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# Alternative solutions for terminal traffic

## A study of short distance transports in Schenker DB Logistics' Swedish network.

*Master of Science Thesis in Management of Logistics and Transportation, 2006*

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Göteborg, Sweden, 2006
Report No. E 2006:126

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**Masters Thesis:**

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**-**

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Date: 2006-12-06

# ABSTRACT

This research project presents an investigation of different alternatives for producing transportation services for terminal-to-terminal goods on relations shorter than 200 kilometres in Schenker DB Logistics' network in Sweden. To be successful in today's transport market, a company must be cost efficient, have high reliability and good customer service. The company can become more successful in the competitive freight transport market by searching for alternatives to decrease costs, increase flexibility, better utilise unused resources and find other alternatives to how transportation services can be produced.

The main purpose of this thesis is to investigate alternatives for producing the terminal to terminal transportation services. How can Schenker utilise unused resources to lower the costs and how will this affect the efficiency and flexibility in the system? Would usage of distribution trucks in terminal-to-terminal traffic be efficient?

The research methodology applied can be described as a combination of qualitative and quantitative methods. The research approach is inductive as inspiration of the presented alternatives originates from the conducted primary and secondary data collection through written materials and structured interviews with experts within the organisation.

The work has been divided in to two parts. First, a weight criteria method has been used to evaluate future transport alternatives. The second part investigates the usage of distribution trucks as an alternative to line haul trucks. The relations investigated are between Göteborg, Borås and Vänersborg.

The main conclusion from the results of the multi criteria analysis reveals that making more use of the distribution trucks for transporting terminal-to-terminal goods during night-time best fulfils the criteria set up in the used analysis model.

The results of the conducted study indicate that using distribution trucks in terminal-to-terminal traffic will cost the same as using line haul trucks, but the capacity is slightly lower. Distribution trucks can serve as an ad hoc solution when there is a capacity problem picking up all the part loads and the terminal goods for the haulier. A distribution truck can that day be used to transport the terminal-to-terminal goods and by doing so save capacity for the line haul truck, which can concentrate on the part loads.

Increased usage of swap bodies and city trailers would create more flexible vehicle combinations. Better flexibility can be used to increase the total efficiency in the transport network. Offering help with making better cargo units at the terminal for the truck driver will probably not result in decreased overall cost. Technical loading is mainly suited for a homogenous freight flow, which Schenker doesn't have. It would therefore not help Schenker to decrease costs associated with the loading and unloading process.



Keywords: *transportation services, resource utilisation, distribution truck, logistics service provider, consolidation.*

# ACKNOWLEDGEMENTS

This research project has continuously challenged the authors during the project process, and represents the closure of the Masters degree studies at Graduate Business School and at Chalmers University of Technology. We are glad for the opportunity to put theory into practise and apply our gained knowledge onto a research problem at Schenker DB Logistics.

We thank all the staff of Schenker DB Logistics Headquarter in Gothenburg that we been in contact with, especially Gunnar Ahldén, Stefan Andersson, our tutor Mats Rasmusson for his guidance, Thorleif Waldemarsson and Jesper Svensson for their thoughtful insights and for their comments. All have been patient with our endless questions and have given us valuable assistance throughout the project. Moreover, a thank you to all the patient people at the terminals.

To direct our gratitude towards our academic tutors, we would like to thank the personnel at the Division of Logistics and Transportation Management at Chalmers University of Technology. A special thank you to our tutor, associate professor Johan Woxenius for his professional guidance and assistance.

Last but not least, we would like to show our gratitude to Graduate Business School, Handelshögskolan for developing our skills throughout the Master's Programme. Special thanks to Arne Jensen, Rikard Engström and Rikard Bergquist.

