Rebalancing the supply chain for greener and more cost efficient logistics solutions

A case study at Volvo Parts Corporation

Master of Science Thesis in the Master of Supply Chain Management

GHAZAERI, AMIR
HOLST, JESPER

Department of Technology Management and Economics
Division of Logistics and Transportation
CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden, 2012
Report No. E2012:063

Rebalancing the supply chain for greener and more cost efficient logistics solutions

A case study at Volvo Parts Corporation

Master of Science Thesis in the Master of Supply Chain Management

Department of Technology Management and Economics
Division of Logistics and Transportation
CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden, 2012
Report No. E2012:063

Reproservice
Göteborg, Sweden 2012

Abstract

Volvo Parts AB is a business unit within the Volvo Group with the function of supporting the Volvo brands with aftermarket services. Maximizing customer uptime is considered to be the company's key goal which is mainly achieved through securing of instant spare parts availability.

The intensified situation within the automobile industry in combination with Volvo Group's evolving business has led to a substantial increase of air shipments. Transportation by air is to be considered as expensive and undesirable from an environmental point of view. However, the nature and characteristics of spare parts logistics together with increasing customer demand favors the transportation mode's significant overtake in lead-time.

The purpose of this master thesis is to help Volvo Parts to analyze the current transportation flows in order to create a holistic view of their current material flows. The aim of the thesis is also to analyze potential improvements through rebalancing of the supply chain and to suggest a feasible solution that ultimately reduces the amount of air shipments.

Two focus areas have been targeted; one towards refinement of their current set-up involving modification of parameters that affect the daily operations. The other focus area refers to a more conceptualized solution with an altered supply chain set-up.

As for the first improvement area it is clear that Volvo Parts needs to encounter, or compensate for, actual gross weights when calculating total transport costs per modal mode. Furthermore other valuable pieces of information such as hazardness and bulkiness that ultimately add surcharges need to be taken into consideration.

The second focus area investigates the possible benefits of incorporating alternative transport set-ups. A multimodal solution involving both sea and air for one of the largest material flows (Ghent – Singapore) is evaluated. This evaluation shows no significance in improvement but forms a valid alternative. Studies are also made on altered departure frequencies as well as changes in lead-time. This solution proves better than the current set-up with less air shipments and hence less costs as well as environmental impact. Furthermore, this solution provides a smoother flow with a relatively small effort in set-up modification making it feasible.

In order to broaden the views within the subject light was also shed on a perhaps futuristic solution consisting of a train-only solution. This solution involves a train route from Europe to China. By todays standards this alternative is unfeasible but remains as an interesting option for the future.

Keywords: LCA, Aftermarket, Spare parts distribution, Green logistics, Trans-continental logistics, Supply chain, Inventory management

Acknowledgements

This master thesis is a study of the current share of air transports and its underlying root causes in an effort of trying gain better efficiency at Volvo Parts. The study is conducted as the last compulsory part of our studies in the programme of Supply Chain Management at Chalmers University of Technology. Our research began at fall of 2011-2012 and has mainly been conducted in close collaboration with the employer at the headquarters of Volvo Parts in Arendal, Göteborg.

Firstly, we would like to thank our tutor Niklas Kilberg and Marius Holmsen, Quality & Environmental Managers, for their confidence in us by giving us this opportunity. Your support and supervision gave us inspiration, courage and motivation to pursue this research. We would also like to thank Joakim Niklasson, Transport Manager, and Kristina Wennerholm, Inventory Manger, for their full support and coaching in the deciphering of replenishment flows.

Our sincerest thanks go to Christian Erichsen, Logistic Concept Development Manager, who never hesitated in giving us his fullest cooperation by always answering our questions or directing towards people whom would. Without your patience and kindness this thesis would never have succeeded.

A special thanks to our supervisor Magnus Blinge, associate professor at the division of Transportation and Logistics, for his full support and wise advices.

Last, but not least, we would like to thank all of the people whom have been kind and patient enough to help us during our research. Your experience and knowledge have been valuable and enriching inputs that we will embrace in our future careers as engineers.

Gothenburg, March 2012

Amir Ghazaeri

Jesper Holst

Table of Contents

Figures

Tables

Charts

1 Introduction

For the reader to be able assimilate with the result of the thesis this initial chapter provides a background of the problem together with objectives and research questions. A brief description of Volvo Group and Volvo Parts, the focal business unit for this thesis, is provided. As a service to the reader a guide of how to read the thesis is also included.

1.1 Background

Volvo Parts is a business unit within the Volvo Group that functions as a service provider of aftermarket solutions for the Volvo Group company brands. The aim and objective is to provide high quality services, that together with the brand products, the *business areas*, help supplement and deliver the assurance of quality, convenience and experience that comes with owning a Volvo product. Thus Volvo Parts is one of the units that assist the Volvo Group in the role of being perceived as a solutions provider. These complementary services consist of aftermarket engineering in early product phases, through parts sourcing, advanced workshop tools, remanufacturing, hard and soft parts supply chain management to end-customer support – all with the purpose of providing and securing the highest possible uptime.

As Volvo Group's business has grown worldwide there has been a continuous growth of these aftermarket services due to acquisitions and joint ventures. Hence one of the core functions of Volvo Parts is to secure the sourcing of spare parts in which other services are highly dependent on. An effective parts sourcing is therefore vital in order to provide instant availability of exchange parts in case of sudden breakdowns.

Sourcing of spare parts within itself is characterized by a continuously increasing diversity in which challenges are growing more complex. Increasing fuel prices along with volatile markets in conjunction to *just-in-time* deliveries are few of the many challenges that are connected to the supply chain. In Volvo Parts case the complexity is further challenged by the uncertainty in predicting when and where breakdowns may occur. This is especially the case for the truck brands with vehicles that are on the move.

Today local and regional warehouses help cutting lead-times in order to maintain high availability. However, the wide range of spare parts requires a relative low depth in stockholding volumes in order to gain profitability. Short lead-times in refilling material flows are thus crucial in order to maintain high service levels. As of today, a lot of the parts sourcing is conducted by air freight; a less favourable mode of transport due to high costs and its environmental impact.

There are many incentives for researching the flow of parts sourcing, as balancing towards an optimum becomes a matter of trade-off between customer satisfaction, environmental aspects and profitability. Prior research[1] has also been made in an effort to highlight the aspects of green logistics. In that thesis report suggestions were given to further investigate the possibilities of material flow balancing in order to achieve greener logistics.

[1] Green supply chain for spare parts distribution: identified challenges of being "green" in aftermarket industry for Volvo Parts / Nader Aminimoghadamfarooj, Maria Shcherbakova

1.2 Problem discussion

Volvo Parts is a transport intensive company where costs of transports represent a high share of the turnover. A successful business requires a high focus on an efficient supply chain. The transport costs are distributed between different transport modes with air as the major post while only being a small share of the total weight. This stipulates that even the smallest reduction in air freight could lead to a significant reduction in cost. On the other hand, air provides fast transports that lead towards better agility and flexibility that ultimately gains higher service levels.

Air transports are not only costly in monetary terms but are also an excessive source of emissions. Thus reduction of air transports is also desirable from an environmental point of view. One of Volvo Group's core values deals specifically with *environmental care*. A core value is supposed to prescribe the attitude, appeal and overall perception of the Volvo brand. Hence the core value should permeate the daily business at all levels. In Volvo Parts case the aspect of environment is mainly present when transporting spare parts. As a consequence the environment should always be a prioritised matter when developing logistics solutions.

Customers of today are more demanding and require a high service level. As a premium provider these requirements are therefor particularly important to the Volvo Group. The service aspect can be seen as a contradiction to the environmental aspect if cost should remain unchanged. This implies that there is a close relationship between cost, service and environmental impact. Therefor changing one parameter will normally affect the other two. Hence, the challenge is to find a compromised optimum between the included parameters.

1.3 Objective

The purpose of this thesis is to conduct a study in order to investigate possible rebalancing options for increased efficiency and greener logistics with the criterion of maintained service levels. Since the thesis is initiated by Volvo Parts the aim is to produce a report where results can be implemented and ultimately gain their daily operations. This implies that the given proposals should be of such nature that they are feasible and profitable.

On an academic level the purpose of the thesis is to show how a supply chain may be improved in both monetary and environmental terms through rebalancing.

The thesis has two different objectives, which are partly interconnected. They are issued by Volvo Parts current desire for reduced air freights together with one of the corporate core values; *environmental care*.

The objectives are:

1. *Map the current share of air freight*
2. *Propose rebalancing alternatives and actions to **reduce cost** and **environmental impact**.*

1.4 Research questions

The thesis objectives will be further specified into question formulations in order to give a clearer view of the main purpose as well as the expected outcome. The following research questions seek to decipher the objectives and are hence to be answered by the thesis.

- ***How, where and why is air used for transports?***

  The aim is to identify how large the air-share is on different flows including a mapping of the distribution between the different transport modes. Root causes of why air is chosen to such large extent should also be identified.

- ***How are decisions taken regarding whether to use air transports or not?***

How is processes and management supporting decision taking when deciding transport mode?

- ***How can the same service level be kept by using less expensive transport modes in terms of both economic and environmental costs (e.g. reduced air)?***

Quantify potential cost savings in both monetary and environmental aspects from implementing rebalancing alternatives.

1.5 Scope and delimitations

For the rebalancing objective the thesis will have a clear focus on the specific links between central- and regional/support warehouses. The nature of the problem is mainly related to these flows since air freight is most frequently used here. With time being limited, in-depth analysis will therefor only be conducted on a specific flow. Emphasis will however be put into providing a context that provides a base to a future framework for further investigation of other flows.

It should also be stated that rebalancing is mainly focused towards the mode of transport rather than the degree of utilization. The reason for this is due to procurement of external transport services at flat rates and the relative large volumes that are sent within these flows.

1.6 Report Disposition

This report is structured into three main parts divided into 9 chapters. The first part consists of describing chapters (1 to 4) that provide the reader with background information as well as some necessary knowledge regarding logistics and supply chain management. The secondary part consists of chapter 5 that describe present situation while the third (6 to 9) evaluates and suggests ultimate solutions.

If you are a Volvo Parts employee we recommend starting from chapter 5.

1.7 Volvo Group

Volvo Group is a one of the world's largest and leading providers of commercial transport solutions with products and competences within the areas of trucks, buses, heavy construction equipment, engines and powertrains for marine and aerospace, as well as industrial applications and financial services. The company has since its start in 1927 grown to incorporate over 10 different brands employing over 115 000 people worldwide. Volvo Group has production sites in 19 different countries with sales and operations present in 180 countries. The turnover for year 2010 reached 264 billion SEK (Volvo AB, 2011).

Figure 1 – Some Volvo brands and their logotypes.

Table 1 – Volvo brands.

Volvo Owned		Joint ventures	
	Volvo Trucks		Eicher
	Renault Trucks		Sunwin
	UD Trucks		SDLG
	Mack Trucks		Silver
	Volvo Buses		Nova Bus
	Volvo Construction Equipment		Prevost Car
	Volvo Penta		
	Volvo Aero		

1.7.1 Corporate structure

The corporate setup of Volvo Group may be described as horizontally brand producing companies (business areas) that are supported by vertically integrated corporate business functions (business units). Each business unit is a subsidiary company specialized within an adequate area of expertise, serving the brands with common competences, services and technology.

Figure 2 - Corporate structure of Volvo Group and its subsidiary companies. The three Volvo business units' 3P, Powertrain and Technology together provide a complete and innovative solutions and technologies that that enriches the product development within e.g. Volvo Construction Equipment.

1.8 Volvo Parts

Volvo Parts is the functioning business unit that is responsible of providing all aftermarket services that together with the associated brands helps perceiving Volvo Group as an overall solutions provider. The business unit was established in 2001 with the mission of maximising customer satisfaction and profitability by providing leading edge in aftermarket services to the Volvo Group and other selected customers. This can be summarized into ensuring maximized *uptime* for the customers' vehicles, machines and equipment by providing the right tools and spare parts at the right time, at the right place.

Today the unit serves all of the Volvo Group's automotive brands globally, employing 4 200 people with operations in over 120 countries worldwide. The headquarters is located in Gothenburg, Sweden.

Figure 3 - Map of Volvo Parts operating locations.

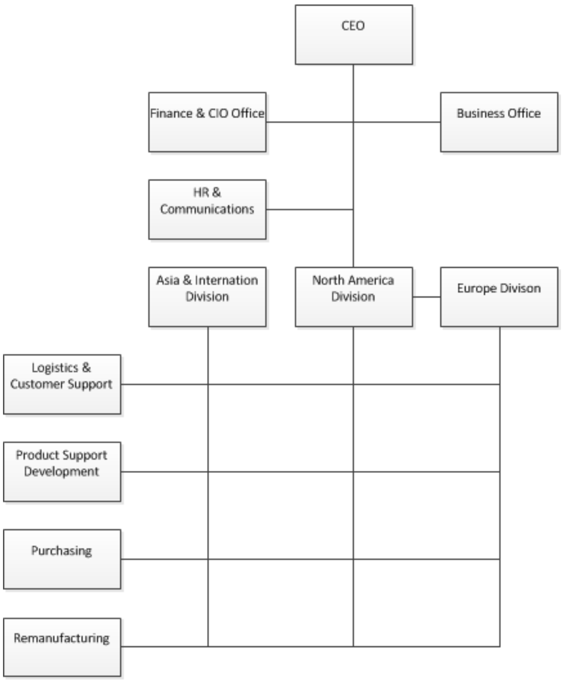


Figure 4 - Organizational chart of Volvo Parts.

The organizational structure of Volvo Parts consists of three main divisions that are supported by vertically integrated supporting business functions. These functions provide some of the business critical services that help maximizing the uptime of customers' vehicles.

1.8.1 Supporting business functions

Volvo Parts provide the following services: product support development, customer support, remanufacturing and spare parts supply chain management. These services are offered and maintained under the operation and management of the following business functions:

- ***Logistics and Customer Support (LCS)***

Logistics and Customer Support is the optimizing staff organization that support, develop and enhance implementation of global best practice processes and solutions. The organization consists of sub functions that work with global logistics concept development, materials management, warehouse development, distribution management and transport development.

- ***Product support Development***

Product support development is a business function within Volvo Parts that develops diagnosis software, spare parts (e.g. older parts or adaption to new markets), workshop equipment and special tools. The unit is also responsible for providing technical support and proper documentation such as manuals and whitepapers as well as education of on-site technical staffs.

- ***Purchasing***

Volvo Parts main business is to provide the customers with spare parts. To do so Volvo Parts has to take care of all physical handling and administration of parts in the entire supply chain, from supplier to end customer. This includes finding suppliers to ensure that the Volvo Group is represented with dealers and service possibilities. Procurement of transportation is not done by the purchasing function but Transport Development under the management of earlier mentioned Logistics and Customer Support.

- ***Remanufacturing***

Remanufacturing is Volvo Parts most recent business function with key focus within refurbishment of automotive parts. The key product ranges are within engines, gearboxes and differential carriers. Key responsibilities include securing business support, customer satisfaction, and synergies in product cost and product quality. The Remanufacturing unit is a global function with six production facilities available in Europe, Asia, North and South America and with the head of each function located at Volvo Group’s premises in Gothenburg, Sweden.

2 Methodology

The following chapter will describe the methods and approaches that have been used in order to conduct the studies for this master thesis.

2.1 Research approach

The idea for this thesis was initiated as a collaboration between higher levels of decision making at Volvo Parts seeking to create a better understanding for the considerable amount of airfreight (and thus to investigate whether areas of improvement exist). Hence the research approach is based on a framework that aims to provide answers and solutions that ultimately help mitigating air-share.

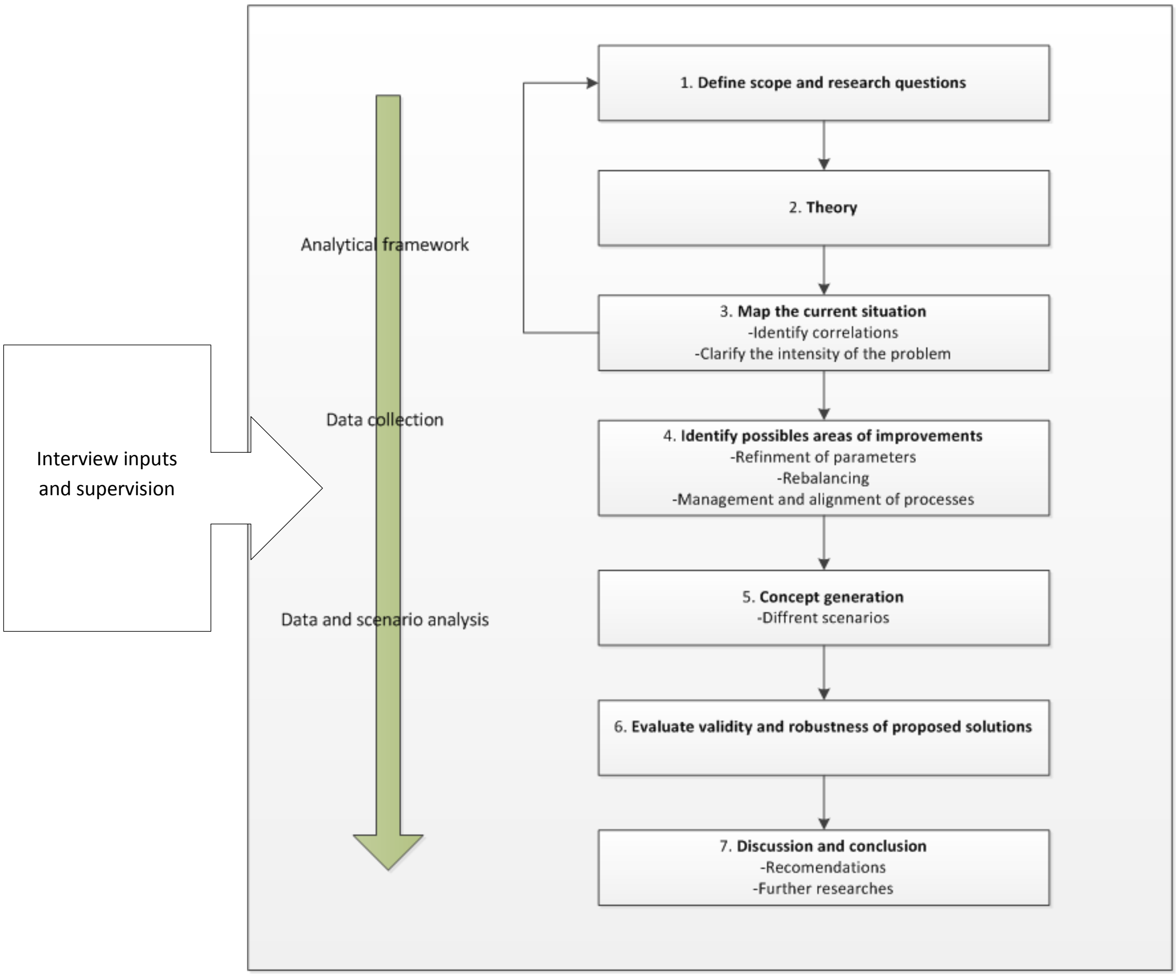


Figure 5 - Flowchart showing the research approach used within the thesis.

The method consists of a preceding iterative process, the analytical framework (box 1 to 3 in figure 5), which seeks to define scope and adequate system boundaries through proper identification of problem characteristics, problem intensity and corporate impact.

This is done through an initial data collection and mapping which is further backed up by relevant academic literature in order secure a conversant and qualitative pre-study on which further analysis may pursue. From this step a more excessive data collection follows in order to further clarify and identify possible areas of improvement. These are rendered in plausible scenarios from which further evaluation proceeds in order to determine robustness and feasibility for proper implementation. Ultimately thesis findings will be summarized into concluding discussions and recommendations as well as future research proposals.

2.2 Sources of input

Sources of input are mainly based on empirical findings at Volvo Parts. These consist of obtained raw data from numerous different business applications, interviews and business reports that are supported with adequate academic literature.

2.3 Validity and appliance

A perquisite for this thesis is to provide a basis for a framework from which future appliance may occur. Hence the research approach incorporates the use of common procedures and terminology used by employees at Volvo Parts. Furthermore the research validity and credibility has been secured through continuous supervision and guidance by key members at Volvo Parts.

3 Frame of references

The frame of references can provide valuable information for the readers that do not have previous knowledge within the discussed field. The chapter provides fundamental information within four areas: supply chain management, aftermarket, inventory and environment.

3.1 Supply Chain Management

Supply Chain Management, or more often just SCM, is a subject in development. Originating from logistics the definition has broadened to include a more holistic view of the entire material flow, from supplying raw materials to the finished product. This chapter will briefly describe the concept of supply chain management together with the in context often mentioned, and closely tied, phenomenon of *the bullwhip effect.*

3.1.1 Definitions of logistics and supply chain management

The term *logistics* has it origin from the military where procurement, maintenance and transportation of material, personnel and facilities are crucial. Today several different definitions are used. From some of the existing definitions Lumsden (2006) has made a suggestion to a condensed version:

"Logistics includes the movement of people and materials. It consists of those activities concerned with managing the right individual, in the right quality, to the right place, at the right time and at the right cost. It aims at satisfying all interest group's needs and wishes with focus on the customer. Logistics is the planning, organization, and control of all activities in the flow of materials, resources, financial assets, information and reverse flows. In the concept operative responsibilities that encompass administration, operation and purchase duties as well as detailed design are included."

The logistic efficiency can be described in the three different terms; delivery service, logistic costs and tied-up capital. Each term can be further divided into different sub factors. Adjustment of one term will affect the others – often negatively. A typical example of this may be reducing of costs in tied-up inventory that can result into lower service to the customer. So a proper manage of this dilemma is to improve the overall effectiveness of the three terms (Lumsden, 2006).

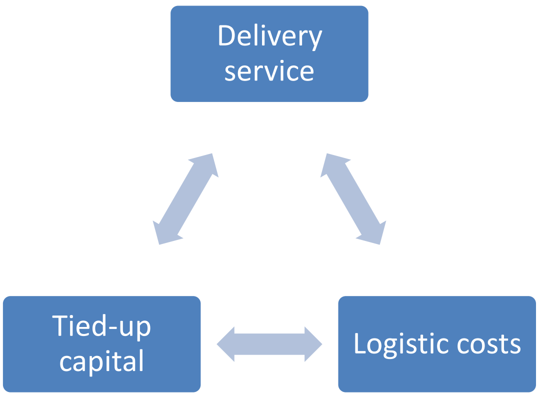


Figure 6 – The logistic dilemma.

A trend that has been on-going for some years is the shift from mass production towards more customized products and services (Skjött-Larsen, et al., 2007) (Phelan, et al., 2000). The trend together with efficient global transports and progress in the area of IT and communication creates possibilities to reach beyond the own organization and geographical area (Skjött-Larsen, et al., 2007). This development leads to an increased need of management within the so-called *supply chain*. The supply chain can be described as everything from raw material to recycling of the scrapped product. Cooper et al. (1997) states the supply chain simply as *dirt-to-dirt* including all steps in between.

There is no accepted general definition of supply chain management. The Council of Supply Chain Management Professionals (CSCMP) own definition is (CSCMP, 2011):

"Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies."

By today's business standards a more common understanding is that it is the supply chains that are competing rather than the companies. And in the end it is the end customer at the market place that determines the performance (Christopher & Towill, 2001). Present day companies do not function as isolated actors instead they are normally a part within the supply chain. For the end customer it is therefore important that the entire supply chain is well-operated, implying that optimization should be on an overall supply chain level. Optimisation of single actors can and will most probably lead towards sub-optimisations that risk creating an overall poorer performance.

3.1.2 The bullwhip effect

A recurrent phenomenon in supply chain management is what goes under the expression of the bullwhip effect. The bullwhip effect is an observed phenomenon in forecast-driven distribution channels where small fluctuations in demand become amplified when moving upstream in the supply chain. Distorted information between interacting actors within the chain is what creates these inefficiencies. The consequence of these inefficiencies lead to: poor customer service, excessive inventory, lost revenue, risk of inefficient transports (Lee, et al., 1997). The bullwhip effect has often been associated with retailing businesses but the phenomenon can be observed in all supply chains including aftermarket businesses. The outcome can however differ since the demand in the aftermarket has more unpredictable and uneven characteristics (see section 3.2).

The following information will be on a general level that may be applied to the aftermarket segment.

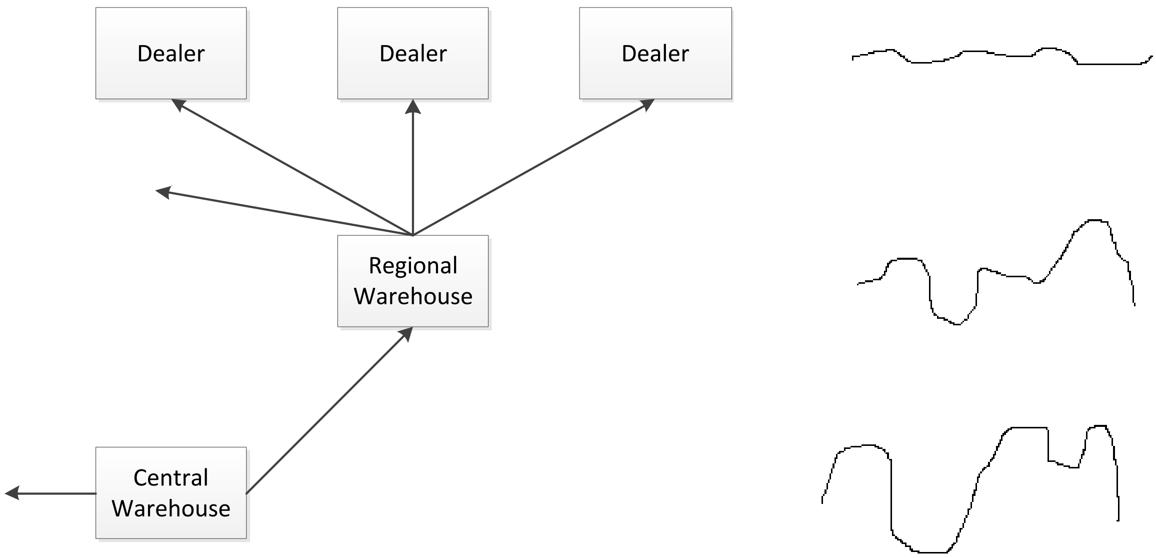


Figure 7 – The bullwip effect, demand fluctuations at three diffrent levels (Jonsson & Mattsson, 2005).

Four different factors have been identified as the root causes of the bullwhip effect. The four causes are (Lee, et al., 1997) (Lumsden, 2006):

- ***Demand forecast updating***
  Each actor within the chain predicts, or forecasts, their incoming demand based on the actor below in the chain. Distorted and inaccurate information can thereby travel throughout the entire chain.

- ***Order batching***
  Order batching is the approach of periodical ordering behaviour instead of frequent ordering. Reasons to use order cycles is to reduce the cost of each shipment since every shipment is associated with a fixed cost. Consequently this leads to a higher variation in the orders compared to the actual real demand.

- ***Price fluctuations***
  Price fluctuation in forms of special offers or campaigns increases variations in demand; therefore such price strategies ought to be avoided.

- ***Rationing and shortage gaming***
  Rationing and shortage gaming occurs when the demand is higher than the actual supply. Shortage gaming means that an actor is ordering much more than he or she actually needs and can thereby cheat the rationing system. When the rationing is over the demand forecasts will be exaggerated.

Actors in the supply chain are most often acting rationally in accordance to their prerequisites and needs. Therefor in order mitigate the risk of bullwhip emphasis should be put into modifying the supply chain infrastructure, and its related processes, rather than decision behaviour. (Lee, et al., 1997)

There are several actions that can be done to counteract the bullwhip effect. Better transparency through information sharing is perhaps the most important. For example, the final customer demand can be shared to all actors in the chain. This creates a better alignment in order to reach better coordination (such as pricing, transportation and inventory planning) between involved actors (Lee, et al., 1997). A better operational efficiency through reduced lead-times and cost improvements can also mitigate the bullwhip effect (Lee, et al., 1997). Trust between actors in the chain is an important factor as well (Lumsden, 2006).

3.2 Aftermarket

The following section will provide the specific characteristics of the market in which Volvo Parts operates within. It is primarily a brief guide to the characteristics of the aftermarket sales followed by the focus on uptime and spare parts.

3.2.1 Aftermarket characteristics

A company's initial relationship with its customer begins from the time when the product is purchased, the selling point. The provided support and services from this point of sales are called *aftermarket* (Phelan, et al., 2000). After-sales services are high profit margin businesses where the aftermarket can contribute for a severe part of a company's total profit even if it has relatively low revenue shares (Cohen, et al., 2006) (Herbig & Palumbo, 1993).

Today's businesses are focused towards providing their customers with comprehensive solutions that both incorporate products and services (Phelan, et al., 2000) (Cohen, et al., 2006). This shift is most evident in today's automobile industry with business models like private leasing where maintenance and support is included together with the vehicle at a flat monthly rate. In that sense the customer is buying a transport service where the seller assures proper functionality over a defined time, which is the same as uptime. For more about uptime see section 3.2.2. The aftermarket is a key feature to the focus of becoming solution providers for companies.

The aftermarket has strategic benefits for the company. Cohen et al (2006) mentioned several reasons. Obviously the economic reason is significant due to the long-term versus low-risk revenue stream that the aftermarket creates. The aftermarket also creates a direct channel to the customers' usage of the product. This also allows for better understanding of the customer context and better planning. Another strategic benefit is building loyalty to the customer through the aftermarket. It is always more cost efficient to keep customers than finding new. Lastly, when winning new customers the aftermarket can work as a key differentiator (Cohen, et al., 2006) (Herbig & Palumbo, 1993).

The aftermarket business can offer a diversity of services including covering the need of spare parts to customers throughout the entire product life span. Typically aftermarket services can be: helpdesks, consulting, on-site support, conducting repairs, installing upgrades, day-to-day maintenance, product warranties and financial arrangements (Cohen, et al., 2006) (Phelan, et al., 2000).

3.2.2 Uptime

A frequently used term in the aftermarket area is uptime. Since the used equipment in present businesses are automated to a high degree, and thereby expensive, it is important that the equipment function when needed. Uptime describes the capacity to produce and provide products and services (Campbell & Reyes-Picknell, 2006). The concept of uptime consists of both availability and reliability. Availability is best described as a failure-free operation at any given instant of time while reliability refers to a failure-free operation during a time-span. According to Aminimoghadamfarooj & Shcherbakova (2010) uptime may generally be defined as:

"a period of time when the equipment is functioning and available for usage"

3.2.3 Spare parts characteristics

Spare parts are essential in two cases, emergency repair or planned maintenance in a technical installation (Fortuin & Martin, 1999). Emergency repair is needed when there is a failure on the equipment. Failure is defined by Fortuin and Martin (1999) as:

"State of a system when a component no longer has the physical condition perceived necessary for proper functioning of that system."

For spare parts it is important to have a high service level since a stock-out may generate substantial economical losses for the customer (Huiskonen, 2001). For example, a failure of a critical part in a production line can stop the entire line. And if the needed spare part is not available it will result in production losses for the customer.

