School of Business, Economics and Law
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# Supply Chain Mapping of Dangerous Goods: Volvo Cars customer Service

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## Abstract

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Title: "Supply Chain Mapping Dangerous Goods: Volvo Cars Customer Service"

**Background**
This paper is a study of the dangerous goods supply chain at Volvo Cars Customer Service. During the past few years, Volvo Cars Customer Service has witnessed a drastic increase in the number of spare parts classified as dangerous in the DC's. Because these goods are considered "dangerous" they are subject to extensive rules and regulations for handling which cause an increase in handling costs. This paper examines the activities and costs associated with handling dangerous goods from the supplier through the central distribution center and on to the local distribution centers spread throughout the world. An effort is made to then use the information obtained to aid in making better informed decisions concerning economic order quantities.

**Purpose**
The purpose of this paper is to provide Volvo Cars Customer Service with a better understanding of their dangerous goods supply chain as well as the activities and costs involved. Additionally, five different product flows to five different distribution centers have been mapped in an attempt to graphically display what is encompassed in the supply chain.

**Method**
Theories, empirical data, and the authors' previous experience are used to examine the situation as it is today. This thesis is based on inductive research and is conducted as a case study through the collection of information regarding activity based costing, the business process at the company, and ending with a final analysis as well as conclusions and recommendations.

**Conclusion**
We noticed that the knowledge of the supply chain was incomplete. This was mainly in regards to the activities behind shipping orders. Due to the amount of extra time and effort that must be placed on handling dangerous goods we noticed that a new order cost should be derived. In this study a new order cost was estimated, which showed to be much larger than the present cost used at the company. If a higher order cost is implemented this will increase order quantities as calculated through the Wilson Formula, thus spreading out the cost of handling dangerous goods over a larger amount of products at one time.

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# 1. Introduction

*The first chapter of this thesis is to provide the reader with general information concerning the company involved, problem background, as well as the problems being addressed. Furthermore, this section will enlighten the reader as to thesis delimitations and the form of the paper.*

## 1.1 Background

Inventory creates costs for each company, but it is needed in order to achieve proper service levels, changes in demand, false forecasts, and unreliable lead times. Inventory is everything that is tied up in the supply chain, not just at warehouses or distribution centers. However, supplies may be piled up in order to save time and money on economies of scale or to lower transportation costs. All decisions concerning inventory must therefore be given great attention, as the capital tied up in inventory expenditures may prove beneficial elsewhere in the company. Meeting all of these objectives requires great skill and it is therefore not strange that organizations spend so much time on questions concerning inventory management. Proper inventory management is the key to satisfying customers while simultaneously holding down costs so that company finances can be put to good use. If inventory is not managed correctly excessive products may have to be written off, leading to higher product costs as well as lower profit margins.

More and more companies are attempting to undercut their rivals by providing excellent after-market service, which in turn leads to higher costs for the company; with the upside being greater customer loyalty and longer term profits due to extended customer relations. A well established and well functioning after-sales supply chain creates just this. "Services such as rapid onsite restoration, returns processing, spare parts fulfillment and equipment refurbishment"[1] all fall under the ideas needed in successful after-market sales. However, if companies want to excel in this area, operation evaluation must be done to ensure that optimal levels of support are being achieved, "while at the same time gaining the benefits of business growth, customer loyalty and premium pricing."[2]

Many of today's businesses have inefficient supply networks or too much inventory locked up at warehouse sites throughout the distribution system. The importance of inventory turns and effective distribution systems are being analyzed to a greater extent by upper level management. Some of the negative aspects that can be seen in inventory handling, which harmfully affect profit margins are "poor visibility into inventory, long cycle times, inconsistent customer service, inventory obsolescence and the significant costs of brick-and-mortar investments."[3] Additionally, in order to hold expected customer service levels, inventory must be maintained at ever large numbers over an increasingly larger distribution network which spans the entire world. Products and parts lists are growing, making the process of controlling the inventory even more difficult. All of this at a time when financial departments are trying to cut costs in order to make business more profitable.

The objectives behind logistics are to minimize total costs while at the same time meeting customer service goals. However, in order to achieve these objectives management must

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[1] http://www.ups-scs.com/solutions/white_papers/wp_cornerstone_postsales.pdf , p. 4
[2] *ibid.*, p. 5
[3] *ibid.*, p. 4

know the costs behind each activity. According to Lambert, et al. "most segment profitability reports are based on average cost allocations rather than on the direct assignment of costs at the time a transaction occurs."[4]

For managers it is important to understand the costs associated not only with one's own department but all of the costs along the entire supply chain. Understanding the costs of a process help in:

- identifying profitable and unprofitable products and activities;
- judging an economic break-even point;
- analyzing business patterns and different options for a company to take
- and lastly it helps in locating opportunities for cost enhancement and tactical decision-making.[5]

One such method which many companies are employing today in cost and process analysis is Activity-Based Costing (ABC). ABC helps management in evaluating the efficiency and cost-effectiveness of program activities through the use of metrics which can be calculated with this method. "ABC systems rank activities by the degree to which they add value to the organization or its outputs",[6] thereby helping "managers identify what activities are really value-added-those that will best accomplish a mission, deliver a service, or meet customer demand-thus improving decision-making through better information, and helping to eliminate waste by encouraging employees to look at all costs."[7] Thus, a clear picture of the processes, products, or organization is needed in order to complete this analysis.

As the world of business becomes more globalized companies are doing more and more business across international boundaries. This has proven to be a huge benefit to people around the world as well as the companies involved. However, longer lead times, greater customer demand variation, as well as various rules and regulations are forcing these players to re-evaluate their methods of doing business.

The transport of dangerous goods is one area of business where companies have had to gain a better understanding of their business processes. According to The Swedish Rescue Services Agency dangerous goods are defined as "substances and articles that have dangerous properties that can cause injury to people, and damage to the environment, property and other goods, unless they are correctly handled during transport."[8]

The rules constituting the transportation of these items within the EU are not the same as when transporting to Asia or the Americas. This idea was brought to our attention by Volvo Car Corporation Customer Service (VCCS) and through this thesis we hope to help the company in researching the costs of distributing dangerous goods within VCCS' supply chain.

Almost all spare parts are shipped directly from the Central Distribution Center (CDC) located in Gothenburg, Sweden to the various National, Support and Local Distribution Centers (NDC, SDC, and LDC respectively) in countries where VCCS does business. These

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[4] Lambert et al. (1998), p. 473
[5] http://www.defenselink.mil/comptroller/icenter/learn/abconcept.htm
[6] *ibid*
[7] *ibid*
[8] http://www.srv.se/templates/SRSA_Page____20935.aspx

shipments are organized and arranged by various groups working within the CDC with the aim of achieving hassle-free movement of products around the world.

The company works with an enormous amount of spare parts which may be broken down into several different categories. The items that will be discussed in this work are considered dangerous goods and thus have different rules and ways in which they must be treated. Due to the fact that these articles cannot be transported in the same way as other spare parts different costs arise, which can be a detriment financially to VCCS.

Lead times between the CDC and the various distribution centers (DC) range from days to weeks depending on distance traveled and type of transport mode used, and therefore it is of utmost importance to gauge proper inventory levels. Not only do VCCS inventory planners need to control inventory levels, but also the safety stocks of the various DC's in order to avoid costly stock outs. Tied up capital in the supply chain is unwanted and due to the fact that VCCS is not certain as to the nature of the costs associated with the dangerous goods distribution channel the company asked us to write this thesis in order to further study this problem.

## 1.2 Problem Definition

Although advanced computer systems are used at VCCS, in addition to a wealth of human knowledge, the company still lacks some, although not all, information concerning costs of purchasing, warehousing, shipping and handling of its spare parts. One such problem that has arisen is the cost of handling and transporting dangerous goods. These products must be treated in a different way than other spare parts, and are subject to additional types of rules and regulations which do not affect items considered as non-dangerous goods. Additionally, rules governing the transport and handling of these goods may vary from country to country. This causes an array of extra costs both in time and money which is not always apparent to the casual observer or even a trained inventory manager. Therefore, our aim is to provide all pertinent information which will enable VCCS to understand:

- its cost situation for dangerous goods
- all of the activities involved in the delivery process of dangerous goods
- the resources used in the activities mentioned above
- the cost of using the resources and activities mentioned above
- the supply chain map for dangerous goods
- and how all of these factors affect optimal order quantities.

## 1.3 Purpose

VCCS, through the use of this paper, would like to map the supply chain of dangerous goods in order to provide accurate cost information upon which strategic decisions can be made concerning inventory levels, warehousing situations, and optimal order quantities. *The purpose of this thesis is to map the dangerous goods supply chain, as well as to highlight the costs associated with the handling and transportation of dangerous goods at VCCS in hopes of making the supply chain more effective.* Once these costs can be presented, suggestions will be made as to how VCCS should work to optimize its operations while at the same time decreasing the cost of handling and transporting its dangerous goods.

## 1.4 Perspective and relevance

VCCS is the sole sponsor of this paper and therefore focus will be entirely on VCCS' business practices. The study itself is being written in cooperation with VCCS in Gothenburg and supporting data from the various NDC's, SDC's, and LCD's within the VCCS business area. Empirical data will be collected using VCCS information; however the theories presented pertain to general business practices, which should make this paper applicable to other business units both within the Volvo Car Corporation, and even other companies outside the automobile industry which work within the areas of dangerous goods.

## 1.5 Delimitations

Presently there are over 30 different distribution centers comprised of Central, National, Support, and Local distribution centers for Volvo Car Corporation spare parts. The business units within the spare parts distribution network are strategically located around the world to provide optimal access to the local markets. Due to time restraints this study will narrow its focus to include only the CDC in Gothenburg (Sweden), the NDC's in Atlanta (USA), Turkey, and Nagoya (Japan), the SDC in Maastricht (Netherlands), and lastly, the LDC in Malmö (Sweden). Furthermore, information may be presented concerning the dangerous goods manufactures as these players may even prove to be important in dealing with the costs of handling such items.

Because this study is being done in cooperation with VCCS the entire focus of the paper will be presented from the side of VCCS. All empirical data will be obtained through contacts within the company, as well as its various business partners.

Items considered as "dangerous" comprise around 2,000 articles numbers. Again, due to time constraints and ease of handling information only five different products will be examined. Air bag modules, transmission oil, car batteries, and two different types of paint will be analyzed. Although we will narrow our focus to these products, we have been provided enormous amounts of product information, and therefore are able to provide a general characterization of order costs and optimal order quantities for a much larger population of dangerous goods. A large percentage of items characterized as dangerous goods follow the same pattern of supply chain, meaning that they are delivered to the CDC directly from the supplier, are stored, picked and packed at the CDC, transported to the DC's in different countries where they are stored locally before being shipped to the end user, and therefore it is hoped that the information obtained for these products will help in understanding a majority of the costs associated with all dangerous goods at VCCS.

These five product ranges were chosen due to the fact that they have had the highest turnover from the previous year until present. Unfortunately we were unable to find the exact same article numbers shipped to each DC, and therefore based our calculations on the products within each product class which had the highest forecasted sales for the last period. In choosing these items, we have attempted to analyze products which have different supply chains and that may face different regulations when being shipped internationally. However, we felt that it was of utmost importance to focus on items which are of interest to the company due to inventory turnover.

## 1.6 Disposition

*The following figure provides a graphical outline of the chapters which comprise this master's thesis.*

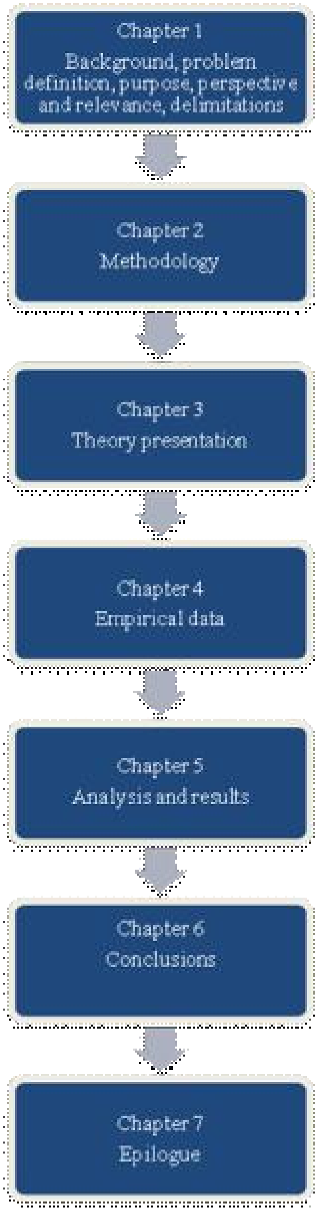


**Figure 1 Disposition**

# 2. Methodology

*In this part of the thesis we will describe how the data has been collected and handled. Moreover, we will discuss the research disposition and scientific approach. The main purpose of this chapter is to explain which and why specific methods have been used in researching this thesis.*

## 2.1 Previous Perceptions

The outline of the thesis is strongly affected by the previous perceptions of the writers. The experience of the writers has also determined the most appropriate methodological course of action. In all projects, the experience of the participants always influences the outcome or the result. In this case the background of the writers varies greatly.

One of the writers is from the US but has been living in Sweden for almost a decade. He has a bachelor's degree in anthropology and has, before his master studies, studied business administration in Sweden. The other writer is from Sweden and has a engineering degree in Industrial Administration and Economics, as well as having studied in Austria.

Both writers are in the Masters Program for Logistics and Transport Management at the Graduate Business School within the School of Business, Economics and Law at Göteborg University, and have acquired the needed basic knowledge for this assignment. The goal is to use all previous experience and perceptions in order to analyze the information obtained from the various sources in order to draw conclusions which will prove useful for the company being researched.

## 2.2 Choice of Scientific Research Approach

In order to achieve the targets that have been set, we have attempted to choose the most appropriate social research method. There are three main types of research methods; deduction, abduction and induction.[9]

The deductive approach is a process where different theories are tested. Here, different theories are assessed through the use of empirical date, where upon completion of the research a theory will have been established or generalized, which can then be applied to certain cases.[10] Basically, with this type of research one works from a general idea to a more specific one or a "top down" approach. "Deduction is used to test a hypothesis: if an implication of a hypothesis in a specific case is theoretically deduced, and the case is then produced experimentally, and the theoretically deduced fact matches the observable fact, then the hypothesis is verified."[11]

The idea behind the abductive approach is to propose new theories. Here, a new theory is applied to an existing one, and through empirical study and corroboration, pre-existing theories can be expanded upon. This is typically used when trying to research observations

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[9] Neuman (2000), p. 59
[10] Spens & Kovàcs, G (2006), p. 374-390
[11] Johansson (2004), p. 11

which are puzzling or cannot be explained through already established theories.[12] "Abductive reasoning is active in creative acts; for instance, in formulating a hypothesis."[13]

With inductive research one begins by observing the actual scenario and then analyzing what actually happens. Models and ideas are constructed, which aids in moving towards a more abstract concept in order to analyze the situation. This way of study is based on observations and basic ideas of the situation. As described earlier, a theory will hopefully evolve during the collection and analysis of data.[14]

Our thesis, which was originally planned by Volvo, is based on inductive research. We began by further specifying the thesis, establishing boundaries, and thereafter collecting information regarding activity based costing and inventory management practices, which is the closest theoretical area to our task. Later we collected data regarding the business process through interviews and observation, which we then analyzed with the help of the theories presented in order to draw conclusions and give recommendations.

### 2.3 Scientific Philosophy

Scientific philosophy is built around three parts. The first assists with information supporting the research. The second shows the connection between the existing theory and the empiric content of the researched data. Lastly, the third is the choice of method used to conduct the thesis research.[15]

In our philosophy of choice, the target chosen for the research is of a more complex nature, with several processes and actions interacting with one another. The first system analysis is conducted in order to map a realistic flow model of our scenario. Secondly, it is used to describe the interactions within the model as a base for future improvement of the system. The interactions identified are analyzed in the third section in hope of finding the cause-and-effect areas within the model.[16] The flows within VCCS' CDC are many, complex and often shifting. The system theory here is used to describe the dynamic processes which are changing and will more than likely continue to do so in the future.

Through the use of ABC/ABM and process mapping we will provide VCCS with cost information for a handful of dangerous goods. It is hoped that this information will then provide a framework in which management can further study the dangerous goods supply chain and make strategic decisions concerning safety stocks, optimal order quantities, and the future of these products and processes within the corporation.

Hence, through an ABC analysis we want to be able to underscore the costs, activities, and resources used in the supply chain for dangerous goods and then to present theoretical insights into Activity-based Management (ABM) with the hope that the company will gain a better understanding of their business processes and thereafter be able to manage the activities, costs, and resources tied up in the supply chain in a more effective manner. Additionally, the activities examined in this paper should have a profound effect on the costs used to calculate optimal order quantities (Wilson Formula) utilized at VCCS in its inventory management

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[12] Spens & Kovàcs (2006), pp. 374-390
[13] Johansson (2004), p. 11
[14] Neuman (2000), p. 60
[15] Newman et al. (1998), pp.13-15
[16] Arbnor et al. (1994) pp.135-136

strategies. A better understanding of these costs should aid in developing a new cost structure which can be used in calculating more economic order quantities.

## 2.4 Quantitative and Qualitative Research

There are two different ways of gathering of data, namely, quantitative and qualitative research. Quantitative data collection is the mathematical angle of approach. It uses statistical aids and places great focus on the variations that can occur and ruin the measurements. Qualitative data collection uses social factors and develops ways to find and plot processes as opposed to using numbers. Qualitative data collection is often strongly connected to an inductive research approach.[17]

Both qualitative and quantitative methods can be used in order to collect the data needed for this study. In this thesis, we wish to map an existing flow and the processes or activities that comprise the flow. Therefore, we have decided upon using the qualitative research method. It is hard to quantify the information needed and the flows that we intend to describe will be mapped out separately. The information collected for this thesis has been obtained mainly from interviews and observations at VCCS' CDC in Gothenburg.

## 2.5 Data Collection

Data can be divided into primary and secondary data. Primary data is information gathered by the researcher and secondary data is data collected from another source. The information used in this thesis is almost exclusively from primary data sources.

Primary data is defined as data that is collected by the researcher through methods such as questionnaires and interviews.[18] Primary data in our thesis was collected through recorded sessions or notes after interviews with key personnel within the supply chain as well as questionnaires emailed to those people in distant locations who we were unable to interview face to face. Observations in the different areas of the business process have been used as primary data in order to map and analyze the present situation.

An interview can either be structured or unstructured. A structured or *"standardized"* interview means that the interviewer asks a number of pre-written questions. The purpose of this is to maintain the same context for all interviews. This makes it possible to summarize all interviews in order to compare the results.[19] An unstructured interview is often used in order to help the person being interviewed to "open up" and subsequently allows for a more "open" conversation. Here, the interviewer only uses an interview guide with more general questions.[20]

The interviews conducted in this thesis are unstructured or semi-structured. There has been no need to compare the information from the different interviews; the people who have been interviewed have usually been in charge of a certain part of the flow in one or several supply chains. Important parts of the interviews have been to both identify the activities conducted in each part of the process, as well as to obtain information concerning the next person or activity in the flow. This has enabled us greatly in being able to follow the process flow, as

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[17] Neumann (2000), p. 181
[18] http://brent.tvu.ac.uk/dissguide/hm1u3/hm1u3text3.htm
[19] Bryman & Bell (2003), p. 135
[20] *ibid.*, p. 138

well as to understand it better. Through the interview process we have seen the importance of talking with the “right” people so that our information is correct.

A large part of several flows are located internationally, and we have therefore been unable to meet the people concerned. When it has been possible a phone conference has been conducted. In other scenarios a questionnaire has been sent out, with additional follow up to allow for more complete answers to our questions.

Our task has been to map existing flows, with the aim of gaining the best possible understanding of the current situation. Direct observations and field visits have been a very good complement to the conducted interviews. Observations have proven to be a useful supplement when acquiring evidence for the analysis, and invaluable in trying to comprehend the processes. We have tried to visit as many locations as possible to get a chance to see as much as possible of the different flows and storage techniques in order to map out all flows in the best possible manner.

Questionnaires are answered or filled in by respondents. In this study, these have been delivered by email. Questionnaires prove invaluable when gathering large amounts of data, as the information obtained, after being summarized, can be used to compare and analyze, in order to understand how people think. Questionnaires used in this study have been sent to the various distribution centers in Japan, the US, Turkey, Holland, and Malmö. Discussion questions were used in our questionnaires to allow for freer answers. Due to the nature of the supply chain flows it has been hard to understand the different processes by asking direct questions. We noticed during our personal interviews that much valuable information came as side notes to our questions. Therefore, we decided that through asking open-ended questions we were able to get more information regarding the entire process in question.

Secondary data is information that has been gathered by someone else. Consequently, this means that the researcher has to rely on someone else’s data. When using this type of information a researcher should be very critical.[21] Keeping this in mind, the only form of secondary data used in this case study has been previously documented costs, which was acquired from sources within VCCS.

This thesis has not followed a text book example of a research project. The research has not taken place in one certain location, we have not been able to compare out results with any previous research, time has not been of the essence, and we have not tried to change anything within VCCS’ business process during this research.[22] As stated earlier, the purpose of this research is to map an existing flow in order to better understand the processes and thereafter determine the costs accumulated during the flow.

Most experts suggest completing a pre-case study, however the idea behind this thesis was established by VCCS and therefore we have been able to avoid this step in the research procedure.[23]

In a case study, the research focuses on one or a finite number of units. We have investigated the flow of five different supply chains to five different destinations around the globe. This thesis uses the case study strategy described in the book *“Case Study Research”* by Yin.

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[21] Bryman (2001), p. 179
[22] D. Bouma (1995), pp. 106-126
[23] Yin (2003), pp. 78-80

According to Yin, the choice of strategy varies depending on the described problem. Because of the fact that we are trying to find answers to the question "what is going on?" our thesis matches the requirements for a case study as defined by D. Bouma.[24]

The case study research design is a work schedule describing how the research should be carried out. The research design includes the use of logic and tools needed to accomplish this.[25]

To begin with, we have thoroughly described the problem we have faced. Secondly, we have mapped supply chain flows through interviews and observations. Lastly, we have analyzed all the processes which take place within the different flows, using activity based costing in order to map out the costs of handling the goods.

**2.6 Case Study Protocol**

In order to make certain that the research is conducted in a structured way; a case study protocol has been used. Earlier we stated that this case study research is an inductive and qualitative research. In the *"Research Design Motives"* we intend to describe the work that will be performed in a structured way and use it as a guideline.