Gothenburg, December 2006

PATRIK STERKY & MARCUS NORELL

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| **LTL** | Less Than Truckload, defined as goods less than 1000 kilograms |
| **Part load** | Defined as goods heavier than 1000 kilograms |
| **CSF** | Critical Success Factor |
| **SIKA** | Statens Institut för kommunikationsanalys |
| **Tonne kilometre** | (tkm) Measurement of transportation work. |
| **EOL terminal** | End Of Line terminal. |
| **BB terminal** | Break bulk terminal |
| **NAV** | (Nytt AVräkningssystem) New Revenue Division Model |
| **Corr** | Correlation |
| **SÅ Calc** | Sveriges Åkeriförbund Calculation, software for transport calculations |
| **SÅ Index** | Sveriges Åkeriförbund Index, monthly updates for cost allocations and factors regarding the haulier industry |

# 1 INTRODUCTION

*In the initial chapter the reader will obtain the necessary information for understanding the rest of the present research project. The chapter includes background information, purpose of the project, problem definition, scope of the thesis, limitations, and an overview of the structure.*

## *1.1 Background*

This research project presents an investigation of how transportation services are produced in Schenker DB Logistics' network. The focus is to look at the terminal goods in Schenker's Swedish network and identify alternative solutions to make the current structure more effective. The flow of goods in the chosen sample of the network is based on existing volumes and the same is valid for the costs involved producing these transportation services. Utilizing a plethora of opinions from experts within Schenker provides an assessment of different alternatives and how these fulfil criteria factors being settled during the empirical research process.

## *1.2 Purpose*

The main purpose of this thesis is to investigate alternatives for producing the terminal to terminal transportation services. How can Schenker utilise unused resources to lower the costs and how will this affect the efficiency and flexibility in the system? Would usage of distribution trucks in terminal-to-terminal traffic be efficient? What other unused resources can Schenker utilize in terms of increasing the efficiency or flexibility of the terminal goods services?

In addition to the above questions, an assessment of the haulier's situation at the terminal when performing unloading and loading activities is included in the study. The terminal processes are examined in terms of physical procedures as to reveal possibilities and restrictions in order to find alternative ways of handling the goods at the terminals. The authors have more specifically looked at the truck drivers situation at the terminal, from where the trucks leave the goods on "the square" until it is loaded on the vehicle and the unloading procedure taking place at the receiving terminal, out from the vehicle and off to "the square" again. The potential alternatives for making the hauliers more profitable and effective are based on the studies made of the employees, the company's processes and procedures as well as interpretation and analysis of numerical data collected from company statistics.

## *1.3 Problem Analysis*

The problems for Schenker are multi-faceted. Their contracted hauliers cannot produce enough profits on the shorter relations making it difficult to sign contracts for this type of transport assignments. The profit problem is an issue by itself. Schenker has through their rather unique business model a close relationship with their hauliers and is solicitous about their situation as well. If the haulier has a healthy economy, Schenker will naturally gain from this mutual cooperation. How the alternatives presented can assist Schenker and their hauliers in the production of terminal goods transport services is the main focus of this master thesis. Another factor contributing to the profit problem is the issue of taxed distance and real transported distance. It is more through for transport services over short distances than longer. The following figure 1 below can describe the situation:

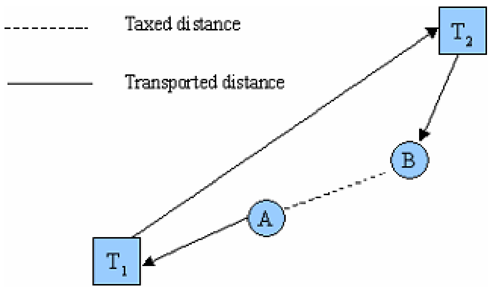



**Figure 1: Taxed versus transported distance.**

The distance that the price is calculated for is often shorter than the distance the shipment is travelling through the network. This means that the income is smaller and the cost of producing the service is not proportional to the income. To come back to the business model with the shared business risk between Schenker and their contracted hauliers it implies that the incomes should be distributed among the involved actors in the transport service production. In reality there can be up to five different actors that have to share the profit, one handling the pickup, the sending terminal ($T_1$), the line-haul contractor, the receiving terminal ($T_2$) and the haulier responsible for distribution. According to the business model, which is based on certain line rights, where hauliers have contract on certain relations the income is distributed according to a certain percentage among the actors. Figure 2 below explains the situation.