Spare parts distinguish from other materials in logistic planning concerning; high service requirements, erratic and sporadic demand as well as high profit per item (Huiskonen, 2001). Despite the erratic and sporadic demand basic estimation models are used for inventory calculation, such as EOQ (see section 3.3.3). These basic models are normally less suitable for the spare part demand characteristics since the distinguished factors are not equal to the ideal situation in which these methods are designed for.

Another special feature is the length of time in which a specific spare part should be available. A common understanding would be to offer availability from the last date of production throughout the whole product lifespan. These long periods in combination with differentiation in models is however challenging due to e.g. predictions in future sourcing etc.

3.3 Inventory

Inventory is a common feature in supply chains. This section will provide a brief overview of some of the fundamental ideas and concepts within theory of inventory control.

3.3.1 Purpose of inventory

There are several reasons to hold inventory (Gourdin, 2001). The most profound reasons are listed below:

- Inventory creates *economy of scale* in a numerous of ways. Normally the production cost per piece can be reduced e.g. due to larger purchase quantities or fewer changeovers. Transport costs can also be reduced if the quantities per shipment increase.
- If *supply and demand not occur at the same time* it is necessary to have inventory. This can be applicable for seasonal products which have significant peaks in demand. For such products it can be good to have levelled production during the whole year and not to dimension the production capacity after the maximum demand.
- Inventory can serve as protection against uncertain demand. Normally the demand is forecasted and does not reflect the actual outcome. There may also be other uncertainties such as delays in transports or quality problems.

3.3.2 Safety and lot size stock, carrying cost

An inventory can be divided in two different parts, *lot size stock* (Q) and *safety stock* (SS) where safety stock is optional. The lot size stock is consumed during a period of time. At the *reordering point* (ROP) the lot size Q is re-ordered (figure 8). It is seldom that the demand has such a predictable and straight curve as in the figure. Therefore it is common to have a safety stock as a protecting buffer in case of either *lead-time* (LT) disturbances or sudden increases in demand. (Lumsden, 2006)

$$ROP = SS + D * LT$$

D = demand

$$SS = Z * \sqrt{LT * \sigma_D^2 + \sigma_{LT}^2 * D^2} = Z * \sigma_D * \sqrt{LT}$$

LT = lead-time

Z = safety factor

σ_D = deviation of demand for a time unit

The quantity Q can be calculated in a numerous ways. Most common is to use the *economic order quantity* (EOQ) formula (section 3.3.3). When Q is chosen the ROP can be estimated since the LT normally is known.

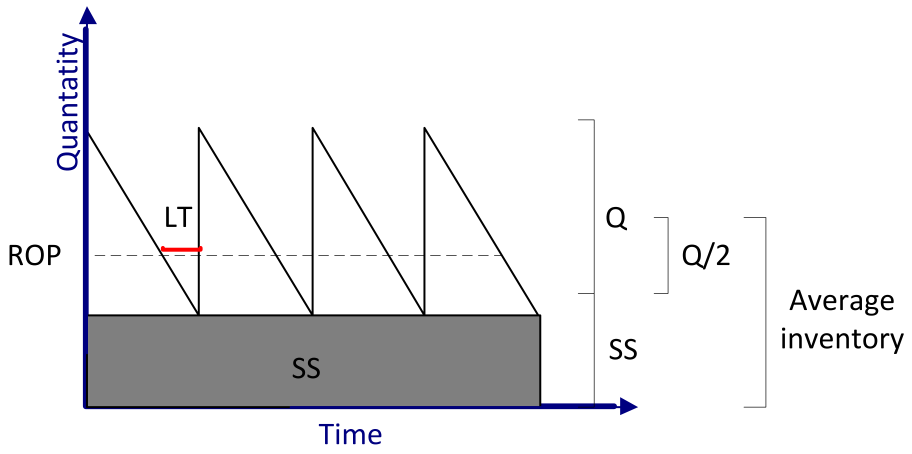


Figure 8 – The inventory principal with included definitions.

Keeping inventory is associated with costs. The cost for keeping an item in stock is called *inventory carrying cost* (ICC) and consists of three parts (Jonsson & Mattsson, 2005):

- Capital cost (financial)
- Storage cost (physical)
- Insecurity cost

The financial cost is equal to the company's general revenue request. So the bank interest is the lowest possible revenue requirement for a profit-driven company. The physical storage cost includes all operative costs for the warehouse. The insecurity cost can include risk for damages, obsolescence and theft. Additional costs for wrong picking and insurance can also be included in insecurity costs. Insurance costs are easy to estimate compared to the other factors. The capital cost can be calculated as follow:

$$ICC = ASL * I * P$$

ICC = inventory carrying cost

ASL = average stock level

I = inventory carrying rate

P = price per item

3.3.3 Economic order quantity

The Economic Order Quantity (EOQ), also known as the Wilson formula, is a common way to determine the optimal ordering quantity in the industry (Jonsson & Mattsson, 2005). Typically the formula is applied when ordering from production to inventory as well as from inventory to inventory.

The formula is based on several assumptions and should therefore be seen as an estimate. Following assumptions is used for EOQ formula (Lumsden, 2006):

- *The demand (D) is constant and known*
- *Deliveries arrive momentary with the total quantity (Q) at one moment.*
- *Purchasing price (P) is constant and known.*

- *Order handling cost (O) is constant and known.*
- *Inventory Carrying cost (I*P) is constant and known.*
- *No shortages exist; the inventory can always meet the demand.*

Despite these limitations the EOQ formula can be useful and easy to use even if some changes and assumptions are necessary. For example the demand is normally not known but a forecast can be used as an approximation.

The EOQ formula identifies the minimum total cost by using deviation. The *total cost* (TC) is the sum of the inventory carrying cost and order handling cost (set-up cost).

$$TC = \frac{Q}{2} * I * P + \frac{D}{Q} * O$$

Q = ordered quantity

I = inventory carrying rate

P = price per item

D = demand per time unit

O = order handling cost per order (set-up cost)

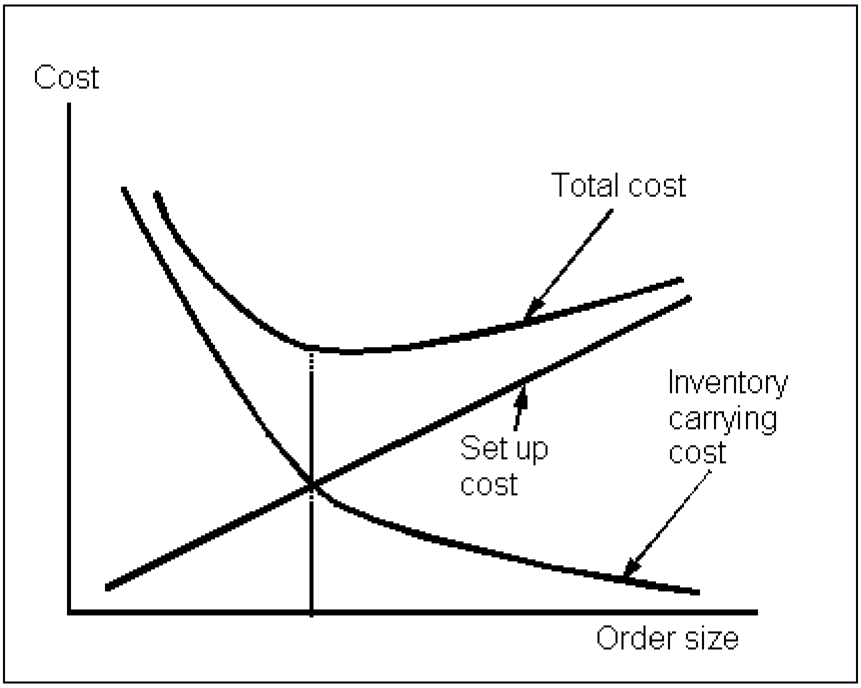


Figure 9 – How to find the economic order quantity.

$Q_{optimal}$ which is the economic order quantity is calculated by deriving TC with respect to Q and setting the function to zero.

$$EOQ = Q_{optimal} = \sqrt{\frac{2 * D * O}{I * P}}$$

3.3.4 Inventory control and inventory turnover

It is important to measure the performance of a warehouse. Delivery service is one of several measurements used to benchmark a warehouse's performance. Lumsden (2006) defines delivery service as:

- Stock availability
- Delivery time
- Accuracy of delivery
- Delivery of security

Inventory turnover is also a frequently used performance indicator for warehouses where the focus is more on the internal processes. Inventory turnover, the ratio between value of outgoing products and average inventory value, expresses the relation between tied-up capital and cycle time (Lumsden, 2006).

$$\frac{Value\ of\ outgoing\ products}{avaerage\ inventory\ value} = Inventory\ turnover\ \left[\frac{times}{year}\right]$$

3.4 Environmental impact

The environment is closely related to transports since the transport sector is a great source of negative environmental impact. The environmental impact is both in terms of greenhouse gases and air pollution which will be further explained below. This section will also cover a method for calculating environmental impact.

3.4.1 Transport modes and their environmental impact

The transport sector represents a large part of the air pollution and environmental problems (TFK, 1998). Emissions from transports can be divided into two main impact categories; greenhouse gases and air pollution. Greenhouse gases mainly consist of carbon dioxide (CO_2) and hydrocarbons (HC) which have a global impact and must be dealt with at an international level (Rogers, et al., 2007). The environmental impacts of the greenhouse gases consist of contributions to the greenhouse effect and thus global warming. However, hydrocarbons also have a range of different toxicity levels and forms ground level ozone in combination with NO_x that can be of concern to human health.

Air pollution occurs mainly because of particle matters (PM) as a consequence of nitrogen and sulphur oxides (NO_x, SO_x) emissions with local to regional effects (Lumsden, 2006). PM emissions occur from both combustion of petroleum fuels and particle that are released from e.g. braking, tire and road wear. PM probably have the largest negative effect on health (Environmental Agency, 2009). NO_x emissions have several severe environmental impacts including contributions to the greenhouse effect, over-fertilization, acidification and forming of ground level ozone (Rogers, et al., 2007). Over-fertilization affects the ecosystems of seas and lakes by an excess in nutrients causing the bottom sediment to die due to lack of oxygen. The acidification is an effect of both NO_x and SO_x emissions and affects the ecosystems vitality of both soil and water (Lumsden, 2006). Furthermore, it can cause metal ions to leak into drinking water, crops and fish ultimately accumulating in humans. SO_x emissions also negatively affect health, such as lungs, eyes and throat. Other types of important environmental impacts are noise, land use and barriers (Lumsden, 2006). Noise has proven to have negative health effects, especially in children (Agency, 2009).

External effects of transport can be divided into three levels: local, regional and global effects. Local effects target the humans directly and locally near the source. The time span for the negative effect is relatively short. This type of problems is normally easy to reduce. The regional effects have a longer time perspective on the damages and the geographical area is much larger. The problems hence become harder to solve since several countries can be involved. Global effects are synonymously to greenhouse gases. The global effect has an even longer time perspective and it is an international problem.

Table 2 – Summary of transports environmental impact (Lumsden, 2006).

	Local effects	Regional effects	Global effects
Physical effects	Air-pollution: CO, NOx, SOx, HC, pitems and lead. Smoke. Smell. Noise. Vibrations. Polluted water. Land usage. Waste and scrap.	Air pollution: NOx, SOx and HC. Land usage. Polluted water from NOx.	Air-pollution: CO2, CH4, N2O and CFC. Using finite resources.
Social and indirect effects	Accidents. Delays, ques. Local land usage.	Economic growth. Regional investments for land usage. Consumer choice and cost for products	
Subjective effects	Fear of traffic. Barrier effects. Visually effraction.	Lifestyle. Expectations.	

Road transport stands for a large portion of the CO_2, HC, NO_x and PM emissions as well as high noise levels (TFK, 1998). The TFK report states that most heavy duty vehicles today are driven with diesel fuel which emits more NO_x and article than petrol. On the other hand the diesel engine is more efficient and thus reduces the amount of CO_2 emissions (Eurostat, 2009). So far regulations (Euro class) regarding emissions from truck transports in Europe have been derived from a focus on NO_x and PM reduction. Railway transports are more energy efficient in comparison to road transport, but emissions depend on the fuel source (TFK, 1998). Most of the freight trains are diesel driven and therefore the complete potential is not exploited.

Shipping is another energy efficient alternative with low fuel consumption in terms of tons of goods per kilometer at lower speeds. However, since most ships use bunker oil as fuel (containing up to 3% sulphur) the emissions from SO_x are extremely high in comparison to road transport (TFK, 1998). Air transports have also increased in frequency and volume since the 1990's and have an enhanced environmental impact due to direct emissions into the stratosphere (Eurostat, 2009) (TFK, 1998).

3.4.2 Green logistics

Green logistics and similar terms have become more common during the last years. It is the growing interest for the environment that has forced this development. There is no exact definition of what green logistic is (Lumsden, 2006). On a general level it can be described as striving towards minimizing environmental impact from the logistical work by using existing resources and technology. This is important since transports often stand for the major portion of a company's environmental impact. Improvements for higher utilisation of resources are often good for both the environment and the economy (Lumsden, 2006). Therefore it is natural for companies to act in a green logistic manner since it will lead to a reduction in cost for the companies as well.

3.4.3 Life Cycle Analysis

Life Cycle Analysis (LCA) is a technique that estimates the environmental impact caused by products and processes during a specified time-span, normally from "cradle to grave" (Reap, et al., 2008) (Baumann & Tillmann, 2004). The method can be seen as a comprehensive method where the whole life cycle is analysed. The method uses quantified figures of resource usage and emissions from the processes (Baumann & Tillmann, 2004). But according to Baumann & Tilleman (2004) LCA can also be seen as the procedure that is used for denoting a LCA. The procedure contains the following parts that are fundamental to the interpretation part:

- Goal and scope definition
- Inventory analysis
- Impact assessments
  - Classification and characterization
  - Weighting

One strength which also can be seen as a weakness is the wide opportunities to use LCA in different contexts. Possible areas could be: decision making, learning/exploration and market claims. Almost every LCA analysis is unique since the goal and scope definition varies for each study. Therefore it is hard to compare different LCA's with each other. The scope is normally a whole system and hence sub-optimisations can be avoided even if a considerable effort is required (Baumann & Tillmann, 2004). Some aspects are not included in a LCA, such as: economic, social and risk aspects. A problem with LCA is the possibilities to suite the result after own purposes. So a critical attitude regarding scope and boundaries is necessary.

3.4.3.1 Environmental Priority Strategies

The Environmental Priority Strategies (EPS) is a Swedish system that defines environmental impact. It is based on the LCA methodology (Steen, 1999). For this thesis the weighting factors is collected from EPS since Volvo Group is using the method to decide environmental impact. Different weighting factors are used for the different emissions. In this report CO_2, NO_x, SO_x and PM are aggregated to one figure. The figure is called *Environmental Load Unit* (ELU). The ELU figure shows the societies willingness to avoid or restore the environmental impact. 1 ELU is approximately 1€.

4 Volvo Parts distribution structure

The following section will provide an overview of Volvo Parts distribution structure. The overview gives a brief explanation of the Volvo Parts warehouses, their main functions and characteristics, as well as the links in between.

4.1 Distribution nodes

Figure 10- Map of Volvo Parts present locations.

4.1.1 Warehouses

Securement of instant spare parts availability is perceived through buffering functionality of warehouses. Today Volvo Parts have more than 40 warehouses situated worldwide. These are separated by different *central*, *regional* and *support* warehouses that each favour the distribution layout that it is operating within.

Central

The central warehouses (CW) function as Volvo Parts main supplying hubs that supply regional warehouses (RW), support warehouses (SW) and ultimately dealers. The central warehouses hold a broader range and depth in assortment. However each of these holds a stronger degree of brand commitment due e.g. prior mergers and acquisitions or differentiations among product ranges[2].

Table 3 – Present Volvo Parts central warehouses and serving markets.

CW Sites	Business areas (main)	Serving regions
Ghent – Belgium	Volvo Trucks, Volvo Buses and Penta	Europe, Asia and North America
Lyon – France	Renault Trucks	Europe, Asia and North America
Columbus – USA	Mack Trucks	North America
Seoul – South Korea	Volvo Construction Equipment	Asia
Eskilstuna – Sweden	Volvo Construction Equipment	Europe, Asia and North America

[2] E.g. Volvo Groups acquisition of Samsung Heavy Equipment in 1998 with CW in Seoul, Korea.

Regional

The regional warehouses function as smaller supplying hubs within distant markets. These are typically situated within Volvo Groups more recently acquired markets in Asia and are hence necessary due to the greater distances to the central warehouses.

Today Volvo Parts has 18 regional warehouses, each manned with their own ordering office, serving different markets worldwide. The range and depth in assortment varies by local brand presence (business areas) as well as serving markets. As previously stated these are mainly supplied from the central warehouses but may also include direct local sourcing[3] which is further discussed in section 4.5.3.

Support

The support warehouses function as supporting day orders hubs. The logic is to reduce distance to the dealers and thereby maintain the shorter lead-times that are associated with day orders. Support warehouses are only present within the European region and their roles are further explained in chapter 4.5.1.

4.1.2 Drop points

A distribution point is typically a dealer or an importer and sometimes temporary customers. In total Parts has approximately 15 000 distribution points in 120 countries. Especially in the old home markets for the Volvo Group, Europe and North America is it a high concentration of distribution points.

A typical dealer performs maintenance and service of the customer's vehicle or equipment for example a bus or a truck. Dealers can also sell trucks and buses or other Volvo brand products to the end customers. The dealer is the interface between Volvo and the end-customer. Most dealers also have their own inventory of spare parts. These items that are stored at the dealer are high frequency spare parts such as oil, wiper blades etc. Spare parts that have a crucial function to the vehicle and a low price can also be stored to avoid unnecessary downtime of the vehicle. The dealerships may be privately held or Volvo owned. Volvo primarily owns dealers in the European region.

4.2 Order classes

As previously stated the core function of Volvo Parts is to provide maximized uptime through availability of spare parts. Therefore, in order to understand the distribution setup a brief description is provided on the classification of incoming orders in which layout and material flow to an extent is derived from.

The flow of material between warehouses and dealers are classified according to three different order classes that help differentiate urgency and importance. These order classes are:

Stock orders (Stock)

Securement of instant spare parts availability is maintained by availability of on hand stock. Stock orders refer to orders that primarily are intended for replenishment of on-hand stock inventory. Such inventory is often characterized by frequent and uptime-critical parts (e.g. oil and air filters). Hence Stock orders, given as an order class, are typically of lower immediate urgency due to the replenishment characteristics with higher safety levels and larger order quantities.

[3] E.g. Air filters are locally sourced within region China.

Day Orders (Day)

Day orders are planned end-customer orders that are dedicated for a specific service/repair. Day orders occur in cases where there is no instant stock availability or replenishment within the appointed time fence. Hence day orders mark a higher degree of urgency as the order has a direct end-customer awaiting delivery. As implied by the name, *day* refers to the ambition of having the items handled and sent within the same day.

Vehicle Off Road (VOR)

A VOR order is the most prioritized order aiming to deliver the spare part(s) within the shortest possible lead-time. The main objective of a VOR order is to resolve an unforeseen incident where a vehicle is out of order. Hence the cost of delivery is secondary as the goal is to minimize the customer's downtime. Most VOR scenarios involve sudden break-downs involving non-frequent parts in areas where parts availability is low. However it is important to point out that VOR orders are not entirely based on shortages in parts availability, but rather a classification of urgency.

As previously stated end-customers and dealers are normally not surcharged with the extra costs of handling Day and VOR order classes of higher urgency. This stresses the importance of a functioning replenishment and all the involved processes in connection to it. Section 4.4 will give a better detail of the involving replenishment processes. Most dealers are also authorized and have thereby agreed to not misuse order classifications.

4.3 Transportation

Volvo Parts does not own its own transportation fleets but instead relies on procurement of external transportation services. Each flow is predefined by a set of independently procured forwarding services corresponding to the desired lead-times and order classes. Used methods of transportation are sea, truck, courier and air. The actual modal choice varies depending on various factors involving cost, goods characteristics (e.g. hazardous), geographical location and local restrictions, as well as the state of urgency.

4.3.1 Transportation modes

Today Volvo Parts have five different transport modes for the outbound flow. They are named in three categories according to IT system definitions. It is sea, air and courier. Sea includes both vessel and truck while air has two different classes, air daily and air consolidated.

Sea

By Volvo Parts terminology forwarding by truck or ferry are system wise both referred to as *sea.* This stems from limitations within early-adopted IT-systems from times when Volvo Parts only operated in the European markets. However, each market is usually declared to the usage of either of the two transport modes, with sea by ferry being the most common in the Asian region while truck in the European.

Transportation by sea, especially sea by ferry, is usually the desired mode of transportation due to economies of scale that its characteristics provide. Low price and cargo flexibility together with lesser risk of cargo restriction are all factors that favour the transportation method making it ideal for Stock orders.

Air

Air refers to consignments sent by airborne transportation methods. The shipments are mainly characterized by short lead-times and calls for cases where a sense of urgency is required. Shipments must either be considered as time critical or economically beneficial[4]. This is primarily due to high costs of air freight but more recently also because of environmental aspects.

Transportation by air is offered by two main services:

- **Air daily**

Consignments sent by air daily are shipments that will depart with the next flight. By default departures occur on daily basis making the order-to-departure less than 24 hours. This may vary from site to site depending on agreements and flight schedules. The service is expensive and mainly intended for cases where time is critical, e.g. Day or VOR orders.

- **Consolidated air**

A Consolidated air shipment is a less frequent and less expensive alternative with longer lead-time compared to Air daily. The service is hence preferred within the air category and commonly used for Stock orders in remote regions in order to e.g. cope with order peaks, catch up lead-time disturbances or to prevent the risk of run-outs.

Courier

Shipments by courier usually refer to smaller consignments of single urgent Day or VOR orders conducted by a local courier company, e.g. taxi. Courier deliveries are rare and often initiated by local dealers not too far away from the supplying origin.

4.3.2 Differentiation

Modal choice is usually determined depending on order class which states the urgency. Stock orders are due to the frequency and amount mainly concentrated towards sea transports that offer economies of scale. There are however cases where modal choice is determined on a part specific range, e.g. hazardous goods that are prohibited by air etc. Some items are also always more beneficial to forward by air. These parts are classified as *air-items*.

The logic behind the air-items classification is to group lightweight and expensive items where the transit costs by sea exceeds those of air. Air-items are derived for each market due to differences in price, frequency, freight costs and lead-times etc. The figure below illustrates the logic and the included components used for determination. Basically calculation compares the frequency-based costs created by the economic order quantities against the actual cost of transit with emphasis on cost of tied-up capital influenced by lead-time.

[4] Cost efficient items – e.g. high cost per weight unit, high profitability etc.

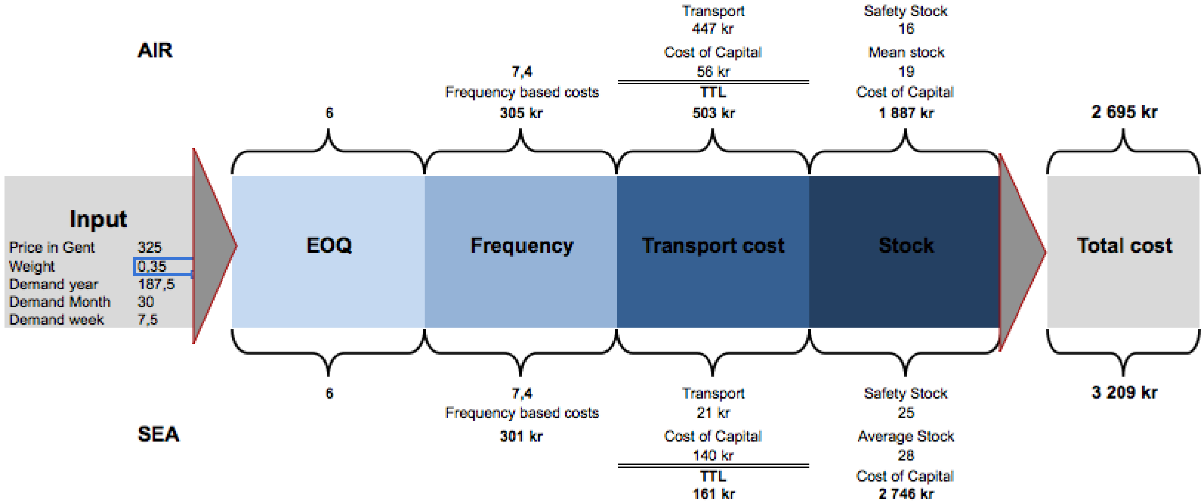


Figure 11 – Calculation of modal choice, eg. defining air-item and sea-item.

4.3.3 Hazardous

Hazardous goods refer to items that are either to be considered as dangerous or harmful. The definition is used in order to determine handling methods and appropriate ways of transportation. Hazardous items are classified according to set of codes that determines whether or not it can be shipped by a specific mode of transportation.

Hazardous goods allowed and sent by air are typically 10 times more expensive than the regular air freight. The definition of what might be considered as hazardous may differ from country to country.

4.3.4 Customs

Some items may vary in transport due to increased total cost from customs and toll fees. The phenomenon exists but is more often subject to temporary restrictions and hence left out of the scope of this thesis.

4.4 Replenishment

The replenishment function within Volvo Parts is mainly conducted by the department of *Material Management*. Material Management is hierarchically a sub-unit within the European division that has grown to incorporate the responsibility for all global regions as new markets have emerged. The department consists of several sub-units, each focusing on different replenishment flows, which in the context may be differentiated among brand, warehouse, agreements and/or order class.

The following section will provide a brief description of the business functions that are present and responsible within the scope of the thesis.

4.4.1 Inventory Management Refill – CW to RW/SW

Inventory Management Refill (Refill) is a sub-unit within the department of Material Management that is responsible for the replenishment, or *refilling*, of the regional and support warehouses. The refill teams hence manage the replenishment stock order flows and are thereby responsible of key parameters that affect the overall warehouse performance; such as service level, turn-over, cost of tied-up capital etc.

4.4.2 Order office – SW/RW to Dealer

The order office is an organizational unit represented locally at the sites of regional and support warehouses. This allows for the establishment of a closer and direct contact with the dealers. These are responsible of handling and securing delivery of incoming day orders including arrangement of e.g. direct transports in case of backorder. Local sourcing, when present, is mainly also operated by the local order office.

4.4.3 Logistic Partner Agreement – CW/RW to Dealer

Logistic Partner Agreement (LPA) is a vendor managed business concept where Volvo Parts offers to manage and replenish the stock inventory of the dealer. The dealer will still own their inventory but with assurance of refunds for proposals that remain unsold. This allows for mutual positive effects as dealers maintain high service levels with lesser risk of obsolescence. In Volvo Parts case the better visibility allows for better planning creating more organized replenishments at lesser total costs. In addition the agreement also allows for reverse allocation of critical VOR parts.

Today almost all large dealers are connected to the LPA concept which is managed by the *Dealer Inventory Management* (DIM). The DIM team is a sub-unit within the department of Material Management that are responsible for the management and replenishment of dealer inventory.

4.4.4 Volvo Action Services

Volvo Action Services is a team consisting of around 100 white collar workers that are in charge of handling incoming VOR orders. The team is located at the very heart of the material flows, namely the central warehouses. Their task is to locate and allocate the desired spare parts and to arrange the shortest possible lead-time of delivery.

4.5 Distribution layout (Volvo Trucks, Volvo Buses and Volvo Penta)

In this section the distribution layout is explained for the European region and the Asia and International region. The distribution is explained from both directions, upstream including order flow and downstream including material flow.

4.5.1 Volvo Parts – Region Europe

The European distribution layout is among Volvo's first and therefore oldest markets. It is in all characterized by relatively short distances in a region with highly enhanced infrastructure that is free from subsequent customs and duties. Today the region consists of over 800 dealerships, each with their own stock inventory, differentiated among the Volvo brands. Most of these dealers are connected to the earlier mentioned LPA giving Volvo Parts the responsibility of their stock replenishment (DIM function).

The supply chain is setup according to a vendor-managed approach that creates push replenishment of on hand stock inventory. This creates a rather simple order flow whereas the only incoming orders are created by those of Day or VOR classification.

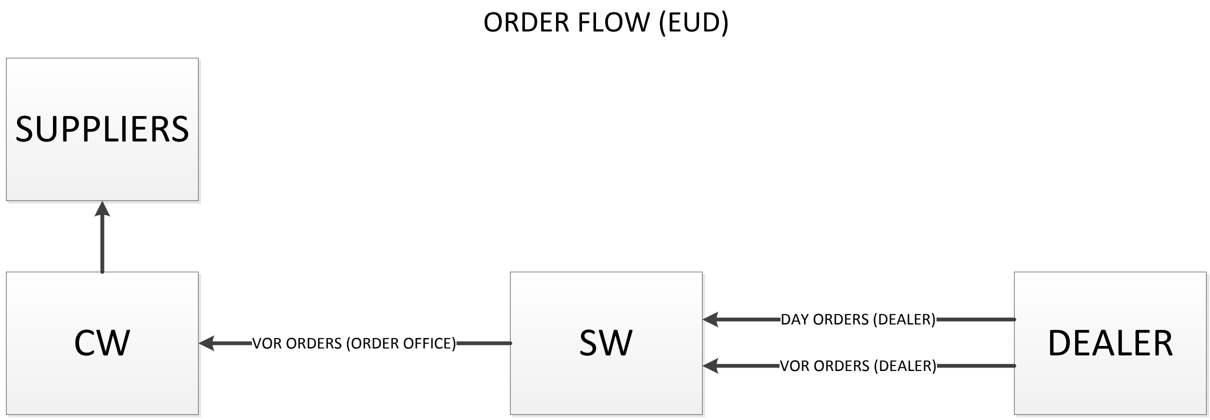


Chart 1 – Flow chart of the ordering flow within the European market with Support warehouses. As shown the only pulling order flow in the setup is created by Day and VOR back orders.

The material flow is somehow more complex. As seen by the chart below Stock orders are forwarded both to the support warehouses as well as the dealers, each under management of its own functional replenishment team. The main material flow within the distribution layout is obtained through these direct stock flows.

The direct stock replenishment frequency to the support warehouses is on a daily basis while varying between one to five occurrences to the dealers (depending on dealer size, volumes and distances). This creates a setup with better consolidation possibilities and a centralized buffer in the close adjacency of the dealer.

Dealers may also have direct deliveries on other orders than stock from the central warehouse or even suppliers – a scenario that occurs when the support warehouse fails to meet instant availability of a Day or VOR order.

Truck (sea) is by far the most common method of transportation for all order classes with the exception of distant markets in the Nordic and Spain where Day backorders are covered by air freight.