In this section we discuss our choice of theory and information sources that we will use to support and analyze our findings. We will use mapping theories from production design to map out the flows and processes, and use Activity Based Costing to find the costs of the handling. Lastly, we will attempt to show how the costs of each activity affect the economic order quantity of dangerous goods.

In order to analyze the supply chains we needed an efficient way of mapping the different flows and their business processes. We decided upon using modified methods described by Jan Olhager in *"Produktions Ekonomi"* in combination with the symbols used by VCC.

When choosing the correct way to handle costs in order to analyze them, we examined three different calculation models:

The first, marginal costing can be defined through a product which carries all indirect costs alone plus a calculated sum of the common costs. The sum should be positive if the prices cover the indirect costs. This is mainly used for manufacturing companies.

The second, activity based costing, calculates the costs of all processes. This proves useful when analyzing how company resources are consumed in different steps of the supply chain.

The third, step calculations allows one to see how different parts of a business process contribute to earnings from a specific method when only looking at the incomes and costs for that specific procedure.

Activity Based Costing was chosen due to the number of activities which take place within VCCS' supply chain. In our opinion, this was the best method which would aid in mapping the different activities and process of the supply chain as well as to adequately assign costs to

[24] D. Bouma (1995)
[25] *ibid.*, p20

each activity. This, as well as mapping techniques, will be further discussed in the fourth chapter, Empirical Data.

We have based our structure on the theories described in Yin's "*Case Study Tactics*".

| Tests | Case Study Tactics | Phase of research in which tactics occur |
|---|---|---|
| Construct Validity | Mapping out the entire chain in order to get a larger picture of the situation | Data Collection |
| | Establish chains of evidence by choosing interviews as the main method of collecting data | |
| | Have reviews with guidance councilor at both Handels and Volvo to get helped with determining the validity of the information collected | Advisory review of composition |
| External Validity | Methods from production line mapping is used when describing the flows | Research design |
| | Existing theories have been used in order to structure the work and better understand the flows. They have also been used to validate our conclusions and helped us in our analyses. | |

**Figure 2 Model of Quality Research**[26]

[26] Yin (2003), p. 34

## 2.7 Case Study Analysis Methodology

In order to validate the data collected and used in a case study we have used the following reference: *"The Six Sources of Evidence"*. Through the use of at least three sources, we have been able to check our findings and compare the data.[27] During our work we have tried to collect the same information from several people in order to compare and validate the data. The sources from which the data has been collected are:

- Reports and documents within VCC
- Direct observations at several locations
- Interviews with key personal within the flows

This type of qualitative case study has focus on a few flows over a period of time. We have mapped the processes as they looks today; therefore, time is not of the essence.[28] The time frame of this case study is one semester and the supply chains have been mapped according to their present structures.

Our research is mainly built around data collected from several interviews conducted with key personal within the supply chains of dangerous goods at VCCS.

In the limitations that we set, we decided to focus on five NDC's, SDC's, and an LDC around the world to which we would map the flow. The flows that we have mapped start at the supplier and continue through the CDC to its designated DC. The five locations that we have chosen are:

- NDC Atlanta
- NDC Nagoya
- NDC Turkey
- SDC Maastricht
- LDC Malmö

## 2.8 Validity

Concerning the validity of this work, one can name two types, external and construct.

The source of all data in this case study has been VCCS, Eurobag and Svenska Airbag, and in order to validate our data we have been forced to generalize the data gathered. This was necessary in order to limit our research and validate our findings externally. The process mapped in this thesis is unique to VCCS; however it may also be similar to flows outside the Ford Group, which makes our conclusions something that can be used by other business units within the Ford Group or other companies that have similar business processes.

Construct Validity aims to find and treat the data in the best possible way in order to get the most accurate results possible.[29] When mapping the flows and processes in the specific supply chain we have tried, when possible, to both interview the people who are involved in the day to day operations of dangerous goods handling, as well as to observe the actual processes. All

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[27] *ibid.*, p86
[28] Neuman (2003), p. 31
[29] Yin (2003), pp. 34-36

information has been handled in a structured way as mentioned in the previous Case Study Protocol.

### 2.9 Reliability

We consider the reliability of this work to be good. The performed mapping has been controlled by interviewed personnel, in order to determine that our reporting of the business practices is, in fact, correct. Unfortunately, it has proven difficult to find anything similar to our work, in which we could compare our results. We have not had a chance to re-do this case as it does not occur over a period of time and is not an experiment. In order to prove that this thesis it reliable we can only have our writing corrected by personnel involved in the studied business process.

We have experienced that misleading information has been given to us during some interviews. This has not been because people have intentionally mislead us, but instead have had different perceptions on how things are connected and tasks are performed. In those cases where we have had conflicting information we have gone deeper into the area in order to collect correct information. The work areas studied in this thesis often overlap, thus providing us with a chance of obtaining the same information from two different sources, in order to check that our data is accurate.

# 3. Theory

*Theoretical frame reviews literature and differing theories, which will be used in order to provide both a structure and foundation upon which we can base our final analysis and conclusions. This section focuses on process flow analysis, ABC/ABM, and basic concept within inventory management such as safety stocks, reorder points, and the Wilson Formula, that will provide a theoretical support to our study.*

## 3.1 Inventory Management

Most companies have some kind of inventory in order to protect against:

- uncertainty in customer demand
- product shortages
- uncertainty in lead time
- and which can create benefits in economies of scale

However, holding inventory creates costs. The basic idea behind inventory management is to balance the benefits of having inventory with the drawbacks of its associated costs.

For companies that have storage operations it is important to understand the business environment and to adapt inventory strategies to meet the needs of:

- Customer demand
- Replenishment lead time
- Number of different products
- Length of planning horizon
- Costs – order and inventory holding costs
- Inventory management

In many situations a warehouse is continually emptied due to customer demand. When the inventory levels reach a certain point a new shipment of products is sent out and the inventory levels rise to the appropriate levels. This type of scenario can be seen below in figure 3. This model is used to show how the storage level is changed when goods are consumed over time and new goods delivered to the warehouse.

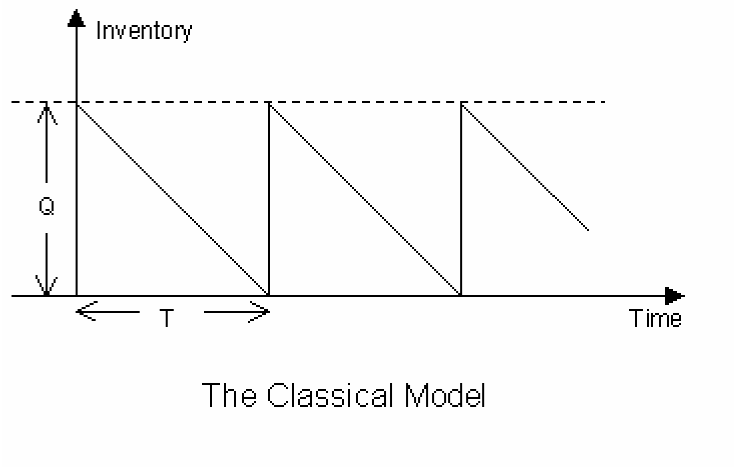


**Figure 3 The Classical Model**[30]

As is commonly understood in inventory management absolute demand is hard to forecast, and therefore safety levels are implemented in inventory levels in order to avoid the chance of stockouts. The following model (figure 4) shows how the safety stock protects against variations in demand.

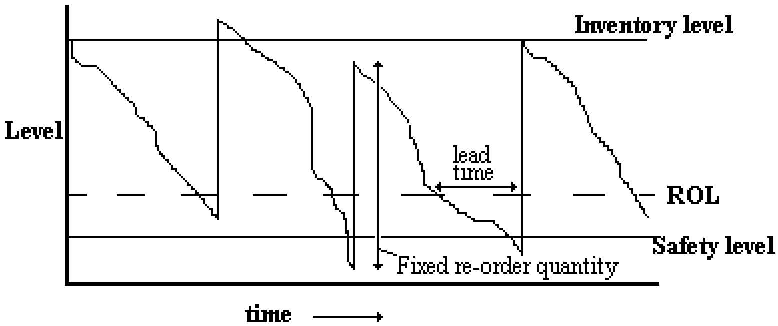


**Figure 4 Reorder Level Model**[31]

As is mentioned earlier companies typically refill inventory levels at one time. However, there even exist situations where a warehouse can be filled over time as products are manufactured and then shipped to the warehouse/distributions center. The following diagram presents a graphic illustration of how this appears..

[30] http://home.ubalt.edu/ntsbarsh/stat-data/Forecast.htm
[31] http://www.bola.biz/operations/stock/maths.html

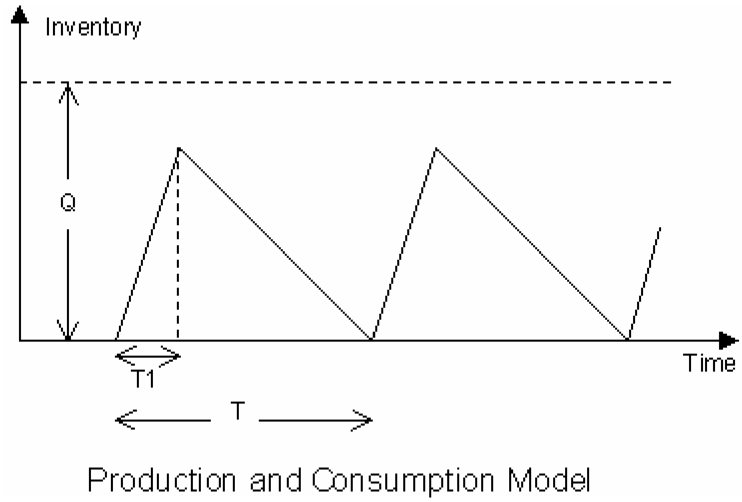


**Figure 5 Production and Consumption Model**[32]

### 3.2 Process Flow Analysis

In order to map VCCS' existing supply chains, we have decided to map these different flows using a process flow analysis. The purpose of using a process flow analysis is to, in detail; graphically plot the company's current activities. The main usage of these kinds of flow analyses is to map a production flow; however our intent is to adapt this system in order to draw a logistics flow.[33] The basic steps when completing a flow analysis are the following;

1. Identify and categorize the process activities.
2. Document the process as a unity.
3. Analyze the process and indentify possible improvements.
4. Recommend suitable changes.
5. Implement decided changes.[34]

When designing schemes and diagrams, symbols are used in order to map the flow. The use of these symbols helps the reader to better understand the different aspects of the diagram. The following symbols have been used in the creation of our diagrams;

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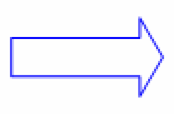
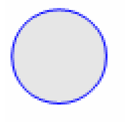
[32] http://home.ubalt.edu/ntsbarsh/stat-data/Forecast.htm
[33] Olhager (2000), p. 91
[34] *ibid.*

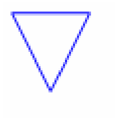
= Process



= Transport or Movement



= Inspection



= Storage

[35]

*Process*
When an operation is performed the material in use is treated in such a way that it is changed or altered. In our scenario this can be labeling or packaging the goods or the documentation which must be done before the goods can be shipped. The handling of goods is also included in this section, for instance the receiving of goods and the work associated with this.

*Transport or Movement*
Transport is the act of moving an object from one location to another, for instance between two different warehouses. This can also include the work of moving the goods within a specific facility.

*Inspection*
Inspection is when the documents or the goods are controlled in the supply chain, for instance in customs or at the receiving end of the chain.

*Storage*
The goods are placed in storage when they are not in movement, due to control or awaiting delivery.

### 3.3 Process Flow Analysis Methods

According to Jan Olhager there are three different kinds of process flow analysis methods. The three different ways of mapping flows are; process flow scheme, material flow scheme and layout flow diagram.[36] In this section we will describe what encompasses the different flows so that the choice of method is easier to understand.

Process flow scheme is also known as production scheme and is constructed so that it is easier to follow the different kinds of tasks in a complete flow. The different tasks are written in the correct line according to the order in which they are performed and thereafter categorized, in addition to mapping the time each task takes, as well as the distance between stations.[37]

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[35] VCCS Process Symbols
[36] Olhager (2000), p. 93
[37] *ibid.*, pp. 93-95

With this method, two flows can be mapped out simultaneously in order to see how they interact with each other. All operations are mapped out and then connected through transport or similar performance in order to show the flow graphically.[38]

The layout flow diagram is very similar to the material flow scheme except for the fact that the actual physical spot in the production line is shown as well. The different areas are drawn as they are located in the actual scenario and then the different processes in each department are added in order to see a more exact flow.[39]

It is understood that these models were created to display production processes. The process that is being mapped in this thesis is not a production process, but instead a service process. It is felt, though, that these models can be applied to our process flow and through standardization of the model it will be made as graphic as possible so that the flow of dangerous goods through the supply chain at VCCS can be displayed and easier to understand for the reader.

## 3.4 Activity Based Costing

### *3.4.1 Why ABC?*

More and more companies are beginning to understand the importance of analyzing the entire supply chain in order to reduce costs. Managers cannot analyze the supply chain as one entity, but instead must see each actor as an own entity with own costs and goals. It is therefore important to try and cut costs across the entire supply chain, which in the end should lead to greater profitability. However, there still remains the problem of assigning and managing costs due to lack of information. Without proper data, management is unable to gauge the effectiveness of the supply chain and where changes, if any, should be made. To judge performance of the supply chain, accurate cost data is needed. In an effort to overcome this companies use activity based costing (ABC) to analyze and manage costs.

The cost data needed to complete an ABC study already exists within company accounting, however these costs need to be assigned to the different activities associated with the supply chain. Drucker suggests that "ABC may have its greatest impact within the service industries since they have practically had no cost information at all."[40]

Many companies base their cost accounting practices according to what Turney describes as the "old" system. This system is based on the following:

- It reports financial facts by department and not processes. Furthermore, the large emphasis on direct labor costs can be misleading.
- It is conservative and does not value economic cost
- It is dependent on government rules such as how a machine depreciates, not on what is actually happening.
- Accounting systems organize information by legal entity and not by activity which may meet somewhere between the "legal entity" part of the business. Two different products may need to be produced in order to create the final product. The question remains: how should these activities be treated?

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[38] *ibid.*, p. 96
[39] *ibid.*, p. 97
[40] http://www.cob.ohio-state.edu/supplychain/pdf_files/ABC%20Best%20Practices%200397.pdf p. 2

- Conventional cost systems deal with units and not batches. It is better to spread out costs over 100 products being worked on instead of just 1.[41]

"ABC is a costing model that identifies the cost pools, or activity centers, in a firm and assigns costs to products and services (cost drivers) based on the number of events or transactions involved in the process of providing a product or service."[42] ABC is a method of collecting cost data in order to complete budgets and in order to analyze processes so that overhead and operating expenses can be evaluated, which in turn can allow for the assignment of costs to customers, services, products and orders. This helps managers to determine which products, customers, etc. are profitable or non-profitable for the company involved.[43] "ABC assigns all costs, including both direct costs and so-called indirect overhead costs, to products and customers", thus providing a complete picture of how the company's resources are being used and what sort of outputs are being produced.[44] ABC looks into a process in order to evaluate costs. This information can then be used by management to identify problem areas within a business process and how best to tackle them. Additionally, knowing costs helps in understanding why resources are used. Costs associated with different activities places attention on "the structure, flow and performance of the process"[45], which can then be used to help in answering the following questions:

- Which activities require the most resources?
- What types of resources are required by these activities?
- Where are the opportunities for cost reduction?"[46]

"ABC helps reveal the true cost of doing business with a particular customer, supplier or distributor by comparing the revenues earned to the cost incurred on each particular party", which, in turn enables the company to focus on products, customers or suppliers which give the highest profit to the company.[47]

Concerning logistics processes ABC is "well suited for costing and measuring the performance" as the area is faced with "many of the same conditions that make manufacturing firms good ABC candidates."[48] Basically, logistics practices consume resources which are not well measured through traditional volume-based distribution events, thus making it a primary candidate for ABC. Lastly, logistics can benefit through the use of ABC as it can help in identifying opportunities where the logistics process can be remodeled to either decrease costs or improve service performance. ABC helps in locating redundancies in the supply chain or members that over-consume resources, or even in finding new candidates to be included in the logistics process.[49] However, it is vital to remember that ABC only helps in tracing and measuring costs through business practices, but not in allocating them.[50]

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[41] Turney (2005), p. 27
[42] Stapleton et al. (2004), pp. 584-597
[43] *ibid.*
[44] Cokins (2001), pp. 25-31
[45] Turney (2005), pp. 49-50
[46] *ibid.*, p. 81
[47] Binshan et al. (2001), pp. 702-713
[48] Stapleton et al. (2004), pp. 584-597
[49] *ibid*
[50] Cokins (2001), pp. 25-31

The basic idea behind ABC is that:

- Cost objects consume activities.
- Activities consume resources.
- This consumption of resources is what drives costs.
- Understanding this relationship is critical to successful budget management.[51]

In order to appreciate how ABC works one must understand the terminology used within this type of cost management system. Expressions such as resources, activities, activity centers, cost elements, activity drivers, cost drivers, cost objects, and resource drivers are all associated with ABC. These terms will be described, in short, below.

*Resources* can be defined as all that is needed in order to produce a service or product. In their most basic form they can be referred to as labor, material or capital. Resources can be described as the material, time, or energy that is consumed through the different activities that take place in a process. Resources help to add value to a product or service and are the source of a cost. In terms of VCCS, personnel, equipment, and packaging materials can be resources that are consumed.

*Activities* are the tasks or sets of tasks which require expenditure or employment of resources, in turn, resulting in the completion of a specific service. They can be seen as the actual job that is done around the product or service, such as order taking, purchasing, packaging, transportation, warehousing, or billing. These are processes which cause work within the business. Moreover, they can be described as either core or enabling, meaning that "core activities directly benefit the products, services, and customers of the organization", while an enabling activity is an activity that works as a support for the core activities.[52] For dangerous goods, there is extra documentation that must be completed before the products can be delivered. There are activities surrounding the handling of documentation that increase or decrease depending on the amount of dangerous goods shipped. Additionally, the goods must be specially handled at the CDC and thus require a certain amount of activity to process these goods.

As may be understood, there exist numerous amounts of activities within an organization and its different business processes. Therefore, it is recommended to aggregate activities into groups based on activity characteristics in order to avoid measuring costs at levels that will be lower than the benefits provided. Once activities are aggregated they should be easier to work with and understand when trying to analyze the end results. Keeping this in mind, *activity centers* are used in order to group similar activities and thus make an ABC calculation easier to complete. At the CDC there are activities involved with the deliverance of products, which can be grouped together. Additionally, one can group the picking and packing part of the process into the same activity center. All of this is done to make management of the ABC model easier to understand and calculate.

Activities are typically classified into hierarchical levels. The number of levels most likely varies from company to company because of organizational differences. It is therefore important to understand this when completing an ABC study using information from other

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[51] http://www.defenselink.mil/comptroller/icenter/learn/abconcept.htm
[52] Turney (2005), pp. 97-98

companies. In general though, one can break most service organizations into the following activity levels.

- Batch level activities are the same for each order produced irrespective of the amount of products shipped (for example printing an order list or purchase orders)
- Product level activities are conducted for specific dangerous goods such as airbags; transmission oil, etc. (for example DC areas that are dedicated to certain products.)
- Customer level activities are conducted for specific DC's (such as having to follow specific packing instructions for certain markets.)
- Organizational-supporting activities are for the company as a whole and cannot be identified with units, batches or individual products (such as most centralized activities).

*Cost elements* are created in order to break down costs. This can be further explained as a part of a total cost. For example, a budgeted amount for the dangerous goods part of the warehouse may be 50,000 SEK. Of this amount 40,000 may go to salaries, while the remaining 10,000 may go to supplies. Each of these figures can be seen as a cost element of the total cost of 50,000 SEK.

*Activity drivers* are ways to assign costs to cost elements. They are used to measure, for example, how often an activity is preformed or how long an activity takes. These measurements are used to gauge the profitability of a customer, product or service. These are factors that cause a change in the performance of an activity which affects the amount of resources that the activity requires. Examples of these drivers can be the number of customer orders in relation to billing or number of people within a respective department.[53] These help determine the amount of work which is required in order to perform an activity. They include features linking the performance of prior activities in the chain as well as factors within the activity. They help to explain not only why an activity is being done but how much effort is used in the completion of the activity. This information, can in turn, help with improving the process.

According to Turney, activity drivers can be defined as transaction-based or time-based.[54] A transaction-based activity driver can be the number of shipments by part number, while a time-based activity driver can be the time spent on the handling of different products, in our case airbags, spray paint or car batteries.

*Cost objects,* as the name implies, are costs that are assumed through the use of resources and activities. The basis of ABC is to calculate costs, where they originate, and to enable analysis so that costs can either be cut or re-dispersed in order to lead to more effective business practices. These items are what the calculations are based upon. These can be product groups, products, orders, customers or different segments within the market. Cost objects are the reasons for performing actions. This is the final point where a cost is traced. Costs traced to this destination reflect the cost of the activities utilized by the object. "Entering the details of a customer order at a computer terminal (the activity), for example, is performed because a

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[53] Billgren (1995), p. 23.
[54] Turney (2005), p. 108

customer (the cost object) wishes to place an order."[55] In other words, a cost object is the reason why work is performed at all.

An additional term, which is referred to as *Resource Drivers*, is a measure of the amount of resources used by an activity. This is used to assign the cost of resources to activities.

The following diagram helps in providing a graphic presentation as to how these different concepts within the ABC system pertain to the process on a whole. From the diagram one is able to see that all processes are interconnected however they all have different outputs for different activities.