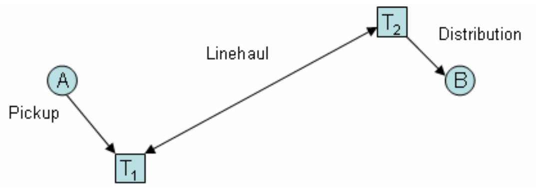



**Figure 2: Actors in the transport chain.**

## 1.4 Delimitations

The type of cargo forwarded in the Schenker's network is of four main types, part loads, terminal goods, bulk goods and parcels. In the current study, the focus is on the terminal goods and how this service is produced. Normally the truck driver is forwarding the part loads and cages with parcels in the truck and the terminal goods in the hanger, if using a truck and a hanger on the relation. This is a very common vehicle combination. Even if the focus is on terminal goods, the research cannot entirely disregard the other type of goods in certain situations as they are forwarded on the same vehicles. In addition to this, terminal goods are forwarded from terminal to terminal whilst the part loads can be picked up and distributed directly from origin to destination. Bulk goods are collected at other locations in the terminal area, as another example of different handling depending on the type of goods. There are situations where hauliers can make certain exceptions from the normality. Therefore some attention is needed regarding the data collected for the study as they have an impact on the solutions presented in the research project.

Moreover, the investigation of the terminal processes disregards the internal process but instead more specifically look at the driver's situation when loading and unloading the vehicle. Note that it does not involve the internal flow at the terminal between the "arriving" and the "departure" gates. Finally, fixed and variable costs concerning the vehicles are the type of costs used for the transport calculations, other costs, such as the external costs of transportation are disregarded.

## 1.5 Structure of Thesis

The first chapter describes the rationale and the platform needed to get an initial insight into the research problem of this study and an initial introduction to Schenker DB Logistics. The second chapter provides a broad theoretical background of road transportation, network configurations, cargo unification, terminals and basic transport economy. Chapter three covers the methodology applied to the study, including a description of the methods and strategies applied and used to fulfil the objectives of the study. In chapter four, the empirical findings regarding Schenker, their business model and their relations to the contracted hauliers, the network and the specific relations that are investigated are presented. Chapter five continues to present the analysis methods, underlying assumptions, calculations and an introduction and a description of the different handling alternatives. Chapter six covers the results and in chapter seven these results are discussed as well as the final conclusions are presented. The chapter also includes the recommendations and future research opportunities. Figure 3 can give a useful overview of the thesis:

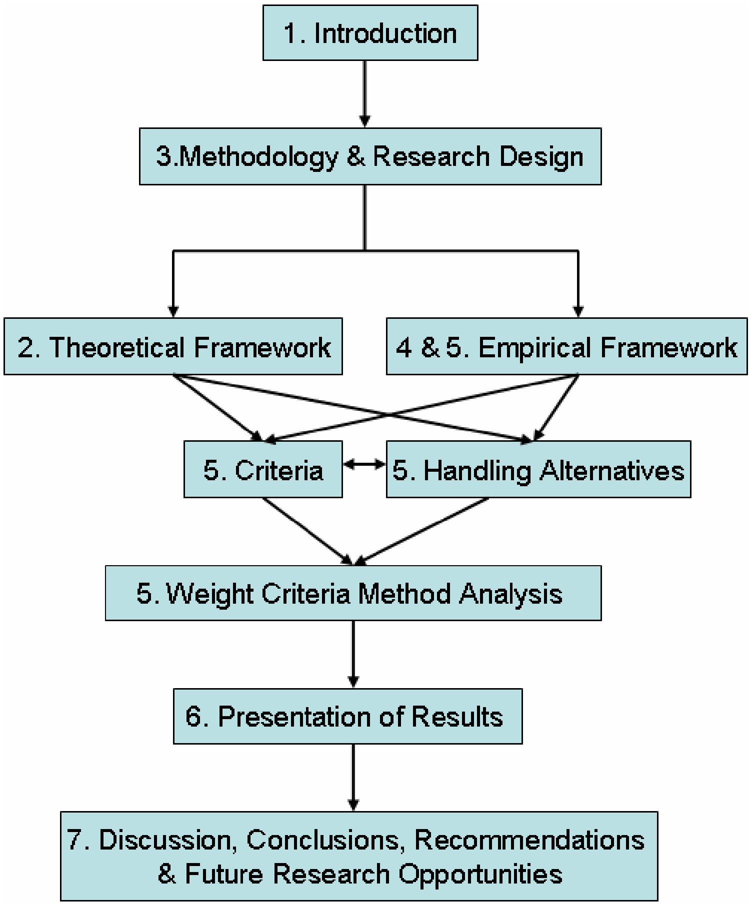



**Figure 3: Disposition of thesis.**

## 1.6 Reading Instructions

Instructions for reading the thesis can be useful depending on who the reader is and why she or he reads this thesis. The introduction guides the reader into the rationale why the research problems are looked upon and provides a platform for further go into the details of the study. Therefore all readers are recommended to read chapter one. Having an interest for the actual research problems and the solutions or handling alternatives presented may oversee methodology, the analysis and the methods. By instead reading the chapter containing results, discussion & conclusion will hopefully fulfil the needs of the readers with this perspective.

If you want to take an academic view reading the thesis, the methodology chapter and the analysis methods used is of special interest before reading the actual results of the study, so they can be evaluated and assessed from an academic point of view in terms of acceptability and feasibility. The theoretical framework provides the connection to earlier academic findings and the present study. Finally, reading the abstract will give you a general overview of the whole study and a quick hint of the most important findings presented in the research project.

# 2 THEORETICAL FRAMEWORK

*The chapter will present theory from relevant academic fields to build the basic platform that the study will be based upon. The six following subchapters cover the large areas, road transportation, transportation networks, terminals, unification, and transport economy.*

## 2.1 Introduction

The cost of producing the transportation services versus keeping a satisfactory level of service to customers is widely discussed in the literature. For example, Daughtery and Pittman (1995) argues that the road to success in business is the effective management of time (Staude, 1993). This is crucial to gain competitive advantage and only competing on manufacturing excellence is not enough. They continue to dissect time management into several factors, like fast cycle capability, total lead time, distribution lead time, and customer tolerance levels.

The solution to meet these challenges is to increase the corporative responsiveness and flexibility in the transportation/distribution operations. By doing so, substantial cost savings can be realized. However, these constraints put a lot of pressure on the operations, such as; more demand on the transport carrier which has resulted in longer contracts with the carriers to ensure the level of customer service (Juga, 1993; Bookbinder & Lynch, 1997), the fast market changes demanding faster information flow to allow firms to be more responsive to customer needs.

In addition to the time factor, Eilon (1995) states two reasons for the manager to show interest in transportation issues (or in his case distribution). –"First, the problem of rapidly increasing transportation costs and the natural interest of management to hedge these increased costs. Second, and this is derived from the first reason, the scope to employing modern management techniques to examine problems in the transportation area" (Eilion, 1995, p.5).

Eilon (1995) continues to list a number of problem areas and some of them are important to mention for the empirical study conducted in the current research project. Especially vehicle scheduling, information retrieval and fleet management are areas relevant.

In vehicle scheduling, a number of constraints can be associated with the transport operations. Four types of restrictions are mentioned:

- Restrictions associated with vehicles – capacity in weight or volume.

- Restrictions associated with personnel – number of operations per vehicle, time and mileage allowed for driving, overnight stays (subsistence allowance), specified terminal destination of operators.

- Restrictions associated with consignments – weight, size (odd measures) or when two consignments are not allowed on the same vehicle.

- Restrictions associated with customers – priority of service, prescribed times for delivery, limitations on the type of vehicle that can access the customer's facilities.

Eilon (1995) continues with stating that effective information retrieval must have certain attributes, such as: relevance (the information needs to be constantly updated), accuracy (level of accuracy must be compatible with the type of action), format (must be communicated in a convenient format for management), and speed (is vital to retrieve information rapidly).