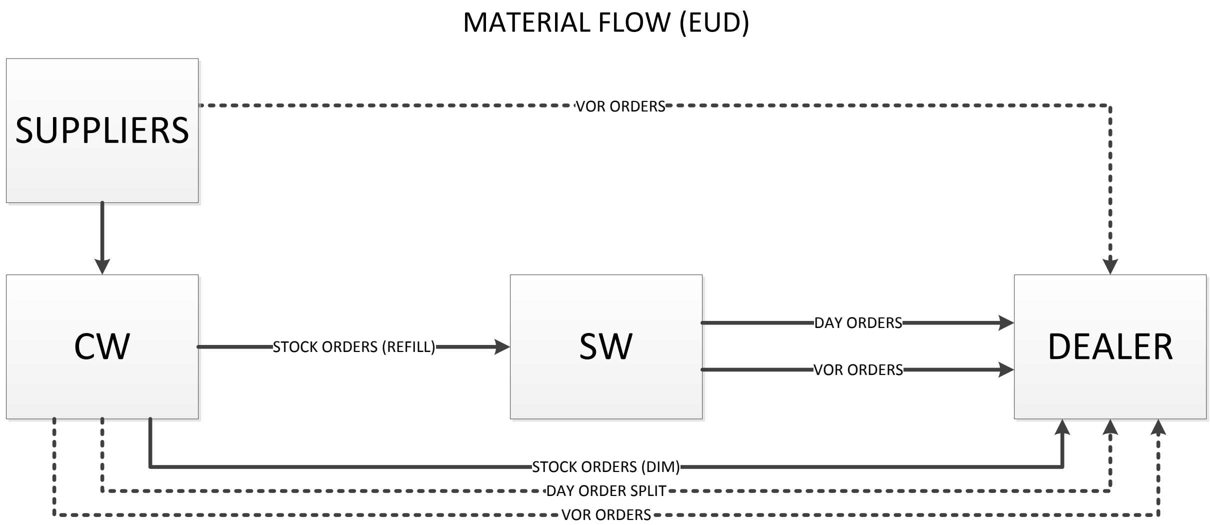


Chart 2 - Flow chart of the material flow within the European market with Support warehouses.

4.5.2 Volvo Parts – Region North America

The North American regions distribution layout stems from the acquisition of Mack-Trucks. The setup differs in the way that outgoing flows from Europe are complementary supplement to a central warehouse that primarily services the Mack brands. Hence all the flows to the region are central warehouse refills and thus out of scope.

4.5.3 Volvo Parts – Region Asia and International

The Asian region consists of Volvo's more recently acquired markets with new brands that create an even broader range in assortment. Unlike the European flows these are typically associated with the complexities that descend from the greater geographical distances from the central warehouses. Also, the lack of coherent trading union, political restrictions along with customs and duties further affects the way the layout is setup. The most significant difference is the presence of regional warehouses that are characterized by self-driven functioning organizations, each with their own procurement and order handling. This is to a large extent driven by the geographical constraints but also because of limitations that prohibits full ownership of e.g. dealerships. As a result LPA is less common as customers are mainly represented by private dealers and/or governmental institutions.

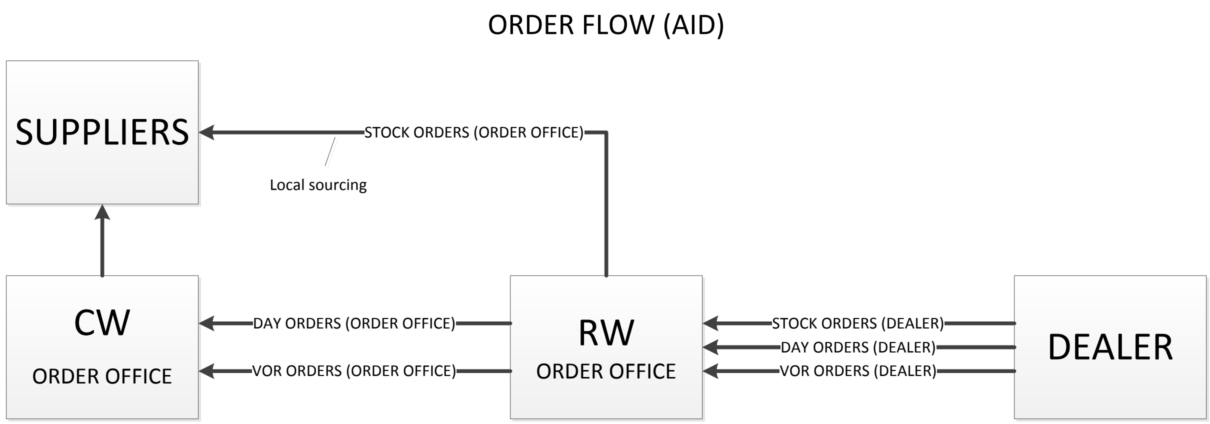


Chart 3 - Flow chart of the ordering flow within the Asia and International region with Regional warehouses.

This creates a larger flow of incoming orders generated over all order classes as dealers place all of their orders directly to the regional warehouses. Responsibility between the replenishing functions is divided by order class with the local order office in charge of all backorders (dashed lines in figures) created by Day and VOR orders while refill for all stock backorders.

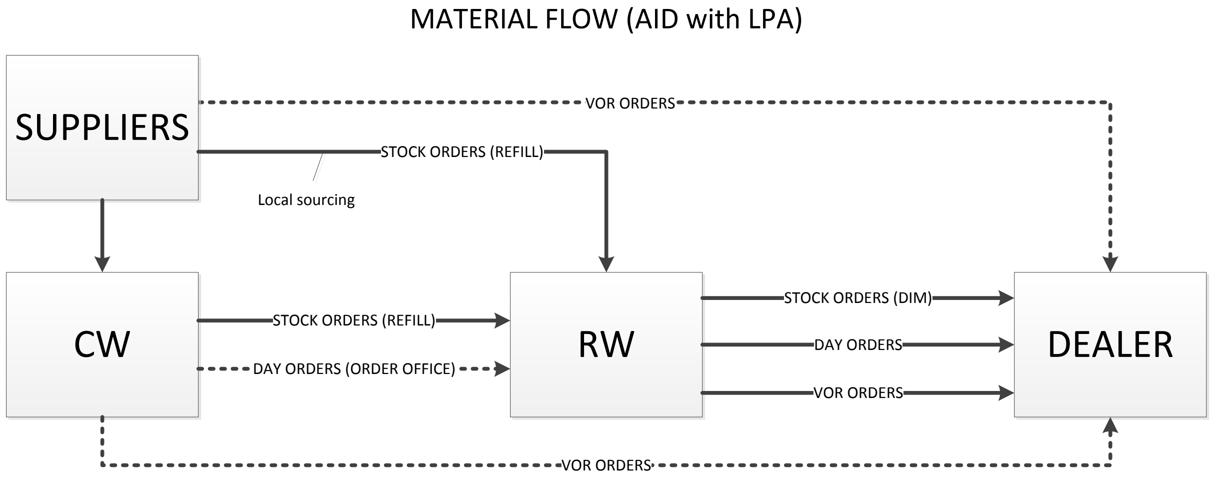


Chart 4 - Flow chart of the material flow within the Asia and International market with Regional warehouses.

The material flow is centralized towards an outbound flow from the regional warehouses. Some of the regional warehouses also have local sourcing that is handled by the order office. Similar to the European setup, direct deliveries to dealers may also occur but in most cases related to delayed orders with urgent classifications.

The replenishment flow is conducted by both air and sea with the latter being the most common in terms of actual gross weight. Sea departures occur on an average of one departure per week. Long lead-times and low departure frequencies increases the risk of disruptions. Thus, it can be deduced that overall performing quality and precision is of a higher importance since even the smallest disruptions may trigger air.

4.6 Metrics and performance Indicators

Volvo Parts measures their performance by a set of different performance indicators that together describe the overall performance situation. These are divided into two main categories that are divided by sub-operational level and overall company level. The following chapter will briefly describe some of these indicators that are within the scope of relevance for the study.

4.6.1 Instant availability of all order classes (KPI2)

The purpose of this performance indicator is to measure the instant availability disregarding of order class and urgency. The indicator applies to the supplying material flow in order to determine whether the receiving instance gets the expected quantity.

Table 4 – The table illustrates how KPI2 is calculated for all order classes.

Order Class	Part Nr.	Description	Ordered Qty	Allocated Qty	in %	Delivered Qty	in %
VOR	1234567	Oil filter	5	5	100%	5	100%
Day	981234	Air filter	10	8	80%	8	80%
STOCK	123453	Flange screw	100	90	90%	85	85%
Number of order lines: 3			**115**	**103**	**270%**	**98**	**265%**

$$KPI2 = \frac{sum\ of\ delivered\ quantity\ in\ \%}{number\ of\ orderlines} = \frac{265\%}{3} = 88\%$$

KPI2 hence measures the overall availability over all order lines and is commonly used as an overall performance measurement of e.g. regional warehouses. Measurements are carried out on a weekly basis.

4.6.2 Transport costs (KPI5)

The objective of this performance indicator is to follow the cost development of the outbound transportation flow between the warehouses. Measurement is based on the accumulated transport costs in relation to standard value of the transported volume. The measurement is done a monthly basis.

$$KPI5 = \frac{Accumulated\ YTD\ outbound\ freight\ cost}{Transported\ volume\ in\ std\ value}$$

4.6.3 Capital tied-up in inventory (KPI6)

Capital tied-up in inventory is a performance indicator that measures the overall stock turn-over and the efficiency of utilised capital. The scope of the performance indicator includes all stock managed by Volvo Parts which incorporates goods in transit, work in progress, goods in receiving and yet not invoiced orderliness as well as obsolete material. Measurement is based on a monthly basis and presented as the fraction between the last 12-months accumulated deliveries divided by the last 12 months average stock.

$$KPI6 = \frac{Last\ 12\ months\ outgoing\ invoiced\ deliveries}{Last\ 12\ months\ average\ stock}$$

4.6.4 Day order availability (KPI3) and backorder recovery (KPI8)

KPI3 is the measurement of instant availability of incoming Day order lines. KPI8 is an extension of KPI3 as it measures the recovery of the unfulfilled customer order lines. The purpose of the indicator is to follow-up the responsiveness in backorder resolution. Measurements are done a daily basis whereas targets are set availability after x-days.

Table 5 – Example illustrating calculation of KPI3 and KPI8.

			Backorders											
WEEK	Incoming order lines	(KPI3) Instant	D+0	D+1	D+2	D+3	D+4	D+5	D+6	D+7	(KPI8) D+8	D+9 or greater	Cancelled backorder lines	Not solved
45	1000	901,6	0,1	3		4	6				1		80	4,3
46	844	810	2							32				
47	791	678		20			50						2	41
WEEK	Incoming order lines	Instant	D+0	D+1	D+2	D+3	D+4	D+5	D+6	D+7	D+8	D+9 or greater	Cancelled backorder lines	Not solved
45	1000	90%	90%	90%	90%	91%	91%	91%	91%	91%	92%	92%	8%	0%
46	844	96%	96%	96%	96%	96%	96%	96%	96%	100%	100%	100%	0%	0%
47	791	86%	86%	88%	88%	88%	95%	95%	95%	95%	95%	95%	0%	5%

5 Results of empirical study

In this chapter the empirical data will be presented. Air-share in terms of gross weight for different countries is in main focus. Distribution over time and transport cost will also be presented. It is a purpose of its own to map the usage of air transports today. But the data is also pointing out the direction of where and how the research should continue e.g. which links are suitable for a case study.

5.1 Choice of sample and how data is collected

All data in the charts are for year 2011 starting from week 1 to week 48. The reason why all 52 weeks are not covered is due to the time of data collection that was done in week 49. Hence, our data sample lacks the last 3 weeks which could be considered as a drawback. Fresh data was prioritized due to the volatile recent volatile market situation. The last weeks of the year could however be of importance since some strange phenomenon occurs.

According to experience some dealers want to fulfil sales goals or earning bonus by buying in large quantities in the end of the year to fulfil these requirements. These orders have to be invoiced before the New Year and that often creates a pressure to fly the parts so they can arrive in time to the dealer. However this can be seen as an isolated problem that does not require any rebalancing activities to be counteracted. Therefore is the three missed week negligible. See section 7.3 for more information about the phenomena.

The data has been acquired and aggregated from various business applications within Volvo Parts. The source data is based on outgoing goods from the central warehouses.

5.2 Region Europe

Air-share is presented for the following companies; Volvo Trucks, Volvo Buses and Volvo Construction Equipment. Region Europe mainly consists of countries within European Union with some exceptions.

5.2.1 Volvo Trucks and Volvo Buses

The charts shown in this section present the actual flows from the central warehouse in Ghent to their destinations in Europe. Due to the shorter distances sea is the most common mode of transportation.

Four countries are distinguished due to their geographical location far away from Ghent. Three of these are located in the north: Sweden, Finland and Norway while the fourth, Spain, is located in the south. These countries together represent the main portion of the air freight. While Ireland also has a high air-share their volumes in terms total gross weight are lower compared to each of the four. The charts also include courier share but the credibility for these figures are lower compared to the other data.

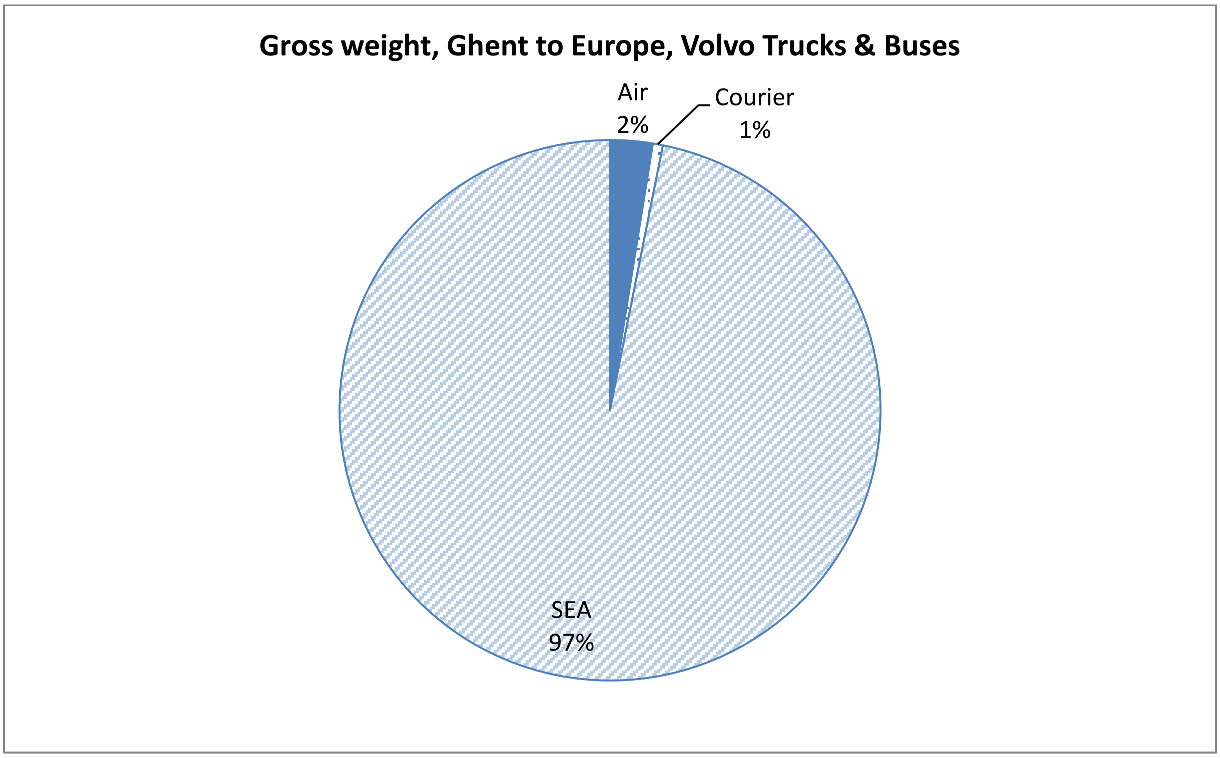


Chart 5 – Gross weight per transport mode, from Ghent to Europe with Volvo Trucks and Volvo Buses.

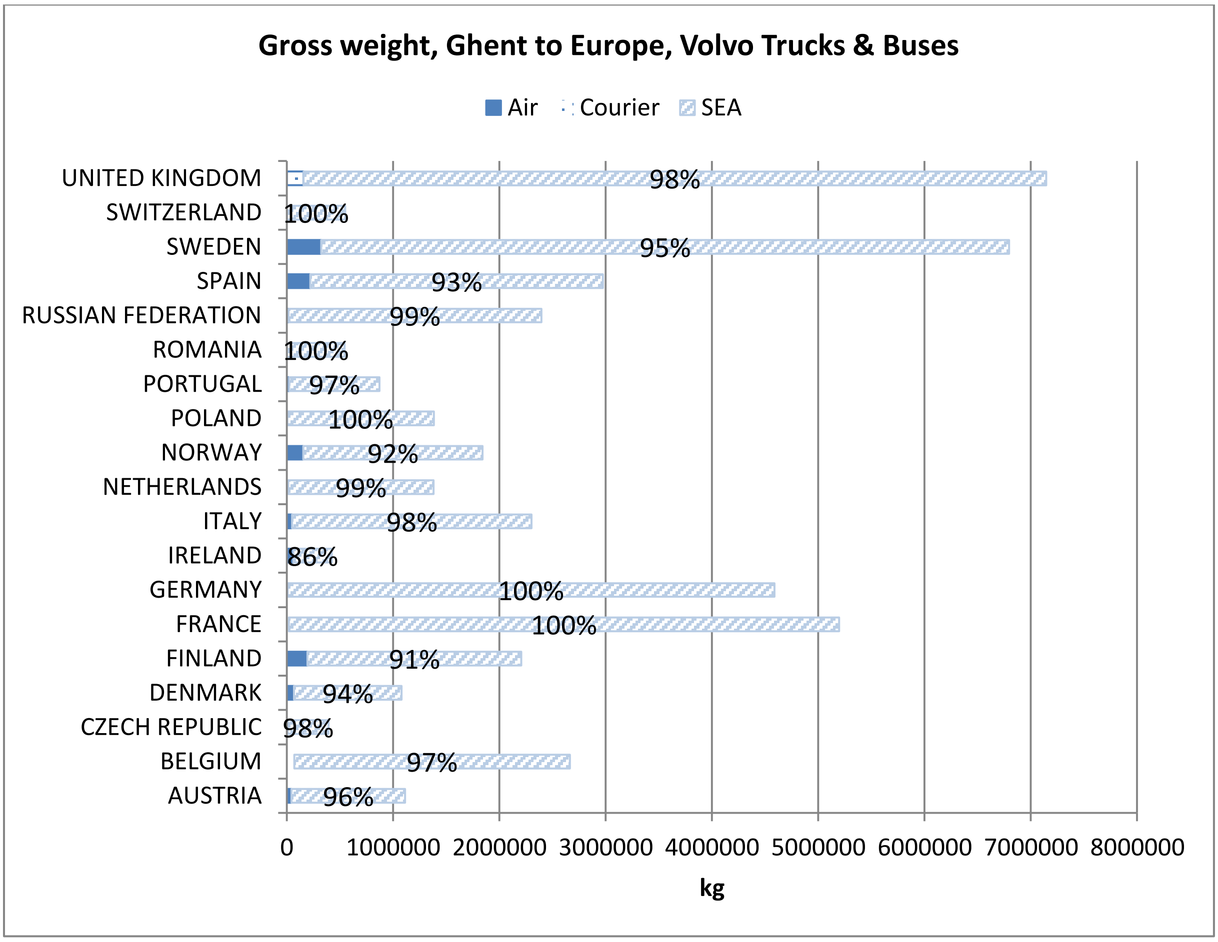


Chart 6 – Gross weight per country and mode, from Ghent to Europe with Volvo Trucks and Volvo Buses.

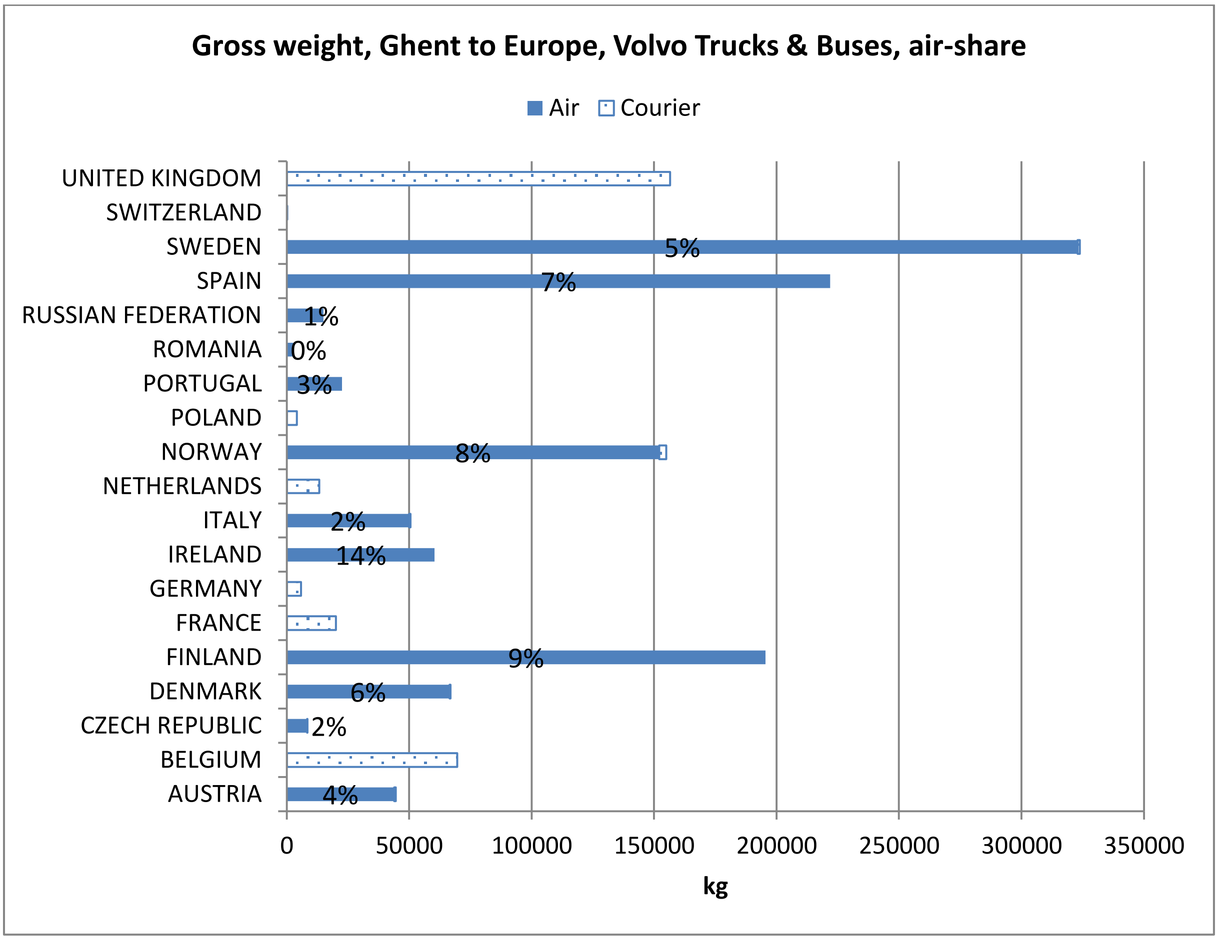


Chart 7 – Gross weight only air and courier per country, from Ghent to Europe with Volvo Trucks and Volvo Buses.

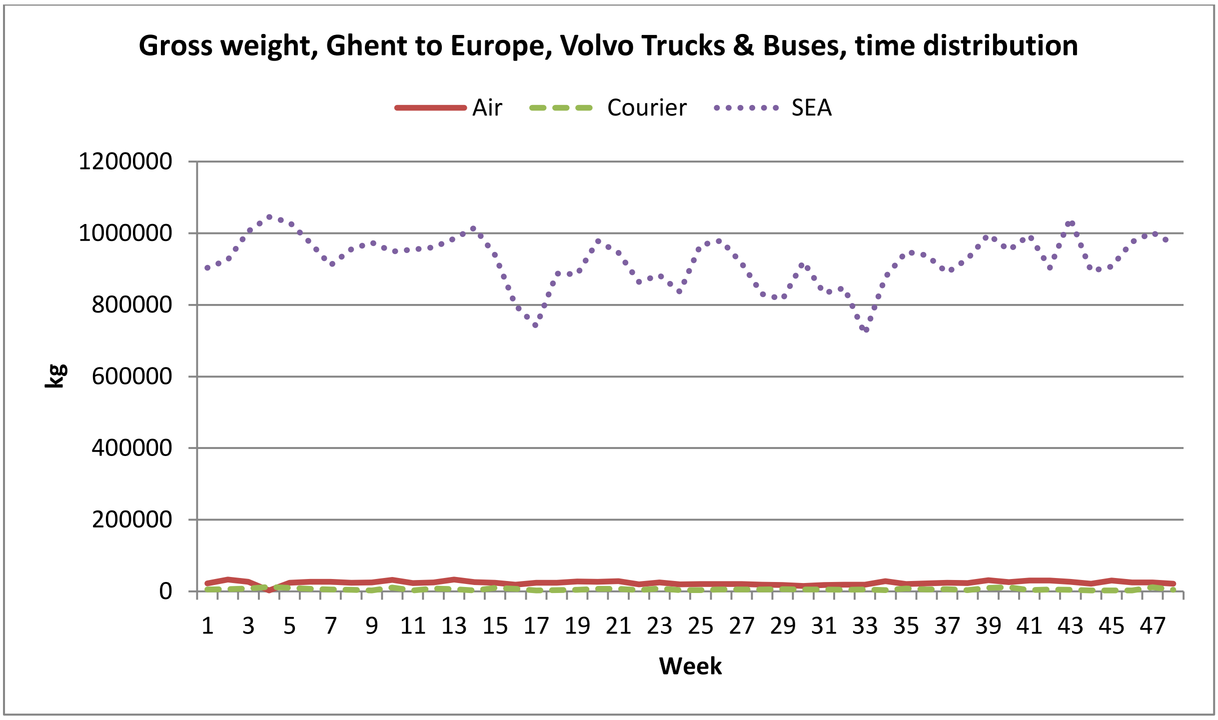


Chart 8 – Gross weight distribution over time for all modes, from Ghent to Europe with Volvo Trucks and Volvo Buses.

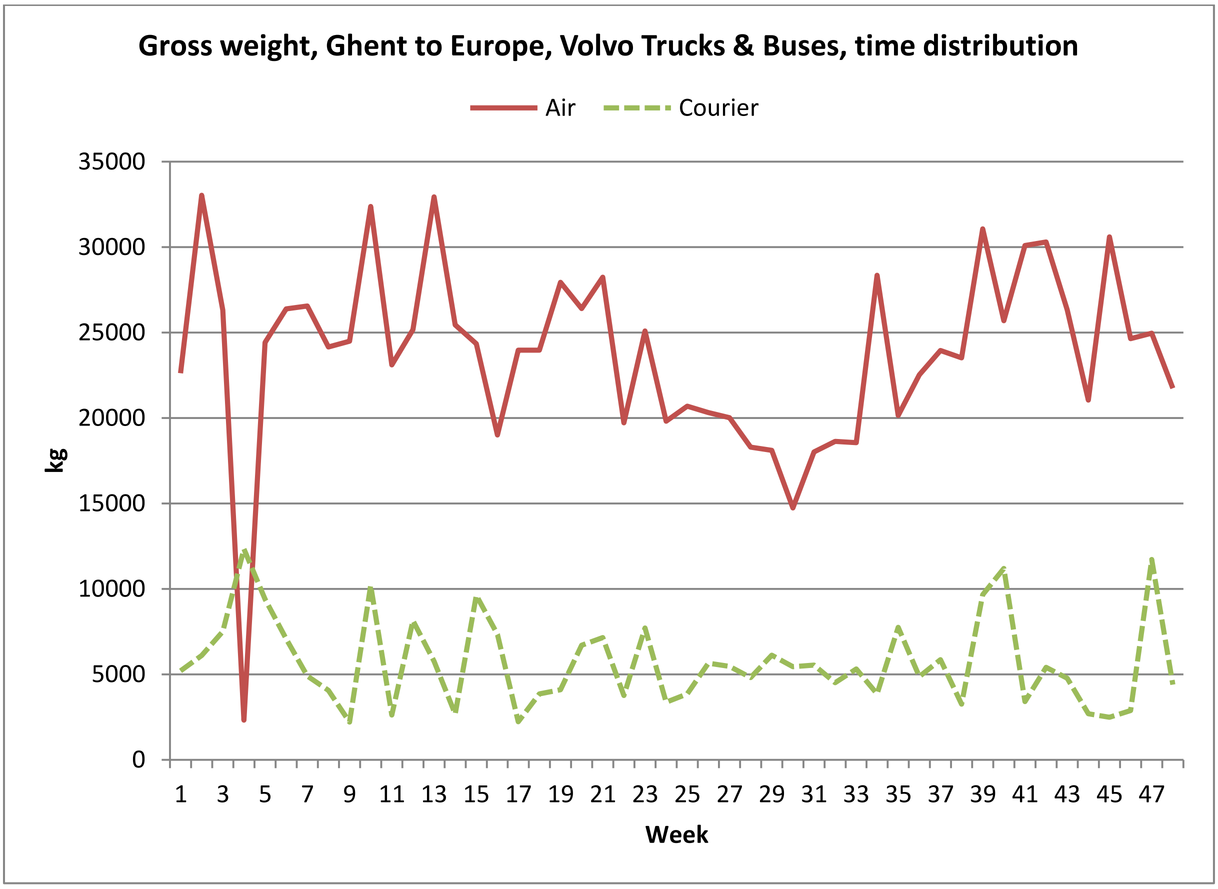


Chart 9 - Gross weight distribution over time for air and courier, from Ghent to Europe with Volvo Trucks and Volvo Buses.

5.2.2 Volvo Construction Equipment

Here the charts show the flows from the central warehouses in Ghent and Eskilstuna to destinations in Europe. The warehouses have a differentiated product range. Eskilstuna has slightly larger volumes (60% of gross weight) compared to Ghent. Due to the shorter distances sea is mostly used. Smaller countries are aggregated to the last bar, called “EUD other”. Unfortunately data for Sweden is not included here.