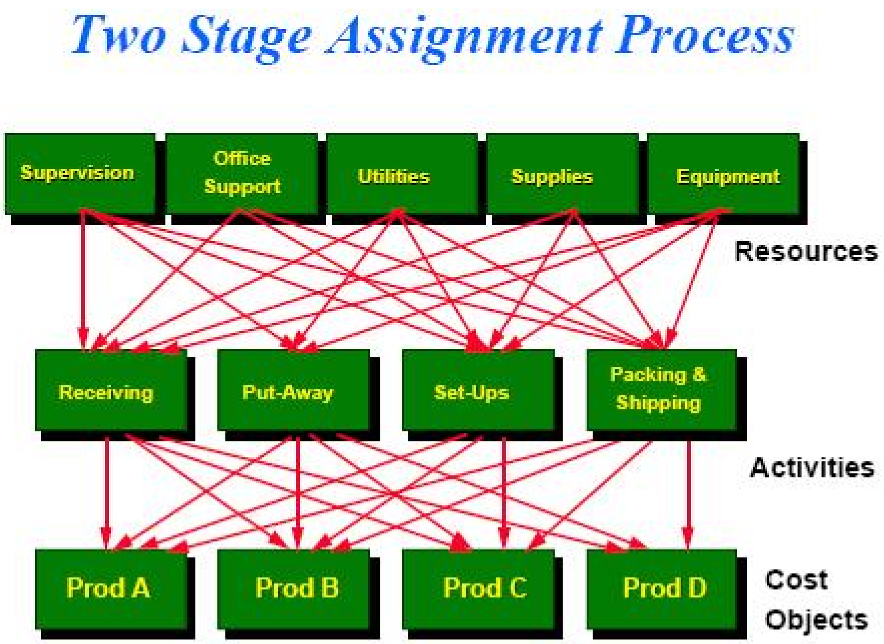


**Figure 6 Two Stage Assignment Process**[56]

*3.4.2 Benefits*

A huge benefit of ABC is that it provides a cost platform from where management can base strategic decisions concerning the organization's business practices. It sheds light on surplus capacity within the company in addition to lack of capacity or even misallocation of capacity. With knowledge concerning the capacity of the organization, management can make well guided decisions pertaining to the future of the company. Another major advantage of ABC is that it circumvents or reduces misrepresentations in product costing which typically result from uninformed allocations of indirect costs. "ABC supplies a powerful combination of nonfinancial and cost information. These two types of information help in managing – and improving – the performance of the organization."[57]

Additional benefits which are achievable through the use of ABC are:

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[55] *ibid*., p. 47
[56] http://www.cob.ohiostate.edu/supplychain/pdf_files/ABC%20Best%20Practices%200397.pdf
[57] *ibid*., p. 59

- More precise product and service costing, principally where non-volume-related expenditures are significant.
- Better understanding of cost performance in addition to identifying the costs associated with servicing customers.
- Due to the method's ability to show activity costs there is a reduction in uncertainty, which in turn provides a better platform from where strategic decisions can be based.

*3.4.3 Disadvantages*

"One of the major misconceptions of ABC is still that it is an improvement program."[58] The data collected is simply a tool which may be used in process and strategic analysis, which may not always be forthcoming upon completion of an ABC study.

Even though there are a tremendous amount of advantages through the use of ABC there are however some drawbacks, which must be considered when conducting an ABC analysis. First, there is a large amount of work involved in collecting accurate data. This has to do largely with the fact that many activities can be associated with different partners within the organization thus making it difficult to distinguish which activity is responsible for the cost. The process of gathering and collecting data is time consuming, and the organization must be aware of the fact that the cost data retrieved will not always be perfect.[59] Another aspect is that this may not be suitable for every company due to the fact that not all firms have large overhead costs. The process of completing an ABC analysis can be costly, so the organization must use caution so that the costs do not outweigh the benefits of implementing the analysis. It is also important that the firm not lose focus of the customer, which is the reason for the company's business. Lastly, once the activities are mapped and costs are known, relations within the company may suffer because of some who are not willing to accept the results and others who may be scared for their existence in the supply chain.[60]

*3.4.4 Implementing ABC*

In the previous section we mentioned the ideas behind the usage of ABC and its benefits and weaknesses. We will now present the ways in which an ABC model is implemented in an operative way. Depending on which literature is studied there are different phrases and terms used. Our description is based on a simple outline taken from an article written by Stapleton, et. al., duly titled "Activity-based costing for logistics and marketing".

In order to apply ABC, a few steps need to be followed to trace costs to the products being researched. The first step is ascertaining the activity centers and activities. Here, activities within VCCS might include document handling, order filling, shipping, and warehousing. Resources are the essential materials required in order to perform activities, for example warehousing facilities, personnel, material, distribution and handling equipment, etc. As discussed earlier resource or cost drivers help to determine the amount of resources devoted to an activity. Activity drivers relate activities with cost objects. They aid in the measurement of frequency and intensity of use of an activity by a cost object.

The following step is to establish the cost drivers for each activity. Once the cost drivers have been established variable costs must be separated from the fixed costs. Additionally, activities should be defined as value adding or non-value adding. This information will prove beneficial

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[58]Cokins (2001), pp. 25-31
[59] Griful-Miquela (2001)
[60] Stapleton et al., (2004), pp. 584-597

when analyzing the activities and their associated costs upon completion of the study. Next, costs for each activity should be determined.

Lastly, costs of each activity must be traced to the cost objects, which in our case are the dangerous goods being researched. This information will give insight into products which are profitable and which activities prove to be too expensive or non-value adding and can thus be candidates for elimination.

### 3.5 Activity-Based Management

An ABC study is only the beginning of a much larger process. Upon completion of an ABC study management will have a better understanding of the processes, activities, resources used, and costs within the organization. They must then use this knowledge to effectively manage the company. What should be considered is that focus should be placed on improving value for customers, which should lead to improved profits. Management must concentrate on using resources in the best possible manner so that they lead to strategic benefits. This is termed as Activity-Based Management (ABM). This type of management enables the company to perform various types of analysis such as: strategic analysis, value analysis, cost analysis, storyboarding, lifecycle costing, and target costing.[61]

Strategic analysis can provide aid in "pricing…customer value analysis, competitive studies, sourcing, and product strategy analysis."[62] In contrast to this is value analysis, where focus is placed on the business process in order to make improvements or cut costs. Cost analysis can be done once the costs of activities and resources used are highlighted through and ABC study. In order to cut costs, storyboarding ("a detailed analysis of a process that is targeted for cost reduction and improvement"[63]) can be done. This will aid in developing action plans for the reduction of costs and non-value adding processes. Lifecycle costing examines the entire lifetime of a product or service as opposed to a short time-frame. Here, management is able to see the larger picture and thus make educated decisions concerning the future of a product or service. And lastly, target costing which starts with the design of a product or service. By focusing on this, costs can be reduced at early stages and thus reduce negative effects later on in the process.

### 3.6 Inventory Management

Many, but not all companies hold inventory. In order to effectively manage these inventories, organizations follow a few different theories which, in turn, should lead to smaller inventory levels and tie up less capital. The basic premise behind inventory management is to achieve the lowest possible overall costs and inventory levels without negatively affecting product availability.

*3.6.1 Service Level*

When deciding upon the proper safety stock one must take into consideration either the costs of not being able to deliver to customers or the desired service level. Analyzing costs due to loss of business is quite difficult and it is therefore easier to set a certain service level.[64]

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[61] Turney (2005), p. 153
[62] *ibid*., p. 154
[63] *ibid*., p. 166
[64] Axsäter (1991), p. 68

Service level can be measured in the percentage of time that an order can be filled from inventory upon request or even the amount of time that a customer has to wait for items to be delivered. This is typically done in cooperation with each respective customer. It is important, though, that everyone who is involved in the supply chain is aware of the services levels and how it affects each respective link in the chain.

There are, however, limits to how far a service level can reach. This has much to do with costs. According to Axsäter there are different service levels for different products. Furthermore, this can lead to problems within the distribution system, and therefore, many companies decide on service levels for groups of products.[65] Again, though, it is important to remember that the higher the service level the greater the chance of larger inventory if proper inventory management is not utilized. Although larger inventory levels can be used to achieve proper service levels, other approaches can be the use of better, faster transportation or even improved communication between customers and suppliers to reduce uncertainty.

*3.6.2 Reorder point*

A crucial aspect of inventory management is to understand how much of a certain product must be ordered and when it should be ordered. To achieve this, companies need to determine a minimum inventory level, taking into account associated costs as well as customer service level. Moreover, an understanding of lead time and lead time demand should be maintained. With this knowledge companies can order enough products, which in theory, should arrive on the shelves at the exact time that the first batch sells out.

Due to constant demand goods are taken from stock, which decreases the amount of inventory being held. After a certain time period the stock levels reach a pre-determined point, at which time an order is placed to bring the inventory up to the optimal inventory levels. An order point should be calculated to occur when inventory reaches a level that should cover the average demand over the time it will take to replenish the inventory.

If, for example, it takes four weeks for products to arrive from the supplier, an order should be sent when inventory levels decrease to the point at which they will end after four weeks. In theory, inventory levels should reach zero at the same time that new products arrive from the supplier. (See figure 7)

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[65] *ibid.*, p. 68

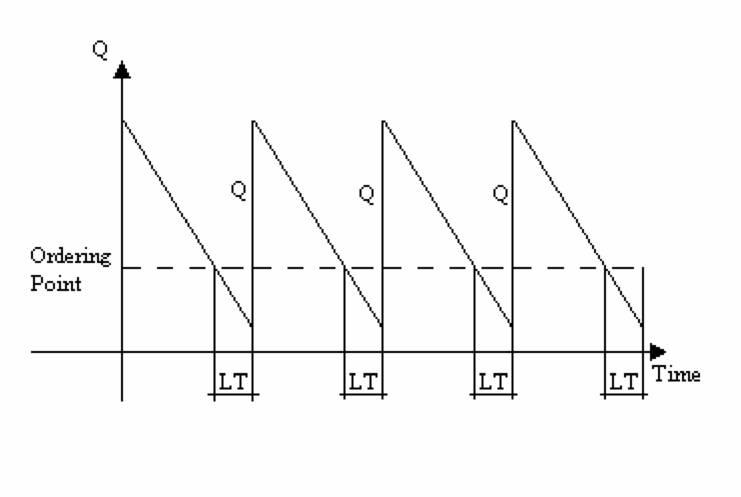


**Figure 7 Ordering Point**

The basic formula used to calculate a reorder point is R = D x T,

Where

- R = the reorder point in number of products or units
- D = the average daily demand in products or units
- T = the average lead time calculated in days

In order to combine safety stock and the reorder point the following formula is used. The appropriate reorder point is calculated and then the safety stock (SS) is added to this amount.

Reorder point = D x T + SS

*3.6.3 Safety Stock*

The purpose of a safety stock is to avoid stock outs due to variations in demand or lead time. Inventory managers typically have to balance two individual variables: demand and performance cycle uncertainty. Because of this some sort of buffer must be built into the system to avoid costly stockouts. (See figure 8) By calculating the probability of demand and performance cycle variability inventory managers are better able to gauge the effectiveness of their inventory levels. The following equation is used to calculate safety stock.

$SS = K \times \sigma_{DDLT}$

K is a factor whose value is based on predefined stock out risks and the situation concerning lead time demand during distribution.

$\sigma_{DDLT}$ is the standard deviation of demand during lead time.

The safety stock is largely determined by service level. If stockouts are not an option than the safety stock needs to be large enough to cover all areas of risk associated with receive the products.

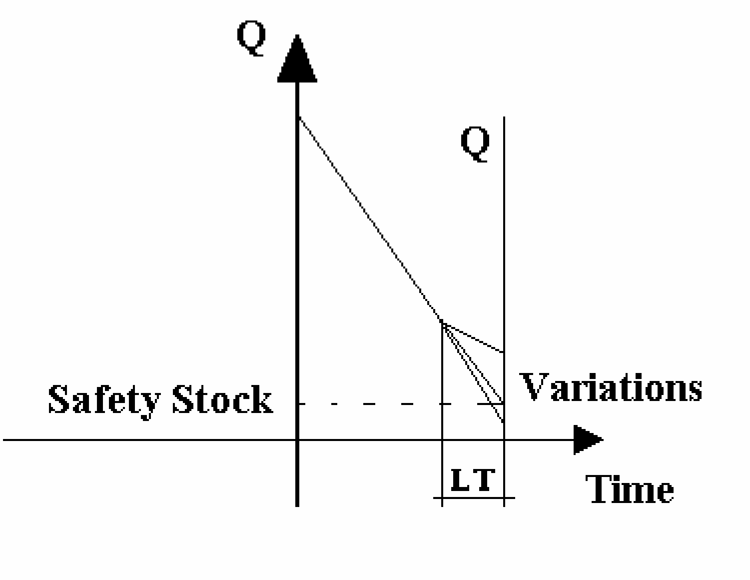


**Figure 8 Safety Stock**

*3.6.4 The Wilson formula*
The purpose of using the Wilson formula or Economic Order Quantity (EOQ) is to determine the optimal order quantity. The EOQ refers to the best order batch which results in the lowest total order and carrying costs for a product given its expected demand, holding and ordering costs. The benefits of using this formula when deciding upon order batch size is that it weighs the costs against ordering more often at a higher price against ordering fewer batches at a lower cost, but being forced to have higher inventory levels. Vonderembse and White use an excellent analogy for how this formula works in their book *Operations Management*. They describe the interaction of holding costs and order costs as two children on a see-saw. As the one cost goes up the other goes down and vice versa.[66]

The formula is based upon the cost for storage and ordering, and certain criteria must be fulfilled in order for the formula to provide adequate numbers.

- Demand must be known and constant.
- Every delivery must arrive as one batch.
- The purchase price is known and constant
- The order cost is known and constant
- The holding cost is known and constant
- No stockouts are permitted.

When all of these requirements are fulfilled the following formula can be used:

$$Q = \sqrt{\frac{2 \times R \times S}{I \times C}}$$

The formula consists of these parts:

[66] Vonderembse & White (1996) p. 607

- Q= Order quantity, expressed in number of batches.
- R=Demand, expressed in number of units per time period.
- S=Direct order cost
- C=Value of the item when kept in Stock
- I=Storage, holding cost

These costs can be used for different time variables as long as each cost is recalculated to fit the desired period. For example, if an optimal order quantity for a one month period is to be calculated all costs must be recalculated to reflect a one month period. This can be accomplished by dividing all yearly results by twelve. Of the costs used in the Wilson Formula two costs must be given extra attention: order costs and holding costs.

Order costs are associated with all activities that are affected by the process of ordering products. If this cost is under, or overestimated, it will provide misleading calculations concerning the optimal order quantity. This cost consists of a fixed and variable cost. A fixed cost is independent of the size of the order and usually consists of the costs associated with staff or office furniture. A variable cost, on the other hand, is based on a per unit basis, meaning that it increases as the number of goods increases. These costs can consist of the cost of:

- Placing an order
- Receiving and inspection costs
- Export documentation
- Transport
- Packaging
- Handling

Storage or holding costs are those costs associated with having inventory on hand. Again, one must differentiate between fixed costs, such as all costs concerning the DC, capital costs on real-estate, taxes, operating costs, and personnel costs. On the other hand variable costs characteristically are made up of:

- capital costs, insurance, and taxes for inventory
- losses due to breakage, theft, or obsolescence
- as well as the fact that all of this tied up capital could be used in other areas of the business which possibly could give a better return on investment

As was mentioned earlier, the EOQ formula provides an acceptable answer to appropriate order quantities, however certain criteria must be met for this formula to prove optimal. This is not always the case in a dynamic environment so inventory managers must have a good understanding of the DC's and business practices which they manage in order to aid in decision making concerning the best order quantities.

Other factors which can affect the optimal order quantities can be “volume transportation rates, quantity discounts, and other EOQ adjustments” such as fixed batch size from the supplier, multiple product purchases, and restrictions regarding capital.[67]

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[67] Bowersox (2007), pp. 140-141

Many companies base their purchase order sizes on numbers calculated using the Wilson Formula. This formula has proven beneficial to many companies; however one must consider some of the negative aspects of the formula. As was mentioned earlier, this equation works best if certain criteria are met, such as that demand is unchanging and can be forecasted. Also, the formula assumes that each batch arrives together and never leads to stockouts. Lastly, the formula is quite static meaning that the product cost, order cost and inventory handling costs are known and remain the same over time. Having mentioned all of these assumptions it should appear quite obvious that in a dynamic business environment things change constantly, and forecasts are always wrong. Therefore, this formula should be used as a guideline, while at the same time trying to adjust order sizes to transport discounts, earlier experience with inventory levels, or product discounts.

# 4. Empirical Data

*In this section we will present a general background of the Volvo Car Corporation, as well as a description of the business processes at VCCS which have been examined. This information is provided in order for the reader to gain a better understanding of how the company works at present. With this information we will then be able to analyze the company and discuss improvements.*

## 4.1 Company Background

The Volvo Car Corporation was founded in 1926, the same year as their first car Jakob was produced. Volvo was originally a subsidiary of SKF, which wanted an automobile manufacturer in the vicinity in order to establish a stable customer.[68]

By 1932 Volvo had produced more than 10,000 cars. Production slowed during the Second World War but close to the end of the war, Volvo launched their new PV444 and PV544 which came to be a huge success, and stayed in production until the mid sixties. Other car milestones were the Volvo 150 or the Amazon as it is more known as, the sports car Volvo P1800, Volvo 140, Volvo 240, Volvo 740 and many more.

Over the years, Volvo bought several different firms, forming the Volvo Group which consisted of Volvo Cars, Trucks, Buses, Penta, Aero and BM.

The company was quick to spread its brand around the world, and Volvo Trucks was the most profitable section until the 1950's, when car sales began to increase. Volvo's first, and still one of the main, production plants was on the island of Hisingen, just north of the city of Gothenburg. In 1964, Volvo opened the doors to their new facilities in Torslanda. With this new factory, Volvo had the capacity to produce 200,000 cars a year.

In 1971, the most recognized Volvo president, Per G Gyllenhammar, came into position. He was the leader of several interesting projects, such as the proposed merger with Saab-Scania and Renault. He subsequently left company in 1993 after the deal with Renault was cancelled.

In 1999 Volvo cars was sold to the Ford Group, and is still a very important part of it. The main Volvo production plants are still located in Hisingen, Arendal, and Torslanda. Volvo's total production today is approximately 450,000 cars per year.[69]

The Ford Group consists of several different brands such as Volvo, Jaguar, Ford, Land Rover, Aston Martin and a large part of Mazda. Turnover for the Ford group is currently 165 billion dollars with 7 million cars produced annually and 350,000 employees.[70]

VCCS works with a concept revolving around a CDC, with distribution centers strategically placed around the world in order to be closer to the end customer. The idea is that a centralized DC is better able to service the needs of the local markets through vendor managed inventory. This reduces the spare parts inventory at all levels, as the CDC is better

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[68] http://www.volvoclub.org.uk/history/index.shtml
[69] http://www.ne.se.ezproxy.ub.gu.se/jsp/search/article.jsp?i_art_id=172898&i_word=volvo%20personvagnar&i_h_text=1&i_rphr=volvo%20personvagnar
[70] *ibid.*

able to adjust inventory levels to meet demand. Benefits at the local level include reduced logistics costs, reduced cost for storing space, optimized inventory planning, less chance of articles becoming obsolete, and easier reverse logistics. Additionally, the CDC is better able to plan its activities because of the data received from the local level concerning demand.

### 4.2 Dangerous Goods

Dangerous goods, which are to be transported by air, sea, or land must follow different regulations, based on United Nations (UN) recommendations, regarding the transport of such goods. There are different organizations within Sweden, and throughout the world, which regulate the rules regarding transport of hazardous items. The objective of these organizations is to ensure that the commodities are transported in a safe manner, thus minimizing the chance of accidents and even greater difficulties which can arise from the introduction of dangerous substances into the natural environment.[71] The agreements upon which regulations are based and followed internationally and by VCCS are laid forth in the following agreements or codes:

- ADR (The European Agreement for the International Carriage of Dangerous Goods by Road)[72]
- IMDG (The International Maritime Dangerous Goods Code)[73]
- IATA – (International Air Transport Association Dangerous Goods Regulations)[74]

According to the Swedish Rescue Services Agency dangerous goods can be defined as "substances and articles that have dangerous properties that can cause injury to people, and damage to the environment, property and other goods, unless they are correctly handled during transport."[75] Goods that are considered to be dangerous are then classified into nine different categories based on risks associated with the products, in accordance with the system laid out by the United Nations Committee of Experts on the Transport of Dangerous Goods.[76]

Following is a list of these categories, which has been taken from the Swedish Rescue Services Agency:

- "Class 1 Explosive substances and articles
- Class 2 Gases
- Class 3 Flammable liquids
- Class 4.1 Flammable solids self-reactive substances and solid desensitized explosives
- Class 4.2 Substances liable to spontaneous combustion
- Class 4.3 Substances which, in contact with water, emit flammable gases
- Class 5.1 Oxidizing substances
- Class 5.2 Organic peroxides
- Class 6.1 Toxic substances
- Class 6.2 Infectious substances
- Class 7 Radioactive materials

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71 http://www.srv.se/templates/SRSA_Page____20935.aspx
72 http://www.unece.org/trans/danger/publi/adr/adr_e.html
73 http://194.196.162.45/Safety/mainframe.asp?topic_id=158
74 http://www.iata.org/ps/publications/9065.htm
75 http://www.srv.se/templates/SRSA_Page____20935.aspx
76 *ibid.*

- Class 8 Corrosive substances
- Class 9 Miscellaneous dangerous substances and articles"[77]

The types of articles that have been researched in this paper fall into categories 1, 2, 3, 4, 8, 9, meaning that they can be considered as explosive, gases, flammable, corrosive, or a mixture of miscellaneous substances which have proven to be dangerous according to the above mentioned definition of dangerous goods.

### *4.2.1 UN Numbers*

A further restriction when transporting dangerous goods is that actual products, boxes, crates, etc., depending on shipping needs, must be labeled with UN numbers. These consist of four digits, which quickly help in identifying any hazards present in the shipment. The numbers represent a chemical or group of chemicals that are used as ingredients in the products being transported. In other words, "each UN number is a three character hazard identifier, defining the Hazard Class, Division, and Compatibility Group."[78]

### *4.2.2 DOT Numbers*

An expansion upon UN numbers is so called North American (NA) numbers, which are also referred to as Department of Transportation (DOT) numbers. These numbers are provided by the US and Canada and are either the same as UN numbers or can be assigned to those products which lack a UN number. Typically, these numbers contain four digits and begin with an 8 or 9. [79]

### *4.2.3 PSN Numbers*

A PSN number is used within VCCS in order to better understand the proper methods needed to handle and package dangerous goods. Following is a list of the UN and PSN numbers for the products examined in this work.

- Airbag – UN 3268, PSN 90-91
- Spray Paint – UN 1950, PSN 20
- Paint Pencil – UN N/A, PSN N/A
- Car Battery – UN 2794, PSN 80
- Transmission Oil – UN 3082, PSN 52

## 4.3 Inventory Management at VCCS

VCCS currently uses a storage control system named PULS (Parts Universal Logistics System), which was developed solely for and by Volvo in 1995. This tool is used to control VCCS' distribution centers worldwide.

