filling station for chlorinated solvents

Building a filling station for Safe-tainers is likely to become economically viable if the extra capacity can be utilized. See section 3.2 (Filling of Safe-tainers).

Reduce replenishment times and study the possibility of cross-docking

This general recommendation is a major opportunity to reduce inventories and handling. See section 3.2 (Acceleration).

UNIVAR

Table of Concepts

Concept	Description
Availability	Number of unused Safe-tainers at the distributor
Backlog	An order that could not be satisfied from stock immediately but is put into a queue and is to be delivered as soon as a Safe-tainer becomes available
Backlog	Number of backlogs
Contribution margin	Revenues less all variable costs
Cross-docking	Cross-docking is a concept where a site does not store products but has a consolidation and break-bulk function. Goods come in from the hubs, are unloaded and reloaded again in a very short time span.
Cycle	A steps in a supply chain of a reusable container from dispatch at the initial step until the container is back at the initial step and ready for the next dispatch.
Delivery lead time	Time from placement of an order with Univar by a customer until the product is delivered to the customer
Distributor	Party that buys Safe-tainers from Safechem, resells them to a customer, and takes care of all transport, storage, and handling in between.
DRP	Distribution Requirements Planning - Part of the company ERP system that generates replenishment advice for the hub based on fixed target stock levels at the spokes
Dwell time	Time that a Safe-tainer remains at a specific step in the supply chain. (E.g. customer dwell time = time that a Safe-tainer is at the customer.)
Economic inventory position	Physical on-hand stock plus any stock that is due in less any customer backlogs
Expected backlogs	Number of backlogs that are expected if standard procedures are followed (that is, no extra effort is made to avoid backlogs)
Filler	Party that performs maintenance and quality checks, and refills the Safe-tainer
Hub	A site where the majority of stock for a certain product is kept
Nominal lead time	Lead time if there is no shortage where the order is placed (and thus no extra waiting time)
Pool	Univar pool: all Safe-tainers at Univar, at Univar customers, or at the filler for Univar
Replenishment lead time	Time from placement of an order with the hub until the product is available at the spoke
Shortage	A shortage arises if an order at any place in the supply chain where Safe-tainers are kept on stock, cannot be fulfilled directly from stock.
Site	A physical warehouse location of the distributor (also see figure 3)
Spoke	A site that delivers products to all customers in its region (also see figure 3)
Stocking time	Average time that a product is kept on stock

Concept	Description
Supply lead time	Time from placement of an order with Safechem until the product is available at the hub
System backlogs	Backlogs at all spokes
System backlog	Sum of backlogs at the spokes
Utilization (customer)	The number of Safe-tainers that minimally needs to be in use at the customer divided by the total number of Safe-tainers at the customer
Utilization (vehicle)	Percentage of the total vehicle capacity (weight or space, depending on which one is the limiting factor) that is used

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