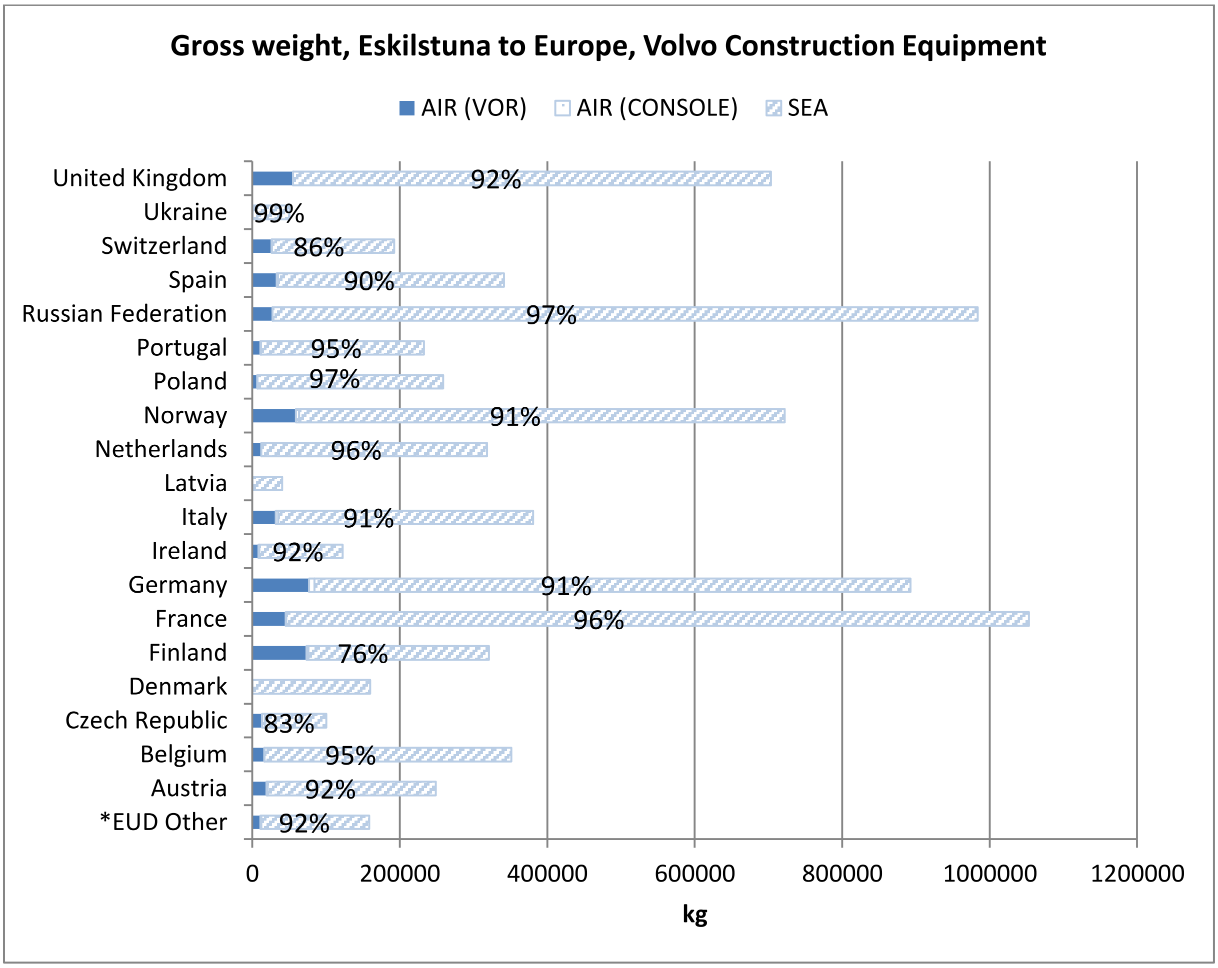


Chart 10 - Gross weight per country and mode, from Eskilstuna to Europe with Volvo Construction Equipment.

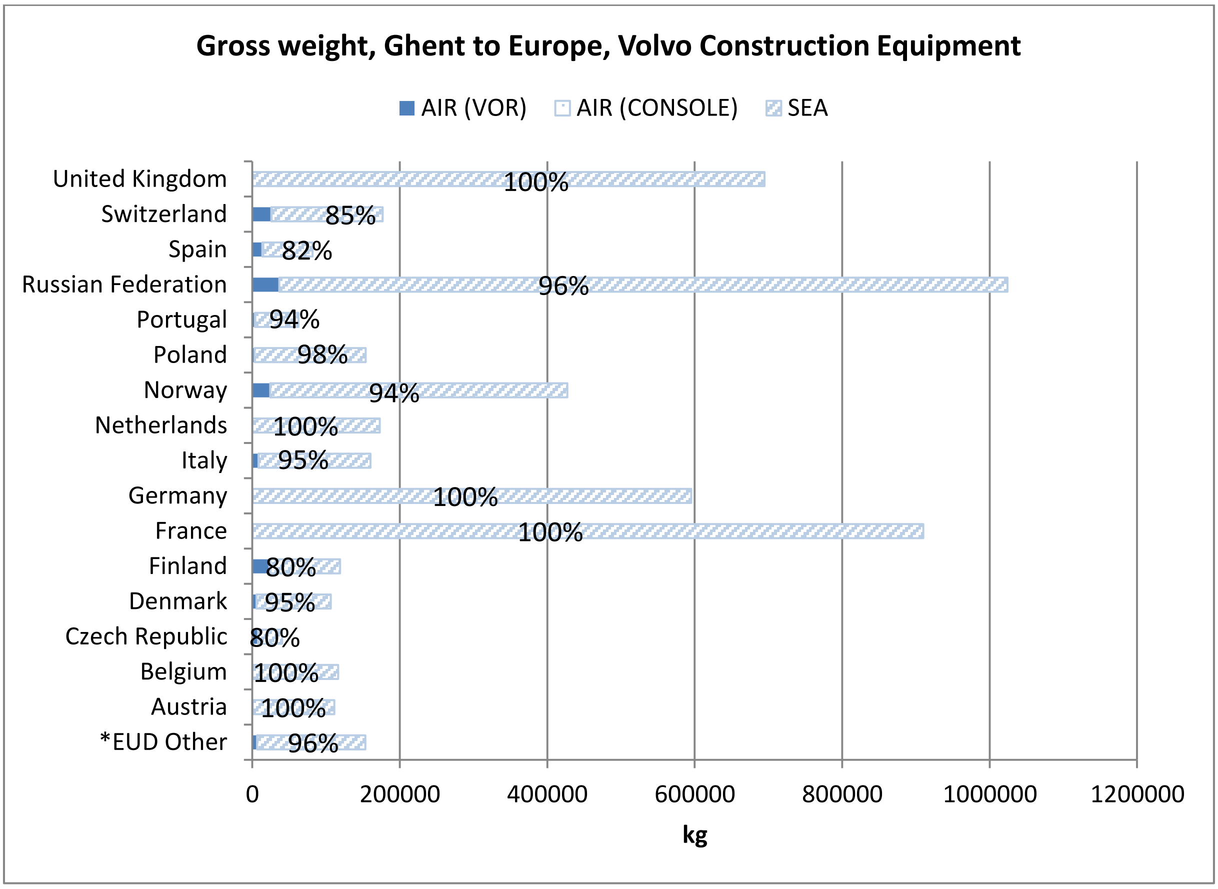


Chart 11 - Gross weight per country and mode, from Eskilstuna to Europe with Volvo Construction Equipment.

5.3 Region North America

Air-share is presented for the following companies; Volvo Trucks, Volvo Buses, Volvo Penta and Volvo Construction Equipment. Region North America is dominated by United States and Mexico. Some other countries are also included in some of the charts.

5.3.1 Volvo Trucks, Volvo Buses and Volvo Penta

From the raw data the mode of transport called courier has been neglected. For North America the courier stands for less than 3% of the total gross weight. Thus the impact from courier can be seen as low. The amount of goods transported during the year is not even. During summer it is seen that the quantities are increasing for all modes of transport. The peak has almost doubled amount of gross weight compared to the year average for both consolidated air and sea.

The outcome was in general what could be expected. Clear differences are however evident between the two countries. Especially noteworthy is the larger amount of air freights to the United States even though distances to Mexico are greater. This outcome is rather unexpected but could be explained by possible differences in market maturity.

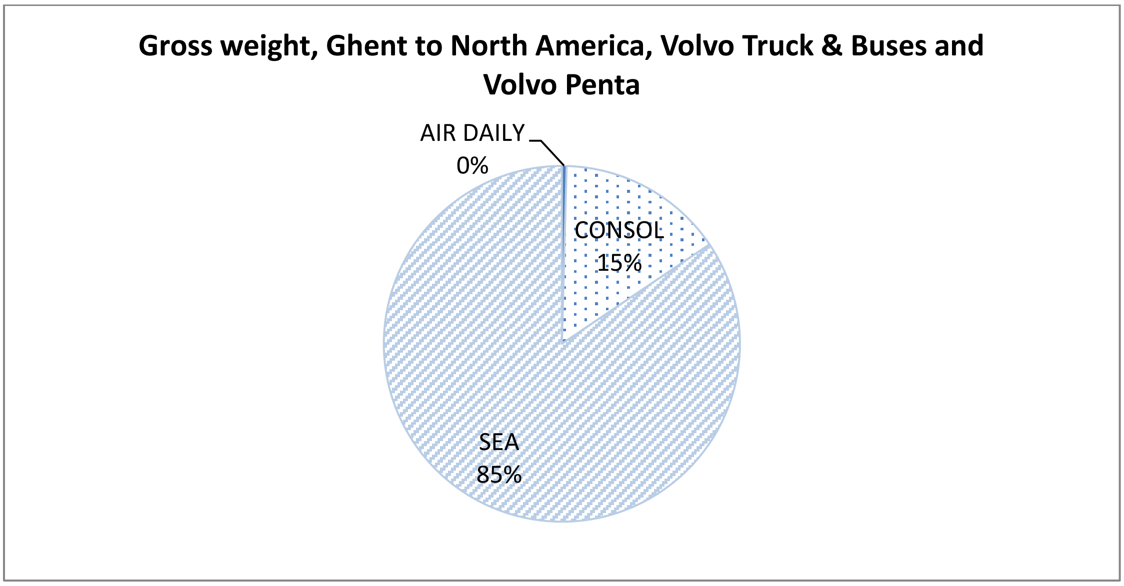


Chart 12 - Gross weight per transport mode, from Ghent to North America with Volvo Trucks, Volvo Buses and Volvo Penta.

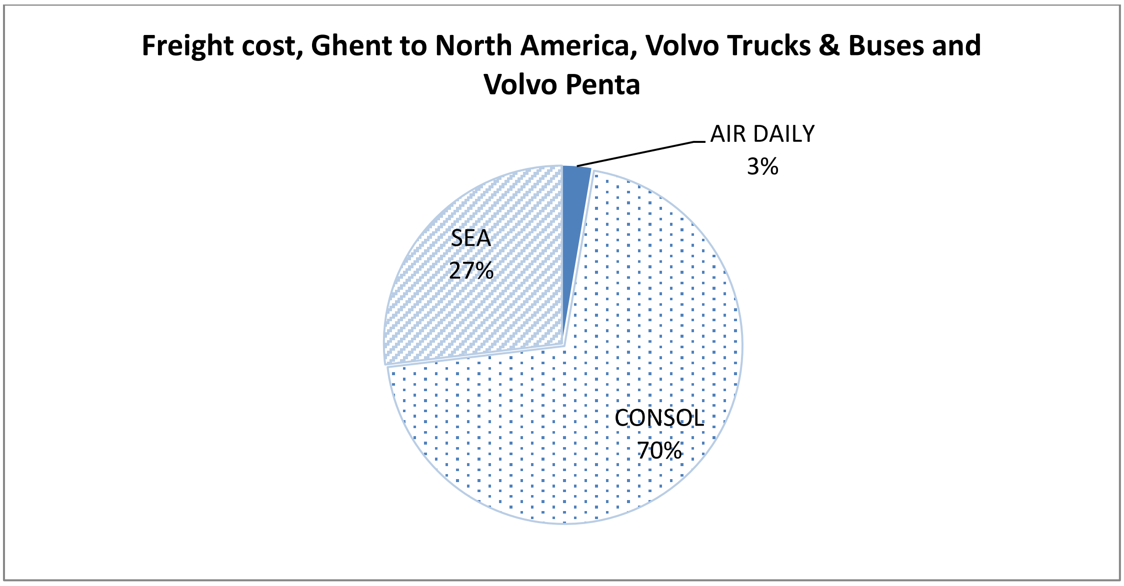


Chart 13 – Freight cost per transport mode, from Ghent to North America with Volvo Trucks, Volvo Buses and Volvo Penta.

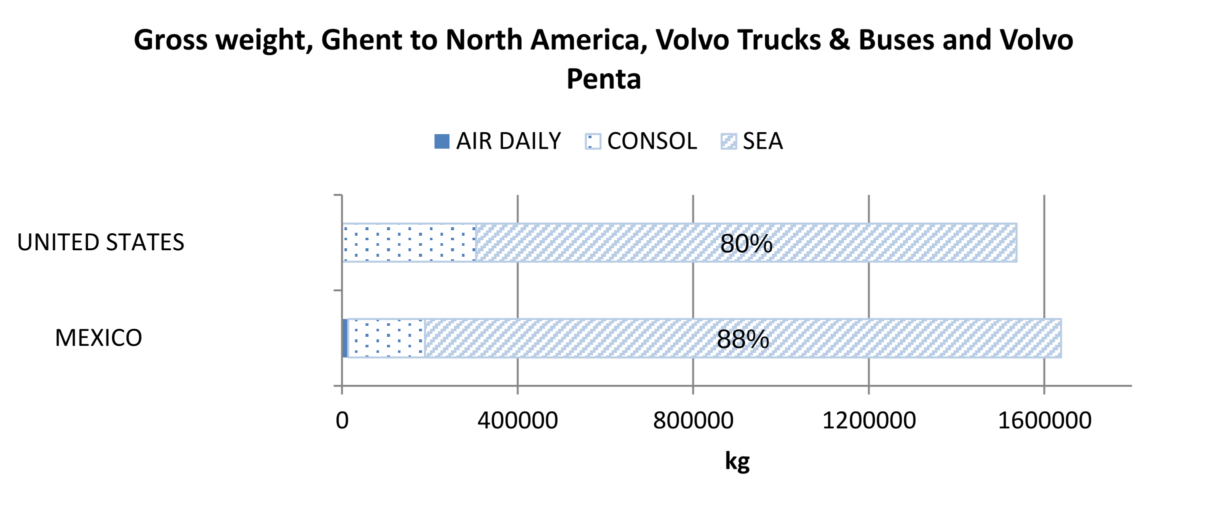


Chart 14 - Gross weight per country and mode, from Ghent to North America with Volvo Trucks, Volvo Buses and Volvo Penta.

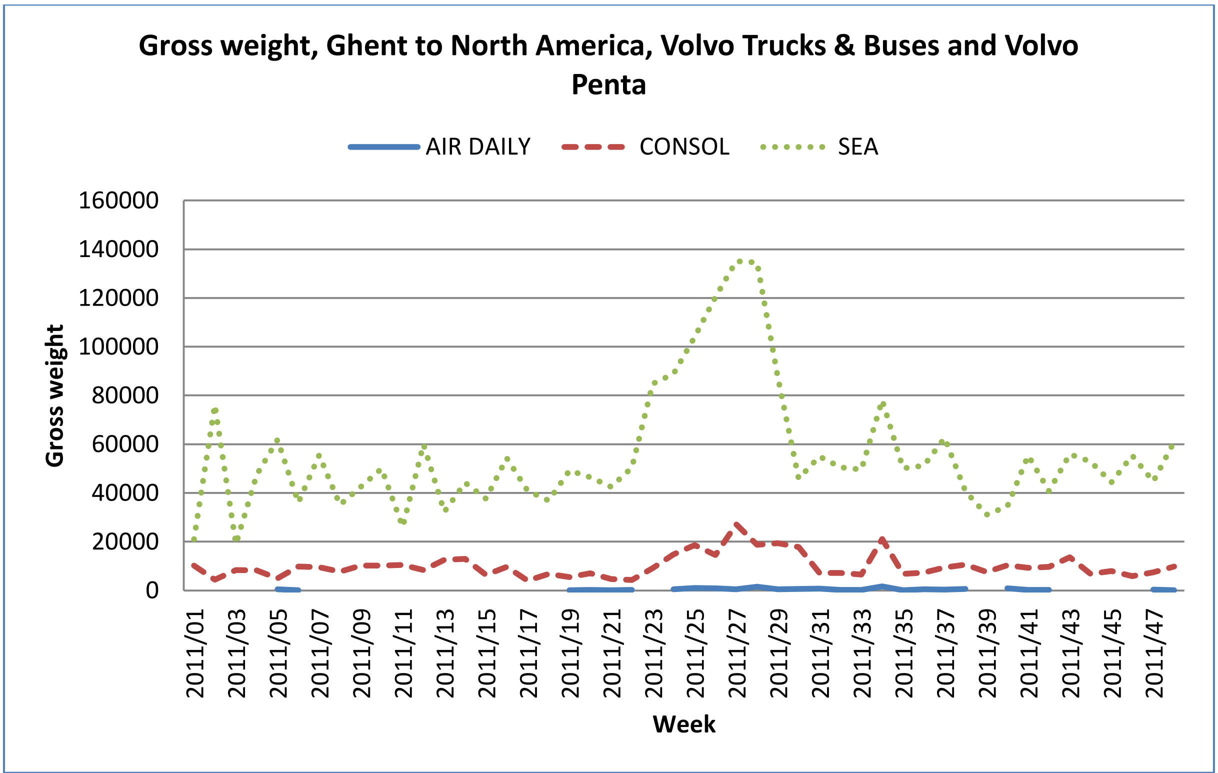


Chart 15 - Gross weight distribution over time, from Ghent to North America with Volvo Trucks, Volvo Buses and Volvo Penta.

5.3.2 Volvo Construction Equipment

For Volvo Construction Equipment the charts are divided depending on warehouse origin, which is either Ghent or Eskilstuna. The two warehouses have different ranges in assortment. The amount sent from Eskilstuna to United States is around 10 times larger compared to the link Ghent – United States. The pattern regarding usage of the different transport modes is also diversified. Ghent has a lot of VOR orders which in total lead to higher air-share.

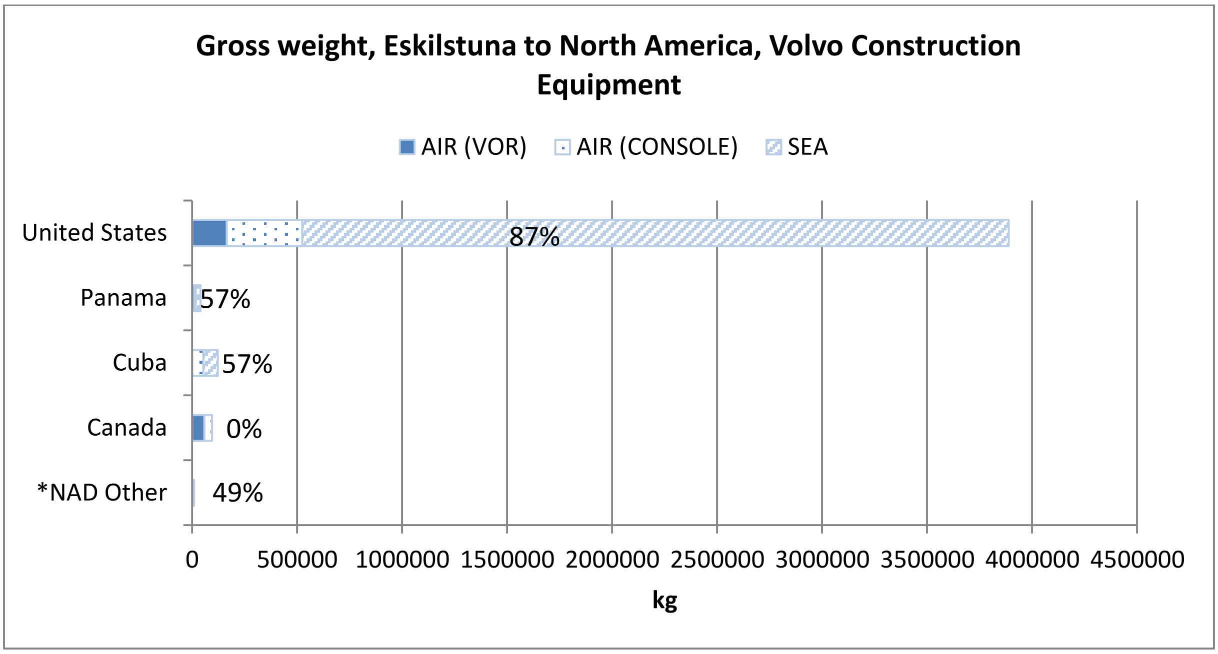


Chart 16 - Gross weight per country and mode, from Eskilstuna to North America with Volvo Construction Equipment.

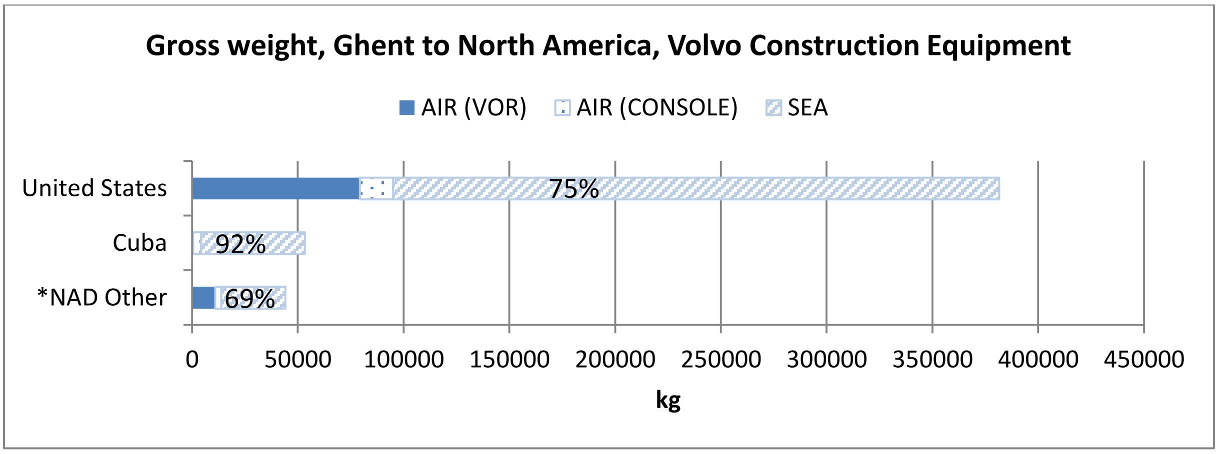


Chart 17 - Gross weight per country and mode, from Ghent to North America with Volvo Construction Equipment.

5.4 Region Asia and International

Air-share is presented for the following companies; Volvo Trucks, Volvo Buses, Volvo Penta and Volvo Construction Equipment. Region Asia and International consists of all countries that are not covered by region Europe or North America.

5.4.1 Volvo Trucks, Volvo Busses and Volvo Penta

The presented data in this section shows the flow from Ghent to regional warehouses within Asia and International. Similar to region North America, the data for courier has been neglected. For Asia and International the share of courier transports is less than 1% of the total gross weight making it infinitesimal.

The charts for Asia and International in general also follow an expected outcome. Some countries perform better than others and vice versa. The largest market is Singapore with an air-share of 16%

which could be considered as a poorer result compared to the other largest two markets Australia (12% air) and Brazil (14% air). Together these three markets stand for 43% of the total gross weight. Japan also performs rather poor with 29% in air-share. Some overall seasonal trends are also evident with severe peaks for both sea and air during the summer.

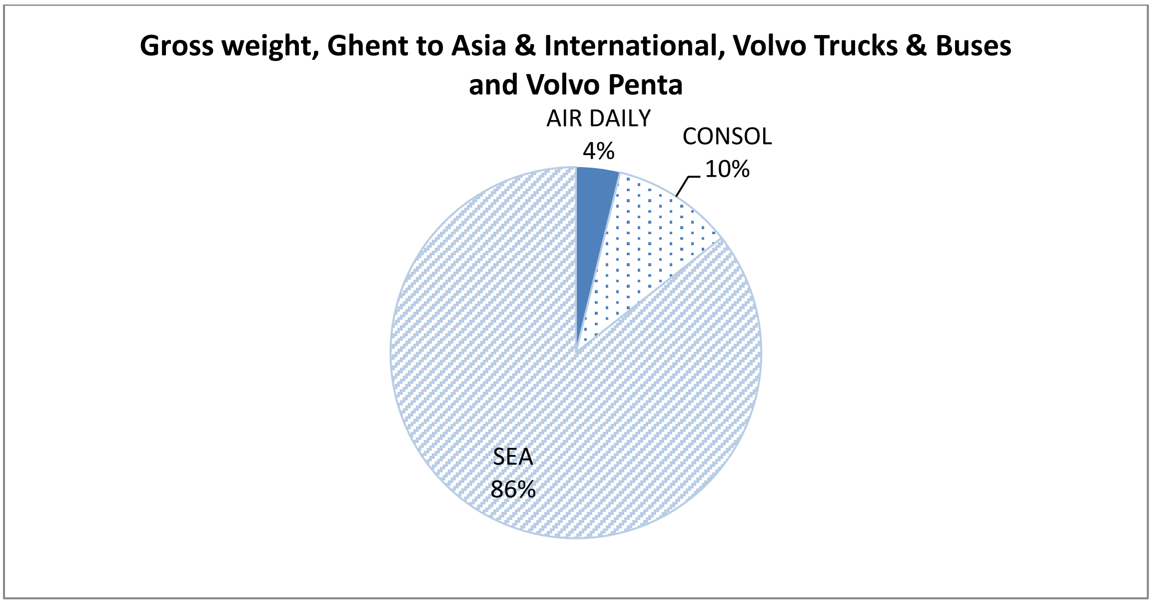


Chart 18 - Gross weight per transport mode, from Ghent to Asia and International with Volvo Trucks, Volvo Buses and Volvo Penta.

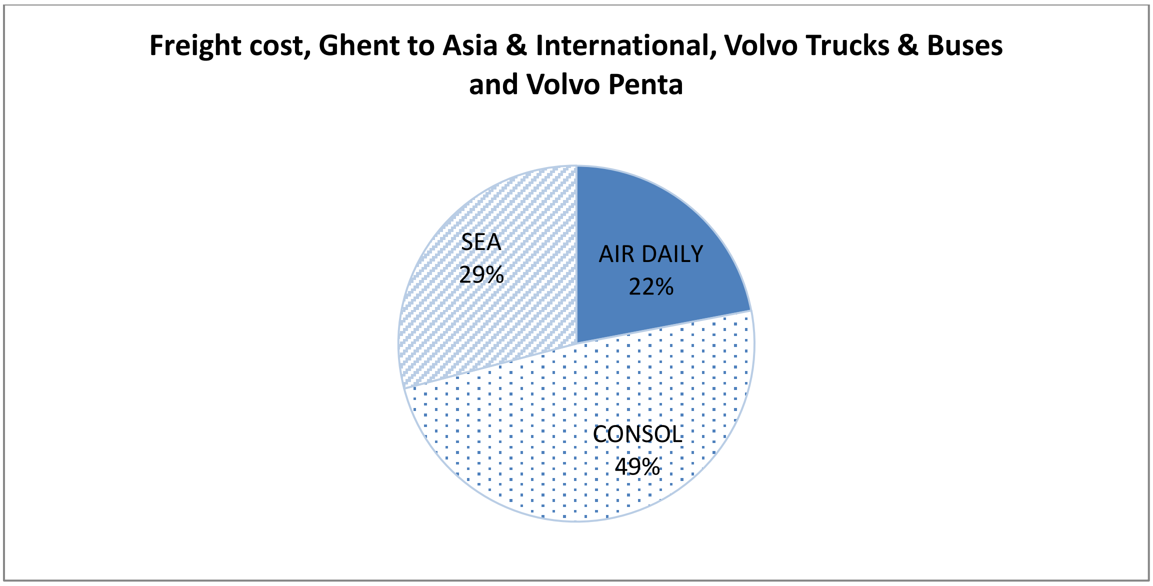


Chart 19 – Freight cost per transport mode, from Ghent to Asia and International with Volvo Trucks, Volvo Buses and Volvo Penta.

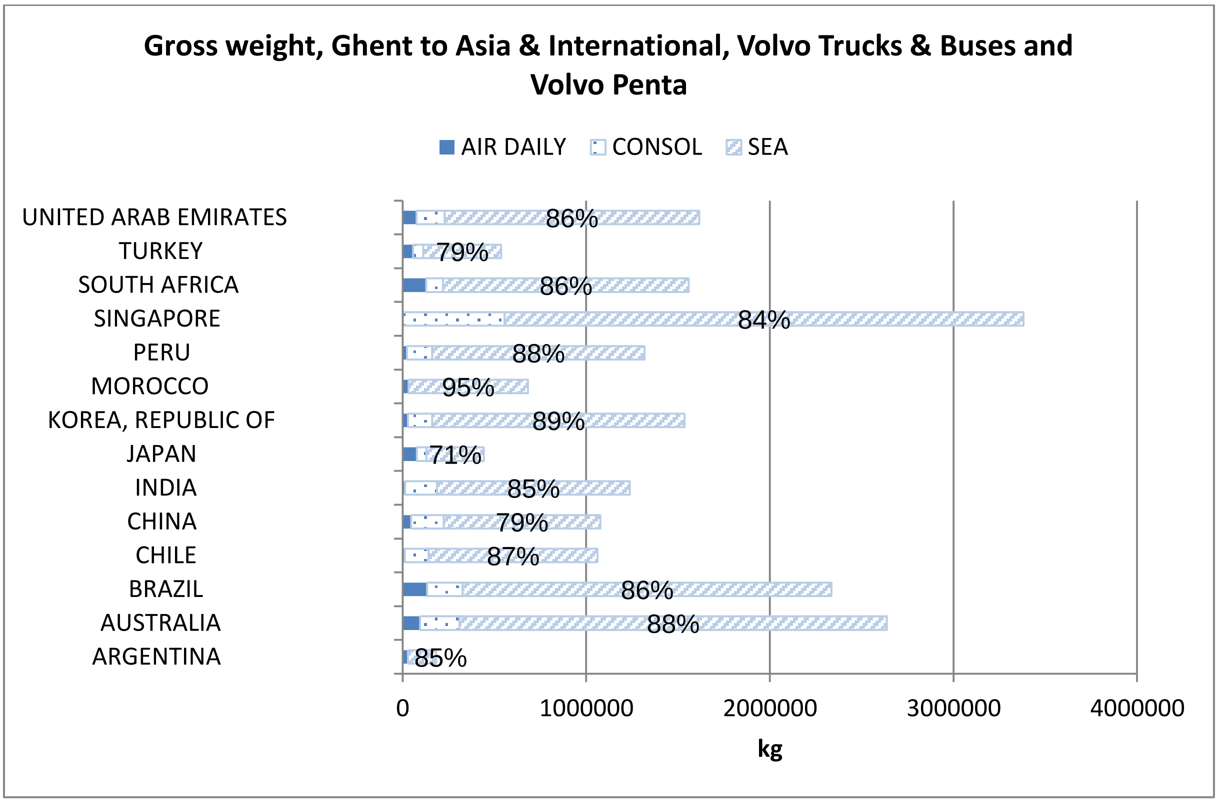


Chart 20 – Gross weight per mode and country, from Ghent to regional warehouses in the Asia and International region with Volvo Trucks, Volvo Buses and Volvo Penta.