Forecasts are determined at the end of each week for all refill articles, however new prognosis are done each night based on products that have been sold enough times to mitigate a recalculation. Each night an automatic refill order is placed by PULS which is based on actual

[77] http://www.srv.se/templates/SRSA_Page____20935.aspx
[78] http://www.ribbands.co.uk/genpages/unnumber.htm
[79] http://www.ilpi.com/msds/ref/unna.html

storage balances plus refill order points. These orders can be blocked if the inventory manager feels that a refill order is unnecessary. Additionally, even manual orders can be placed by inventory managers. Each forecast is based on order statistics for the following twelve periods.[80] Forecasting can be done with the help of PULS or manually, and can also be determined giving consideration seasonal variations in sales.

Depending on the DC, the different refill quantities are calculated either through an order quantity Table or the Wilson Formula (EOQ formula). The Tables are based on price and sales frequency for each product, but, at the core, the Wilson Formula is an influencing factor. On the other hand, the DC's managed through the Wilson Formula rely on cost information such as an inventory holding rate, product and order costs, as well as forecasted demand. Inventory management decisions within this program are built according to the EOQ formula. However, there are two different ways to manage DC inventory: EOQ or through the use of Tables. It should be mentioned though that the Tables used are based on quantities which are derived from an EOQ. One deciding factor in the use of Tables is that each inventory manager is free to adjust the Tables according to products and DC. Thus, various Tables have been created in order to optimize inventory management at the DC's. If a DC is managed through the use of Tables there are two different Tables which are utilized: one to determine the economic order quantity, and the other for safety stock. When deciding the ordering point for the system, one uses the value from the safety stock Table plus the demand during lead time. The EOQ is found in the price/frequency Table or is calculated using the Wilson formula.

Order points are based on safety stock tables and forecasted lead time demand. When an inventory level drops to a predetermined order point PULS automatically creates an order to bring the inventory levels up to the previously agreed upon levels. Of course, the type of transport used to refill each DC affects the speed and amount of times the DC is refilled.

DC's which are controlled through the use of the Wilson Formula are to a large extent LDC's and SDC's. Those DC's that are controlled by Tables are NDC's. However, it is possible to adjust PULS to calculate quantities according to either formula for all DC's.

In the present situation, inventory managers at the CDC use the same order and inventory costs for all products. The standard order cost, which was set during the 1990's, is currently at 9.25 SEK, while the inventory holding cost, and also established in the 90's is at 30%. These costs are then used in conjunction with demand and product cost to calculate appropriate order quantities.[81]

An additional factor, that was highlighted, was that each inventory manager is free to choose which quantities to send as there are other factors which are not considered in the EOQ, such as transport options, how many products can be sent simultaneously, the unwillingness to break certain quantities which have already been packed and so on. Although one can rely on the computer to make decisions, it is also up to the inventory manager to have a "feeling" for the inventory situation and to either send more or less of the best order quantity suggested by PULS.

In decision making concerning transportation of goods each inventory manager tries to utilize the cheapest and most effective form of transportation to the various DC's. We were informed

[80] Note: one period is 4.33 weeks.
[81] All information concerning how PULS works in terms of EOQ, etc., has been take from the PULS handbook dated 2007-07-06

that approximately 80% of all goods sent to the US and Japan are sent automatically by boat. The remaining 20% has to be handled manually by the inventory managers, and here a decision can be made as to which form of transportation should be used. For Japan and the US the most cost effective form of transportation when only factoring in the transport cost is boat, with air freight being more expensive. Considering Istanbul, Malmö and Maastricht truck is the cheapest. We were informed that air freight is not used for dangerous goods within Europe except for Malta, Cyprus and Turkey. However, special situations do arise, such as stockouts or pending stockouts, at which time air freight is typically used, however, these situations are few and far between.

## 4.4 Process flow

The following diagram provides a picture of a typical supply chain for goods from the supplier to the CDC and then on to the distribution center. Although we have examined dangerous goods this flow is similar for all goods except for the fact that more time is needed in the handling of dangerous goods.

### *4.4.1 Purchasing*

A majority of the purchase orders are automatically sent through the system (PULS). These orders are based on different prognoses which typically are derived from sales from the previous year. The producers receive their orders from VCCS, and in turn are able to plan accordingly. The purchaser maintains steady contact with the supplier in order to acquire accurate information regarding current and future deliveries. The purpose of this job is to limit the problems that can arise when goods are late due to production failure or delayed transports.

The information flow travels in two directions, which allows the procurement manager to make last minute changes in orders according to variations in demand. On average, the procurement manager spends little to no time ordering these products, but instead monitors all flows in order take care of deviations concerning the flows.

*Spray Paint*

In examining the supply chain for spray paint, the supplier has added a restriction that orders cannot be altered within six weeks prior to delivery, thus allowing Kwasny, the supplier, to easily plan their production. This means that the average lead time for this product in this section is six weeks. The minimum quantity that Volvo has to order is 300 liters, however, when the goods are received at the CDC this amount can vary by a few liters, which according to the purchaser is negligible. When needed, the purchaser has the possibility of contacting the supplier and asking them to send goods outside the normal flow either by taking it from additional stock and sending an extra delivery or just adding it onto one of the normal deliveries, however, this only applies to restricted amounts of goods. The production facilities for this product are in Frankfurt, Germany. Due to the nature of these goods they can not be sent to the CDC through air transport. This needs to be considered when accounting for emergency orders.

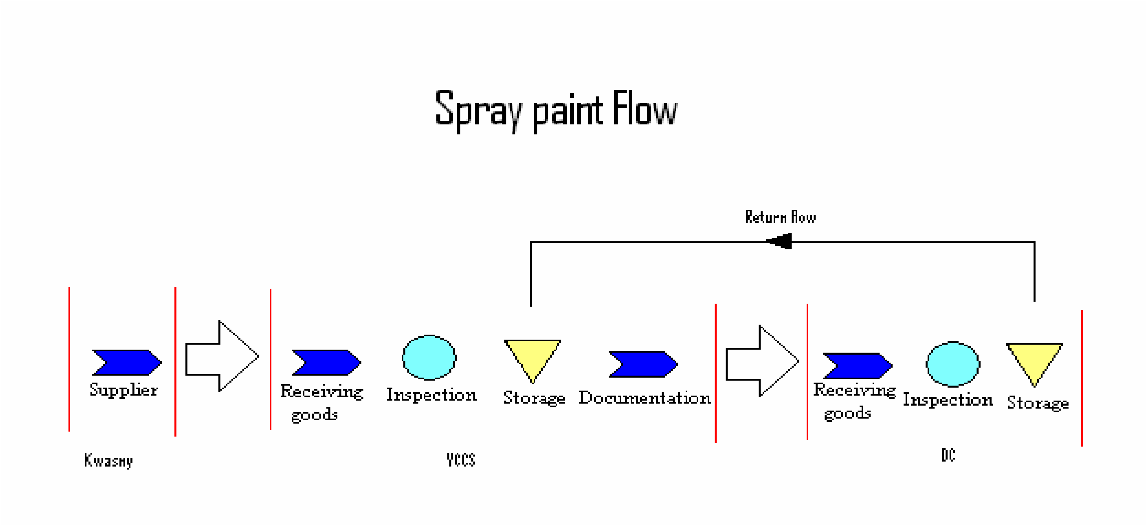


**Figure 9 Spray Paint Flow**

*Transmission Oil*
The transmission oil studied is delivered from Carpmans AB in Hjo. However, for some markets this product is sourced locally. The producer is very flexible when it comes to deliveries but it is preferred that orders not be altered within 2 weeks before delivery The minimum order quantity is 720 bottles of oil and the minimum quantity to increase the shipment after that is 120 bottles at a time, this is due to the number of bottles which one can fit onto one pallet. The procurement manager must order full pallets at all times.

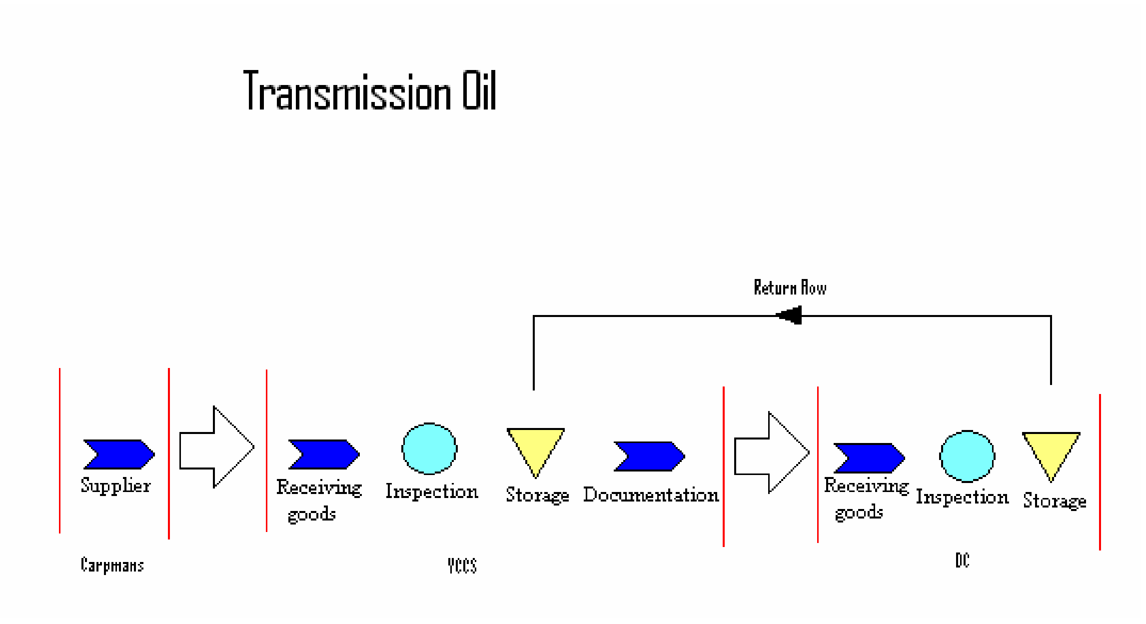


**Figure 10 Transmission Oil Flow**

*Airbags*
Prognoses and orders are sent from Volvo to Autoliv in Vårgårda and Eurobag in Kungälv. The airbags, which are produced in Vårgårda are trucked to Kungälv where they are packaged by Eurobag and then further shipped to the storage area at Svenska Airbags, also located in Kungälv. This storage area is actually an extended section of VCCS' CDC, referred to as storage area 42. The average lead time for these goods is 3 weeks, however due to the fact

that the goods are stored at Svenska Airbags, shipments to the CDC can be sent daily. The purchaser's job varies very little from the other scenarios and much of the work is monitoring the flows and dealing with deviations.

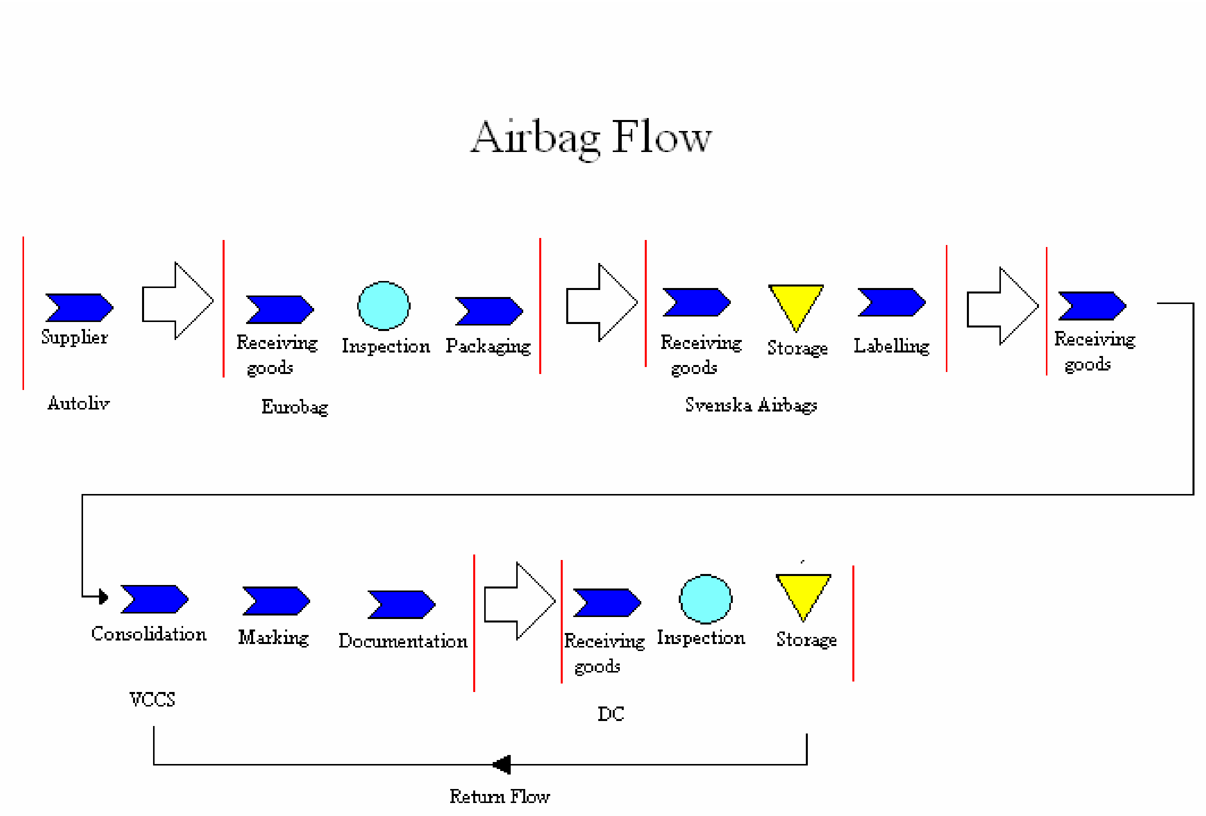


**Figure 11 Airbag Flow**

*Batteries*
A large majority of battery shipments are sourced locally either through Varta, as is the case for the US and Holland, where they are ordered directly from the producer or through the CDC. Countries with local sourcing use their own procurer to acquire goods. In general the DC's try to use the standard supplier (in this case Varta).

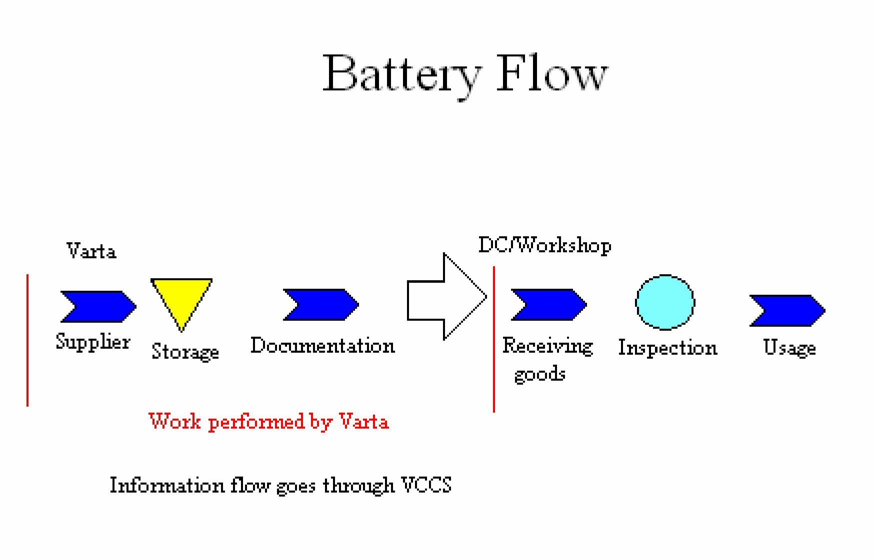


**Figure 12 Battery Flow**

*Paint pencils*
The flow of these items differs from the previous ones due to fact that they belong to Land Rover. The storage department here in Gothenburg is an NDC and the quantities handled for this brand is much smaller than Volvo's. The procurer works as both procurer and DC's manager.

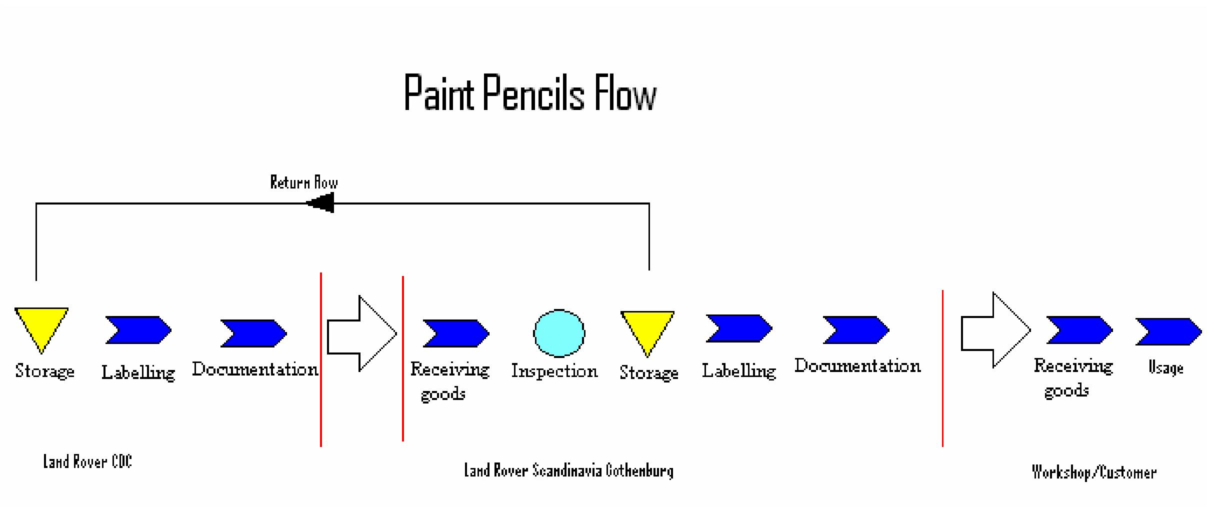


**Figure 13 Paint Pencil Flow**

*4.4.2 Delivery to CDC*
Not all goods are transported to the CDC. Some are shipped straight from the supplier to the various DC's without ever coming through the CDC, however aside from all explosive products housed in Kungälv as well as car batteries, all other products go through the CDC. The main supplier of VCCS' transports is Volvo Logistics. All goods are bought ex works meaning that Volvo arranges the pickup of these goods.

*Spray paint*
Spray paint is delivered directly from the supplier, Kwasny, in Frankfurt, Germany to the CDC in Sweden. These transports are exclusively done by truck. When needed, special arrangements can be made and the goods can then be shipped with smaller express vehicles.

*Transmission Oil*
All transports are done by truck from Hjo in Västergötland to CDC in Torslanda. This is due to the short distance between these two facilities. Shipments are sent often and therefore there is never a need for sending the goods with special express deliveries.

*Airbags*
The Airbags are stored in Kungälv at Svenska Airbags. VCCS has purchased a service from Volvo Logistics, which requires that a truck drives a specific tour twice a day. The truck starts at Eurobag where the airbags are packed, then on to Svenska Airbags to pick up the airbags or other dangerous goods housed here that have been marked and prepared for shipment to their final destination via the CDC in Torslanda.

*Batteries*
The flow of batteries varies depending on the market. The DC's in Maastricht and Atlanta never handle any car batteries as they are sent directly from the supplier in each respective country to the end customer. The DC in Nagoya is serviced directly by the local Varta supplier. Batteries are sent to the Japanese DC and then onto the final customer. The situation for Malmö and Istanbul is much the same as in Japan, as they get their batteries through the CDC, which arrive exclusively by truck.

*Paint pencils*
The customer distribution center for Land Rover is in England and the goods are mainly transported by boat to Gothenburg and further on to the DC in Arendal using truck. When needed, the goods can be delivered by airplane.

### *4.4.3 Goods received*
When the goods arrive at the CDC they are randomly checked to make sure that the supplier has sent the correct product and correct quantity. The goods are reported in PULS by the storage personal. They enter the number of goods received, and where they are stored and thereafter transport them to their correct storage location. Some goods are not stored at CDC but only cross docked.

*Spray paint and Transmission Oil*
Spray paint and transmission oil are stored in a separate part of the CDC in Torslanda. This dangerous goods area is an enhanced room with a metal door that can be quickly closed if a fire breaks out. Additional products, such as paint, chemical, and oil products are also stored in this area.

*Air Bags*
Air bags are stored at Svenska Airbags in Kungälv. This is included in the additional 46 SEK that VCCS pays for each air bag. Svenska Airbag has a fixed price for the storage of all products, which is not affected by the length of storage time of the goods.

*Batteries*
Batteries are currently stored outside the CDC in a specific location. The batteries used to be dry batteries in which the customer could add the liquid acid later on in the process, however,

today; the batteries are wet batteries throughout the entire chain, which makes them more dangerous, thus, the process of storing them on the outside perimeter of the CDC.

*Paint pencils*
Paint pencils are stored in Arendal in a small cage together with all other Land Rover spare parts.

*4.4.4 Packaging*
When the goods are shipped to the CDC in Torslanda, they are usually already packed in Volvo boxes. The packaging that takes place in Torslanda is usually only to consolidate the goods and make larger batches. It must be mentioned though that a percentage of goods must be repackaged by VCCS locally, in efforts to reduce costs from the suppliers. However, the goods studied in this thesis are not affected by this step. Most goods are transported in containers from the CDC and they are thoroughly packed in order to make sure that no goods are damaged during transport. Many of the dangerous goods shipped have quantity limitations, meaning that only a certain amount of each type of goods can be transported in each batch. These limitations vary depending on the chosen transport mode.

*Spray Paint and Transmission Oil*
Spray paint and transmission oil are stored inside the CDC in Volvo boxes and the packers go to the dangerous goods area when they need any of the specific products for their order. There are many specific limitations regarding these products in terms of maximum quantity in each box. Only 30 liters of liquid can be stored in each box so the packer needs to make a very large number of these boxes for larger orders.

*Airbags*
Airbags are packed at Eurobag and stored at Svenska Airbags as previously mentioned. When an order is sent to Svenska Airbag they mark the boxes, prepare them and send them to the CDC, where they are consolidated onto a container or other freight carrier. The packer at the CDC also “Flags”[82] the article in the system.