Lumsden *et al.* (1997) agrees with Eilon, but goes further in explaining the attributes of valuable information. They start with distinguish data, information and knowledge from each other using the model in figure 2.

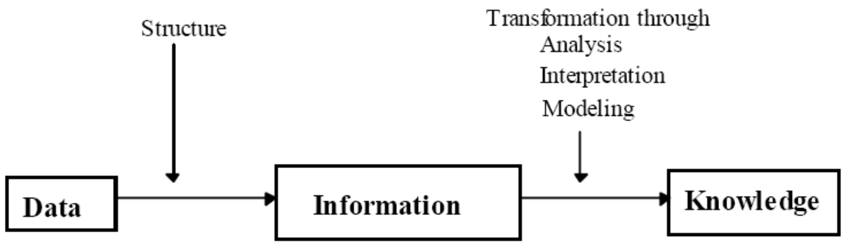



**Figure 4: The information value chain. Source: Lumsden *et al*. 1997, p.3.**

Lumsden *et al.* (1997) list a number of attributes, similar to Eilon's shortlist; accuracy (whether the information portraits the situation as it is or not), form (difference between qualitative and quantitative, numerical or graphic etc.), frequency (how often is the information needed?), breadth (narrow or large scope of the information), origin (where does it originates from?) and finally time horizon (is the information directed toward the future, presence or the past).

Eilon found one area particularly relevant and that is the management of the vehicle fleet. There are a number of questions concerning this concept; should the transportation function have its own fleet or employ road hauliers? If the answer to this question is a mixture, what is the optimum mix? What is the optimum composition of the company's own fleet in terms of vehicle capacity, design and age distribution? What is the best replacement policy? What maintenance procedures should be used? (Eilon, 1995).

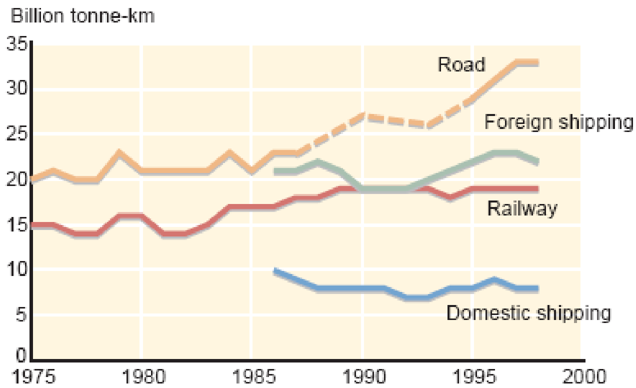
Waller (1995) is describing the nature of strategic distribution planning and he claims that this is often mistaken as the same as the depot (terminal) location problems. He describes this as problems associated with deciding how many depots are needed? How big should they be? Where should they be located? However, Waller claims that these questions are only a fraction of all the decision elements that interact to a greater or lesser extent with the terminal location problem. These elements are; inventory strategy, choice of transport mode, fleet size and mix, unitisation methods, level of warehousing technology, split between own and third party distribution, guidelines for direct delivery and delivery frequency implications.

Waller (1995) continues by claiming that – "There are many situations where broader logistics planning decisions need to be addressed in the context of the impact of the total distribution system". He suggests that one should include issues/questions like choice of supplier/raw material source, the location of production facilities, direct deliveries for bought out items and production sourcing.

## 2.2 Road Transportation

Transportation is in general said to be the physical movement of goods (and people) from one place to another. Transport is one of the major activities in logistics, where a creation of time and place utility is created (Coyle *et al*. 2006).