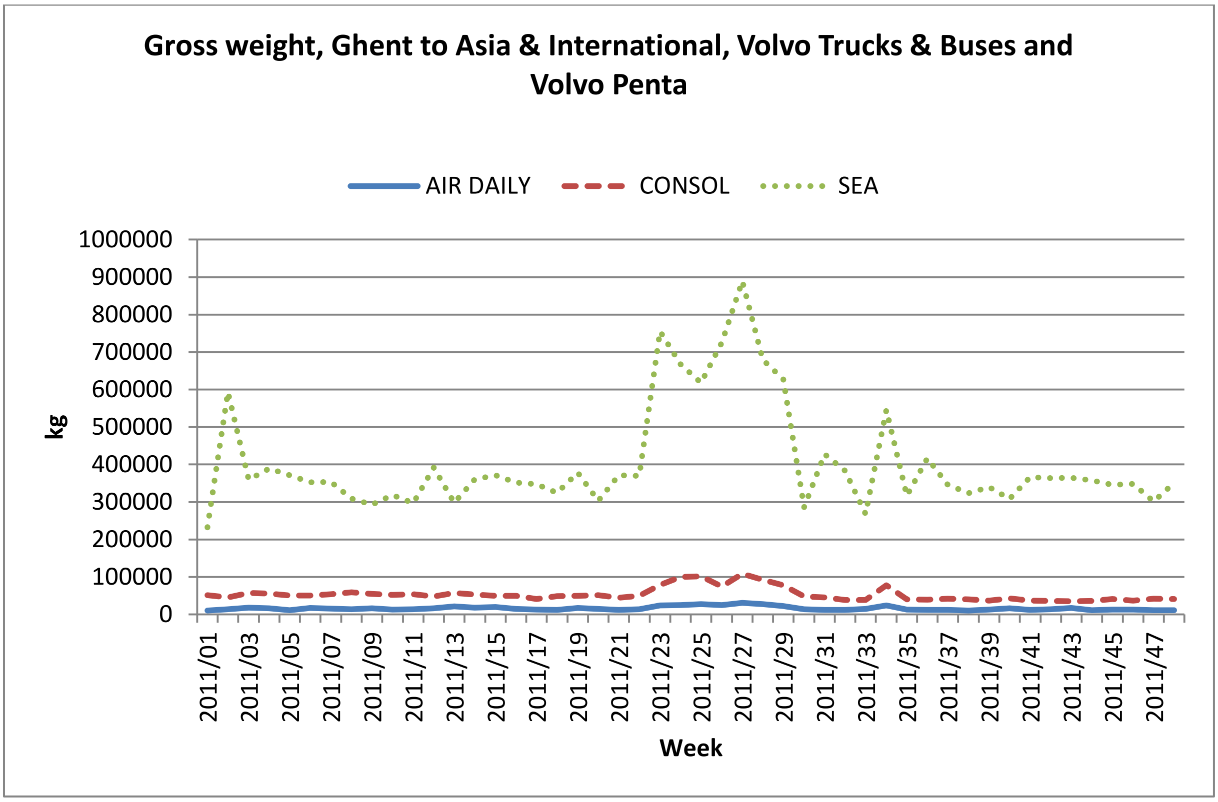


Chart 21 - Gross weight over time, from Ghent to regional warehouses in the Asias and International region with Volvo Trucks, Volvo Buses and Volvo Penta.

5.4.2 Volvo Construction Equipment

For Volvo Construction Equipment the charts are divided by warehouse origin, Ghent or Eskilstuna. Eskilstuna has larger quantities compared to Ghent. The sample of countries is not the same since countries with small transport volumes are aggregated to the last bar called "AID other".

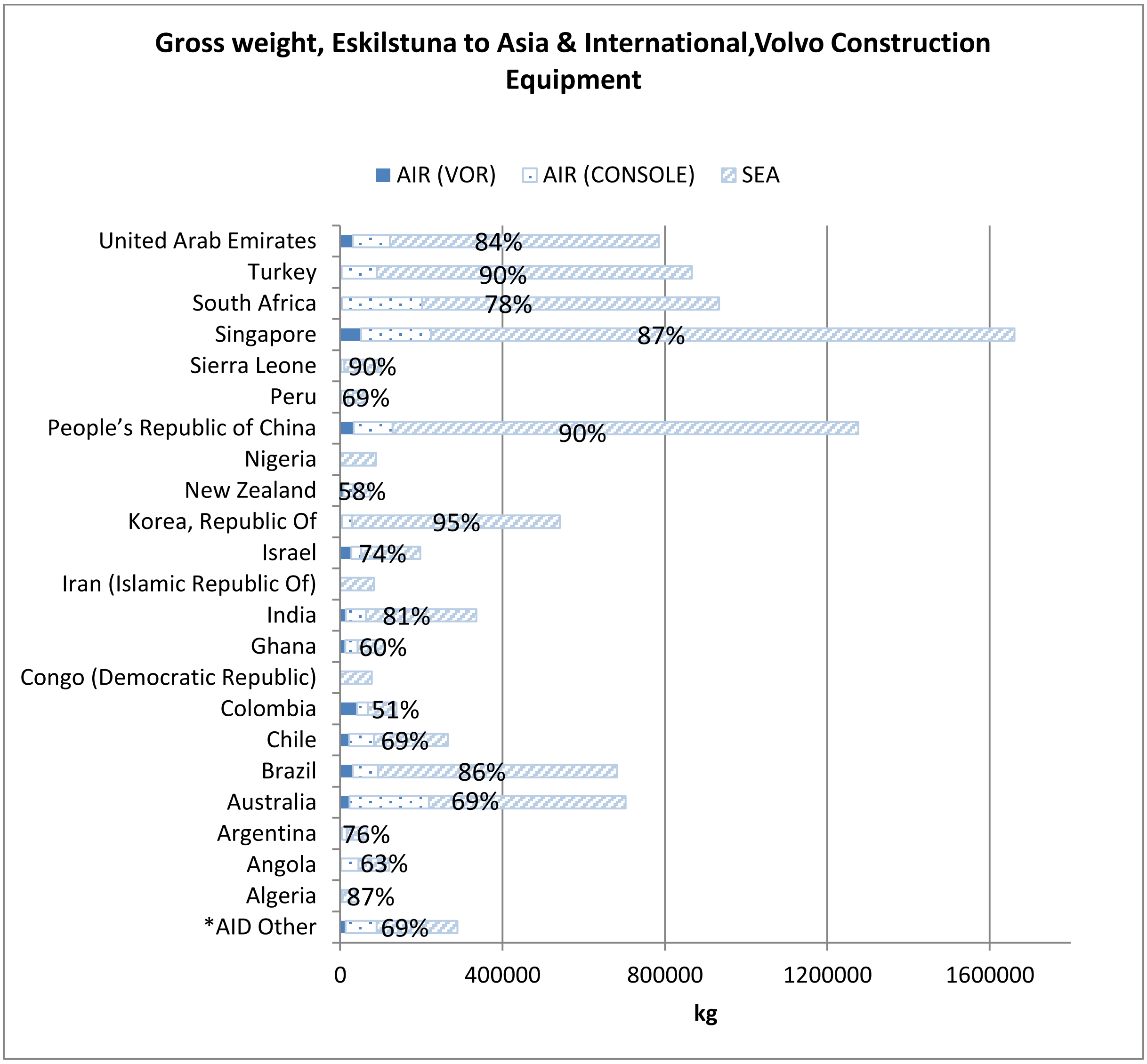


Chart 22 - Gross weight per mode and country, from Eskilstuna to Asia and International region with Volvo Construction Equipment.

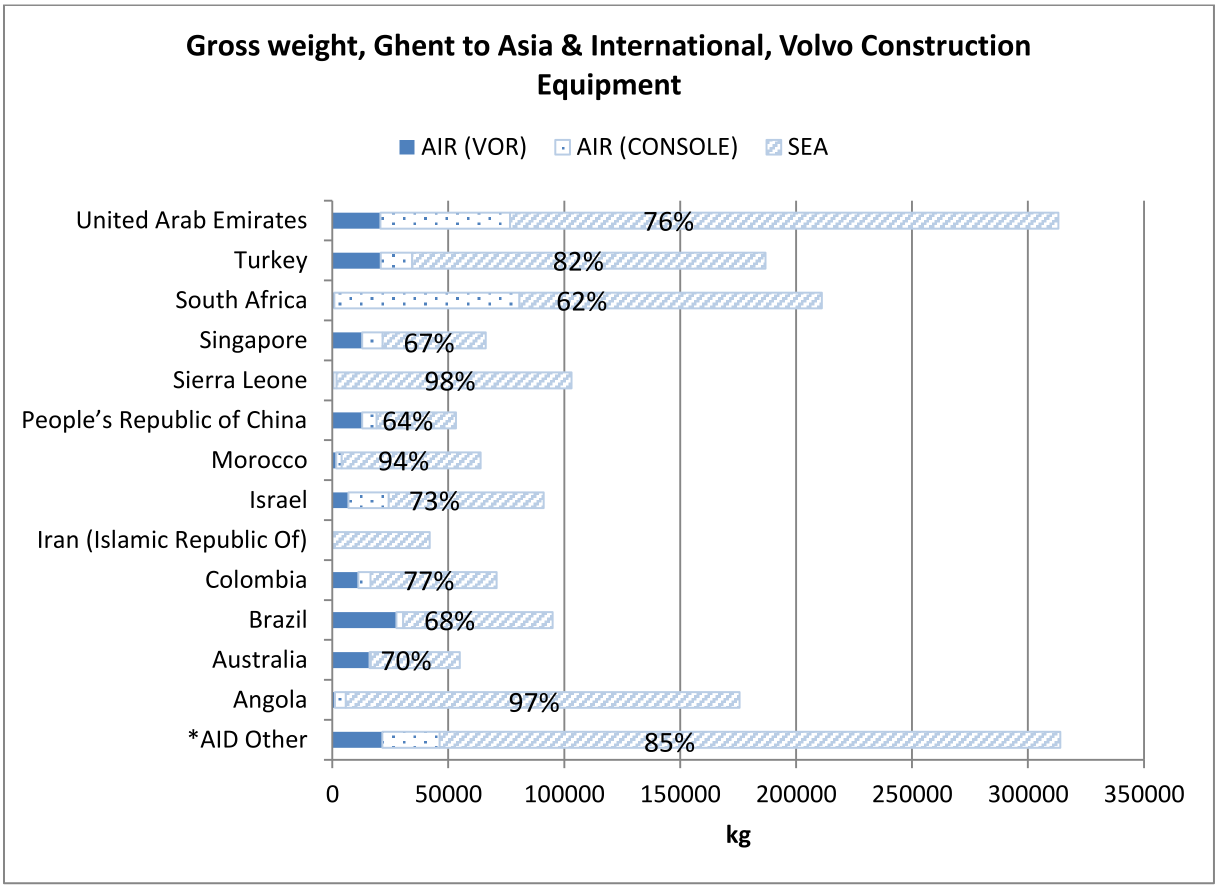


Chart 23 - Gross weight per mode and country, from Ghent to Asia and International region with Volvo Construction Equipment.

5.5 Analysis of empirical data and how to continue

Data collection and gathering of adequate data for mapping of the flows has by far been the most complex task in this thesis. The amount of time spent has been substantial but necessary in order to grasp the complexity and vastness of the problem. Our empirical findings point towards two main categories for further investigation; one with focus on tangible and quantifiable metrics, and another one with focus on more intangible and managerial aspects. The latter is not visible in the charts but will be further discussed in section 7.

The pie charts showing cost and gross weight distribution confirms the assumption that it is effective to reduce air freight since it represents a massive part of the transport cost. For example Asia and International for Volvo Trucks and Volvo Buses have figures close to the Pareto[5] principle, where air represents 14% of gross weight but 71% of the transport cost. Small reductions in air gross weight will hence have a larger impact in reducing transport costs. The environmental impact will also be significantly lower since air is considered to be worst mode of transport from an environmental point of view.

With this reasoning in mind a deeper case study will follow on a specific link between a central and regional warehouse. The air-shares to the European destinations are considerably lower and therefore of no initial interest. Our empirical findings suggests that the link Ghent – Singapore can be a suitable

[5] Pareto principle – also known as the 80-20 rule

choice for further analysis due to their high air-share. Their general characteristics will also allow for the analysis to be applicable on other links.

An interesting finding in the charts above is the uneven distribution of volumes over time for the non-European markets. Charts show a clear peak during the summer for both air and sea. This peak is so distinct that it will be further investigated in the case study, section 6.3.4. Fluctuations in demand are negative for an efficient flow and can work as a trigger for air freight. This is evident for North America (chart 15) where the increase for air is larger than the increase for sea during the summer.

6 Case Ghent-Singapore

In this chapter a case study is conducted of the link between Ghent and Singapore. The chapter consists of four main sections describing the air-share project, the refinement of parameters followed by a rebalancing part where some different scenarios are tested. Finally results for an LCA inspired investigation is presented.

6.1 Case introduction

The flow between the central warehouse in Ghent and the regional warehouse in Singapore is Volvo Parts largest of destinations outside Europe for Volvo Trucks, Volvo Buses and Volvo Penta. Hence improvements will have a noticeable impact on the total result. The flow's absence of special characteristics also makes it ideal as a reference for comparison with other flows.

Table 6 - Basic facts about the flow between Ghent and Singapore.

Period	2011-01 to 2011-48
Districts	8035 (VO), 70420 (VOP)
Total gross weight	3381 ton
Total numbers of order lines	80514
Total value (STD cost VPLE)	284,15 MSEK
Total freight cost(without courier)	1 M€≈9,07 MSEK

Table 7 – Lead-times for diffrent modes from Ghent to Singapore.

	Packing etc Ghent	Ghent-(Air)Port	Transport time	(Air)Port-Warehouse	Binning	Total (days)
Sea	8 days	2 days	22 days	0	10 days	42
Air - VOR	2,5 hours	14,5 hours	24 hours	10 hours	3hours	4-6
Air - Day	10,5 hours	14,5 hours	24 hours	16 hours	3 hours	4-6
Air - Stock	29 hours	14,5 hours	24 hours	16 hours	27 hours	9

Table 8 – Decomposed per brand.

	Truck and Bus	Penta
Gross weight	96%	4%
Freight cost	90,6%	9,4%

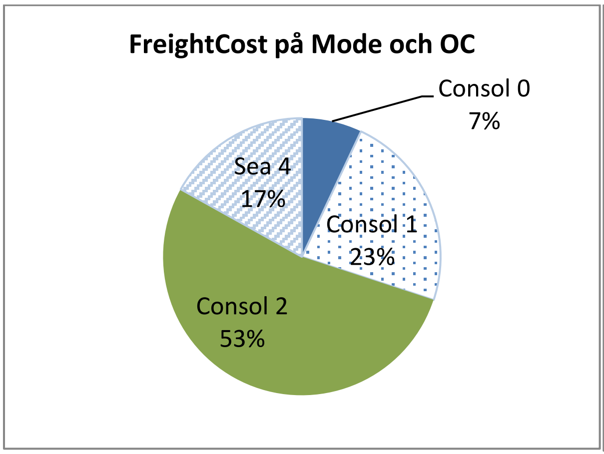
Table 9 – Freight cost for different transport modes.

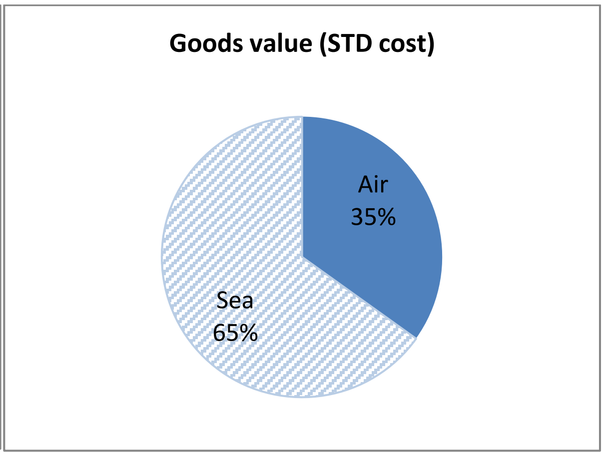
	rate/kg €
VOR order	1,85
Consolidated Air	1,5
Sea	0,06

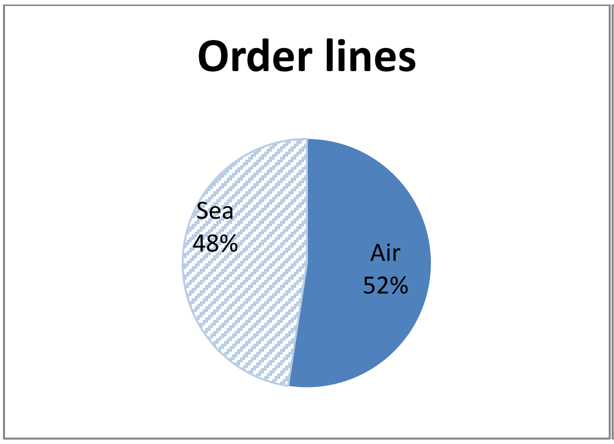
As seen in table 8 Volvo Penta has a divergent result compared to Volvo Trucks and Volvo Buses. A sensitivity analysis was made to determine whether Volvo Penta results affected the total sample. The difference is minor when excluding Penta from the sample due to their low volumes. Thus Penta is kept in the sample since it does not mislead the results in any larger degree. But it is interesting to see such large variations in result between the brands. Reasons for Penta to not perform as good as Volvo Trucks and Volvo Buses can have various reasons. A likely answer is the lower volumes for Penta. Since Penta has smaller volumes with a lot of different items is it more likely that the transport costs are higher than for Truck and Bus. To reduce air freight for Penta it is therefore necessary to have more items in stock at the Singapore warehouse. This would however result into extremely low figures for turnover as the volumes are low. Consequently, that would lead to a lot of scrapping and a lot of tied-up capital. The only way to be certain of a proper choice is to weight the alternatives towards the most profitable.

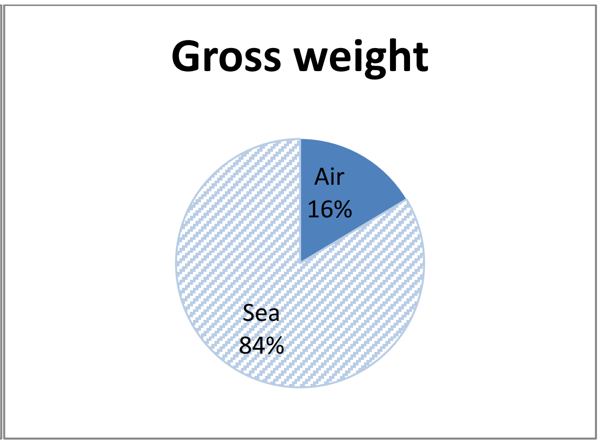
The lead-time for sea is rather interesting (table 7). Activities related to packing and binning stand for 48% of the total lead-time. The lead-time could be reduced to around 26 days just by improving the activities in the warehouses.

Calculations of transport costs are based on a mean value provided by Ghent. In general it can be said that the prices of moving cargo from Europe to Asia are lower due to increased ratio of empty containers.









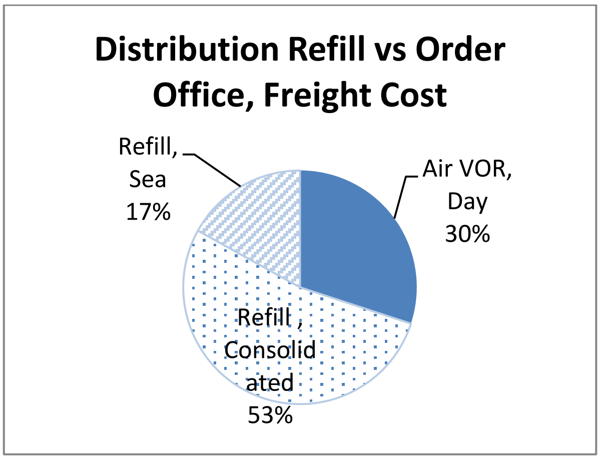


Chart 24 - Some basic fact about the flow between Ghent and Singapore.

The trend shows a declining development of Stock orders (refill orders) sent by air for 2011. This is confirmed by Kristina Wennerholm, team leader for the Refill function at Material Management, who states that the high air-share is a consequence of the recovery from the recession in 2009.

6.2 Chosen focus area

Figure 12 illustrates the transport costs and gross weight distribution from a flow perspective. Day and VOR orders are not in focus for this thesis. There is however a connection between proper Stock refill and availability that leads to a potential reduction of Day and VOR orders.

Two focus areas were chosen. The first area is the upper box (A) which contains unwanted air freight in the refill flow. These consist of items that are normally classified as sea-items but due urgency caused by backorder or being critical (risk of run-out) are sent by air. Together they represent approximately 2/3 of the refill air-share. The second focus area (box B) is the normal refill flow excluding backorders and critical items.

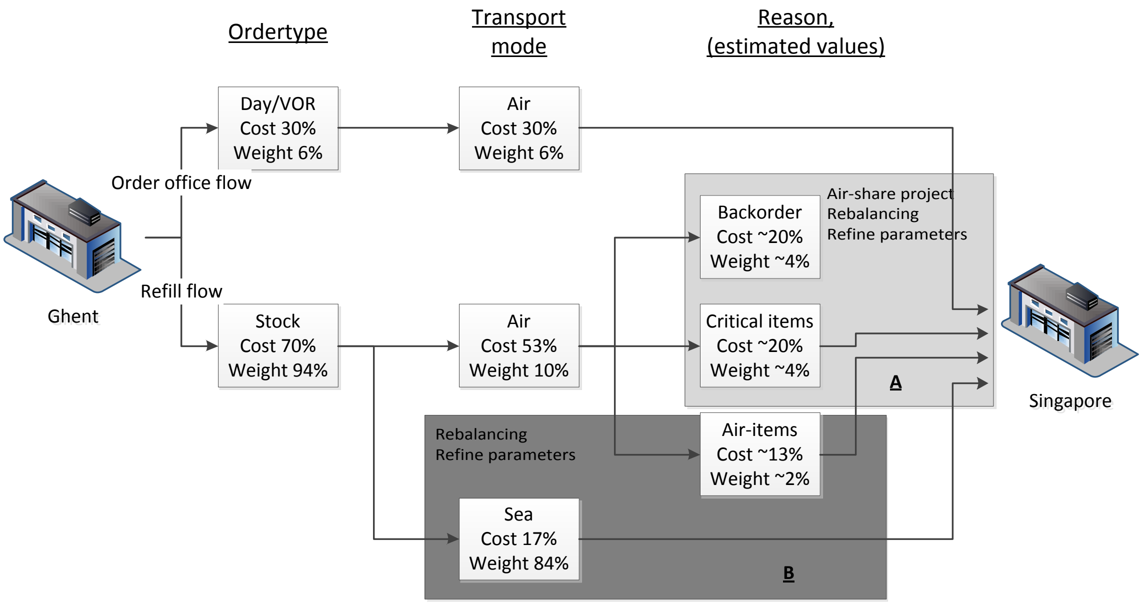


Figure 12 – Map of the flow with two focus areas (A and B).

From these two areas three approaches are used for further investigation.

- Air-share project – finding root cause to backorders and critical items
- Refinement of parameters – adjustments to reduce all types of air freight
- Rebalancing – to reduce air-share of refill flow

A LCA inspired study is also conducted in order to evaluate environmental impact.

6.3 Air-share project and how to mitigate critical and backorder air

In order to fully understand why so many of the sea classified items are sent by air, the air-share project was initiated. The aim was to track root causes of behaviours and occurrences that triggers air freight.

6.3.1 Air-share project

At most destinations consolidated air has the majority of the air-share while also being mostly represented within the refill flows. In order to fully understand the underlying driving forces of what triggers unwanted air freight the air-share project was initiated. The project began as a simple logging procedure where a number of material managers from the refill team were chosen to keep record of their reasons for flying goods. The survey was done in the end of 2011 when the air-share was stable and on a lower level compared to the beginning of the year. In order to not overload the material managers they were assigned to only log the 20 heaviest order lines. These, the top 20, represent approximately 80% of the total weight. The collected data can be seen as representative with sufficient amount of time spent. The data was then put together for analysis. The following links were included in the study:

- Ghent-Singapore (Volvo Trucks and Volvo Buses)
- Eskilstuna-Shanghai (Volvo Construction Equipment)
- Eskilstuna-Dubai (Volvo Construction Equipment)
- Eskilstuna-North America (Volvo Construction Equipment)

The following data presents the outcome for Ghent-Singapore. The data from the other destinations was used in other projects.

6.3.2 Result and analysis of air-share project

The two main categories for reasons to use air were back orders and critical (risk of run out) and the presence were equally distributed between them. The sub-categories specified a more detailed reason why the items were critical or backorders. Multiple sub-categories could be chosen as seen in chart 26. Chart 26 is independent from the main category (backorder or critical). Three of the categories are similar; high sales, sales fluctuation and large order. Large order means that one single customer is ordering a large quantity while the other two are broader taking all customers into consideration.

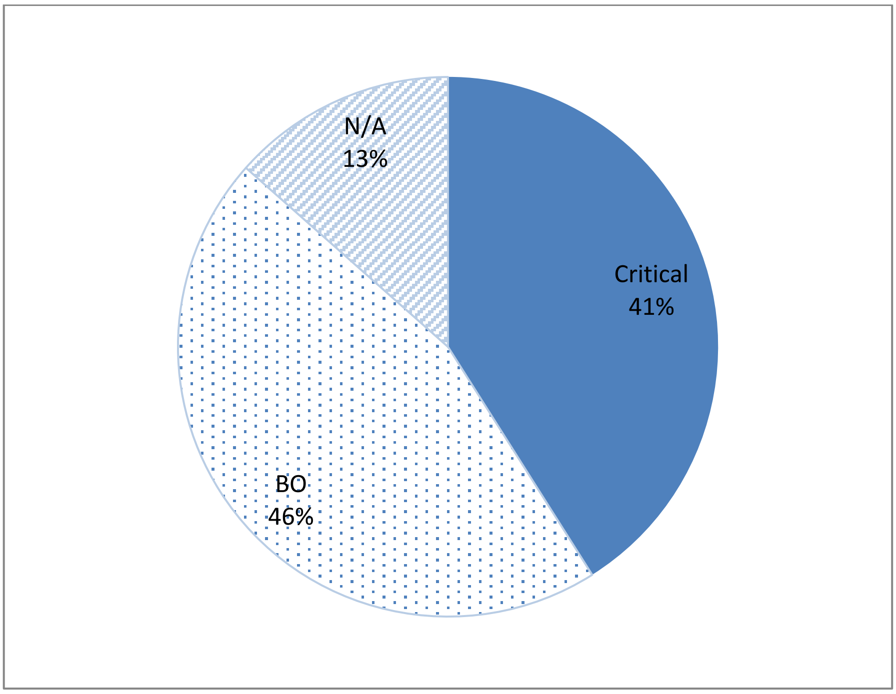


Chart 25 – Distribution between backorder and critical according to the air-share project.

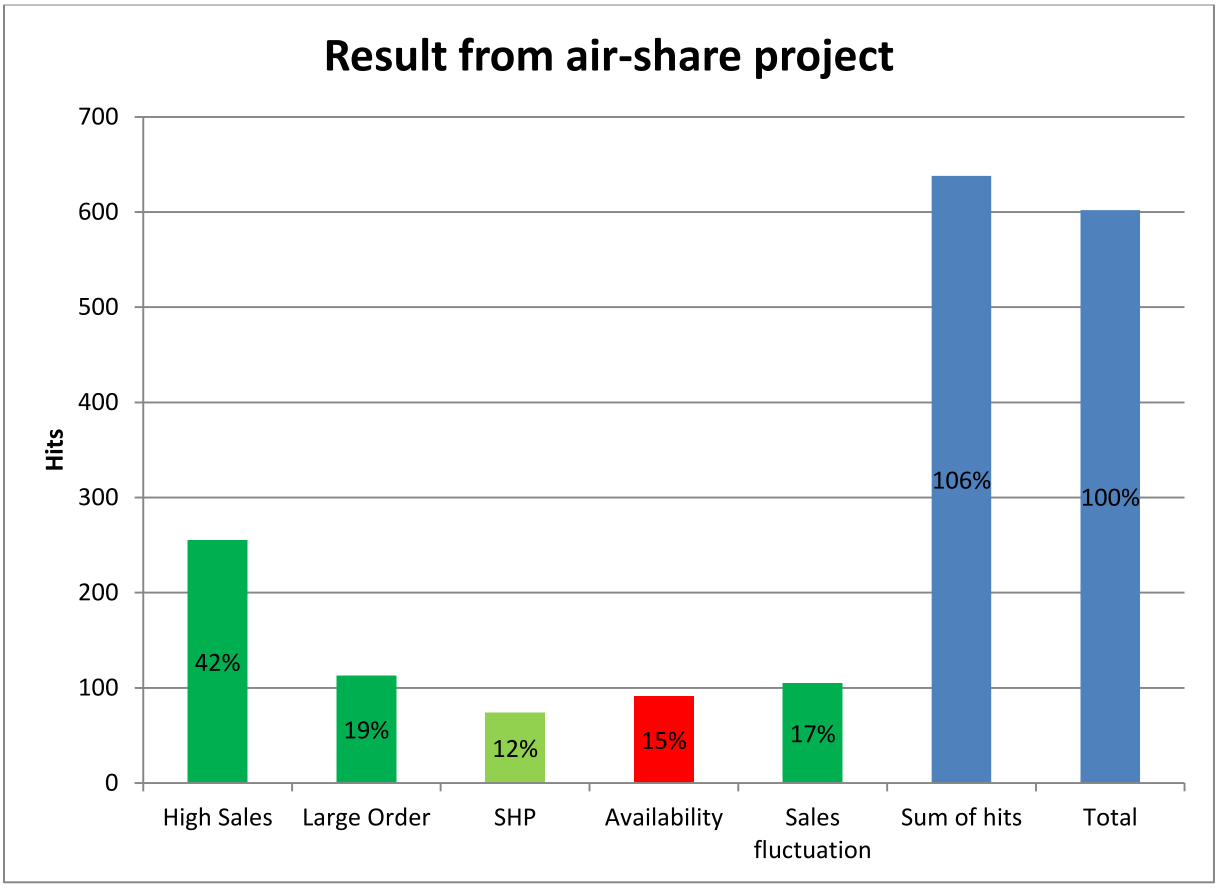


Chart 26 – Result from the air-share project. Independent on main category (backorder or critical). Multiple sub categories could be chosen hence is sum of hits more than 100%. SHP denotes Stock Holding Policy and avalability means no avalability in Ghent.

In 15% of the cases the item is not available in Ghent; a common reason can be that the supplier has closed down. No rebalancing activities can mitigate this problem. No further action will be done regarding this issue since it can be seen as beyond the scope of this thesis.

Stock holding policy (SHP) is decision rule that helps deciding whether or not an item should be kept in stock. SHP is derived from price and frequency (number of hits) for each item. A more expensive item requires more hits before it can be stocked. The aim is to minimize obsolescence as well as tied-up capital. If SHP gives a satisfying outcome remains debatable since 12% (half a million SEK/year) of the refill air is triggered from it. Yet the half million can be seen as an understated since 2011 had a lot of refill air due to the catching up from the downturn. Reducing SHP air is difficult work that requires a deeper study of parameters and that will not be done in this study.