*Batteries*
Batteries present a unique situation for the company as the flow of these products varies depending on the market. Varta sends batteries directly to end customers which are otherwise serviced by the DC’s in Maastricht and Atlanta, meaning that the batteries are never handled by the DC leaving them free from this hassle. Nagoya receives its batteries directly from the Varta supplier in Japan, and then ships them further to the end customer. The final two DC’s, Istanbul and Malmö receive their batteries from the CDC in Göteborg. These batteries are only cross-docked at the CDC, where they are handled as all other dangerous goods, aside from the storage aspect.

Due to the fact that this supply chain is unlike the other products examined, the job of packaging and handling is greatly reduced.

*Paint pencils*
Paint pencils are packed in Land Rover caskets in Arendal before shipment. The main mode used is truck and here the goods can be transported together with other goods.

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[82] Flagging is when the goods are labeled for final destination.

*4.4.5 Order from inventory manager*
Most of the orders placed are done so automatically by PULS. The main reasons for a manual order are seasonal variations or campaigns. The inventory manager then accesses the system and alters an existing order. When needed the inventory manager is also able to place an express order and use the fastest possible mode of transportation.

*4.4.6 Packing*
The order of events for the outbound flow of dangerous goods is similar for all products leaving the CDC; however, the largest differing factor which influences this process is the form of transportation chosen. Through discussions with the various parties responsible for packing it was noted that the time taken to handle dangerous goods varies greatly depending on the order and product, but that it takes at least 20% and even up to twice as long to handle dangerous goods as opposed to normal products. When an order has been placed in PULS, it is sent to the respective packing department on the DC floor. Those who are responsible in each department print out an order list, check the PSN notebook[83] to see what each product contains, and then retrieve each item from the dangerous goods area. Although, as mentioned earlier, there is a special area for dangerous goods, some dangerous goods are still spread out among normal products in the DC, such as gas pumps, which are not included in this study.

The goods are then transported back to the packing area where they are prepared for transportation. It was, however, brought to our attention by Thomas Larsson, who is responsible, among other countries for Turkey, that if the orders are too large they are instead packed at the dangerous goods part of the DC.

Transport of dangerous goods is generally more expensive regardless of which transport method is used. However, in discussions with Stefan Lindberg, who is responsible for the purchasing of transport services from the CDC to the DC's, the transport of dangerous goods is typically 5-10% more expensive.

The way the goods are packed is based entirely on the way the products will be transported. The transport method that requires the most care is air. If goods are shipped by air they must be packed in higher quality cartons, must be weighed more precisely, and labeled with one extra sticker, which contains the name of the consignee. Furthermore, there exist weight limits on how many products can be packed together, and thought must even be given to repacking certain products (mainly oil) to meet the requirements for air transport.

The job of putting on the final labeling is performed by Mikael Olsson who is responsible for loading products that are ready for air transport onto the proper trailer. If, for some reason, these goods are not packaged as required by airport authorities they are sent back to the CDC to be repacked, thus causing extra costs in time and money. One activity that is similar to all transport methods is the labeling of boxes. Each box for dangerous goods must have a warning sticker (picture), UN number sticker, address label, and the weight of the products must be written on each box.

Then next most regulated transport method is boat. Here, there are special regulations as to how the goods must be packed; however, the type of packaging and amount of labeling is less than when shipping by air. Furthermore, the weight of each box can be calculated automatically through PULS, as opposed to the manual procedure which must be done when

[83] This notebook contains packing instructions, UN numbers, as well as product content information.

goods are flown. But, the process of picking and packing is the same as described above. Again, there is less emphasis placed on the actual packing and how the goods are placed in the container as the rules are not as stringent for dangerous goods.

Lastly, if goods are to be sent by truck they can be packed as they are done when being sent by boat. Here, the rules are not as strict as with air or boat. One factor, that was identified, was that dangerous goods are usually separated either in containers or trailers in order to make the process of customs clearance easier. However, only goods that are sent by truck within Sweden are packed according to truck packing instructions as shipments to Turkey and Holland travel by ferry, thus making them susceptible to ocean going freight regulations.

When goods are packed and labeled for final destination they are reported in PULS, which then notifies those who are responsible for moving the goods into the shipping areas and then onto trailers or into containers. The time spent filling trailers and containers can take anywhere from 20 minutes to an hour depending on different factors.

*4.4.7 Documentation*

Before the goods can be shipped abroad they must be properly documented. Depending on transport method and destination there are different people involved. Mats Hermansson is responsible for document handling for goods sent by air to the US, air and boat to Japan, and lastly air and road to Turkey. For goods sent by boat to the US, Monica Lindell is required to handle the proper documentation. Holland and Sweden are prepared by those who pack the trucks, as the work load can be handled by the packers. Although the time spent with this portion of the dangerous goods chain varies it can take up to four times as long to handle documentation for dangerous goods.

Additional responsibilities for these coordinators are arranging transport to the final destinations, documentation of the goods, and verifying that everything is correct with number or articles, labeling, etc. before the goods are sent out. According to Monica Lindell she needs to have sent all paper work to Maersk or NYK at the latest on Thursday the week before the goods are to be sent to Atlanta. This means that the paper work is sent out 9 days before the goods are to be shipped from the harbor in Gothenburg. These goods have already cleared customs in Sweden and should not have to be declared in the US.

One job that the transport coordinator must do before goods are shipped by air is to visit the DC floor and physically inspect all of the goods to verify that they have been packed and labeled correctly, as well as to double check the weights of each package to insure that it is the same as on the documentation. This is done this in cooperation with Mikael Olsson who is responsible for loading all trailers for air transport.

*4.4.8 Transport out/Delivery from CDC to DC/Customs clearance*

Once the goods have been packaged and packed onto the respective modes for transport they are then reported to the Export Coordinators, who begin the process of filling out the paper work needed for dangerous goods.

When the goods have received proper documentation they are sent by road, either to the harbor in Gothenburg (transport from the CDC to the harbor is 1 day plus up to 5 days in waiting), Landvetter airport (1 day for Japan, and 2 days for the US) in Gothenburg, or by road to Turkey (10 days), Holland, and Sweden (1 day respectively). Goods which will be flown abroad are first trucked to Landvetter Airport and then consolidated and re-routed to another airport in Europe, typically Copenhagen, Frankfurt, or Amsterdam. From these airports the goods are then flown to the country of final destination.

If the goods are to be sent by boat they travel either with Maersk or NYK. The goods are moved from the Gothenburg harbor by feeder boat to a larger European harbor and from there, either to Charleston (US) or Port of Nagoya (Japan). The times for these trips are 22 and 32 days respectively. Upon arrival at the port of entry in each country the goods are then moved by truck to the NDC's. This trip takes an additional day when arriving in the country by both boat and air, if everything runs smoothly with customs; however delays at customs of up to two to three days are not uncommon.

*4.4.9 Transport in/Goods received*

When goods arrive at the DC's they are checked so that they have not been damaged, that the correct articles were sent, as well as the correct number of articles. Furthermore, each DC is responsible for printing out "safety data sheets" for all products (4 such sheets in Maastricht) which inform handlers to product contents, and safety information.

*Unpacking/checking/binning/reporting*

The process of unpacking the goods is the same as at the CDC however in reverse order. According to Luis Dorta in Atlanta and Jeffry Boessen in Maastricht goods such as airbags, seatbelts, and fuel pumps come as individual pieces meaning that they can be placed directly on the shelves or binned, while all other dangerous goods come in boxes, which need to be unpacked and then binned. There is no difference in handling these products than any other products according answers from the five different DC's. When the goods have been binned they are reported in PULS, thus completing the supply chain to the DC's.

An additional factor, which must be considered, in this part of the supply chain is that of storage. Dangerous goods must be separated from the rest of the products for safety reasons. In discussions with Kai Lindstam at the DC in Malmö dangerous goods occupy two separate rooms as well as a container. The dangerous goods section of the Atlanta DC is approximately 21 $m^2$ or 5% of the warehouse. Japan has an area of approximately 30 $m^2$ or not even 1% of total space, which is similar to the situation in Maastricht where they have a dangerous goods storage area of approximately 80 $m^2$ or less than 1%. At present, the NDC in Istanbul does not have a dedicated dangerous goods area, but they were able to inform us that dangerous goods account for approximately 2.5% of the goods stored at the DC.

*Lead times*

The following lead times were obtained through interviews with the export coordinators and inventory managers. These times are based on the entire process from when an order is placed in PULS until the product arrives on the shelves at the various DC's. The process is split up into the following steps.


**Figure 14 Lead Time Stages**

- Air to Japan approximately 4 days
- Boat to Japan approximately 55 days
- Air to Atlanta approximately 4 days
- Boat to Atlanta approximately 40 days
- Truck to Istanbul approximately 45 days
- Air to Istanbul approximately 7 days
- Road to Maastricht approximately 4 days
- Road to Malmö approximately 4 days

*4.4.10 Reverse logistics*

Reverse logistics for dangerous goods does not exist for export markets. Occasionally goods may be brought back to the CDC from European DC's, however it is understood that the cost of doing this is very expensive and therefore this practice tends to be avoided. In our study the only object that is present in the reverse supply chain are pallets and collars.

# 5. Analysis

*All processes generate a cost, which we intend to map with consideration to place and size. These different flows generate several different costs during the supply chain. We have focused on mapping all costs associated with the handling of some specific products classified as dangerous goods. Following is the result of our study at VCCS. The costs have been sorted according to which product they belong to.*

## 5.1 Deliveries to the CDC and storage of goods

*5.1.1 Airbags*

VCCS has a contract with Autoliv, making them the primary handler of VCCS' airbags and seat belt tensioners. VCCS pay an additional cost on the purchase price for each product, which includes the packaging, storing and marking of all of these goods. Autoliv, Eurobag and Svenska Airbag work together in this process and Autoliv charges VCCS for this service. An additional activity, which is not included in the initial price to Autoliv, is that of inventory checks. VCCS is in constant contact with Svenska Airbag, who in turn completes manual inventory checks upon orders from the CDC. When demanded, the goods are delivered via truck that exclusively travels on a fixed route, transporting nothing but goods from Eurobag to Svenska Airbags and further on to the CDC. This truck is a service purchased from Volvo Logistics. When the goods arrive at the CDC they are flagged in the computer system and marked with an extra sticker which shows where the goods will be delivered. The freight is then loaded on to a container or other load carrier. The performance time for each of these activities at the CDC takes only a few minutes per article. The goods are normally not stored at the CDC, but can be there for a short time while being prepared for shipment.

- Cost for storage, packaging and marking: 46 SEK / Article
- Cost for truck on fixed route, transporting goods to CDC: 1 MSEK per year
- Cost for inventory checks:
- Flagging the goods and loading on next transport(1-2min/art):

*5.1.2 Spray paint/ Transmission Oil*

The transport of spray paint from Frankfurt to the CDC is also purchased from Volvo Logistics. The flow of transmission oil is the same as spray paint; however the goods are shipped within Sweden. The goods are transported in Volvo cartons to the CDC, where they are randomly checked and reported into the system. The goods are thereafter transported to their proper storage area, in this case the dangerous goods area. The goods are stored there together with other chemical products.

- Cost of transporting the goods to the CDC:
- Cost of randomly checking the goods:
- Cost of transporting the goods to storage location:
- Cost of storing the goods in secure facility:

After discussing these costs with Crister Spång we were informed that together they equal approximately 25%: inbound logistics is approximately 9% which is made up of Volvo packaging (pallets and frames), an air freight factor, unloading, and inspections and binning, an additional 15% comprises inventory charges plus picking.

*5.1.3 Batteries*

The flow of batteries varies greatly depending on where they are to be delivered. Most of the flows that we have examined concerning batteries do not go through the CDC, but are delivered straight from the supplier to the NDC or LDC or even directly to the end customer. This, however, is not always the case as many batteries are in fact delivered first to the CDC where they are cross-docked en-route to their final destination. This creates a problem when examining costs for this supply chain in our thesis, as the costs are not very high. The flow of goods from the supplier to Turkey and Malmö goes through the CDC, but otherwise the flow goes straight to the various DC's from a local supplier or the closest Varta facility. Atlanta, Nagoya and Maastricht get their batteries from Varta. When the goods are delivered to the CDC from the supplier, Volvo Logistics is hired for the transport. The batteries are not stored in the DC, and are delivered to the CDC when needed for an order. The batteries are flagged and consolidated with the other goods.

- Cost of Transport to the CDC:
- Cost of flagging and consolidating the goods(2-3min/art):

After discussing these costs with Crister Spång we were informed that together they equal approximately 25%: inbound logistics is approximately 9% which is made up of Volvo packaging (pallets and frames), an air freight factor, unloading, and inspections and binning, an additional 15% comprises inventory charges plus picking.

*5.1.4 Paint pencils*

The pencils are shipped together with larger shipments, usually in containers on boats from England. The pencils take up so little space so the main cost factors are the handling when they are picked, packed and unpacked.

- Cost of transporting the goods:
- Cost of handling the goods in England and Sweden (5-8min/art):

### 5.2 Deliveries from the CDC to the DC's and storage of goods

When an order is placed by an inventory manager at the CDC it is placed in a queue in PULS. The order is then pulled out by a packer on the DC floor and prepared. First, the packer must retrieve the goods from somewhere within the DC, however, most of the dangerous goods are located within the special area designated for these goods. The goods are then brought back to the different packing areas, depending on which DC the products will be sent. Each product contains a PSN which must be checked against packing instructions located in a folder in each packing area. When the packing instructions are understood, the packer can begin the process of packaging the dangerous goods according to the instructions for transport method. These packing methods differ if the goods are to be sent by air, road, or boat. When the products are packed they must be marked as dangerous goods, weighed and marked with weight, as well as receive an address label. The goods are then left for the next person in the supply chain who will move the goods onto the assigned container or trailer. An additional activity that occurs only when goods are being air freighted is that the export coordinator must come and verify the weights of each carton as well as that the labeling has been done correctly. Although we examined only a few items this routine is followed for all dangerous goods that are stored at the CDC.

- Cost of internal transport:
- Cost of packing goods (cartons, labels, etc. varies for each transport method):

- Costs of handling the goods:
- Cost of time for export coordinator to come and double check when goods are air freighted:
- Cost of document handling:

The first three cost components are included in the 25% that VCCS uses as an inventory handling cost. The last two costs have been estimated based on interviews with export coordinators and are based on time spent during these activities. In handling dangerous goods, export coordinators spend 200-400% more time than if they were to handle non-dangerous goods.

When the goods have been placed on the appropriate trailers or containers they can be further transported to either the airport, harbor, or direct to the next DC via truck. The export coordinators are responsible for arranging transport to the various DC's. It is up to each inventory manager to decide the transport method, however, approximately 10-20% of all goods are sent by air. Upon arrival at the airport dangerous goods are again checked by DGM which accounts for an additional cost. However, if the goods are sent by boat or road they do not need to go through this extra check. A break down of these costs per method of transport is presented below in Table 1.

| DC | Air | Boat | Truck | Dangerous Goods Checks (DGR) |
|---|---|---|---|---|
| **Nagoya** | 14.30 SEK/kg | 4990 SEK | N/A | minimum 750 SEK |
| **Atlanta** | 15.50 SEK/kg | 18400 SEK | N/A | minimum 1750 SEK |
| **Maastricht** | N/A | N/A | 1284 Euro (FTL) | N/A |
| **Istanbul** | 17.20 SEK/kg | N/A | 350 EUR | 1350 SEK |
| **Malmö** | N/A | N/A | 3000 SEK (FTL) | N/A |
| Cost of time goods spend in transit: 3.5 MSEK per year for all products combined | | | | |

**Table 1Transport Costs**

These costs vary according to needs at the local level. In a perfect world all inventory management procedures work and the cheapest transport alternative can be used, however we understand that this is not always the case. Consideration should be given, however, to the fact that aside from the cost of air transport being more expensive, DGR checks are routine at the airport, which had an entirely new cost element.

Upon arrival at the DC's the goods are randomly checked and reported into the system. The goods are thereafter transported to their storage area which typically is a dedicated dangerous goods area. The goods are stored there together with other chemical products.

- Cost of randomly checking the goods:
- Cost of transporting the goods to storage location:
- Cost of storing the goods in secure facility:
- Cost of printing safety sheets:

This area has been outside of the range of our study, but it should be examined by those with decision making powers within VCCS. In exploring the total costs of the supply chain these costs effect different strategies. We assume that there should be a similar inventory holding cost to the one used at the CDC (approximately 25%).

## 5.3 Activity costs and how they affect EOQ

In its simplest form goods are taken from inventory at an even level and then can be replaced almost at the same time as an order is placed. However, demand is hard to forecast and it is therefore vital that companies protect themselves against stock outs, and therefore introduce safety stock into their inventories.

VCCS bases its economic order quantities on practices derived from the use of either the Wilson Formula or order Tables, which in turn have their base in the Wilson Formula. This practice is acceptable for the inventory management principles at VCCS mainly due to the fact that they are replenishing DC's with ready made spare parts. Additionally, the company assumes that there is a fairly even demand pattern, and that when inventory levels have reached an order point new products can be shipped, which in theory, arrive when they are needed at the DC. If, for example, VCCS produced the parts and sent them continuously out to the DC's a different order quantity formula might be more acceptable, however because product parts are complete and can bring inventory levels to the right level economic order quantity at once, the use of Wilson Formula principles are functionally sound for this type of organization.

The inventory management practices exercised within VCCS today rely on costs which were calculated 10-15 years ago. Much has happened during this time which can have affected these costs, mainly order costs, causing either an increase or a decrease in the 9.25 SEK which is used today. Because of the fact that inventory managers base their decisions on figures that do not reflect the true costs of handling dangerous goods, occasionally incorrect decision are made as to the most economic order quantities.

EDI and other forms of electronic order handling have become more prevalent in the company since the advent of this cost. Furthermore, assigning one order cost to cover all costs is quite dangerous as all orders are not handled in the same fashion. It is understandable that a company the size of VCCS has used a generic cost to make calculations cheaper; however the use of a generic cost does not provide the right foundation for sound inventory management decisions. This is much the same as comparing apples to pears.

As discussed earlier in the thesis the Wilson Formula is calculated using the following formula consisting of demand, order cost, product cost, and lastly storage cost.

After mapping the flows and the costs of the spare parts at VCCS we discovered that the cost which had the greatest difference between regular and dangerous goods was order cost. The handling of related documentation as well as the packing of goods is more complex and more time consuming than the same procedure for normal goods. The cost of shipping the goods is also several times higher due to the safety procedures needed in order to ensure a controlled transport through different countries using different modes.

The holding cost may also be higher for dangerous goods due to the increase of work needed to pack the items in a correct way.

In order to determine the best way of shipping goods in specific batch sizes, several methods can and currently are used at VCCS. VCCS currently uses Tables which can be individually altered in order to fit specific markets with different needs. The Wilson Formula is also used in its more natural form with different articles and various DC's, as well as serving as a distant base for the Tables used in PULS.

We will focus on the Wilson Formula in order to compare the results of altering the order cost. The order cost has a default setting in the business system PULS used at VCCS today, which according to our calculations and observations, is very low number.

When looking at the total cost from a Wilson perspective it easy to see that total costs have a very visible low point before they begin to steadily rise. This is the shape of the graph when the batch sizes increase (See Figure 15).

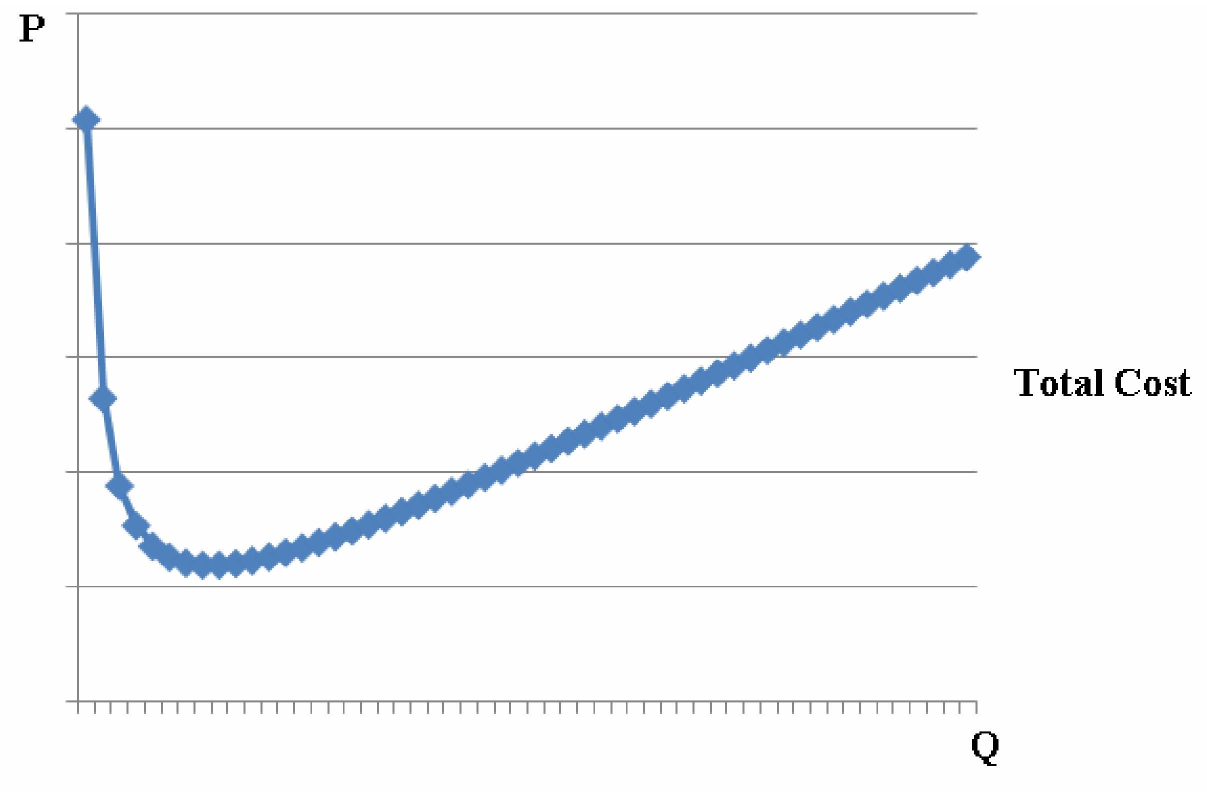


**Figure 15 Total Cost**

When using the Wilson Formula it is easy to see that they alter differently depending on which variable is changed. When comparing normal goods and dangerous goods it is easy to see that the cost of handling the goods is in general much higher. Though the results from our activity based costing varies, in some scenarios we have observed that the order cost increases due to different reasons, and in the same scenarios we have also seen that the storage inventory cost has decreased. When the inventory cost is increases, the batch sizes start to decrease according to the Wilson Formula (See Figure 16).