The remaining three sub-categories high sales, large orders and sales fluctuation are all connected to demand pattern, forecasting as well as possibilities to react on trends. To mitigate the problem several actions are necessary as no universal solution can solve all problems. One root cause that was found on this issue is the less desirable buying behaviour from dealers. Also campaigns can trigger air freight and can be seen as a potential root cause. Some of these management related issues are further described in the following chapters. It should be remembered that a zero percentage in air-share is a non-realistic scenario. The demand characteristics of spare parts are lumpy and not all forecast can foresee everything. Therefore some air freight is acceptable in order to meet high sales and minor sales fluctuations.

6.3.3 Buying behaviour

The buying behaviour is an important factor to reduce unwanted and unnecessary air freight. From the air-share project cases were found where inadequate buying behaviour clearly triggered unnecessary air freight. For example dealers were ordering items even though having sufficient amounts in stock which at the time were not available at the Singapore warehouse, resulting into backorders. As a consequence this triggered air freight from the central warehouses in order to meet an unnecessary backorder. In such situations orders should be transferred to sea, regardless of it being a backorder or not, where there is not an instant demand. This would however require total transparency to the end-customers stock levels. It would probably be more feasible to act more restrictive on flying infrequent sea-items in backorder that ought to be kept in stock.

Situations like this can be mitigated in several ways:

- Better education of dealer
- LPA
- Stronger management at local order office

Better education of dealers will help to an extent but an even better solution would be to affiliate more dealers with the LPA concept. LPA would give Volvo Parts the control of the entire refill flow which has proven positive effect.

A stronger management from the local order office could also have a positive impact by e.g. questioning of unnecessary orders that requires air freight. The order office’s local presence could also be used to highlight the backlashes (increased prices) that are created from these inadequate ordering behaviours and hence create a better cooperation with mutual benefits. This would also eliminate dealer confusion regarding perceptions of discounts that are associated with larger order quantities.

6.3.4 Irregular weight distribution over time

In chapter 5 charts 15 and 21 illustrated the irregularities in distribution for transported goods in the North American and the Asia International regions. These regions had a peak in transported gross weight during the summer period for all transport modes. A further breakdown of the Asia International markets shows that same trend is present for Singapore (chart 27). The chart also follows the declining trend of flown refill orders. The summer peak however violates the trend of reduced air usage. It is also interesting to see that Day and VOR air have a more stable demand hence decoupled from the consolidated air.

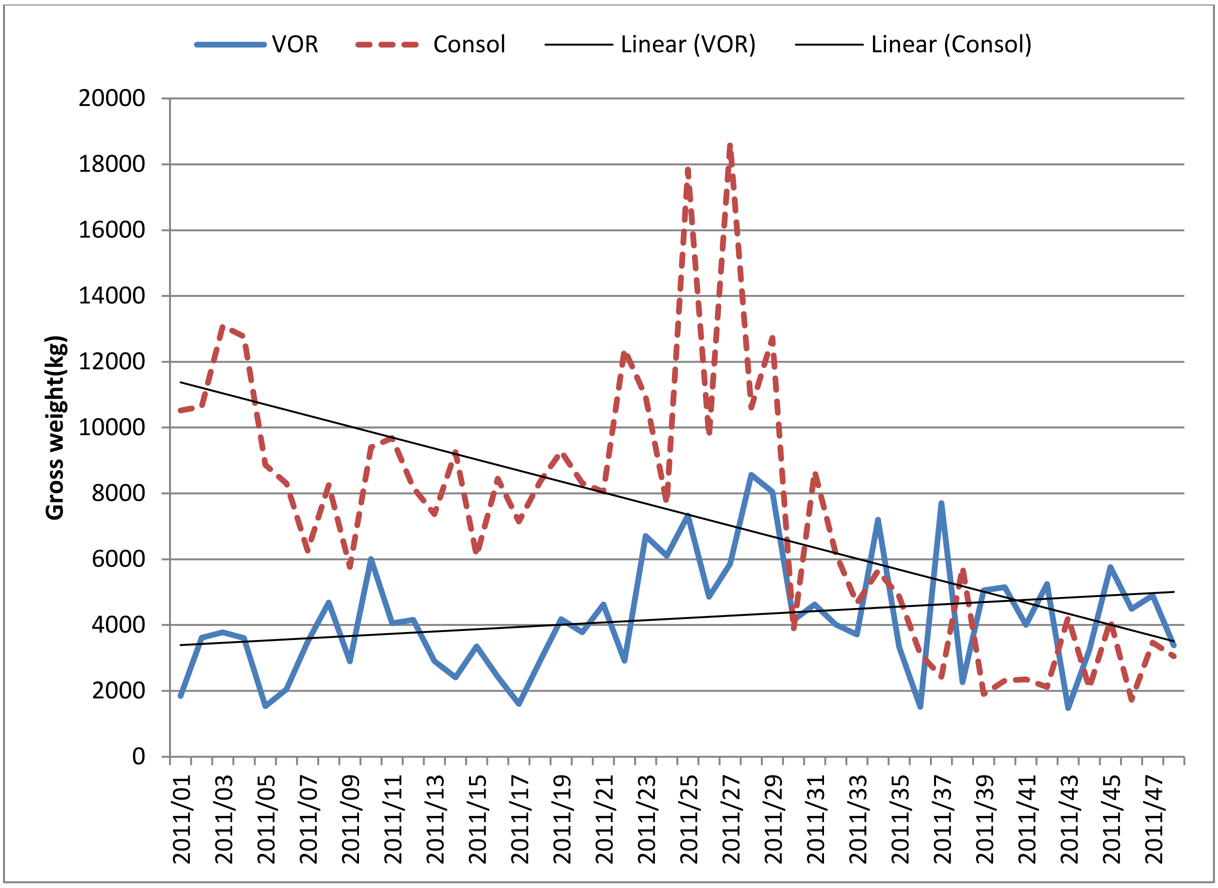


Chart 27 – Gross weight distribution over time for air. VOR denotes both Day and VOR orders.

The volumes for sea increases as well but not to the same extent as for consolidated air. For week 22 to 29 air increases with 69% compared with the yearly average while the same figure for sea is only 45%. This means that the main amount of the air increase is represented by backorders and critical refills. Our research shows that the summer peak is not a unique phenomenon for year 2011 as the same type of pattern occurs in earlier data from 2010. This stresses the importance of finding the root causes off the problem. Hence an extension of the air-share project could help clarifying reasons to why the air-share is increasing during this period.

There seem to be no obvious reasons for the summer peak within the Asia and International region when discussing the matter with workers at Volvo Parts. Neither is there any distinction between brands, which could be a plausible scenario with Volvo Penta's seasonal characteristics. With this seasonality in mind a rather interesting comparison can be made with the European region. While one would assume a larger plausibility of seasonality patterns in the European region the outcome shows a stable demand during the whole year. One certain reason for the peak is the sudden increase in demand. Whether needed or not the variation in demand may have numerous reasons (see chapter 3). A distinguishable difference between the regions is however the better presence of LPA dealers in Europe. This can indicate that LPA has a positive effect on mitigating the demand variations over the year. So an increased usage of LPA could have a positive effect for this problem for Singapore.

The potential savings can be seen as significant. If the summer weeks were to perform as the rest of the year, the total freight costs would be reduced by 5% (calculating with sea as substituting mode) and moreover the cost of consolidated air freight would decrease by 10%. The calculation can be seen as a simplification since the year average is especially biased by the summer weeks. On the other hand the transported total weights for all modes represent relatively large volumes for these weeks.

6.4 Refinement of parameters

The following section analyzes some different parameters and how these can be refined. These parameters are of importance since non-adequate settings may trigger unnecessary airfreight. Most important in the chapter is the initial section that estimates a factor to calculate gross weight which later will be showed to have a relevant impact on reducing airfreight.

6.4.1 From net weight to gross weight

The weight of an item is used as input when deciding whether it should be classified as either sea or an air item (see section 4.3.2). Today weight data are based on each unique items fixed net weight. This means that all calculations regarding material management are deduced from the pure product weight. In reality the actual weight, *the gross weight*, consists of additional masses such as packaging and load carriers, and will therefor always exceed the net weight. The gross weight is thus a variable parameter that can differ from case to case depending on item and the combined coli.

This states that the actual cost of transports will exceed the theoretically calculated. However this increase will not be proportional per mode of transport. Thus it is reasonable to conclude that the results of current sea-air calculations have further potentials of improvement.

Correlation between net and gross weight

An estimation of the gross weight is necessary. The main problem is that the gross weight is dependent on the packaging weight. Here are some influencing factors on the packaging weight:

- Number of items in the parcel
- Fragility
- Type of load carrier
- Type of packaging
- Need of protection for the surroundings/environment
- Type of transport mode

In table 10 some freight data is presented. The mean increase from net to gross weight is 22%. The figure of 30% for all countries is probably little high due to some inequalities in the data. The difference is larger when calculating mean values for both “increase of weight” and “reduction of price density” compared to the median value. The distribution for Singapore, all modes, is showed in chart 28.

Table 10 – Relationships between net and gross weight.

	All modes, All countries Int.	All modes, Singapore	Air, Singapore	Sea, Singapore
Sample size	7573	461	343	118
Increase of weight, Median	19%	18%	18%	19%
Increase of weight, Mean	30%	22%	22%	22%
Min	0%	4%	4%	7%
Max	17300%	243%	243%	90%
Price density (price/kg) Median	-16%	-15%	-15%	-16%
Price density (price/kg) Mean	-20%	-17%	-17%	-17%
Average weight per parcel (kg)	85	103	69	202

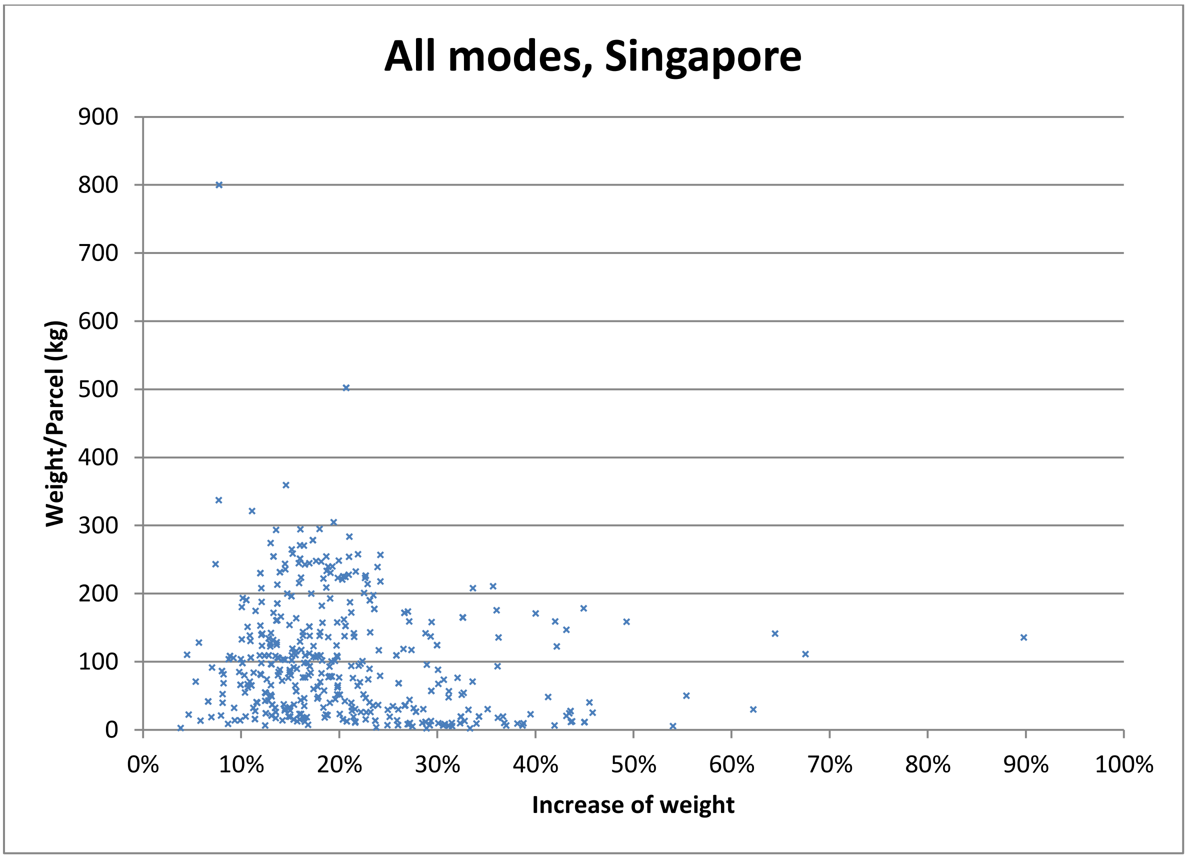


Chart 28 – Increase of weight (from net to gross) plotted against parcelweight.

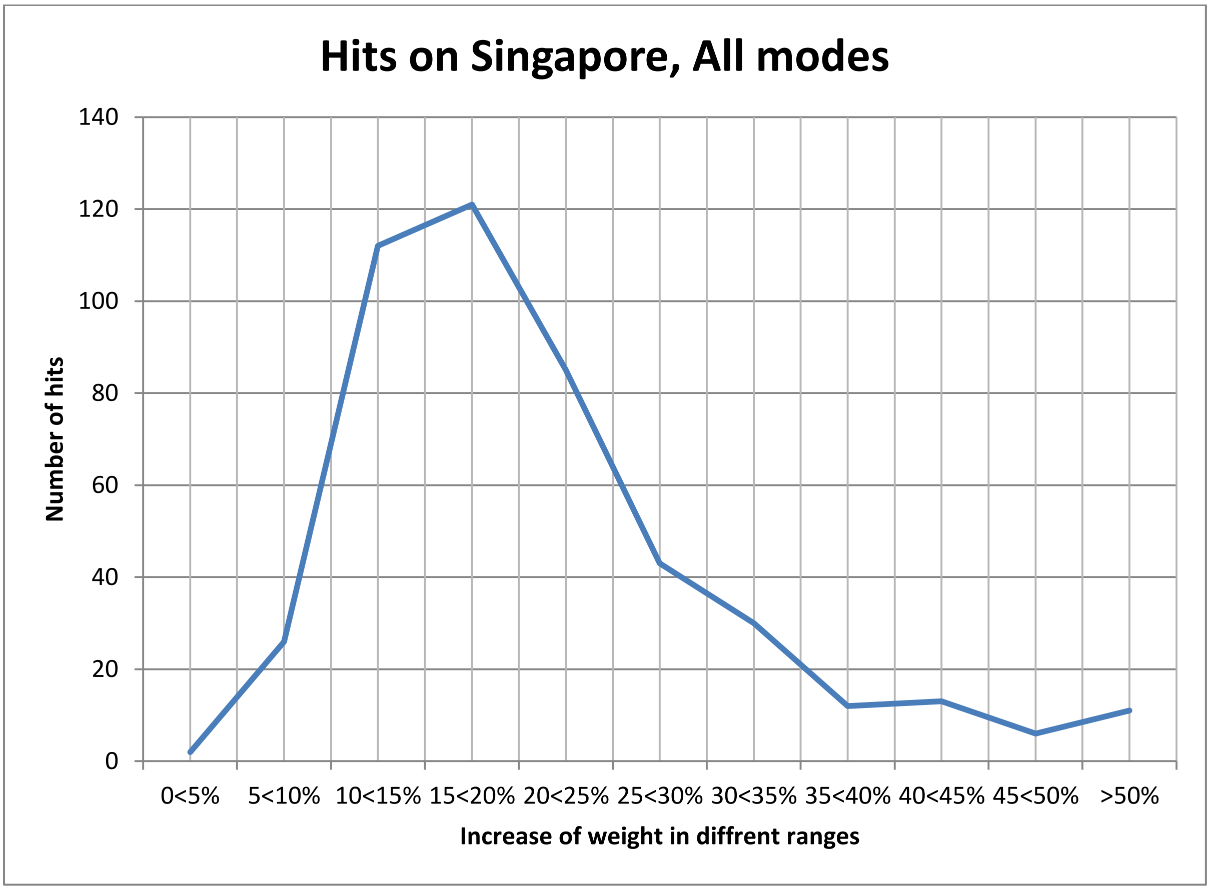


Chart 29 – Distribution of weight increase (net to gross).

The data has a distribution that is similar to the normal distribution and the characteristic bell curve (Gaussian function), which can be seen in (chart 29). The tail is shorter on the left side which is positive when finding a good estimation for the gross weight. As a result the mean value is misleadingly high. The median value is lower in all cases we have investigated and can be seen as a better approximation of the gross weight.

The distribution differs depending on the parcel weight. Heavier parcels have more concentrated distribution around 14% to 23% while the low weight parcels have a wider distribution from 10% to 40%. A reasonable assumption is that low weight parcels only consist of one or few items while the heavier parcels consist of many items. The difference between net and gross weight normally becomes higher for a sole item since the packaging weight can be assumed to have a fixed minimum weight. The wider distribution for sole items can also be explained by the assumption these more often are subject to special packaging.

Approximation of correcting factor for gross weight

The goal is to gain higher accuracy through usage of more realistic data rather than using simplified net weights. Using the median value of 18% (factor 1,18) as a factor to approximate the gross weight gives a perfect match in 25% of the cases. The 39 % that actually needs a higher factor than 1,18 will however have a much better accuracy than not having any factor at all. The problematic area is those cases when a factor of 1,18 is too big. The gross weight will be overestimated in 36% of the cases. Since the curve (chart 29) is steep on the left side, and no tail exists the negative impact of the estimation is minor.

Table 11 - Outcome of the factor 1,18 in comparison with the sample

Span	Hits	Hits in %	Match to factor 1,18
<10%	28	6%	Bad match, poorer than today
10->16%	138	30%	Slightly bad, but better than today
16->20%	116	25%	Good match
>20%	179	39%	Better match than today
	461	**100%**	

So implementing 1,18 as factor for calculating the gross weight would be better than today's situation of using net weight. Today the net weight gives a credible result in less than 6% of the cases. With the factor 1,18 the accuracy will be better in 94%.

The difference in net and gross weight between different destinations ought to be investigated more thoroughly, but it is probable that the same factor can be used for all destinations. Our analysis shows consensus between "all international destinations aggregated" and Singapore.

6.4.2 Minimum weight and efficient consignment quantities

As previously mentioned all transports are arranged through procurement of transportation services. The cost setup of the air transports consist of a minimum charge corresponding to a minimum weight. This stresses the importance of efficient weight quantities for air consignments and especially of those sent by more urgent order classes as they are more often characterized by frequent and smaller quantities.

A quick breakdown of the Singapore flow shows that minimum quantities are fulfilled at a satisfactory level with less than 2% of the consignments being inefficient. However, this is only true because of the consolidation that occurs from the setup of departures.

Table 12 – Breakdown of consignment quantities for air freight.

	VOR	Day	STOCK	Consignment
Above min weight:	36	207	192	**247**
Below min weight:	118	44	12	**6**
Below min weight in %	47%	17%	5%	**2%**

In Singapore's case, air consignments are consolidated for all order classes in three out of four weekly departures. Table 13 shows the outcome of the efficiency for the non-consolidated departure.

Table 13 – Outcome for the non-consolidated departure.

VOR on Day 3	Consignment
Above min weight:	15
Below min weight:	29
Below min weight in %	57%

The table confirms the logic behind the importance of minimum quantities for urgent order classes. This particular case illustrates all of the VOR consignments on a non-consolidated shipment. The above result equals a loss in 3 tons of actual air freight cost with an average extra surcharge of 107 kg per consignment.

Reduction of non-efficient consignments is either to be made through increased quantities or through lower frequencies (better consolidation). Increased efficiency does not necessarily improve environmental aspects, e.g. increased quantities where cost is decoupled from environment.

A third alternative is to negotiate and revise transportation agreements and debiting models. In VOR case costs could be greatly decreased through the addition of a single day in lead-time. This is of even higher importance for destinations with smaller volumes.

6.4.3 Voluminous goods

Voluminous goods refer to items with relative large ratio between actual volume and weight. These may be items that are bulky and light (e.g. air filters) or items that require special packaging (e.g. windshields etc.) which in turn adds up to a substantial increase in volume. Voluminous goods are costly since airlines surcharge extra. Today Volvo Parts does not have any established processes for tracking of these items as decisions only are based on net weight. Hence situations occur where these items are neglected and sometimes even inaccurately classified as air items.

Unfortunately we were not able to obtain any reliable data in order to provide any further analysis on the matter. However, interviews with people from the transport department confirm the existence of the issue.

6.4.4 Hazardous goods

Hazardous materials deserve a higher degree of attention considering the higher costs associated with special handling and securement of consignments. As for today inventory managers are not alarmed at an initial stage when making refill proposals. Neither is the associated costs taken into account when deriving air items creating a gap with the risk of creating unaware expensive air shipments.

Table 14 – Distribution of Hazardous reasons for all unique items sent by air to Singapore 2011, classified by hazardous group.

Hazardous reason	Number of order lines	in % of total
Undeclared	182	0,62%
Chemical product without transport limitations	54	0,18%
Classified as hazardous	1	0,00%
Classified as not hazardous	28983	98,58%
Sealed asbestos	5	0,02%
Under inspection - to be classified	174	0,59%

Our in depth research of all unique items sent to Singapore during 2011 shows that the outcome fortunately is not suffering from numerous hazardous consignments. However the worst-case scenario of 1,6% of the items being hazardous still does not eliminate the risk and its actual impact. Table 14 stresses the importance of a clear transparency since most of the goods classified as hazardous, or potentially harmful, in fact is being sent by stock air.

6.4.5 Lead-time fluctuations

The replenishment is to a great extent affected by the actual lead-time from which safety stock and hence re-ordering points are derived from. With Singapore being a distant market from its supplying warehouse we decided to follow-up on the actual lead-times and its components in order to clarify whether correct parameters are chosen for inventory management. Our analysis is based on a sample of chronologically following weeks where shipment data has been registered throughout the supply chain.

The table below illustrates the variation in actual total lead-time for each container, as well as the average mean, of the entire shipment within the week of arrival. Lead-times are measured from the point of order cut-off to the point in time where all items of the container have been binned.

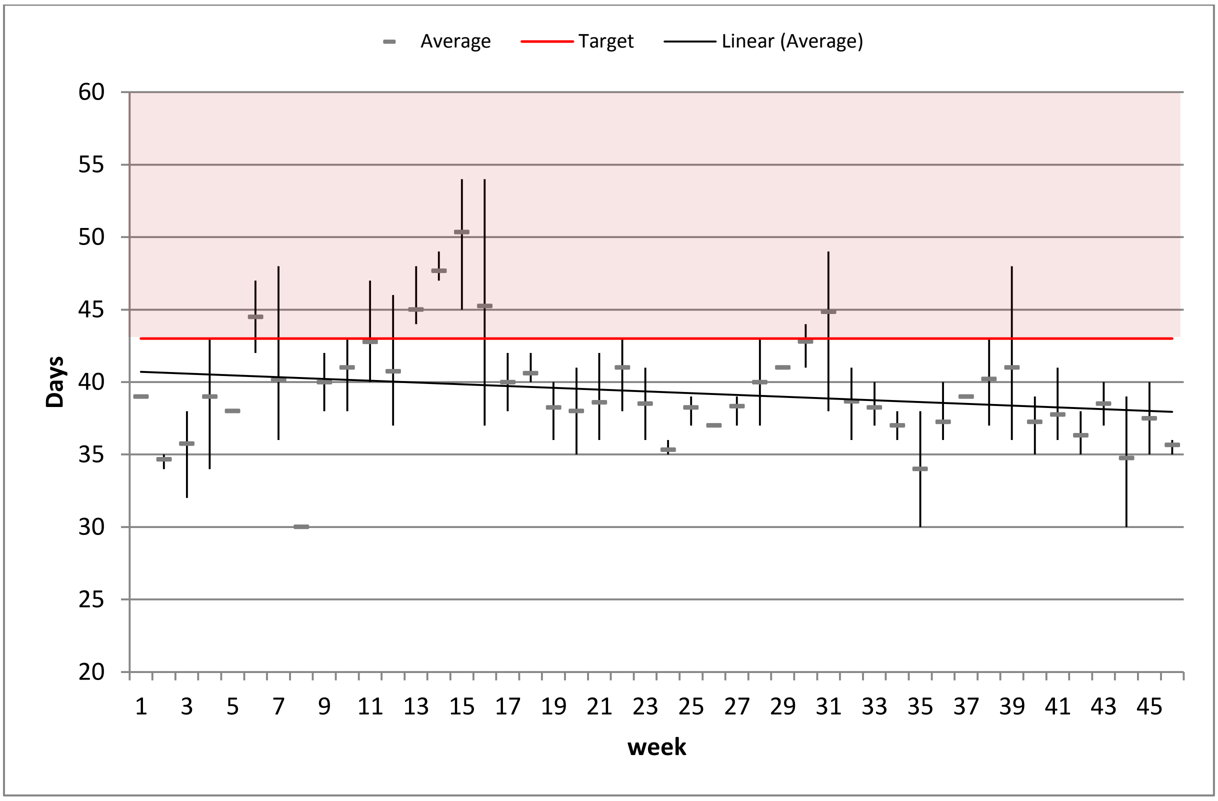


Chart 30 – Lead-time fluctuation for each week. Some weeks are missing. Upper red area is above system lead-time (43 days).

As seen the variations within each week are prominent, especially for the prior part of the year with an average variation reaching 4.7 days (11% more than the presumed system wise lead-time). With a positive trend (within target) we wanted to further investigate where the delays occurred. Chart 31 shows breakdown of the lead-times for the very same weeks plotted against the number of containers.

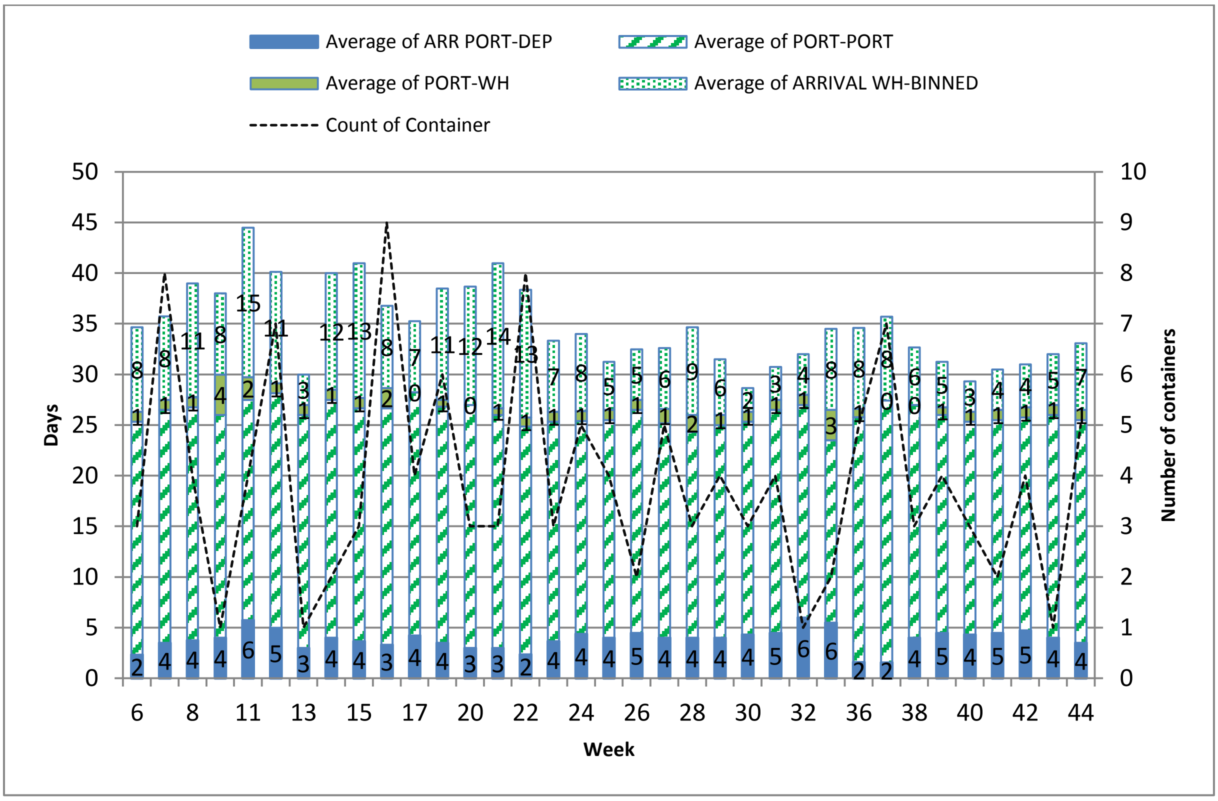


Chart 31 – Lead-time follow up for Singapore, 2011. The bars denote average lead-time while the line shows the number of containers shiped during the actual week.

As seen here the most prominent variation occurs at the end nodes involving manual handling of goods. Assuming that the container goods are of same characteristics, there is no clear correlation between the number of containers and the actual lead-times.

6.5 Rebalancing

Rebalancing a logistical flow contains three main components: service, tied-up capital and logistic costs. The scope of this thesis does not allow any changes to be made on the service element. Hence the following parameters have been identified in relationship to the main components for further investigation:

- Departure frequency
- Lead-time
- Transport cost (transport mode)
- Safety stock size

The analysis was conducted on a reference data sample consisting of healthy[6] stock items. The reference sample corresponds to around 66% of the stock gross weight sent to Singapore during 2011.

The sample cannot be equalized or extrapolated to correspond with whole stock order flow since the air-share is lower than in reality. The reference sample also assumes perfect outcome of the forecast and therefore does not contain any critical items or backorders. Adjustments of the identified parameters are summarized into different scenarios that are further analysed. The possible rebalancing scenarios are:

[6] Healthy stock items refer to parts that have had activity (hits) during the last 12 months.

A. Using gross weight instead of net weight
B. Shorter lead-time on sea (27 days with gross weight)
C. Shorter lead-time on sea (34 days with gross weight)
D. Multi modal, sea and air solutions (low price with gross weight)
E. Multi modal, sea and air solutions (higher price with gross weight)
F. Combination of alt. B and alt. E

As previously concluded it is more accurate to use gross weight for calculations (section 6.4.1) thus it is included in all above scenarios.

An analysis corresponding to the original definition of the air-matrix (section 4.3.2) was conducted on the reference sample (see table 16). In reality the original definition is not used to the full extent. Some items are sent by boat even if it is economically more beneficial to use air freight. Reasons for that are e.g. seasonal demands.

Table 15 – Outcome of the reference sample tested against original air-matrix definition. "Total logistic cost" includes both transport costs and tied-up capital cost.

	Sea	Air	Total
Weight (tonne)	1992	32	2023
Total logistic cost (MSEK)	12,93	3,06	15,99
Transport cost (MSEK)	2,30	0,73	3,02
Number of items	6317	4759	11076
Environmental impact (ELU)	146870	17616	164486

Table 16 – The different scenarios tested against the reference samples (table 16).