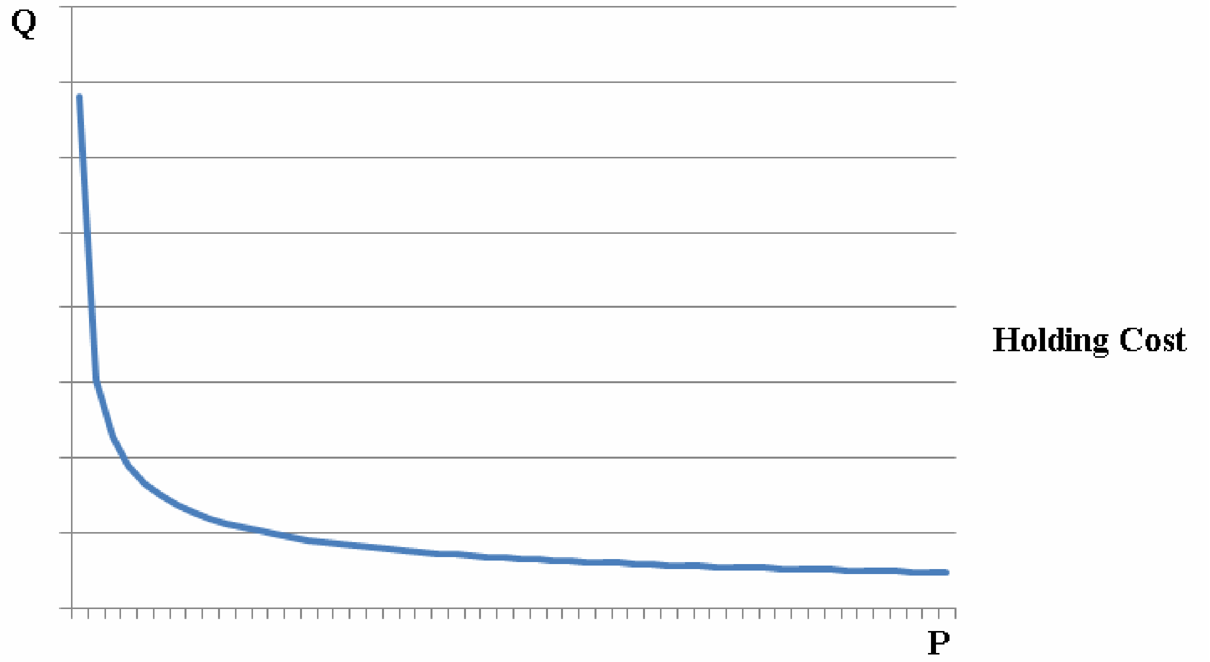


**Figure 16 Inventory Storage Cost**

This is the opposite of what happens when the order cost is increased. When we increase the order cost in order to compare it with the order cost of shipping normal goods we see that the recommended batch sizes increase (See Figure 17).

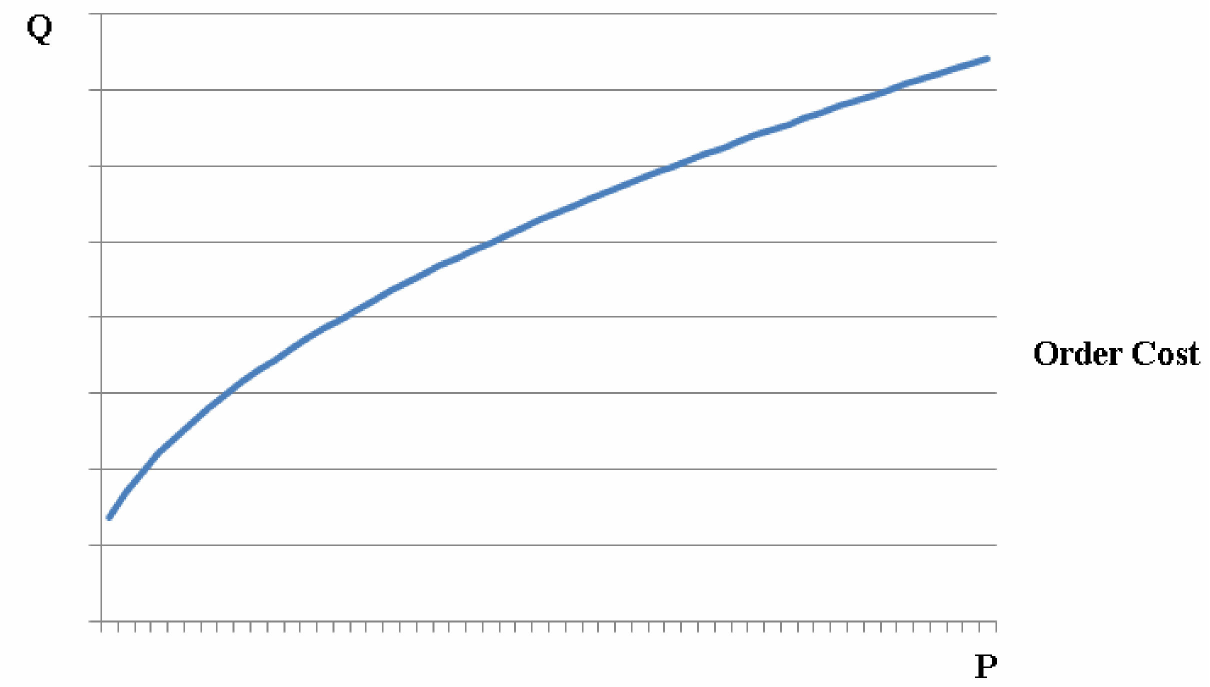


**Figure 17 Order Cost**

When comparing both of these results we see that when the order cost is increased it is easy to assume that the storage inventory cost should be decreased which leads to an even larger difference in batch sizes. For instance when VCCS uses Autoliv, Svenska Airbags and Eurobag to store and pack the airbags and similar equipment they pay a fixed price of 46 SEK for this service. This increases the product cost but at the same time decreases the inventory storage cost. When the product cost is increased the recommended batch sizes from the Wilson formula is decreased. (See figure 18)

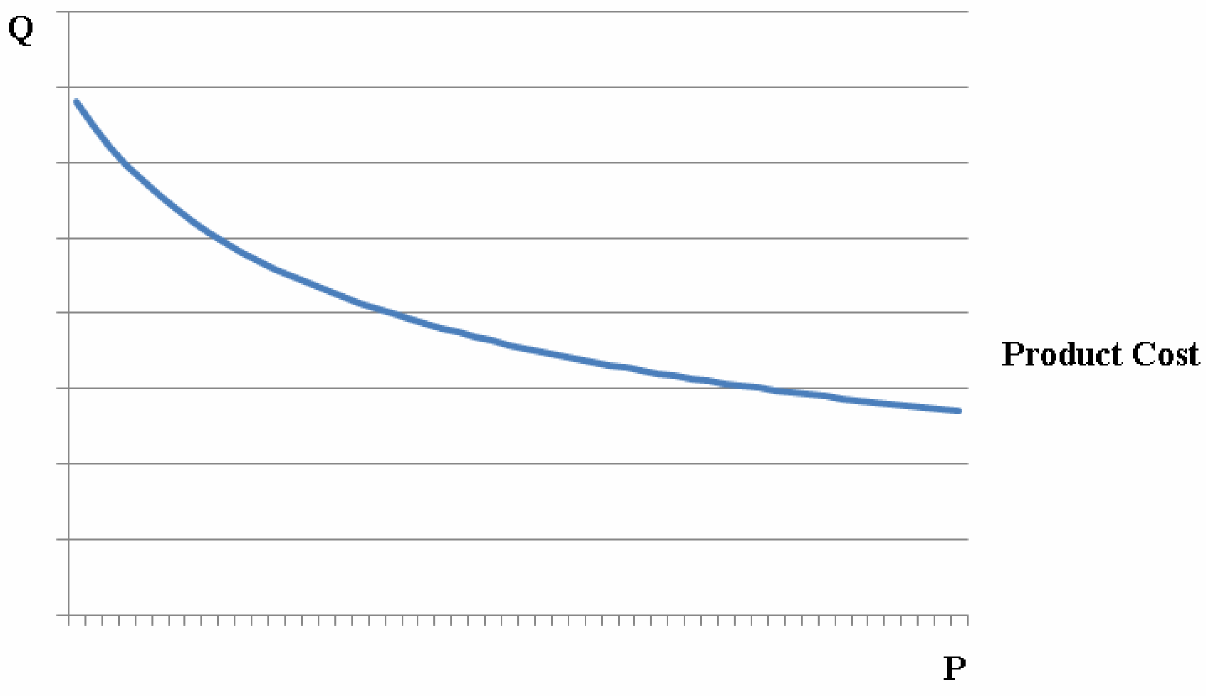


**Figure 18 Product Cost**

We would also argue that order costs are greatly influenced by the decision to transport dangerous goods, in addition to the transport method chosen. Because of the increase in handling procedures, transport costs, knowledge needed to handle dangerous goods, safety regulations, and document handling order costs increase with the shipment of dangerous goods. This in turn should affect the optimal order quantity.

In our calculations concerning optimal order quantities we have not considered that transport costs or DGR checks which are mandatory when shipping by air. We have, however, noted that handling goods that are to be shipped by air require more attention in packing, as well as more expensive packaging. Furthermore, there is an extra cost in that Mikael and Mats have to do extra work with the shipment in double checks and extra stickers. This is not a problem, but consideration should be given to these factors when deciding upon using air as a transport method.

In gauging DGR checks we found that the cheapest check in the flows analyzed was 550 SEK when air freighting to Turkey, while the most expensive was 1750 SEK when air freighting to Atlanta. Aside from these costs, air transport is typically more expensive. The plus side though is the fact that the goods have a shorter lead time than if another form of transportation is used. However, it is important to consider DGR checks and to add them in some way into the equation when deciding upon order quantities and transport methods.

During the mapping of the supply chain we have compiled a list of activities and resources that revolve around the distribution of dangerous goods. Many of these activities exist even for non-dangerous goods, however extra consideration should be placed on the amount of time and supplies that are utilized during the handling of dangerous goods. We have therefore, decided to steer away from the purchasing and inbound logistics part of the supply chain as there appears to be nothing in these operations which affect the best order quantity from the warehouse management end. Certain activities, such as extra documentation and double checks for proper weighing and packaging/labeling are affected by the fact that goods being shipped are considered dangerous. Additionally, there are added costs associated with double checks at the airports. The chart below is an attempt to establish the activities and resources that are consumed within the supply chain at VCCS from the time that an order is placed to a DC. With access to additional information the costs can be derived through taking the total monetary amount of resources divided by the cost drivers. With this knowledge, proper costs can be established for the different activities. Through discussions with personnel involved in the supply chain we have attempted to estimate costs for each activity based on time spent working with orders. The activities described the following chart are much the same for all products. Those costs which are specific to dangerous goods are:

- Extra documentation work for the export coordinators.
- Extra work for the export coordinators in examination of goods.
- More expensive transports.
- Extra checks at the airport.
- More expensive packaging.
- More time spent in handling the goods by personnel on the DC floor.

We feel that the extra time spent with each product as well as the better packaging should be reflected in a new order cost which in our best estimation can be derived from costing the following activities (See Figure 19).

| Resources | Activities | Cost Drivers |
|---|---|---|
| Computer/Personnel/ Supplies | Placing an order (PULS/Inventory manager) | Number of orders |
| Computer/Personnel/ Supplies | Printing the order (Floor) | Number of orders |
| Personnel | Read manual for handling instructions (Floor) | Number of different dangerous goods on order |
| Truck/Personnel | Retrieving the goods (Floor) | Number of products to retrieve |
| Personnel/Supplies | Packing the goods (Floor) | Number of products to pack and transport method |
| Personnel/Supplies | Weighing the boxes (Floor) | Number of finished boxes and transport method |
| Truck/Personnel | Loading the goods (Floor) | Number of finished cartons/pallets |
| Computer/Telephone/ Personnel/Supplies | Export documentation (Export Coordinator) | Number of orders |
| Personnel/Supplies | Extra dangerous goods sticker (for air) (Mikael) | Number of finished cartons/pallets |
| Personnel | Double checking weight of goods (for air) (Export Coordinator) | Number of finished boxes transported by air |
| Personnel | DGR check at airports/even road to Istanbul | Number of finished boxes transported by air |

**Figure 19 ABC Costing**

We do not feel that product costs (C), storage cost (I), or demand are affected by the dangerous goods (except for airbags), but instead the extra costs that arise when a decision is made to ship dangerous goods are those that fall under order costs (S).

For inventory managers at VCCS optimal order quantities are derived from either Tables or the use of the Wilson Formula. Because we were provided EOQ, product costs, and inventory holding costs we have been able to calculate present order costs for these products. The two major costs associated with inventory management, inventory holding and order costs, at present, are 30% and 9.25 SEK respectively, and through PULS we have been provided the following EOQ for each product. However, it should be noticed that due to various factors order costs do not match 9.25 SEK, but instead vary greatly from DC to DC (See Table 2).

| DC | PARTNO | DESCR | Forecast | STDPRICE SEK | EOQ | Holding Rate/month | Order Cost |
|---|---|---|---|---|---|---|---|
| 21/Maastricht | 30631444 | AIRBAG MODULE | 17,5 | 823,45 | 4 | 0,03 | 9,41 |
| 42/Atlanta | 30631445 | AIRBAG MODULE | 15,4 | 823,45 | 7 | 0,03 | 32,75 |
| 61/Nagoya | 8686707 | AIRBAG MODULE | 1,6 | 886,6 | 1 | 0,03 | 6,93 |
| 1B/Malmö | 30631445 | AIRBAG MODULE | 1,8 | 823,45 | 1 | 0,03 | 5,72 |
| Istanbul | 30754337 | AIRBAG MODULE | 0,9 | 3854,94 | 1 | 0,03 | 53,54 |
| | | | | | | | |
| 21/Maastricht | 30772227 | BATTERY | 0 | 636,75 | 0 | 0,03 | N/A |
| 42/Atlanta | 30772236 | BATTERY | 0 | 702,48 | 0 | 0,03 | N/A |
| 61/Nagoya | 30772222 | BATTERY | 1246,7 | 449,35 | 288 | 0,03 | 373,70 |
| 1B/Malmö | | BATTERY | 0 | 0 | 0 | 0,03 | N/A |
| Istanbul | | BATTERY | 0 | 0 | 0 | 0,03 | N/A |
| | | | | | | | |
| 21/Maastricht | 1161745 | TRANSMISSION OIL | 132,7 | 39,53 | 50 | 0,03 | 9,31 |
| 42/Atlanta | 1161540 | TRANSMISSION OIL | 1072,7 | 33,45 | 248 | 0,03 | 23,97 |
| 61/Nagoya | 1161540 | TRANSMISSION OIL | 490,5 | 33,45 | 113 | 0,03 | 10,88 |
| 1B/Malmö | 1161540 | TRANSMISSION OIL | 186,5 | 33,45 | 63 | 0,03 | 8,90 |
| Istanbul | 1161521 | TRANSMISSION OIL | 113,5 | 32,03 | 80 | 0,03 | 22,64 |
| | | | | | | | |
| 21/Maastricht | 9437545 | SPRAY PAINT | 30,3 | 22,27 | 32 | 0,03 | 9,41 |
| 42/Atlanta | 9437284 | SPRAY PAINT | 10,7 | 22,27 | 20 | 0,03 | 10,41 |
| 61/Nagoya | 9437284 | SPRAY PAINT | 0 | 22,27 | 0 | 0,03 | N/A |
| 1B/Malmö | 9437208 | SPRAY PAINT | 22,6 | 11,67 | 38 | 0,03 | 9,32 |
| Istanbul | 9437471 | SPRAY PAINT | 0 | 66 | 0 | 0,03 | N/A |

**Table 2 Present Order Costs Dangerous Goods**

After calculating these costs we were curious as to what the order costs were on average for each of the examined DC's. When we gauged these numbers we received the following results (See Table 3).[84]

| Warehouse | Highest Order Cost | Lowest Order Cost | Number of Dangerous Goods | Average Order Cost |
|---|---|---|---|---|
| Nagoya | 373,70 kr | 0,10 kr | 235 | 9,25 kr |
| Atlanta | 186,37 kr | 0,05 kr | 468 | 13,21 kr |
| Maastricht | 372,67 kr | 0,27 kr | 837 | 17,28 kr |
| Istanbul | 143,79 kr | 0,78 kr | 69 | 20,58 kr |
| Malmö | 249,77 kr | 3,74 kr | 625 | 14,78 kr |
| average | 265,26 kr | 0,99 kr | 447 | 15,02 kr |

**Table 3 Average Order Costs Dangerous Goods**

Upon calculating these averages order costs for dangerous goods we did a further breakdown in order to graphically display how many of the products have unusually low order costs. The following graphs show our results for each.

[84] Note: In doing these calculations we disregarded all costs equal to zero.

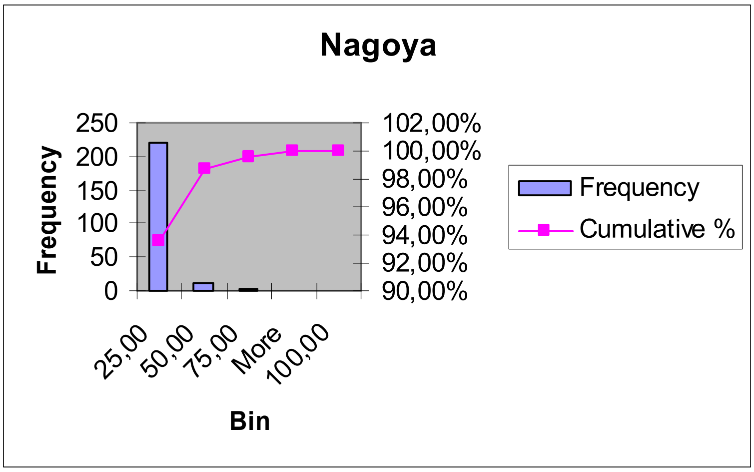


Figure 20 Order Costs Nagoya

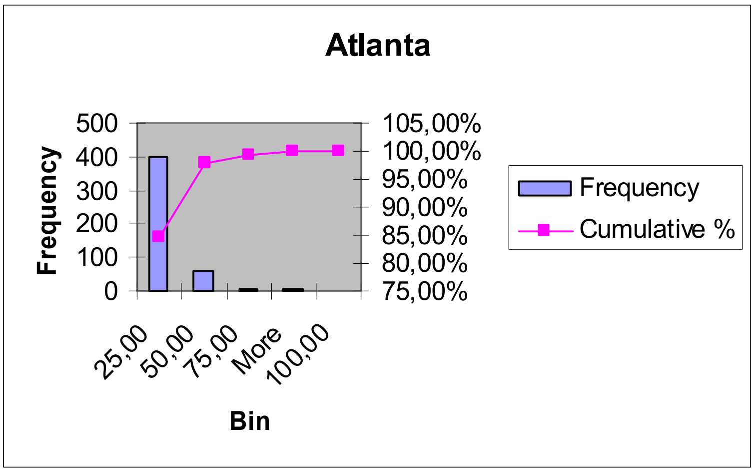


Figure 21 Order Costs Atlanta

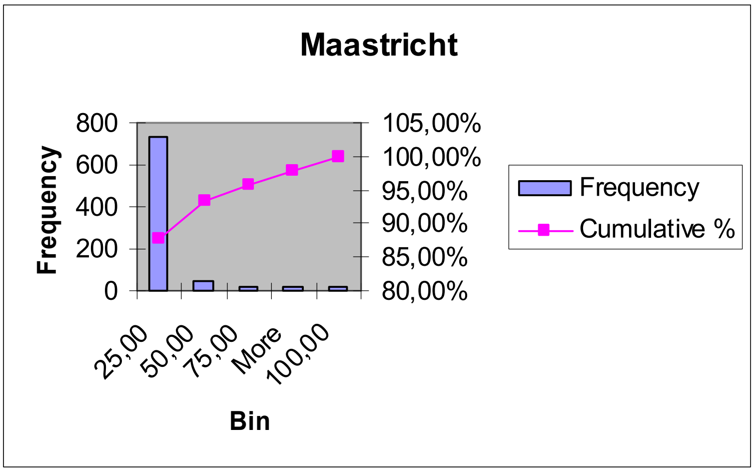


Figure 22 Order Costs Maastricht

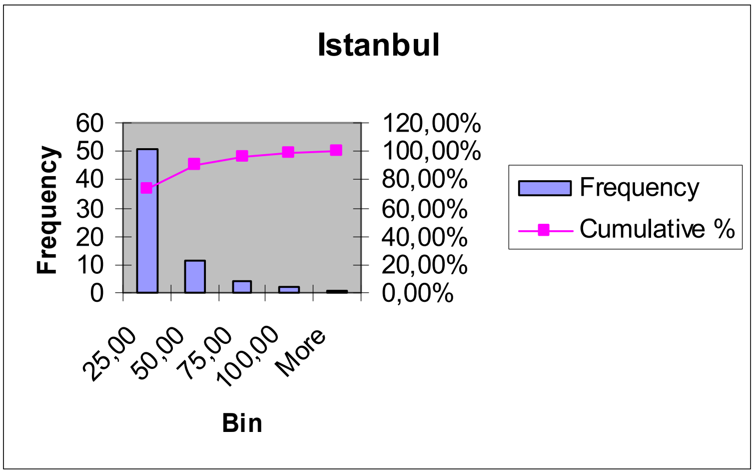


**Figure 23 Order Costs Istanbul**

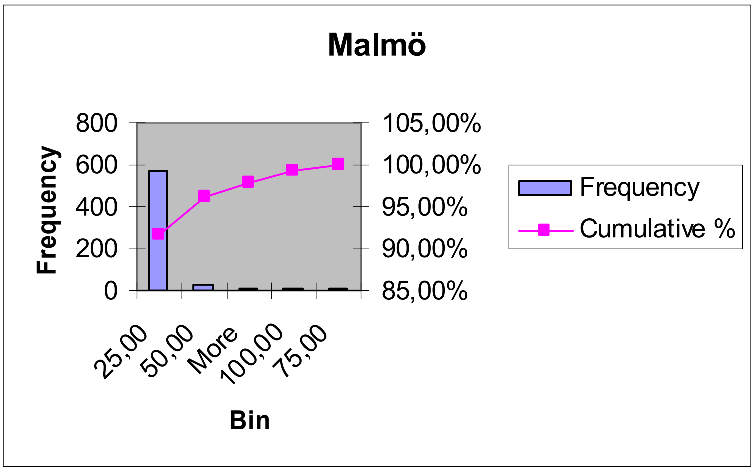


**Figure 24 Order Costs Malmö**

A striking fact from these numbers is that in almost all cases closer to 90% of the order quantities are based on order costs of less than 25 SEK. Furthermore, only 2% of the product order quantities are based on order costs larger than 100 SEK. We will later show that 100 SEK is closer to an actual order cost as calculated through the different activities involved in handling and transporting dangerous goods at the CDC, and based upon this higher order cost, theoretically, greater order quantities should be experienced.

As was mentioned previously PULS, today, does not consider the extra work required for the transport of dangerous goods, for both documentation and packaging of goods. The order cost used in inventory management decisions does not provide an accurate picture of the time and effort spent on each order decision. Therefore, a new order cost is suggested here thus providing a more factual picture when making decisions concerning order quantities. The calculations leading to our order cost are presented in the appendix (Table 5), while the EOQ's are presented in Table 4. The new cost that we have calculated is 140 SEK. We understand that this is a very general cost, and consideration should be given to the fact that there should be a unique order cost for each product, for each transport method, and for each DC. It was noted that if goods are to be flown an extra DGR check must be covered with a minimum cost for the flows studied being 550 SEK. Our study shows the effects of an increase in workload surrounding dangerous goods, and how this extra effort should be apparent in order costs, but does not take into consideration the DGR checks associated with air transport. With this new cost one can see that order quantities increase to the following (See Table 4).

| DC | DESCR | Forecast | PRICE SEK | EOQ | Holding Rate/month | old order c | new order | new EOQ | Difference |
|---|---|---|---|---|---|---|---|---|---|
| 21/Maastricht | AIRBAG MODULE | 17,5 | 823,45 | 4 | 0,0042 | 1,57 | 94 | 31 | 27 |
| 42/Atlanta | AIRBAG MODULE | 15,4 | 823,45 | 7 | 0,0042 | 5,46 | 94 | 29 | 22 |
| 61/Nagoya | AIRBAG MODULE | 1,6 | 886,6 | 1 | 0,0042 | 1,15 | 94 | 9 | 8 |
| 1B/Malmö | AIRBAG MODULE | 1,8 | 823,45 | 1 | 0,0042 | 0,95 | 94 | 10 | 9 |
| Istanbul | AIRBAG MODULE | 0,9 | 3854,94 | 1 | 0,0042 | 8,92 | 94 | 3 | 2 |
| | | | | | | | | | |
| 21/Maastricht | BATTERY | 0 | 636,75 | 0 | 0,025 | N/A | 0 | 0 | 0 |
| 42/Atlanta | BATTERY | 0 | 702,48 | 0 | 0,025 | N/A | 0 | 0 | 0 |
| 61/Nagoya | BATTERY | 1246,7 | 449,35 | 288 | 0,025 | 62,28 | 0 | 0 | -288 |
| 1B/Malmö | BATTERY | 0 | 0 | 0 | 0,025 | N/A | 0 | 0 | 0 |
| Istanbul | BATTERY | 0 | 0 | 0 | 0,025 | N/A | 0 | 0 | 0 |
| | | | | | | | | | |
| 21/Maastricht | TRANSMISSION OIL | 132,7 | 39,53 | 50 | 0,025 | 1,55 | 134 | 190 | 140 |
| 42/Atlanta | TRANSMISSION OIL | 1072,7 | 33,45 | 248 | 0,025 | 4,00 | 134 | 586 | 338 |
| 61/Nagoya | TRANSMISSION OIL | 490,5 | 33,45 | 113 | 0,025 | 1,81 | 134 | 396 | 283 |
| 1B/Malmö | TRANSMISSION OIL | 186,5 | 33,45 | 63 | 0,025 | 1,48 | 134 | 244 | 181 |
| Istanbul | TRANSMISSION OIL | 113,5 | 32,03 | 80 | 0,025 | 22,64 | 134 | 195 | 115 |
| | | | | | | | | | |
| 21/Maastricht | SPRAY PAINT | 30,3 | 22,27 | 32 | 0,025 | 1,57 | 134 | 121 | 89 |
| 42/Atlanta | SPRAY PAINT | 10,7 | 22,27 | 20 | 0,025 | 1,73 | 134 | 72 | 52 |
| 61/Nagoya | SPRAY PAINT | 0 | 22,27 | 0 | 0,025 | N/A | 134 | 0 | 0 |
| 1B/Malmö | SPRAY PAINT | 22,6 | 11,67 | 38 | 0,025 | 1,55 | 134 | 144 | 106 |
| Istanbul | SPRAY PAINT | 0 | 66 | 0 | 0,025 | N/A | 134 | 0 | 0 |

**Table 4 New Order Costs and EOQ’s Dangerous Goods**

As can be seen from the information above (table 3), the economic order quantities increase, in most cases, due to the fact that our new order cost is so much higher than what is presently used. Special attention must be given to the case of batteries as this supply chain goes directly from the supplier to the end customer in the cases that we have studied. Because of this fact we have not been able to obtain the necessary information needed to determine an order cost which can be used by the inventory managers at VCCS. However, we have shown that the order cost of 9.25 SEK (which is suggested in the PULS handbook) is seldom used in calculating order quantities. After determining an order cost through the Wilson Formula we see that average order costs (after discounting all articles that have a forecasted demand for the period of zero) for all dangerous goods are 9.25 (Nagoya), 13.21 (Atlanta), 17.28 (Maastricht), 20.58 (Istanbul), and 14.78 (Malmö). The exception to our study is the order cost for Turkey, which is much higher, on average, than the other DC’s studied. The fact that the EOQ’s increase so drastically does not appear to be strange. VCCS has used such low order costs in the past that the EOQ’s have been quite small. This is far from an absolute order cost, but through our supply chain study we have been able to show that there are a number of activities that lead to greater costs when dangerous goods come into play. With greater order costs, the company would be wise to send greater amounts of products at the same time in order to cut down on the amount of work that has to be done each time a dangerous goods order is placed.

## 6. Conclusion

As we were able to show during our analysis, VCCS currently works with a decision support system which does not provide factual information. The costs used to provide a basis for making decisions regarding inventory levels and orders is old and outdated. It is therefore of utmost importance that the company see over its cost structure to insure that proper decisions can be made based on up to date cost information.

We feel that the company uses the appropriate tools for inventory management such as the Wilson Formula and the various Tables used at the NDC's. Working as an inventory manager requires not only the factual figures which can be obtained through the use of a decision support system, but also experience and a "feeling" for the industry. As everyone knows, forecasting is never correct and therefore the knowledge of inventory managers should not be underestimated. However, in order to make their lives easier, a new cost structure should be implemented within PULS, which would provide for different order quantities, which in turn should lead to a decrease in the cost of handling these goods at the CDC. One drawback, which we have not discussed in this paper, is the effect of increase in inventory levels at the DC's around the world, which will undoubtedly be a consequence of our ideas. However, theoretically, if proper consideration is given to the use of either the Wilson Formula or Tables, increased inventory levels may not be a problem, as the costs of handling fewer dangerous goods orders at the CDC should offset this cost. It should be noted, though, that there should exist decision making tools for each product, for each DC, and for each type of transport method, thus providing the inventory manager with an abundance of information upon which to base decisions.

Upon starting this thesis VCCS was not fully aware of its current situation concerning the costs surrounding dangerous goods in its supply chain. An additional area of worry was that of the various activities within the supply chain. Through our mapping we have graphically shown the different supply chains for car batteries, transmission oil, airbags, spray paint, and even an alternative flow of paint pencils at Rover. One thing that was noticed was that, aside from airbags and car batteries, the supply chain is much the same for all dangerous goods coming into and leaving the CDC. We have been able to show that the present order costs being used to base batch size decisions upon is too low and needs to be further studied in order to establish a cost which works for different products, different transport methods, and even for the different DC's. Lastly, we have been able to show the effects on the economic order quantities when the order costs are increased.

One of the main reasons which lead to the idea for this thesis was a product which was transported as a single unit by airplane. When not consolidated with other goods, the costs for this article become very high. All goods sent by air must be cleared by the inventory manager. One way to consolidate all goods sent by air would be to only approve air shipments to specific regions, once or twice a week. When doing this, one could hopefully avoid sending only one or very few articles and getting a chance to spread the order costs over a large number of articles.

# 7. Epilogue

After looking at the different flows in order to map them out we found a few details which could be altered within each flow. Here is a list of a few suggestions which we feel could improve the current situation.

Air bags and seatbelts have a special supply chain which has received much attention during the last few years. It would appear that everything is in order here, but two things struck us as unusual when examining this flow: return logistics and the dedicated transport between Kungälv and the CDC.

One of the main costs in the current flow of airbags is the cage in which the airbags are stored during the transport. These cages allow the airbags to be shipped as cargo, classed as 1.9 instead of class 9. The downside here is though the price of the cages. The cages that explosive goods are placed in are expensive both in terms of economics and to the environment. We were informed that these cages are discarded at the end customer. Here, we feel the VCCS could save money and the environment by looking into a way of collecting these cages. We recommend that consideration is given towards a recycle system in order to reuse these cages. There is a return system for some of the packaging materials, however, only the distribution center and back the CDC. In the scenario with the cages a return system would need to be developed all the way from the retailers and workshops where these goods are unpacked. A follow up to this thesis would be to calculate the cost of returning these cages in comparison to buying new ones. An additional aspect to the cages which should be considered is how packages are shipped from one of Autoliv's main competitors, Delphi. This company currently uses a cardboard box without a cage. Therefore, we recommend that VCCS analyze the possibility of using a similar solution for the Autoliv airbags. This solution may prove to be better both economically and environmentally for VCCS.

Furthermore, we discovered that the truck assigned to drive a fixed route between Kungälv and the CDC is never filled to max capacity. At present, a full size trailer is used as a route truck which goes from Eurobag to Svenska Airbags and then to VCCS in Torslanda. Afterwards it goes back to Eurobag and starts all over. According to the people who we talked to at Eurobag, Svenska Airbags and VCCS the truck used is never completely filled. This transport service has been purchased by VCCS from Volvo Logistics and due to the complexity of the current flow it is not utilized for any other transport than this. Therefore, it would appear that either a smaller truck could be used or a restructuring of the trucks route should be considered in order to better exploit its capacity.

Thought should be given to aiding in the explosive goods consolidation process at VCCS. In order to speed consolidation up at VCCS we suggest that Svenska Airbags be allowed to flag the goods while still in Kungälv. The company already has the possibility of accessing PULS, and should therefore be able to flag the goods before arrival at VCCS, thus saving time for the packers at the CDC. This would put a greater responsibility on Svenska Airbags, but considering the long term relationship between Volvo and Svenska Airbags, this should be a very small risk.

According to Stefan Lindbergh VCCS has calculated the cost of having capital tied up in transit to 3.5 MSEK per year. Considering transport in the flows examined here, we noticed a few flows, which, in our eyes, show great room for improvement. The time frame for an article to arrive on the shelves in Istanbul from the time it is ordered by the inventory manager was reported as 6-7 weeks when sent by truck. We were informed by Mats Hermansson that the actual transport time to Turkey by truck is 10 days. Furthermore, the work done at the CDC to prepare the packages is not more than 2-3 days, with approximately the same amount of time needed (mostly like less) for binning the products in Istanbul. Adding this together one can see that the goods are tied up somewhere along the supply chain for approximately 3-4 weeks. Similar situations can be witnessed in the shipping of goods to Atlanta by container. Monica Lindell informed us that the goods sit in a container for 9 days from the time that they are packed at the CDC in the container before they leave the Gothenburg harbor. We were not provided similar information to our other flows; however, this situation should be studied for all supply chains to see if any lead times can be shortened. We feel that a huge amount of money can be saved by making these transport chains more effective.

During this paper we have only examined a small fraction of dangerous goods as the CDC. As was pointed out to us more and more goods and being classified as dangerous and it is therefore vital for the company to examine this supply chain in order to be able to make sensible consideration concerning the handling of these goods. We were also informed of situations for supply chains that we did not examine, such as Saudi Arabia, where each product must be relabeled in the local language. Such occurrences are apparently not uncommon at the CDC. We understand that in order to have an effective supply chain one should use the principles of postponement, but if this scenario continues or expands it might prove beneficial to discuss other business practices with suppliers and even end customers. For example, if a DC is to receive a large batch of products which must be relabeled at the CDC it might be beneficial to discuss with the supplier the chance of placing the labeling job on them so that personnel at the CDC are not tied up with this job for such a long time. Further research could be conducted into an expanded analysis of VCCS' suppliers in order to determine the possibilities of outsourcing the handling of dangerous goods and only perform cross-docking at CDC. The project with airbags being packaged and stored in Kungälv should be considered as a success and a role model for other dangerous goods.

Moreover, a situation that may arise from our study is the fact that more products may be moved out from the CDC to the DC's. An interesting continuation on this study would be to examine the consequences of having larger inventory at the DC's. At times, during this study, we have heard that one or two dangerous goods have been sent to DC's, which in the eyes of many can seem very costly. Often times, sending so few goods is a decision made by the inventory managers because they have access to information concerning the demand at their storage sites. Sending out one dangerous good might seem costly, however, not having to stock the same goods for longer periods of time at the local DC's, especially if they are infrequent sellers, my even out the costs in the long run.

For follow up regarding this thesis we would recommend a new project in which they more specifically try to determine a more exact order cost for all specific products, both dangerous and normal. Our thesis is a very good base for this project due to the fact that all information needed should be found from our activity based costing analysis. This would lead to more accurate EOQ's in VCCS' PULS system. We would also recommend that one order cost is calculated for the first line, in other words, what it would cost to ship an order with only one line and thereafter calculate an order cost associated with the order lines that follow.

As an addition to this, the same group could also focus on determining more exact inventory holding cost. We have found two different costs from alternate sources at VCCS today. They do not differ that much but it would be of great help if one could break it down to more specific parts.

In ending, we are extremely thankful to everyone at VCCS who provided us with information for this paper, and we truly hope that something good comes of it. We have only begun to scratch the surface of the area concerning dangerous goods, but we expect that this paper will prove a starting point for further studies which will lead to even better business practices at VCCS.

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## Appendix A

**Mattias Backan 070912**

Mattias works as an inventory manager/purchaser for Rover and is responsible for the Swedish and Norwegian Markets. We talked with him regarding article 32018548 (Paint Pencil). The reason for this interview was to receive information concerning a different supply chain which may prove beneficial in our analysis later in the study.

He bases his decision based on sales history for various products. We were informed that PULS creates orders once a week for high frequency orders and as needed for low frequency orders. Deliveries are then sent from the CDC in Desford, England to Rover's DC in Arendal. Lead times for dangerous goods can be anywhere from one week to one month, however for normal products the lead time is typically only three days. All products are first sent by boat and then further trucked to the DC. For the discussed product there is a safety stock of thirteen and when placing an order he must order at least 25 at a time. However, this article is only handled about 3-4 times a year, meaning that not much effort is put into it.

**Kjell Nilsson 070913**

Kjell is responsible for the purchase of article number 9437223 (spray paint) and 1161540/1161649 (transmission oil).

Spray paint has to be ordered in quantities of 300; however it is always plus/minus. Sometimes they get 297 liters and sometimes they get 305. This product comes from Kwasny in Germany.

Lead time is 6 weeks; or rather changes cannot be made within a 6 week interval. Contact person is Andreas Neuberger 0049-6269 9561 or neuberger@kwasny.de

This article is transported by land/boat only. This must be taken into consideration with panic ordering. There is always the possibility to arrange for faster delivery but it costs more.

Transmission oil is bought from Carpmans AB in Hjo. This product is transported to the CDC by truck. For one liter bottles he must order at least 3168 liters and after that in intervals of 288 which is the amount that goes on a pallet. The safety stock for this product is 3010.

Lead time is 2 weeks, meaning that changes in order size cannot be changed during the two weeks prior to shipping. This product arrives at the CDC each week.

Kjell does not spend much time at all on these products as the computer does all of the inventory management. He is there basically to oversee all of the processes. He also informed us that basically all dangerous goods except for car batteries and explosive products follow the same pattern of being brought from the supplier to the CDC and thereafter out to the various DC's.

**Pia Persson 070918**

Pia works in the purchasing department and is responsible, for among other products, the purchasing of airbags and seat belts. The products that we discussed with her were article numbers 8614675 (seatbelt left), 30865195 (seatbelt tensioner), and 30631445 (airbag module).

In terms of purchasing these products she said that there is no difference in the way they are handled as opposed to other goods. She estimated that approximately 30-40% of her time is spent handling dangerous goods orders.

According to Pia, the goods are brought from Kungälv by truck and then sent from the CDC by road, air or water. Volvo takes ownership of the products from Autoliv (produced in Estonia and Vårgårda) when they are delivered to the warehouse in Kungälv. Autoliv owns the warehouse that Volvo uses. This warehouse is referred to as area 42. All of the goods are prepared at the warehouse in Kungälv, so when they arrive at the CDC they sit until they are to be shipped. The only handling that is done at the CDC is the unloading and loading of transports. Volvo Logistics is responsible for the transport part of the products. Orders and shipments are done everyday. VTech is responsible for documenting all of the packages.

- Lead time is 3 weeks and safety stock is 5 for 30865195
- Lead time is 4 weeks and safety stock is 3 for 8614675

**Sören Karnerfors 070921, 071017, 071114**

Sören is responsible for educating employees in quality, environment, transportation, etc. We talked with him quite extensively as he is the resident expert on dangerous goods. One long conversation we had with him concerned the transport of article number 30772222 (car batteries)

According to him when flying goods the authorities are extremely tough when it comes to all documentation. This must be done correctly to avoid costly delays or repackaging.

There is a set of 16 rules (international) that each manufacturer must follow when producing dangerous goods for Volvo.

Apparently each battery delivery is a loss as they pay approximately 1000 SEK extra for each battery due to problems at Landvetter airport. Almost all batteries are flown due to time constraints and problems finding batteries when being shipped or transported by truck.

Packages flown to the US can't be heavier than 25 kg and to the rest of the world 30kg. This leads to different packing times at the CDC.

Volvo owns all of the products from the time they leave Varta in Germany. The supply chain is a mess, but will be changed on October 1, 2007, with the batteries being shipped directly from Germany to Arendal and then on to the CDC. Today, batteries are sent, with Schenker, from Hanover to Nässjö. In Nässjö they are transferred and sent by DHL to Arendal, where they are cross-docked and sent to the CDC with Volvo Logistics. From the CDC there are many different transport companies used to the airport and harbor or by truck to the rest of the EU.

A good amount of time is spent on documenting, labeling, and repackaging the products. When batteries arrive at the CDC they are placed on the outside of the DC.

Lead time is 3 days for larger quantities. When we discussed our flows we were informed that direct car battery deliveries are used in Maastricht, the US, and Japan. Turkey and Malmö receive their batteries from the CDC, and thus subject to the previously described supply chain.

**Christer Spång 070924, 071031**

Christer works as a project manager and has access to warehousing costs, handling costs and hourly wages. He has already done a study concerning airbags and seat belts, when they decided to outsource these products.

Costs were reduced from 130 SEK to 45 SEK per product with outsourcing.

Supply chain

- Autoliv (Vårgårda) to Eurobag (Kungälv) where they are packaged in Volvo packing to Svenska Airbag (Kungälv LGO 42) to CDC. The final products are dropped off either at 13 or 17 each day at Norden, Europe, or FarEastStates where they receive new labels. Otherwise everything is done in Kungälv.

Products which are ordered from Delphie are sent to Eurobag if the have to be repackaged or direct to Svenska Airbag if they are ok.

Volvo pays for an inventory check at least once a month at Kungälv.

There is also a Volvo transport which does a milk run between Kungälv and the CDC each day. (J Trans).

Eurobag /Svenska Airbag – warehousing, picking, and movement (trucker)

Transport is the responsibility of Volvo

We later discussed inventory holding costs with Christer. His group has calculated that this cost is approximately 25%: inbound logistics is approximately 9% which is made up of Volvo packaging (pallets and frames), an air freight factor, unloading, inspections and binning, an additional 15% comprises inventory charges plus picking.

**Mats Hermansson 070926**

Mats works as an export coordinator and is responsible for export documents for Turkey (air/road), Japan (air/sea), USA (air). He informed us that Linda Jansson takes care of coordination for Sweden and that Monica Lindell has USA (sea).

According to Mats car batteries to the US and Japan are direct deliveries and never come through the CDC.

All products are packed and prepared at the CDC, then Mats takes care of the documentation.

Japan and the US - shipping is done with Maersk and NDK

Airbags documentation takes just as long whether it is sent by boat or air

There are 6-8 people who work with export questions.

Transports to Turkey have to have 7 different transportation cards because of the different lands that the truck passes through. He estimates that it takes 20-25 minutes to document goods to Turkey if they go by truck as opposed to 5 minutes if dangerous goods are not involved. If the products are sent by air it goes much faster because there is less documentation (only one page).

All dangerous goods must be checked one more time at Landvetter (approximately 1000 SEK per package)

Volume is the deciding factor for price.

Various costs associated with transports to the different DC's.

Japan (air) DGR min. 750 SEK, under 45 kg, 54.00 kr/kg over 45/45.00 kr/kg. No difference in the price for boat.

Atlanta DGR air min. 1750 SEK.

Turkey (air) min. 550 DGR 800/shipment, by truck dangerous goods cost 350 EUR/truck.

Lead times to the different DC's.

- Boat to Japan 32 days to harbor in Nagoya + a few days if there are problems with customs.
- CDC to Goteborg harbor, 1 day when the container has been filled.
- At the Goteborg harbor the container can sit for up to five days before being placed on the boat.
- Air to Japan 4 days plus 1 if there are problems in customs. The goods arrive at Landvetter the same day that they are packed at the CDC.
- Air to Atlanta 4 days. The goods are held an extra day at Landvetter for dangerous goods checks.

Costs of transport to various DC's.