	Air weight(%)	Total logistic cost (%)	Transport cost	Environmental impact (ELU)	Comments
Scenario A, using gross weight	-33%	-0,1%	-7,4%	-3,1%	
Scenario B, shorter LT sea 27	-71%	-12%	-16%	-6,5%	*Includes gross weight scenario*
Scenario LT C, shorter LT sea 34	-53%	-6,1%	-12%	-4,9%	*Includes gross weight scenario*
Scenario D, multimodal Sea/Air	58%	-0,9%	-4,7%	-2,4%	*Includes gross w. The air length is half compared with other scenarios*
Scenario E, multimodal Sea/Air 12	28%	-0,4%	-5,8%	-3,7%	*Includes gross w. The air length is half compared with other scenarios*
Scenario F, combination of B and E	-62%	-13%	-17%	-7,6%	*Includes gross weight scenario*

6.5.1 Scenario A - possible impacts if changing from net to gross weight

Estimating the gross weight is beneficial in two situations. It would allow the refill team to have more accurate data when deciding upon transport modes, backorder quantities and critical products. The logic is that accurate weight information provides more efficient transports. This should lead to a reduction of air freight since the supplemental surcharge of 18% can be seen as rather high.

The estimated gross weight will have its main impact on the input to the air-matrix. A subsequent effect would be that air-items close to the borderline most probably would reclassify themselves as sea. This would result into reduced air and thereby a minor reduction in transport costs. However the environmental winnings would be greater. A rough estimation shows that 950 items (out of 4759) will be reclassified for Singapore. Over a year these 950 items would represent a total weight of around 11 tonnes (gross weight). The impact is a reduction of 33% of the planned stock air freight. But since the planned stock air freight is in minority the impact for all air will be less. Assuming a lower and more stable air-share to Singapore the reduction can be around 5%.

6.5.2 Scenario B and C - Reducing lead-time for sea transports

Today the lead-time for sea shipments are as previously mentioned long. The pure transport time is not adjustable but the time for packing and binning can be reduced. Two scenarios are presented in chart 18. The handling times for scenario B is corresponding to the existing handling times for consolidated air freight. The scenario C has a lead-time in between present lead-time and the lead-time for scenario B.

Table 17 – Lead-times decomposed. Todays sea lead-time but also potential lead-times according to scenario B and C.

	Packing etc Ghent	Ghent-(Air)Port	Transport time	(Air)Port-Warehouse	Binning	Total (days)
Sea, today	8 days	2 days	22 days	0	10 days	42
Scenario B, LT 27	*29 hours*	*14,5 hours*	*22 days*	*16 hours*	*27 hours*	*27 (3,6 days handling)*
Scenario C, LT 34	*124 hours (5,1 days)*	*14,5 hours*	*22 days*	*16 hours*	*124 hours (5,1 days)*	*34 (6,6 days handling)*

Table 18 – Outcome scenario B (LT 27)

	Sea	Air	Total
Weight difference (ton)	22,54	-22,54	**0**
Weight difference	1,1%	-71%	**0%**
Total logistic cost, difference (M SEK)	-0,21	-1,70	**-1,91**
Total logistic cost, difference	-1,6%	-56%	**-12%**
Transport cost, difference	1,4%	-71%	**-16%**
Environmental impact (ELU)	1,13%	-70,44%	**-6,53%**

Table 19 – Outcome scenario C (LT 34)

	Sea	Air	Total
Weight difference (ton)	16,73	-16,73	**0**
Weight difference	0,8%	-53%	**0%**
Total logistic cost, difference (M SEK)	0,15	-1,13	**-0,98**
Total logistic cost, difference	1,2%	-37%	**-6,1%**
Transport cost, difference	1,0%	-53%	**-12%**
Environmental impact (ELU)	0,84%	52,28%	**-4,58**

The effects of a changing the lead-time can be seen as positive. The reduction of air freight is impressive, for scenario B reduction of the air will be 71%. It should be remembered that the reduction in handling times at the warehouses can result in higher costs to perform according to the new time limits. To cope with a higher speed in handling activities it can be necessary to increase the staffing or improve the warehouses efficiency with better resources such as pick by voice or similar. But changes can be done to improve the handling time without making any expensive investments. See next chapter for such suggestions. It should also be mentioned that the handling times today are not forced by any challenges or incentives for improvement. So probably there is an intrinsic potential for improvements in cutting the lead-time for handling activities.

The reclassification of air to sea from the scenarios will also lead to fewer disturbances at the regional warehouses. Air cargo has shorter handling time and requires immediate actions. These disturbances may explain the long binning times for sea orders since they are postponed by incoming air arrivals.

A shorter lead-time will also provide the advantages of better agility to react against possible disruptions. This should reduce the amount of items that are flown due to critical reasons. The exact amount is hard to estimate. But the difference between the present situation, with a worst case lead-time of 50 days, and the proposed scenario of worst case 30 days, is rather large. This means that the time in between refills can be reduced by almost three weeks.

6.5.3 Departure frequency for sea

Doubling the departure frequency is closely connected to scenario B and C. A reduction of the sea lead-time must be supported by an increase in frequency accordingly to following suggestion.

Delivery frequency is an interesting parameter for rebalancing a flow. In the present setup sea departures to Singapore from Ghent occur on a weekly basis. A higher frequency creates smaller batches and more even flows. The idea is to double the frequency to two departures per week. There are two main positive effects of such change. Firstly the work-load will be more even for the binning activities at the Singapore warehouse. Secondly the maximum lead-time will be reduced by 3,5 days. Furthermore the central warehouse in Ghent will gain from smoother flows as batch sizes per departure decreases thus giving shorter handling times. One major concern will however be the risk of lower filling degrees as the number of containers will be split by two. Such change may result in difficulties in satisfying filling degrees. Chart 32 shows that approximately 10% of the present departures are consist of only one container. In these situations the filling degree would result into less than 50% making it highly unprofitable since freight price is not weight based. The average value is 3,78 containers/week and together with future actions, including moving cargo from air to sea, would make it possible to have two departures/week with satisfying filling degrees in most departures.

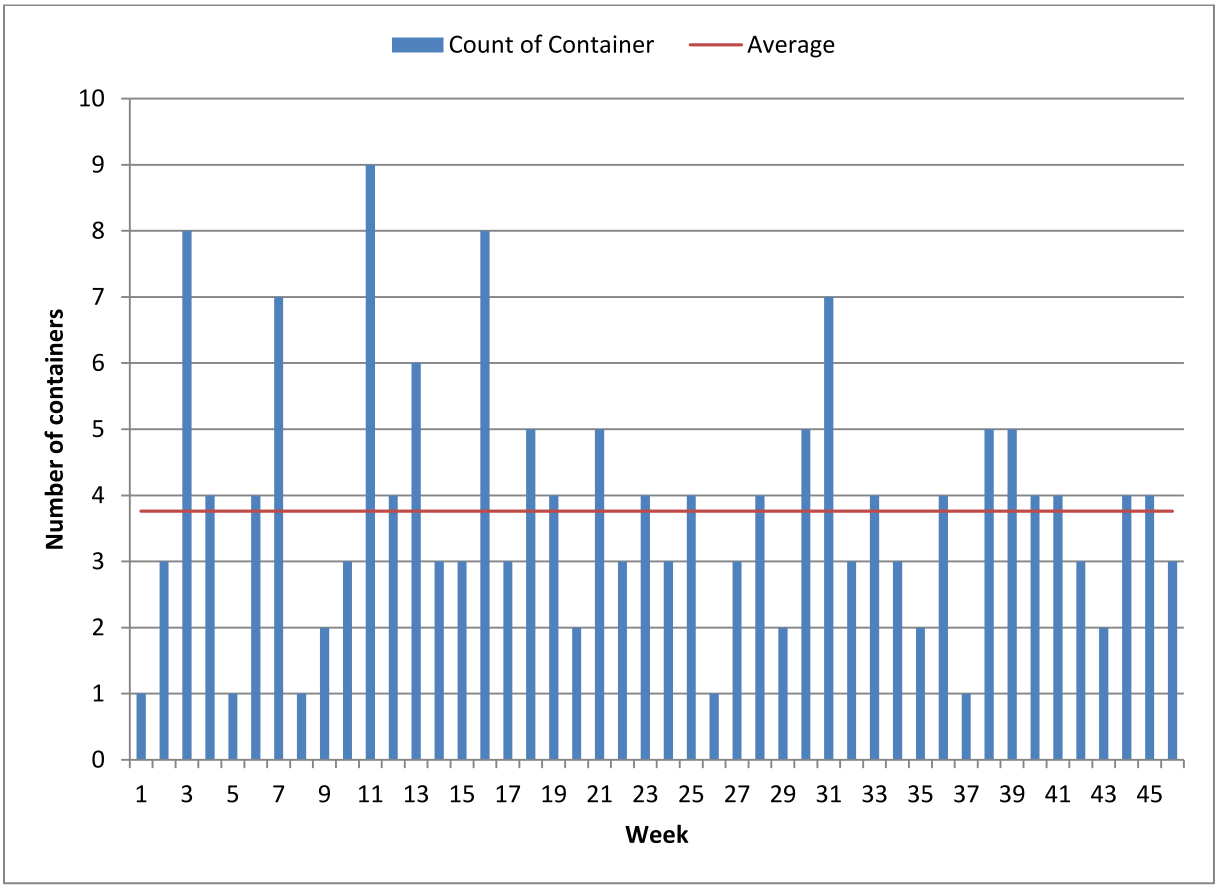


Chart 32 – Number of containers/departure, Ghent – Singapore, 2011.

6.5.4 Alternative transport solution- reasons for a third LT

For destinations that are remotely located from the central warehouses in Europe the lead-time is a problem. This is due to the lack of alternative lead-times between the two existing transport modes.

This rather large lead-time difference, from the relatively fast air to the slow ferry, makes the system stiff and creates unnecessary air freight. If there is a lead-time requirement for a critical order or a backorder that lies in zone B (in chart 33) air freight is necessary to fulfil the lead-time requirement. However it is unnecessarily costly to use a transport mode with a lead-time of ten days when the actual lead-time requirement is for e.g. is 30 days. So implementing a third alternative which lies in between the today's existing transport modes would probably lead to cost savings and easier balancing of the system. This new alternative would preferably have a lead-time that would be placed around the center of zone B. However the lead-times are relatively similar (see chart 33) to other destinations which is why figure 33 can be seen as general.

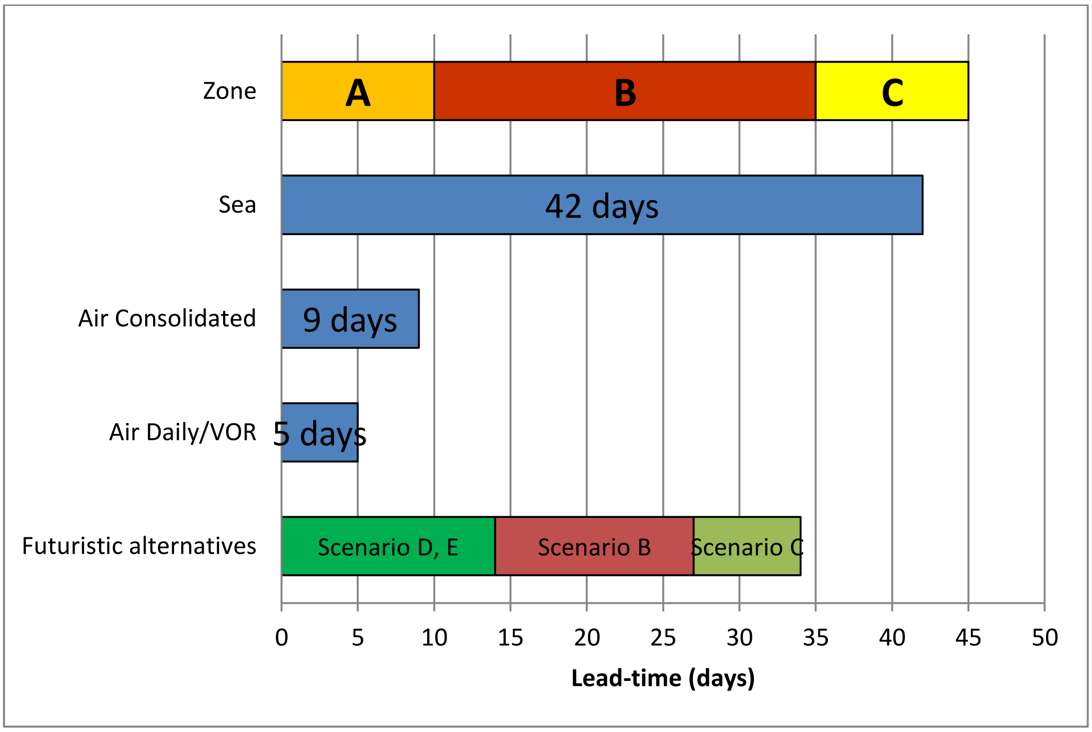


Chart 33 – Lead-times Ghent – Singapore. Order cutoff to binning.

A drawback is that the amount of goods shipped on sea will decrease since some items will be classified as a third alternative. Another issue is that the environmental effects are unclear. Having more transport modes will increase the complexity of the entire logistical system. However the main influence will be towards the warehouses. The filling rate will probably be negatively affected resulting into higher transport costs. In extreme cases it could however lead to a scenario of reduced amount of total departures as a result of obtaining feasible filling rates.

Implementing a new transport alternative is associated with several obstacles. As of today, there are no good alternatives that fully satisfy the requirements of price, lead-time and environmental impact. The price for the new alternative should lie in between the current alternatives. A case involving rail in connection to this discussion is presented in chapter 7. The next section will discuss a multi modal solution as a substitute to the air freight.

6.5.4.1 Scenario D, E and F - Multimodal solution including air and sea

A multimodal solution with a combination of air and sea could be possible to destinations in Asia and Africa. The basic idea is to combine two modal modes in a hub that is located halfway from one another. For Ghent to Singapore the scenario follows as: air freight between Ghent and Dubai where the goods are transhipped to a vessel that takes pursues the transport to Singapore. This means that an extra transhipment is added which drives costs and increases the risk for damage etc.

Table 21 is an attempt to exemplify the potentials from a multimodal solution. All figures for the multimodal solution are estimated figures. Lead-times have been estimated from a multimodal transporter named SAT Albatros. It seems to be common with a pure transport times of 10 days from Singapore to Europe (reversed direction!) according to available public timetables. According to the transport department at Volvo Parts it is a lack of capacity in the interesting direction (from Europe to Asia) at the moment. That is off course an obstacle for implementing the solution on a short time horizon.

Table 20 - The potential with a multi modal solution for Ghent – Singapore.

	Sea	Air/Sea, estimation	Air consolidated	Air VOR
LT days	43	*16(10+1+5)*	9	4-6
Price €	0,06	*0,78((1,5+0,6)/2)*	1,5	1,85
Price/LTday	0,001	*0,05*	0,17	0,37

Two scenarios were tested to evaluate the possibilities with a sea/air solution. Limitations in systems support limited us to test only two modes at the time. Since the difference in lead-time between air and sea/air is relatively small it was assumed that air should only be used for VOR and Day orders. This exclusion of air for Stock orders also implies a positive effect on the environment.

The tested scenarios included two transport modes, sea and sea/air. The difference between the scenarios D and E is the price for the sea/air transport. Since reliable prices were missing two different prices were assumed. A third scenario including both scenario E and scenario B (LT 27) was also tested.

- Scenario D: $transport\ price = \frac{(sea\ price)+(air\ price)}{2}$, LT=15 days
- Scenario E: $transport\ price = \frac{(sea\ price)+(air\ price)}{2} * 1{,}14$, LT=15 days
- Scenario F: $transport\ price = scenario\ E,$ LT=15, plus scenario B

These three scenarios were tested in the same manner as the other rebalancing actions in this chapter.

Outcome scenario D

In this scenario the price is set rather low. The freight forwarder has to cover the cost for the transhipment in some way, probably by reducing the margin. The low price does however not result into any satisfactory results. This is due to the large amount of items that are reclassified from sea to sea/air as consequence of the rather low price. So 1% of the sea items plus the old air items will be classified as sea/air. That is 58% more weight than the original air-share. However, the flown distance is approximately half compared to the original solution.

Table 21 – Outcome for scenario D.

	Sea	Sea/Air	Total
Weight, difference (ton)	-18,4	18,4	**0**
Weight difference	-1%	58%	**0%**
Total logistic cost, difference	-5%	18%	**-1%**
Transport cost, difference	-1%	-16%	**-5%**
Environmental impact (ELU)	-0,92%	-14,44%	**-2,37%**

Outcome scenario E

In this scenario the price was set a bit higher than scenario D. That led to less items moving from sea to sea/air. As a result the transport costs decreased more than in scenario D. But the total cost reduction was almost untouched. Both scenario D and E however performed better than the original solution.

Table 22 – Outcome for scenario E.

	Sea	Sea/Air	Total
Weight difference (ton)	-8,9	8,9	**0**
Weight difference	-0,4%	28%	**0%**
Total logistic cost, difference	-2,1%	7,0%	**0%**
Transport cost, difference	-0,6%	-22%	**-5,8%**
Environmental impact (ELU)	-0,45%	-30,57%	**-3,67%**

Outcome scenario F

Scenario F was a combination of both scenario E and scenario B (LT 27). As seen in table 24 the combination does not provide any super positional effect. On a short time horizon the winnings of combining the two methods are limited. It is therefore better to focus on implementing one solution.

Table 23 – Outcome scenario F.

	Sea	Sea/Air	Total
Weight difference (ton)	19,71	-19,71	**0**
Weight difference	1,0%	-62%	**0%**
Total logistic cost, difference	-2%	-58%	**-13%**
Transport cost, difference	1,3%	-77%	**-17%**
Environmental impact (ELU)	0,99%	-79,44%	**-7,59%**

6.5.5 Impacts from increase safety stock

One way of approaching unnecessary Stock air freight that is classified as sea items is to increase the safety stock. A larger safety stock would reduce the air freight but at the same time increase tied-up capital. The question is if the cost of increased tied-up capital is lower than the difference in extra cost generated by air freight instead of sea freight.

A general increase for all calculated safety stocks is not logical from an academic point of view. If the in-data used for calculation is accurate then the determined safety stocks should be enough. Worth pointing out is that all air cannot be mitigated, since the cost of having 100 % assurance against stock-outs is extremely high. Assuming that the used formula for calculating safety stock is credible, the in-data quality was examined. The credibility of the variation in demand (σ_D) may be questioned but rather difficult to determine and therefore left out of scope

Volvo Parts method of calculating safety stock follows from the formula below, which assumes fixed lead-times that section 6.4.5 proved to be wrong.

$$SS = Z * \sigma_D * \sqrt{LT}$$

.

For cases with fluctuations in lead-time the original formula for gives a more accurate estimate of the safety stock.

$$SS = Z * \sqrt{LT * \sigma_D^2 + \sigma_{LT}^2 * D^2}$$

A rough estimate of the applied lead-time variance $\sigma_{LT} = 4{,}2$ gives an increase of safety stock with 30% compared with today's situation. Calculations are based on the earlier mentioned reference sample. The cost for such increase would be around 2 million SEK for one year of the reference sample. The air freight cost is estimated to be similar so no easy winnings can be done here. These figures are partly based on estimations so the credibility can be arguable. But the problem with a 30% increase in safety stock is that it still would not be enough. Matching the logs from the air-share project together with the reference sample showed that out of 92 hits the larger safety stock would only help in 35% of the cases. An interesting remark from the air-share log is that the quantity flown is often larger than the monthly forecast. In 40% (326 hits) of the cases the flown amount is larger than the forecasted. A reason for that may be the individual opinion of adding up some extra quantity to prevent subsequent backorders on the item while also reducing handling at binning. Hence the 35% can assumed to be underestimated.

In short an increase of the safety stock due to deviation in lead-time is not the right way to mitigate the problem. Firstly no particular cost winnings can be seen and the trend for the moment is less delayed transports (see chart 30). Also the fact that the increase of safety stock has to be substantial to cover the demand is important. So probably the cost of avoiding air freight for back orders and critical items would lead towards a huge and cost inefficient safety stock.

An interesting thought would be to classify sea items that have a high air freight cost compared to the tied-up capital cost in a separate group with higher safety stock. Two elements from the air-matrix (figure 11) are used to calculate following ratio:

$$\frac{Transport\ cost\ Air}{Tied\ up\ capital\ warehouse}$$

A high value of the ratio indicates that if the item has to be flown (due to backorder or critical) it will be costly compared to having an increased safety stock. This stipulates that for the same price as the air transport cost several extra pieces could have been stored in safety stock instead. This is particularly interesting for items with large variation in demand (σ_D). If the demand is predictable it is unnecessary to increase the tied-up capital. So a solution would be to group items with a high ratio and add up some extra safety stock. The result would be less environmental impact since air freight is avoided for stock items that are critical or in backorder. Further improvements of the grouping could be to only include heavy items with a higher transport cost per piece.

$$\frac{Transport\ cost\ Air}{FC * 12} = Air\ transport\ cost/piece$$

6.6 LCA-inspired investigation

A LCA inspired study was conducted to estimate the environmental impact from the different transport result. A comparison between three transport modes is presented in chart 34. The result presented in chart 34 is also used in the previous rebalancing section of the case study to evaluate the environmental impact on the different scenarios (A to F). Calculations of how the ELU:s was estimated are presented in the Appendix.

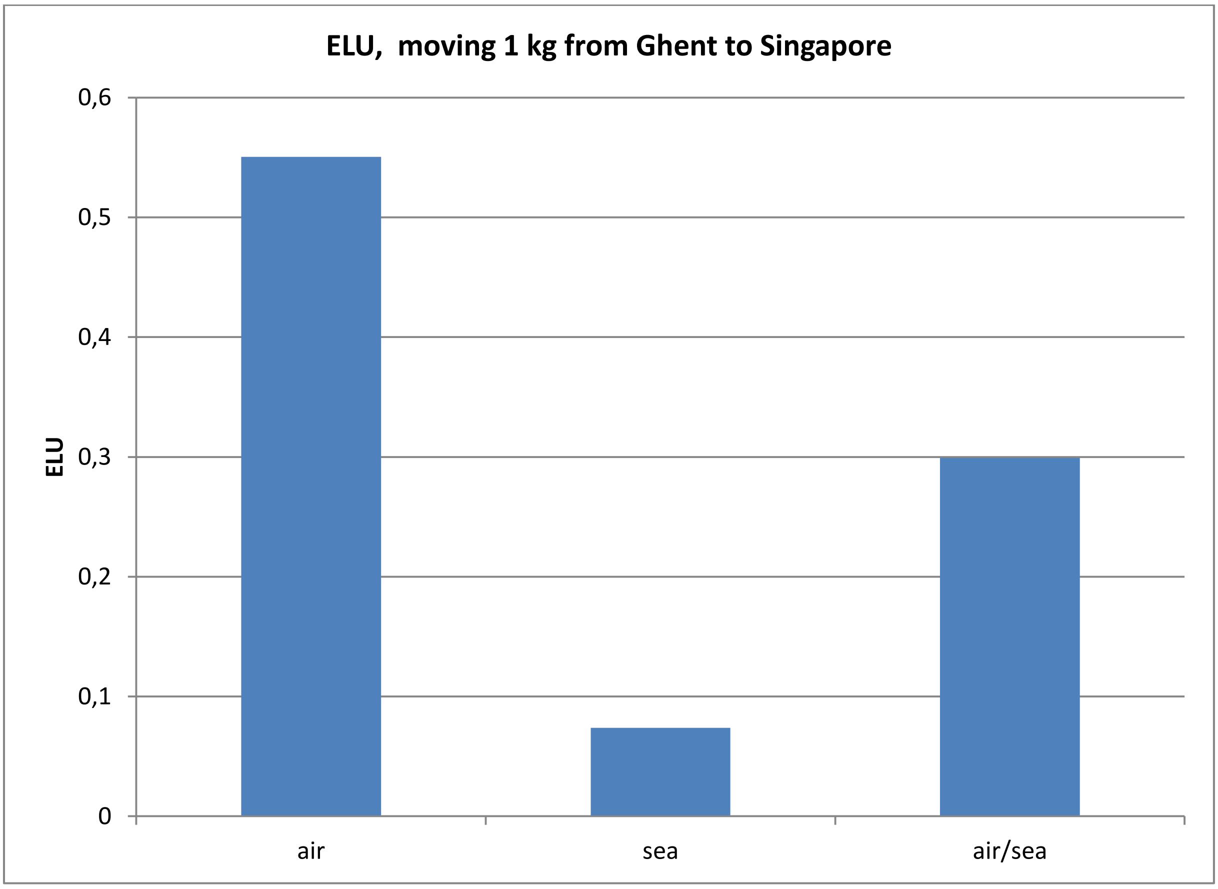


Chart 34 – Environmental impact from the different transport modes. 1 ELU ≈1 €

6.7 Discussion of case study

The case study's aim was to function as a base for testing different rebalancing actions and other improvements with the overall goal to reduce airfreight. This also included the aim of highlighting some of the possible underlying managerial aspects.

The case study uses figure 12, which summarizes how the flow is distributed between the different order classes and the mode of transport, as starting point for the proceeding work. The map identifies two suitable areas for improvements which are investigated further. It is backorders together with critical items for the Stock flow as well as the ordinary stock flow excluding backorders and critical items. Together the two interesting areas represent the complete Stock order flow (refill flow). Making a clear distinction is interesting of two reasons; firstly it hard to estimate potential impacts from the suggested scenarios on backorders and critical items. So to enable a correct and understandable estimations backorders and critical items had to be distinguished. Secondly the two areas represent different symptoms, but more importantly, there are different root causes to the symptoms. Backorders and critical items were substantially affected of the downturn while the ordinary Stock order flow has the same amount of air-share independent on market situation. However this does not mean that backorders and critical items are solely originated from market conditions.

The previous mentioned map, which displays the flow between Ghent and Singapore (figure 12) takes a snapshot. But as we showed in chart 27 there was a dramatic reduction of consolidated air during 2011. This means that the share of backorders and critical items was smaller in the end of the year than showed in figure 12. Therefore it is natural to focus towards the ordinary Stock flow as well. Two of the suggested actions would together make a major impact on reducing the air-share. The first suggestion of using gross weight instead of net weight is a logic conclusion from the aim of using best available input-data for defining air-item and sea-item. The second suggestion, decreasing the lead time for sea transports, can be seen as lean inspired solution which is reasonable hence the handling times today are unnecessary long. It will also have more positive effects that will be discussed further down.

When defining if an item should go by air or sea the borderline between them can be debatable. For all air-matrix calculations zero has been used as the definite boundary. It means that items scoring zero or less ought to be more economical to be forwarded by sea while values above zero favors air. When determining an items classification different logistical cost components are calculated (see figure 11). But the price towards the end customer is not directly affected of the true price. Instead all products have a supplemental surcharge to cover the products that are sold to an under-price. It would be possible to move the boundary upwards to a more positive figure, that is if Volvo Parts are prepared to pay for greener logistics. The lifecycle could also be a parameter for changing the borderline; e.g. initial and prime products could have a higher boundary that eventually would decline towards zero as the product itself reaches the end of its lifecycle. It should be remembered that the impact of fine tuning the borderline in the air-matrix described above is relatively limited.

Backorders and critical items were partly explained by market conditions but it can also be explained of not adequate parameters when designing stock levels as well as the dealers ordering behavior. Both these issues were discussed in section 6.3 and 6.4. It is not right to ignore and leave the problem with backorders and critical items caused market conditions unattended even if the trend for the moment is positive. Volvo Group operates in a volatile market that follows the world economy and therefore will new downturns come in the future with the problem repeated. The suggestion of a new shorter lead time for sea will make the transport set-up more agile, see section 6.5.2, and hence can Volvo Parts easier follow the market condition without using air to the same extent as today. Probably will it also requires better forecast that can follow the fast market changes better.

As stated in frame of reference (section 3.2) it is hard to forecast aftermarket demand. Implementing a shorter sea lead time makes it easier react on inaccurate forecasts without using airfreight or increase safety stock. Increasing the safety stocks was an action that was evaluated in section 6.5.5 and it was seen as less favorable compared to reducing the lead time on sea. Increasing safety stock can be seen as a quick fix that will hide the real underlying problems that is a contradictory to the lean approach. It will also creating a less agile logistic set-up that can be problematic in downturn resulting in massive costs for tied-up capital in the warehouses.

In the case have flow of Day and VOR orders been neglected and left out of scope. They represent a non-negligible share of the air that should not be forgotten in the future work of reducing air-share. The suggested action will hopefully reduce the amount of Stock backorders and hence can VOR and Day orders created by stock-out of Stock articles be avoided.

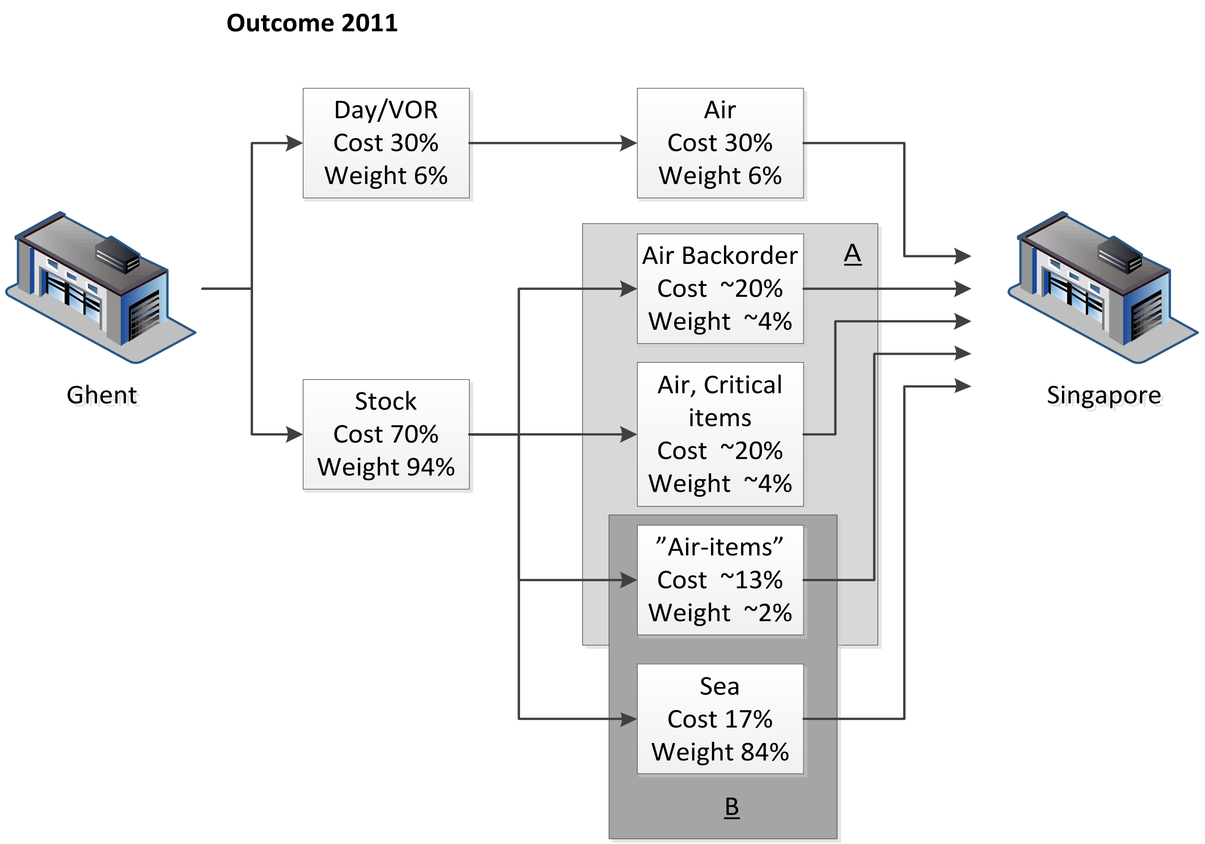


Figure 13 – Chart 35 covers area A and chart 36 covers area B.