- Cost of air transport to Japan: 14.30 SEK /KG

- Cost of DGR check to Japan: minimum 750 SEK, under 45 kg 54 SEK/kg, over 45 kg 45 SEK/kg
- Cost of boat transport to Japan: 4990 SEK
- Cost of air transport to Atlanta: 15.50 SEK / KG
- Cost of DGR check to Atlanta: minimum 1750 SEK

Mats has to check all goods personally that are going to be sent by air. This can take anywhere from a few minutes to a few hours depending on how many packages must be inspected.

Sending by sea requires less paperwork and packing does not demand as much energy.

**Stefan Hallberg 070926**

Stefan is responsible for the warehousing of dangerous goods at CDC

He takes care of deliveries and sees that they are put on the shelves within the defined area. Goods are delivered to different areas of the CDC depending on where the truck has the most goods to deliver. The goods are brought to area 40(inside) or area 45(outside) and placed either just outside of the area on the inside or outside of area 40. This job is done by 2-3 people. Once there, Stefan takes over and places them in the correct shelves or areas.

Certain products have to be rearranged within the DC due to FIFO.

Inventory is completed by another group within Volvo approximately once a month. Differences in product balance have to come up to a certain level before any actions are taken.

Stefan has to count the products when they arrive to see that they are correct. This is also done when the goods arrive at CDC. There are also stick tests which are done when placing them on the shelves. When everything is in place he reports everything in the computer.

**Thomas Larsson 071001**

Thomas works as a picker and packer for Turkey, Old Soviet States, India, Middle East, Africa, South and Central America

There are different rules for packing, depending on the way the product is going to be shipped: ADR for road, IATA for air, and IMDG for sea.

When they pack the products they pack either for air or boat. If you pack for air than the package can be sent by any transport method, but if you pack for road you cannot then send it by air without repacking it.

The product's PSN number says how the product needs to be packed and other considerations that must be considered, such as weight, what other products can be placed together, etc.

They need to read "the folder" each time a dangerous good is to be shipped to make sure that everything is done right. Fines can be administered otherwise.

With SASO they need to mark each individual product (Saudi Arabia).

When sending to Turkey they separate the dangerous goods from other goods to make it easier for customs to control the products.

Process

- Order – PULS, taken by the packer
- Retrieve products and check what they contain.
- Small orders are brought to packing area and packed, while large orders are packed closer to shelf location.
- Goods are packed according to the rules of transport.
- When this is completed the goods are reported so that the export coordinator (Mats) can come and check the goods (if they are to be flown) and arrange for transport.
- When Mats is done someone else is contacted to put the products in a container or on the truck to the airport or Turkey.

Depending on the order they can be sent anywhere from immediately to within 3-5 days.

He thinks that dangerous goods take about 20% more time to pack than normal products because they have to be marked and packed specially.

- Air – demands physical weighing, two different stickers and a special box
- Sea/Road –demands one type of sticker.

Basically, there is less work when shipped by boat or road. The way they transport the goods dictates how much work is necessary at this stage.

He also mentioned that airbags possibly can be reported and flagged in Kungälv to save them from having to do the job here.

Said that paint pencils take about 10-15 minutes to pack (1 paint pencil)

**Håkan Antbro 071001**

Works with picking and packing for the US (Atlanta). Much of what Håkan said was similar to what Thomas Larsson had to say.

He felt that it takes twice as long to package goods that are to be flown. He said that if things are done right from the inventory management side, than everything can be shipped by sea.

There are 12 people that work with just Atlanta.

No car batteries to the US as they are already produced in the US.

The weight of the goods decides the amount of work. If there are too many goods or they are too heavy than they have to be put in other boxes, etc.

He said that they have to mark each antifreeze box, so wondered if that could be done at the supplier so that they do not need to do it here. This was for 1 liter bottles. Can this be done for all similar products?

Felt that there is about 20-30% more work when dealing with dangerous goods.

Pick up products, pack them, mark the boxes, prepare them for further transport to loading area.

Documentation – all of this becomes worse if the transport is by air.

Mats checks the net weight of the goods before they are shipped by air.

**Niklas Hansson 071003**

Niklas works as a picker and packager for Japan

They send by air and sea but most is sent by boat.

One container a week is sent to Japan. They collect orders during the week and then send all dangerous goods on Monday with Maersk.

Car batteries are sent directly to Japan from Varta.

Air bags are ready when they arrive from Kungälv. They just need to be place on the container. If they are to be flown then they need to be reported.

They are only allowed to send 10 airbags per container to Taiwan.

Limited quantities are never sent by air. These goods are “dangerous but not dangerous”. If there are too many together then they can be dangerous.

Containers need to be marked with 4 stickers (one on each side) to note that the container has dangerous goods.

Max gross weight for a container is 30480 kg (67200 lbs)

Max cargo weight is 28160 kg (62 090 lbs)

No special considerations other than that all dangerous goods are sent once a week to Japan.

**Monica Lindell 071016**

Monica is export coordinator for boat shipments to the US.

1 container a week is reserved for dangerous goods to Atlanta.

9 days to prepare paperwork from here to Maersk/NYK and back, so she needs to have everything sent by Thursday week 1 in order to get the container away on Saturday week 2. (Container is sent to harbor on Wednesday and from harbor on Saturday. Thursday to Saturday 9 days)

Goods go through customs in GBG.

The cost for each container is 18000 + 400 SEK (shipping). It does not matter if it is dangerous or normal goods. This price includes transport from CDC to NDC. VCCS pays per container so weight does not matter, it is more important to fill the container as well/much as possible.

After everything is packed she gets a paper with what dangerous goods are onboard. She then fills out the proper paper work and forwards it to Maersk, customs, etc.

The transport route and days are: CDC to GBG Harbor, to middle harbor, to Charleston (22 days), to Atlanta with truck (1 day).

It takes her about 20 minutes instead of 5 minutes for paper work for dangerous goods container instead of regular products.

**Stefan Lindbergh 071101**

Stefan is one of a few people for purchasing the different transports for VCCS. He was able to answer a few of our questions concerning the prices of various transports to our DC's around the world.

air to Maastricht : N/A
dgr check to Maastricht : 100 Euro
road transport to Maastricht : 1284 Euro (FTL)
air to Istanbul : 17,20 SEK/kgs incl fuel + security costs
road trsp to Malmö : 3000 SEK (FTL)
cost of time goods spend in transit : 3,5 msek per year
cost of printing safety sheet : 50.000 SEK per year

**Lasse Magnusson 071107**

EOQ is derived from Wilson or Tables depending on the DC.

Wilson – SDC and LDC (Europe)

Table – NDC and VIPS

No costs in Tables – What do they use to calculate these figures? Service level controls everything!! This is a problem because they know that the costs for dangerous goods are huge.

History, experience, math used to build the Tables.

Tables can be changed to meet the situation. There are no "hard" Tables for each DC.

The Tables can be adjusted by each inventory manager to fit their situation.

Wilson formula does not influence the situation in the US.

Compare the Table calculations to the Wilson calculations and see what happens.

VCCS owns the products in SDC, LDC, Japan and Australia. This can be seen as a part of the CDC.

All other DC's are sales organizations which own the products when they are packed in the containers and billed. (USA, Canada, VIPS)

Bills are 60 day payments. Internal billing is conducted between LDC's etc. and CDC.

Inventory managers are "old" purchasers from the various DC's. They do not manage in the same way as purchasers at the CDC.

They have to buy back products from Atlanta if they want to use it in another DC.

Returns from the airport are usually administrative problems, meaning that products have been packaged incorrectly.

Service level is the big thing!!

Larger safety stock with larger shipments from the CDC to cover the costs of shipping dangerous goods needs to be considered.

When they have safety stock in units and not days the inventory manager sends a quantity to get to the refill point plus the refill quantity. If safety stock is 3 units and the DC sells one then the inventory manager needs to send 1 plus 3.

Safety stock Table or EOQ.

VIPS (Volvo Importer Parts System) this system tracks all financial data and transactions (economy), billing. All sales companies have VIPS. This system is used as warehouse management system for VIPS markets: Mexico, Turkey, China, etc.

DSP (Dealer Support Package) used to manage DC for a VIPS market. Can be seen as a "sidekick" to VIPS.

# Appendix B

**Kai Inseam 071016 (Malmö)**

Kai is responsible for the DHL DC in Malmö which houses VCCS spare parts.

Everything is sent by truck

It takes one working day from when the truck arrives until the products are on the shelves. Everything is treated the same as regular goods.

15 people work for Volvo and VCCS goods share a part of the entire DC.

When packages arrive they have to control article numbers, packages are then unpacked and placed on shelves

There are two rooms and a container to house dangerous goods.

One room is used for flammable (aerosol), and one room is used propellants, while the container houses explosives.

**Shuichi Ikoma 071031 (Nagoya)**

1. What happens in the harbor/at the airport/or terminal when dangerous goods arrive? Do they have to be treated in a different way than Volvo products that are not considered to be dangerous? Does anyone from Volvo need to be there to accept the goods or are they transported directly to the DC?
No, you don't need to be there.

Does anyone have to sign/accept the goods, which would lead to extra costs for each delivery?
No extra cost occurs for transport.

Are there any special regulations concerning the arrival of dangerous goods that are cause for extra costs?
No extra cost has occurred so far for the above items which you are examining.

Air - We've never imported spray paint into this market as far as I know.
Car batteries are supplied directly from Japanese importer of Varta battery in Japan to our warehouse by truck. Genuine Volvo car batteries are stored in our warehouse.
Other dangerous goods in which you are examining: no extra work at the airport so far.

Boat - the goods are loaded in the 40" container, and they are clearing customs, container by container.
So, normally nothing special happens.

Regarding car batteries, Logistics flow is as follows:
Varta in Germany --> Japanese importer for Varta in Japan --> NDC Nagoya --> Volvo dealers

2. How are dangerous goods transported from the terminal to the DC, or to they arrive directly from the CDC in Göteborg? Are there special handling/transport considerations for these goods?
No special transportation method from the terminal to our warehouse. They are transported with other normal goods.

3. What factors influence the decision of transport used from the CDC/local terminal to the DC?
This is not my responsible area. VCCS in Goteborg decides it.
Regarding the local transport, please see the answer on Q2.

4. Who decides which transport method should be used?
Same as Q3. VCCS decides it.

5. How are transportation costs charged to Volvo? Are they based on amount, weight, etc?
As to the air shipment, I don't know the detail because of the forwarding contract including cost with the air forwarder is made by VCCS in Goteborg. Maybe, it's at xxxx JPY per one Kg. On the sea shipment, XXXXX JPY per one 40" container, including customs clearance, local transport fee, unloading fee and so on, from Nagoya port to our warehouse.

6. How long (on average) does it take to get the goods from the CDC/local terminal to the shelves in the warehouse?
Lead-time:
For Air: 5 days in average.
For boat: 50 days.

7. Are there any deliveries that go directly to the end customer/retailer instead of via the DC? If so, which dangerous goods, and why do they go directly to the end customer/retailer?
No direct deliveries from CDC to the retailer regarding dangerous goods as far as I know.

8. When the goods arrive at the DC how many people handle the dangerous goods? For example, is there one group that unloads the containers/trailers/etc. at the DC and another group that transports them into the DC or is it the same group? (We are trying to understand the complete process, so the more details the better.)
We have number of seven inbound workers, and don't have special process for dangerous goods as they are handled same as other products.

9. What is the process of unpacking goods or are they ready to be placed on the shelves when they arrive at the DC? (Again, we want to understand the process better.)
Unpacking process is almost same with other normal products.

10. Do the goods have to be processed/inspected/reported in a database/etc. which calls for extra work?
As you may already understand, almost no extra work occurs here so that we don't feel that these are needed.

**Luis Dorta 071015 (Atlanta)**

1. What happens in the harbor/at the airport when dangerous goods arrive? Do they have to be treated in a different way than Volvo products that are not considered to be dangerous? Does anyone from Volvo need to be there to accept the goods or are they transported directly to the DC? Does anyone have to sign/accept the goods, which would lead to extra costs for each delivery? Are there any special regulations concerning the arrival of dangerous goods that are cause for extra costs?
The containers at the harbor need dangerous goods papers in order for the trucker to move the container other than that I do not know. I have also heard that it takes longer to travel by air than non haz matt. I do not handle any procedures before we receive these shipments at the DC. The batteries go to the retailers directly from the manufacturer.

2. How are dangerous goods transported from the entry point in country to the DC? Are there special handling/transport considerations for these goods?
The containers are trucked from the port to the carrier BTT and then delivered to us when we schedule them. The air freight is picked up by UPS at the airport. With all haz matt there is special handling by the carriers but I will not speculate what they are you would have to talk with the carriers.

3. What factors influence the decision of transport used from the point of entry to the DC?
We use the same carriers for all shipments UPS for air and BTT for containers via Maersk.

4. Who decides which transport method should be used?
Corporate

5. How are transportation costs charged to Volvo? Are they based on amount, weight, etc?
I do not know.

6. How long (on average) does it take to get the goods from the point of entry to the shelves in the warehouse?
Containers take about a day and air freight takes about a day as long as it is cleared by customs.

7. Are there any deliveries that go directly to the end customer/retailer instead of via the DC? If so, which dangerous goods, and why do they go directly to the end customer/retailer?
I do not know.

8. When the goods arrive at the DC how many people handle the dangerous goods? For example, is there one group that unloads the containers/trailers/etc. at the DC and another group that transports them into the DC or is it the same group? (We are trying to understand the complete process, so the more details the better.)
The dangerous goods are unloaded by the receiver and then binned by the binner both are in the same group.

9. What is the process of unpacking goods or are they ready to be placed on the shelves when they arrive at the DC? (Again, we want to understand the process better.)

All of the airbags, seatbelts and fuel pumps come as individual pieces so they just go on the shelf. The paint and most other dangerous goods come in boxes that have to be unpacked and inspected for correct part # and quantity.

10. Do the goods have to be processed/inspected/reported in a database/etc. which calls for extra work?
This process is no different than regular parts that are updated in the PULS system. They are checked for part # and quantity then updated.

11. What percent of the warehouse is occupied by dangerous goods?
We have a paint room that is about 70 feet by 70 feet. We also use a section of rack it is about 50 feet long with 3 levels and we use both sides. When the shipments arrive at the airport they are trucked to us it is about 35 miles from the airport. About 5%

**Jeffry Boessen 071003 (Maastricht)**

1. What happens in the harbor/at the airport when dangerous goods arrive? Do they have to be treated in a different way than Volvo products that are not considered to be dangerous? Does anyone from Volvo need to be there to accept the goods or are they transported directly to the DC? Does anyone have to sign/accept the goods, which would lead to extra costs for each delivery? Are there any special regulations concerning the arrival of dangerous goods that are cause for extra costs?
All the dangerous goods that we receive here are shipped from CDC in Gothenburg, dangerous goods are always invoiced separately (because of necessary papers, CMR's, dangerous goods labels etc). All these papers are necessary because all our transport from CDC goes by road and over water (the ferry from Denmark to Germany ). If you have any more questions about shipping these goods at CDC you can contact Stefan Ivanos he is responsible for shipping dangerous goods to our SDC in Maastricht.

2. How are dangerous goods transported from the entry point in country to the DC? Are there special handling/transport considerations for these goods?
As I told you earlier all the transport goes by road and over water. I am sure that there are extra costs handling these goods but I can not tell you more about this.(CDC ?)

3. What factors influence the decision of transport used from the point of entry to the DC?
This is a question that someone at CDC can answer you. (Sten-Ake Thunberg or Hasse Johannesson is responsible for all the transport.)

4. Who decides which transport method should be used?
CDC, it depends of which kind of order it is. (Class 1, 2, 3 or VOR orders, stock orders)

5. How are transportation costs charged to Volvo? Are they based on amount, weight, etc?
Also someone at CDC can help you with this.

6. How long (on average) does it take to get the goods from the point of entry to the shelves in the warehouse?
For us here in Maastricht it normally takes one day.

7. Are there any deliveries that go directly to the end customer/retailer instead of via the DC? If so, which dangerous goods, and why do they go directly to the end customer/retailer?
All the goods here go via SDC, as far as I know nothing goes directly to customers.

8. When the goods arrive at the DC how many people handle the dangerous goods? For example, is there one group that unloads the containers/trailers/etc. at the DC and another group that transports them into the DC or is it the same group? (We are trying to understand the complete process, so the more details the better.)
Goods are being unloaded and transported by one group of two people directly to the bin area for dangerous goods; another group of four people is responsible for binning and storing the goods to the dangerous goods area. Finally when the goods are stored PULS system is updated.

9. What is the process of unpacking goods or are they ready to be placed on the shelves when they arrive at the DC? (Again, we want to understand the process better.)

Some of the dangerous goods are packed in cardboard boxes (spray paint, bottles of oil etc) and need to be unpacked before we can store them in our dangerous goods area. Airbags, side curtains go directly on the shelves.

10. Do the goods have to be processed/inspected/reported in a database/etc. which calls for extra work?
All the dangerous goods (except airbags, side curtains etc) when they are stored here need a ,, Safety Data Sheet,, . You can find these sheets in http://www.tech.volvo.se/environ/start-en.htm. We keep these sheets in four places (procedures) so extra work I think.

11. What percent of the warehouse is occupied by dangerous goods?
We have around 80 square metres dedicated to dangerous goods, our total plant is around 10.000 square metres, I leave the calculating to you.
As far as I know we do not store car batteries here anymore, the only batteries we receive here from Varta are small ones for remote controles, etc( these are all packed correctly by Varta ) and we store them seperately in our binstore area.

**Orcun Onur 071022 (Istanbul)**

Unfortunately we don't have a separate process description for dangerous goods handling. This is something that I am working on nowadays. I think your thesis would be a very good source for me to get benefit out of.

**Dandik, Timucin 071023 (Istanbul)**

1. What happens in the harbor/at the airport when dangerous goods arrive? Do they have to be treated in a different way than Volvo products that are not considered to be dangerous? Does anyone from Volvo need to be there to accept the goods or are they transported directly to the DC? Does anyone have to sign/accept the goods, which would lead to extra costs for each delivery? Are there any special regulations concerning the arrival of dangerous goods that are cause for extra costs?
Nothing special, treated as normal parts

2. How are dangerous goods transported from the entry point in country to the DC? Are there special handling/transport considerations for these goods?
Nothing special, treated as normal parts

3. What factors influence the decision of transport used from the point of entry to the DC?
Nothing special, treated as normal parts

4. Who decides which transport method should be used?
The stocking policy set by VCCS & national sales Company. For us, a dangerous good has no difference than another spare part to the valid stocking policy affects this. For example, if there is a dealer backorder with a DG, it should be shipped by air. If it is a fast mover parts, then it is shipped by truck.

5. How are transportation costs charged to Volvo? Are they based on amount, weight, etc?
It is better that Henrik Jönssön, our export coordinator will comment on this because he is responsible with the content on the freight cost (he puts this value manually on the invoice after some calculations) & he is located in the same office as Mårten

6. How long (on average) does it take to get the goods from the point of entry to the shelves in the warehouse?
It depends on the freight mode used. For air, it is 3 days & for truck shipments it is 10 days.

7. Are there any deliveries that go directly to the end customer/retailer instead of via the DC? If so, which dangerous goods, and why do they go directly to the end customer/retailer?
No goods are shipped directly to customers.

8. When the goods arrive at the DC how many people handle the dangerous goods? For example, is there one group that unloads the containers/trailers/etc. at the DC and another group that transports them into the DC or is it the same group? (We are trying to understand the complete process, so the more details the better.)

Nothing special, treated as normal parts

9. What is the process of unpacking goods or are they ready to be placed on the shelves when they arrive at the DC? (Again, we want to understand the process better.)
The system used (VIPS) allows the picker to have a document where he can find the part number, shipped qty & the location of the part in the warehouse & the pickers use this document ( printed by VIPS after the picker keys in the invoice number of the shipment) to bin the parts to the correct location. At the moment, the dangerous goods do not have a dedicated area in our warehouse but I assume that we will have a dedicated area for them until the end of this year.

10. Do the goods have to be processed/inspected/reported in a database/etc. which calls for extra work?
Nothing special, treated as normal parts

11. What percent of the warehouse is occupied by dangerous goods?
We have not yet created a designated area for dangerous goods at the moment but our supplier has an aim for it. As we do not have a designated are at the moment, it is very hard to give a figure but after some calculations, they amount to around 2.5 % of the whole warehouse area I can say.

# Appendix C

| Activities | time activi | salary | Holding R | Normal G | Dangerou | Holding R | Airbag |
|---|---|---|---|---|---|---|---|
| Cost for storage, packaging and marking: Airbags 46 SEK / Article | | | | | | | 46 |
| Cost for truck on fixed route, transporting goods to CDC: | | | | | | | 1 MSEK |
| Cost for inventory: | | | 0,25 | | | 0,05 | |
| Cost of transporting the goods to the CDC: | | | 0,25 | | | 0,05 | |
| Cost of randomly checking the goods: | | | 0,25 | | | 0,05 | |
| Cost of transporting the goods to storage location: | | | 0,25 | | | 0,05 | |
| Cost of storing the goods in secure facility: | | | 0,25 | | | 0,05 | |
| Cost of Transport to the CDC: Batteries | | | 0,25 | | | 0,05 | |
| Cost of flagging and consolidating the goods | 3 | 200 | | 10 | 10 | | 10 |
| Cost of internal transport | | | 0,25 | | | 0,05 | |
| Retreive goods | | | 0,25 | | | 0,05 | |
| Cost of packing goods (cartons, packing materials, sticker) | | | 0,25 | | | 0,05 | |
| Cost of handling goods 20% longer time for dangerous goods | 10 | 200 | | 33 | 39,6 | | 0 |
| Cost of time for export documentation | 20 | 200 | | | 67 | | 67 |
| Cost of Double check | 5 | 200 | | | 17 | | 17 |
| DGR Check | | | | | | | |
| Cost of randomly checking the goods: at NDC; SDC; LDC | | | 0,25 | | | 0,25 | |
| Cost of transporting the goods to storage location: | | | 0,25 | | | 0,25 | |
| Cost of storing the goods in secure facility: | | | 0,25 | | | 0,25 | |
| Cost of printing safety sheets: | | | 0,25 | | | 0,25 | |
| Sum of costs | | | | 43 | 133,6 | | 94 |

**Table 5 Order Cost Activities**

An additional fact which must be mentioned is that we have calculated an average order for each warehouse based on the previous months order shipments. Average order size for each respective warehouse is 139 (Maastricht), 441 (Istanbul), 49 (Malmö), 39 (Nagoya), and 70 (Atlanta). We then provided this information to each pack area responsible for the respective warehouses and asked them to estimate the time required to prepare an order of this size.