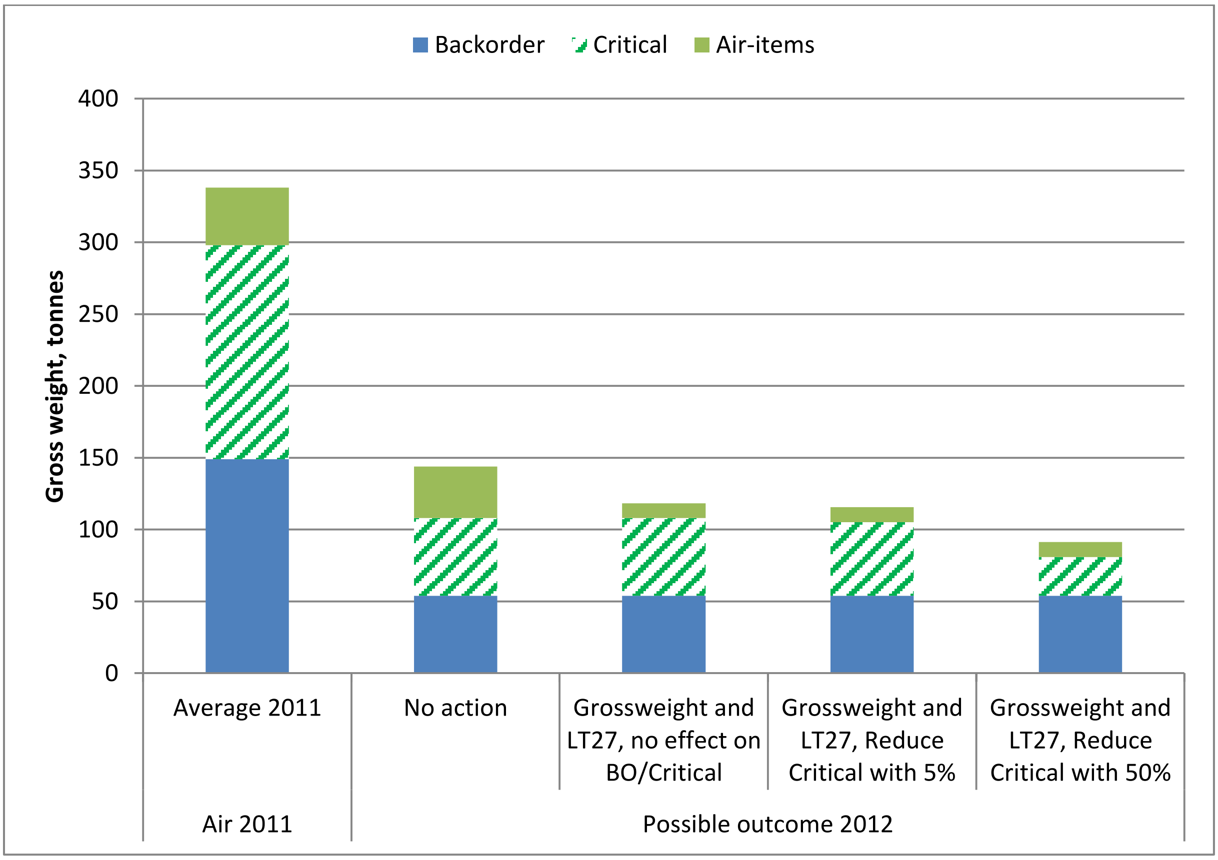


Chart 35 – The refill flow today and possible outcome 2012. Covers area A in figure 13

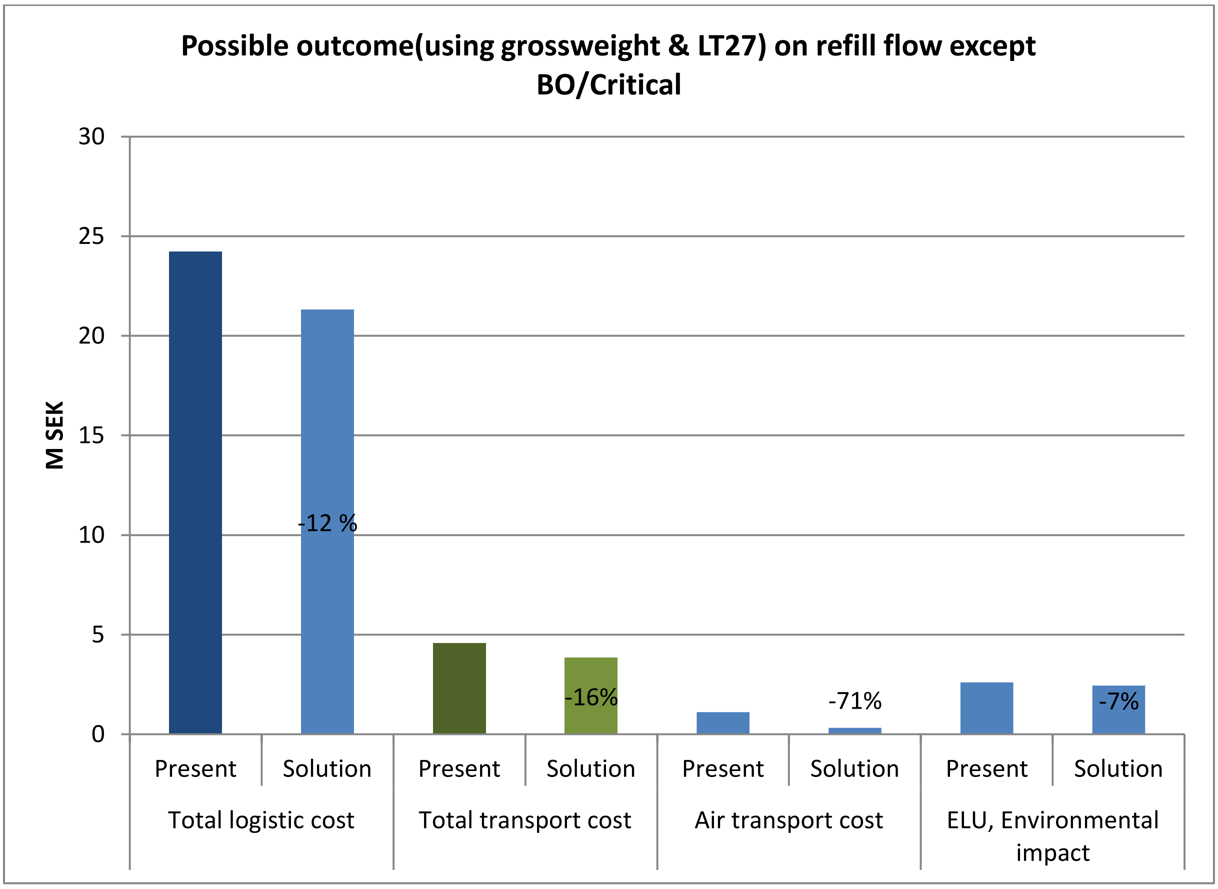


Chart 36 – Possible outcome if implementing a lead time of 27 days and gross weight. Covers area B in figure 13.

7 Other transport concepts

Following chapter is a separated from the other chapters in this thesis but it includes interesting information about using train to the Asian market. A train solution may be futuristic today but can be realized relatively soon depending on surrounding factors. The chapter can be seen as input to further studies.

7.1 Train

Train could be a possible solution for destinations in Asia, primarily China and other destinations in the northern part. Using the Trans-Siberian railway for this type of transports is unusual and a lot of obstacles have to be overruled. This suggestion can be seen as a futuristic idea.

To give the train suggestion some substance a short case with Schenker and BMW is presented (DB Schenker, 2011). Ending of November 2011 traffic from Leipzig to Shenyang with daily and direct container trains was started. Shenyang is located 700 km northeast of Beijing in the hinterland region. The cargo consists of components from a logistical center in Leipzig that is transported to the factory in China. The lead-time is 23 day and includes two transhipments due to different gauge. Since the traffic in the case recently started no evaluation have been done. Therefore no conclusion can be done regarding reliability.

Except from the referenced case it is hard to find any more information about similar cases with train traffic to Asia. By using the figures from the case a similar solution for Volvo Parts would give a lead-time from Ghent to north-eastern China of approximately 34 days. It is necessary to add time for binning (6 days) and picking (5 days) as well as the extra travelled distance from Ghent in order to make the figures comparable. Handling is conservatively based on Stock order handling times. If shorter picking and binning times are to be applied it is possible to reduce the lead-time to 25 days. Future improvements in infrastructure would further reduce the lead-time.

It is also interesting that Volvo Cars is planning to open a production plant in this region. A possible location is Daqing which lies close to Shenyang along the railway to China. This can open up for frequent departures if Volvo Cars decide to have a similar setup as BMW, but with for example Volvo Logistics as transport provider. If Volvo Cars open up a factory cooperation with them could simplify the implementation and create sufficient volumes in order achieve overall efficiency and effectiveness.

Today Volvo Parts have a regional warehouse in Shanghai which lies remote from the Trans-Siberian railway. So a setup with train would require a new warehouse structure in China. Winnings from this could be improved environmental image. Today the Trans-Siberian railway is electrified, if used engines are electrified remains unknown.

Other potential destinations are South Korea and Japan which lies one day respectively two days away with vessel. The distance from Shenyang to a port is 400 km which could make a possible lead-time of approximately 40 days.

7.2 Environmental impact from a train solution

An estimation of the environmental impact was done, see chart 37. The sea alternative was calculated in the same manner as the sea transport to Singapore with the exception that the length that was sailed of the vessel was increased. Since the same destination is not chosen should the comparison only be seen as estimation.

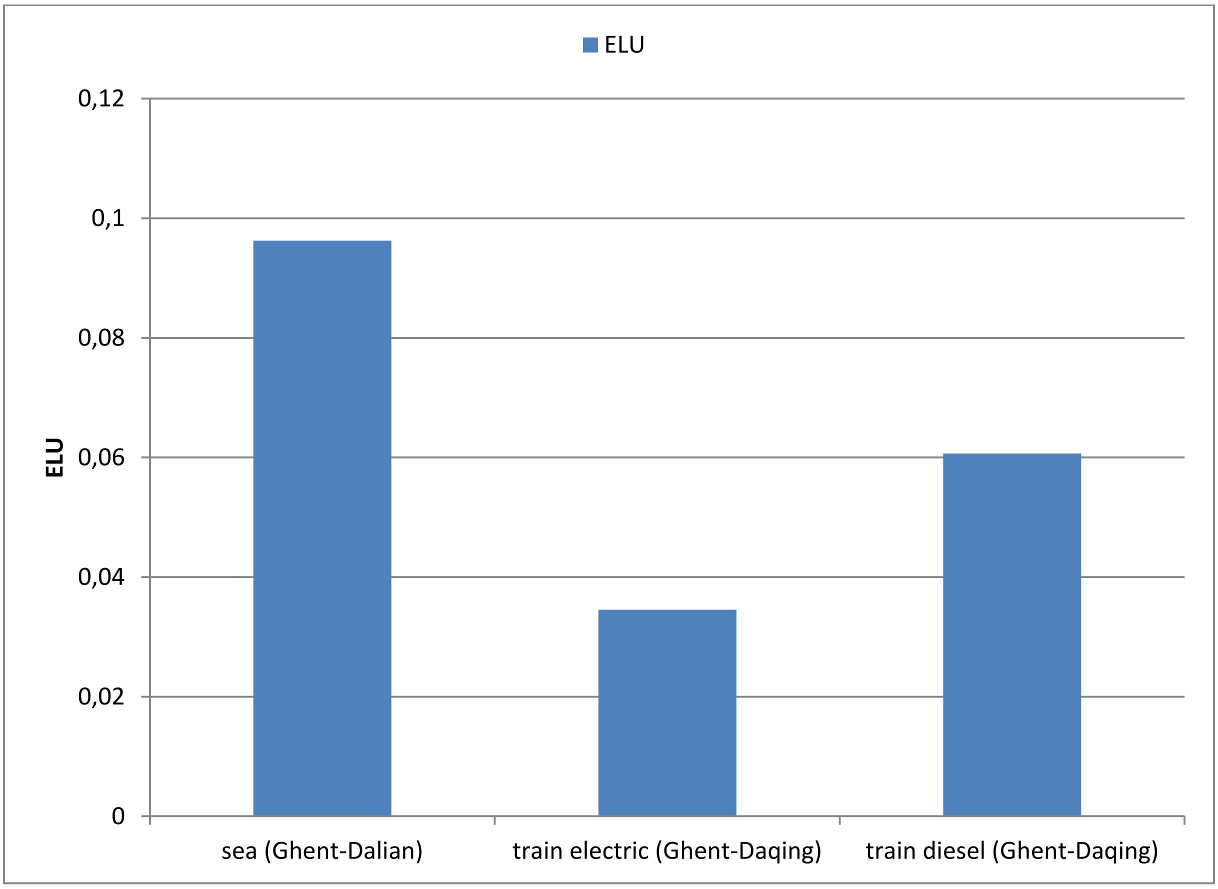


Chart 37 – Environmental impact, sea versus train to north east China

8 Concluding discussions

As an outcome from the empirical findings during this thesis study a number of conclusions have been drawn. This chapter presents these conclusions that have been deduced to be associated with the root cause of high air shares.

8.1 Management and alignment of processes

A multinational company of Volvo Groups size requires it subsidiary units to work in an aligned setup where optimal efficiency is gained through effective processes. This goes especially for matrix organisations with functional units with the primarily task of supporting main business functions. In Volvo Group's case these functional units, the business units, consist of their own legal entities with profit obligations. This suggests that in-house activities not always coincide within an optimum or holistic scope. Our research of Volvo Parts confirms that these complexities exist and not only a corporate level but also within the sub-units themselves. As for the share of air-shipments our findings show that this number could be reduced if better collaboration and/or processes were to be implemented.

8.1.1 Importance of global processes

During our empirical studies a lot of interviews were made with different people within the organization. Our task was to gain knowledge and to create a holistic view of the overall situation with its supporting processes and procedures. Most noteworthy became the incoherency in interpretation and execution of existing processes. As our research went by it was understood that most of the teams established and optimized their processes according to self-obtained data. An approach that we believe leads towards development of own perceptions which in turn creates sub-optimizations that discourages overall performance. A statement that was confirmed during several interviews suggesting that collaboration in between units was less than sufficient. A recent example of this was the change in order cut-off times that was poorly communicated resulting into confusion and irregularities in customer deliveries.

Furthermore it was of our understanding that responsibility and hence performance measurements were not equally distributed in comparison to the power given to those in charge of managing. This was especially evident in our observance of the refill team whom rarely could deny inefficient and/or expensive shipment requests. On the other hand they had the ability to system wise actually grant expensive orders without further questioning and controlling. This creates a rather questionable setup where performance is measured against areas beyond control. For the refill team this is evident for KPI2 that is affected by the performance of the local order offices, which are apart organizationally as well as in processes and procedures. From a greener logistic point of view it would be wiser to e.g. put more emphasis on KPI5 and KPI8. This could probably lead towards an alignment with reduced cost of transports while increasing the supply chain agility (backorder recovery).

8.1.2 Systems support

Today, Volvo Parts existing IT-systems for inventory management consist of a various different platforms (DSP, RHELP, SPICE, MMI et al.). The differentiation among these platforms is mainly based on functionality, e.g. warehousing, forecasting, order management etc. However, some of these platforms are also differentiated within the platform itself, running as isolated setups especially adapted to the operating market. Our research has shown this development has created a fragmentation causing inconsistency in the agreed set of data-parameters. This is partly evident for the order and freight codes where the same set of parameters may differ in actual e.g. modal transport mode. This states an underlying risk of increased air-shipments created by faulty follow-ups as well as possible errors in middleware setups. Moreover inconsistency of data makes it hard to follow-up and measure data in a standardized reliable way.

The platforms used by material managers also lack the support of providing several but yet very important pieces of information on what could help reducing air-shipments. Among these are e.g. the item dimensions that reveal the bulkiness of what otherwise might appear as light and air qualifying goods (e.g. air filters). The provided data also does not indicate any information on the actual gross weight, whereas some items might need extra packaging resulting into increasing bulkiness and/or weight (e.g. wind shields). The systems also lack vital information regarding hazardous goods in which cost of air-shipments increase radically. There are rare incidents where hazardous goods have been shipped together with other goods, resulting into a whole container being classified as hazardous goods.

8.2 Erratic ordering patterns

It came to our knowledge that unnecessary air freight in some cases was triggered in the endings of the year. Research shows that plausible scenario is that the dealers want to build up extra stock before the new pricelist (with higher prices) is released in connection to the New Year. Other reasons for dealers to order unexpected quantities in the end of the year are to reach up to sales goal or reaching a higher bonus level. Activities are measured over a year so December means the last chance for a dealer to fix the figures for the annual report and towards Volvo Parts. So these orders are not having any appointed customers, instead is it a misleading demand created of the contracts between the dealers and the business units. This would not be a problem if the dealers had been more foresighted and placed these orders in time to be delivered with sea transport. However, the dealers are taking actions late which combined with long lead-times for sea transports to non-European countries creates a time pressure. To over win the time pressure is often air freight the only possible solution to reach the dealer in time before the New Year.

The solution for this is to have processes that do not allow such actions. It cannot be supportable to use air freight for spare parts that not have a predetermined customer or if the item is critical. The underlying source is the mechanism that creates this type of behaviour. The mechanism is the contract between dealers and Parts that can include sales goal or bonus levels. The contracts can differ a lot in formation and content. No further investigation of the contracts is done here since it is out of the scope for this thesis. But the trigging mechanisms should be redesigned so such behaviour can be avoided. One simple solution is to have a deadline towards the dealers regarding last ordering date for deliveries before the next year. This should off course only embrace Stock orders (not VOR and day orders).

To see how common the problem is data from 2010 was collected (data from end of December 2011 was not finished), see chart 38. As seen in the chart the problem is not directly visible even if there is a peak in week 49. According to our opinion the problem is not having the proportions that a visible result in the chart was likely. But the charts are rough and can easily hide smaller problem, so it can not be seen as a proof that the problem do not exists. The potential is that some air freight can be avoided with a small effort, but since the problem is of such a rather small extent the topic is not further discussed in this report.

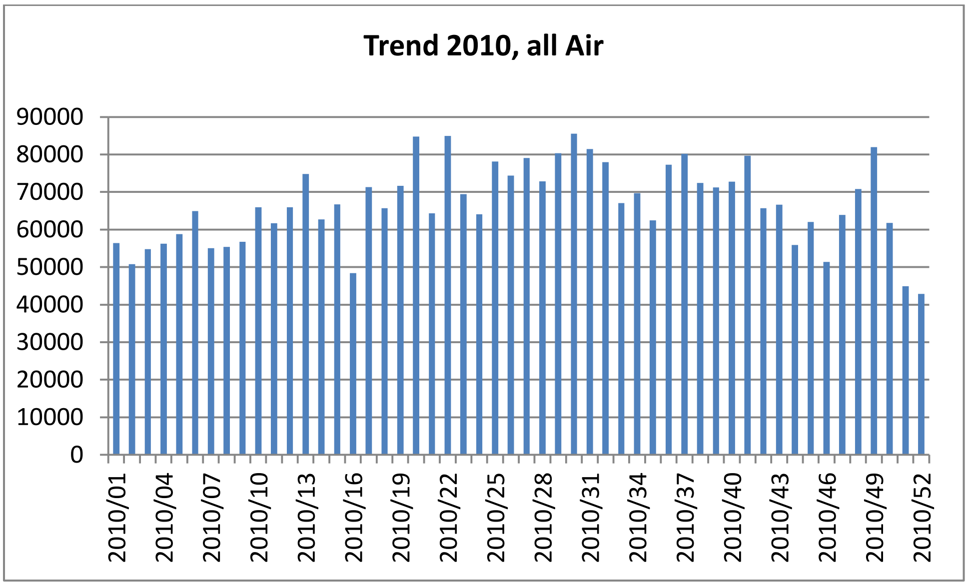


Chart 38 – Trend over 2010. From Ghent to Asia and International. Volvo Trucks, Buses and Penta.

9 Final recommendations and future research

As an outcome of the concluding discussion, and with the immense empirical findings as a base, we would like to state a few recommendations in order for Volvo Parts to mitigate unnecessary air freights while maintaining high service levels.

9.1 Suggested actions

- ***Establishment global and unified processes***

It is our belief that a Volvo Parts needs to establish global process and procedures in order to reach an effective supply chain where overall efficiency is gained. Such global will also highlight the risks, benefits and purposes of the practises that create a mutual understanding along the supply chain. Furthermore existence of unified procedures will allow for better flexibility to adjustments. As for the scope of our study, we strongly argue that all of the replenishment flows should be treated as unique processes.

- ***Unified systems support***

We believe that many of Volvo Parts complexities and limitations arise from fragmented and poor systems support. Being a large corporate company with many subunits requires unified systems in which business functions can fully operate and collaborate to create synergies that ultimately gain overall efficiency.

- ***Adjust parameters for material management***

The material management has a lot of different input-data. By adjusting some of them unnecessary air freight can be avoided. The findings in the study have been more at the level of being *potential risks* rather than severe problems. Examples on parameters are dealing with hazardous and voluminous goods or assure efficient consignment quantities.

- ***Use gross weight as in-data instead of net weight***

Present is net weight used for all calculations. Packaging corresponds to a non-negligible increase of the total weight (gross weight) with average 18%. Introducing the factor of 1,18 will not be correct in all situations, but it will be better than present situation. By using gross weight some items will change definition from air-item to sea-item. The air-share will therefore be reduced.

- ***Reduce lead-time and increase departure frequency for the sea alternative***

The lead-time for sea is today unnecessary long, especially the handling time in warehouses. Reducing the lead-time with 15 days to a total lead-time of 27 days would make the sea to a more viable solution. Doubling the departure frequency to two departures per week would create a smother flow and make it possible for the warehouses to cope with the higher tempo. The maximum lead-time would also be reduced. This solution will reduce the air-share and lowering the logistic cost. However it is plausible that the warehouses need support to fulfil the shorter handling times, the reduced logistic cost can be an asset for cover the new demand on the warehouses.

9.2 Future research

As time has been a limiting factor during this master thesis study has not been able to pursue in as many directions as we would have liked to. Moreover other interesting areas with potential possibilities of improvement have also been discovered along the empirical findings. Here we would like to highlight some of these as we recommend Volvo Parts for further studies within the subject. These are:

- ***Make larger statistical investigations in order to verify the connection between net and gross weight***

In order better estimate the surcharge from gross weight we would like to recommend Volvo Parts to conduct a larger statistical investigation, involving other destinations, in order verify the actual connection between gross and net weight.

- ***Investigate the possibilities of multimodal transports (e.g. rail)***

Investigating and encouraging alternative methods for freight forwarding may help Volvo Parts to acquire leading edge in future transportation solutions. Today Volvo Parts totally rely on solutions offered by external companies who function as intermediaries. Efforts in alternative methods may create long-term profitable as well as greener solutions.

- ***Investigate the usage of VOR and DAY orders***

Our study shows that DAY and VOR orders will be in majority in the future (figure 39). An interesting aspect would therefore be to conduct a study on the usage of these in order identify e.g. abuse. Perhaps the most interesting aspect is to study the consolidation possibilities from DAY orders that come with the associated minimum weight quantities.

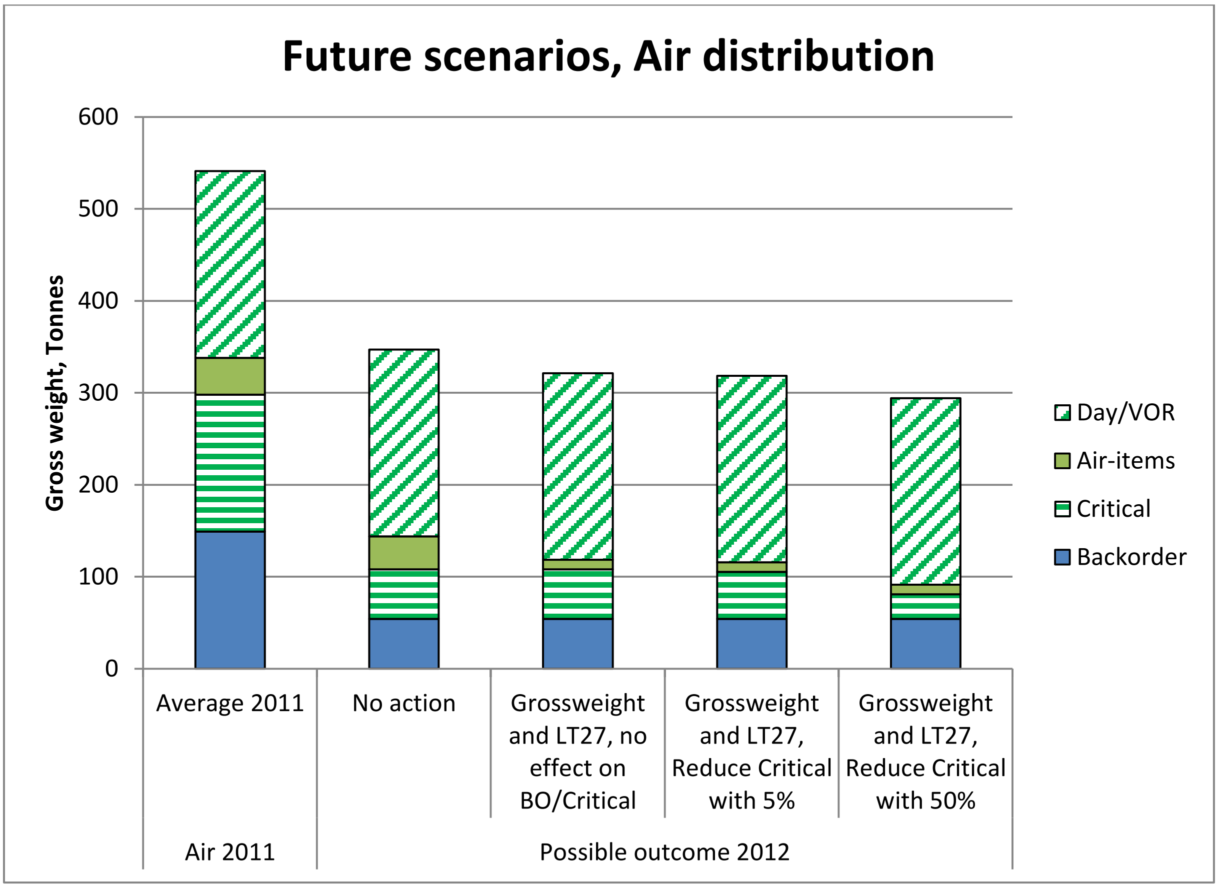


Chart 39 – Future development of air-share.

10 Bibliography

Agency, E. E., 2009. *Transport at a crossroads,* Copenhagen: EEA.

Baumann, H. & Tillmann, A.-M., 2004. *The hitchhiker's guide to LCA: an orientation in life cycle assessment methodology and application.* Lund: Studentlitteratur.

Campbell, J. D. & Reyes-Picknell, J. V., 2006. *Uptime- Startegies for Excellence in Maintenance Management.* 2nd ed. New York: Productivity Press.

Christopher, M. & Towill, D., 2001. An Intergrated Model for the Design of Agile Supply Chains. *International Journal of Physical Distribution and Logistics Management,* 31(4), pp. 235-246.

Cohen, M. A., Agrawal, N. & Agrawal, V., 2006. Winning in th Aftermarket. *Harvard Business Review,* Issue May, pp. 129-138.

CSCMP, 2011. *CSCMP Supply Chain Management Definitions.* [Online]
Available at: http://cscmp.org/aboutcscmp/definitions.asp
[Accessed 27 02 2012].

DB Schenker, 2011. *Press, nyheter.* [Online]
Available at:
http://www.schenker.se/servlet/se.ementor.econgero.servlet.presentation.Main?data.node.id=20614&data.language.id=1&data.document.id=22990
[Accessed 23 02 2012].

Eurostat, 2009. *Panorama of Transport, 1990-2006,* Luxembourg: European Union.

Fortuin, L. & Martin, H., 1999. Control of service parts. *International Journal of Operation & Production Management,* 19(9), pp. 950-971.

Gourdin, K. N., 2001. *Global Logistics Management: A competitive advantage for the new millinium.* s.l.:Blackwell Publisher Ltd.

Herbig, P. A. & Palumbo, F., 1993. Serving the Aftermarket in Japan and the United States. *Industrial Marketing Management,* Issue 22, pp. 339-346.

Huiskonen, J., 2001. Maintenance spare parts logistic: Special characteristics and strategic choces. *International Journal of Production Economics,* Issue 71, pp. 125-133.

Jonsson, P. & Mattsson, S.-A., 2005. *Logistik- Läran om effektiva matrialflöden.* Lund: Studentlitteratur.

Lee, H. L., Padmanabhan, V. & Whang, S., 1997. The Bullwhip Effect in Supply Chains. *Sloan Management Review,* 38(3), pp. 93-102.

Lumsden, K., 2006. *Logistikens grunder.* 2nd Edition ed. Lund: Studentlitteratur AB.

Phelan, A., Griffiths, J. & Fisher, S., 2000. Pushing worlwide aftermarket support of manufactured goods. *Managing Service Quality,* 10(3), pp. 170-177.

Reap, J., Roman, F., Duncan, S. & Bras, B., 2008. A survey of unresolved problem in life cycle assessment. *Int J Life Cycle Assess,* pp. 290-300.

Rogers, Z., Kelly, T. G. & Rogers, D. S., 2007. Alternative fuels are they achievable?. *International Journal of Logistic Research and Applications,* 10(3), pp. 269-282.

Skjött-Larsen, T., Schary, P. B., Mikkola, J. H. & Kotzab, H., 2007. *Managing the Global Supply Chain.* 3rd edition ed. Copenhagen: Copenhagen Business School Press.

Steen, B., 1999. *A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – Models and data of the default method,* Göteborg: CPM, Centre for Environmental Assessment of Products and Material Systems.

TFK, 1998. *Environmental Handbook for Transport Purchasing,* Stockholm.

Volvo AB, 2011. *Årsredovisning 2010,* Göteborg: Volvo AB.