Lumsden (1998) describes truck transportation as a mean of transportation that has been growing steadily from year to year. Bigger cargo units and vehicle combinations has been used and an increase in efficiency have been realized. Recent statistics shows that there are 53.000 registered trucks (heavier than 3.5 tonnes) in Sweden and they transported totally 355 million tonnes during 2005 (SIKA, 2006). A further development of truck transportation is likely to have negative effects on the infrastructure and the external effects of road wear and traffic congestions become too severe for the society. To hedge this, authorities have implied means of controlling the amount of heavy vehicles on the roads with road tolls, and rules of maximum weight, measures, and speed to restrict the capacity of the vehicles. Truck transportation is growing and the explanation is the flexible nature of the truck and the different combinations of wagons and trailers. Consumers ever increasingly demand of fast and effective transports are favouring the use of trucks instead of other modes of transport. Statistics Sweden (2001) indicates that road transport is increasing and as much as 80% of all the goods transportation (in tonnes) is accounted for. Trucks perform nearly all goods transport shorter than 300 km, but on longer distances rail transportation is dominating (Statistics Sweden - SCB, 2001). Graph 3 compare the different modes of transport.




**Graph 1: Comparison between different modes of transport in Sweden, 2001. Source: SCB, p.24.**

Larger consignments in less than truckload segment and over (above 1000 kilos) can easily be forwarded door-to-door with trucks. The number of transhipments is minimized as well as cost reductions and the risk of transport damages. There are a number of conditions and attributes of the truck that explains its popularity. First, the vehicle *capacity* is rather small in comparison with the other means of transport, which means it is easy to adapt to the individual customer. At the same time this is a condition that is needed to create the effective and attractive direct relations when producing the transport service. Second, the *flexibility* of the truck vehicles makes it easy to redirect during ongoing mission. The different combinations of the vehicles make it possible to change the capacity with short notice. It is also fairly easy to redirect vehicles and in this way change the capacity of a road based network, on certain relations temporarily. Third, *security* is higher because smaller amount of goods is transported on each vehicle and there is always a driver present, or near the goods.

As a result of this, damages and thefts are avoided. Fourth, the *reliability* of the transport mode is seen as good, because the driver is always near the loaded goods. A stop in the transportation of the goods is also a stop for the driver. Fifth, the *service level* is considered to be good, because the experience of the driver and the direct contact between the transport buyer and the transport company. Finally, the *adaptability* is great as the vehicle is most often an individual economical unit and the driver is trying to solve the economical problems on a local level, for example, by searching for other cargo to load if the vehicle utilisation is low (Lumsden, 1998).

### 2.2.1 Vehicle Combinations

There are a number of different vehicle types available. In this chapter the focus lies on the three main types of vehicles. These truck combinations are distribution, semi-trailer, and long distance vehicles. Distribution is taking place near and around the different terminals in the network. This smaller type of vehicle has a rather low driving time utilisation since it is standing still instead of driving for long periods of time. This is because of the many stops and deliveries they have to make every day. Loading and unloading time exceeds driving time. In the table below you can find information regarding the general information about distribution vehicles. The vehicles often have 2 axles, but in the form of district distribution the vehicles can be slightly bigger and equipped with 3 axles. These vehicles operate in the outskirts of the terminal’s receiving area. See figure 4 and table 5 below.

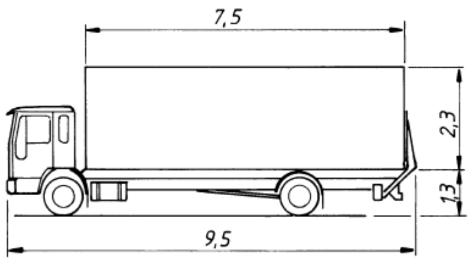



**Figure 5: Distribution vehicle. Source: Lumsden, 2006.**

**Table 1: Measures and weight for a distribution vehicle. Source: Lumsden, 2006.**

| | |
|---|---|
| Total weight [tonnes] | 14.0 |
| Weight in working order [tonnes] | 7.6 |
| Loading capacity [tonnes] | 6.4 |
| Internal width [m] | 2.5 |
| Volume [$m^3$] | 40.5 |

Another very common vehicle type is the tractor and the semi-trailer. The trailer has been increasingly popular because the tractor can be separated from the cargo carrier, whereby one avoids to have the expensive, more technical part of the equipage non-productive, for example during loading and unloading at a terminal. The semi trailer equipage is common in international short sea shipping and in ferry traffic. See more information about the semi-trailer combination in the figure 6 and table 7 below.

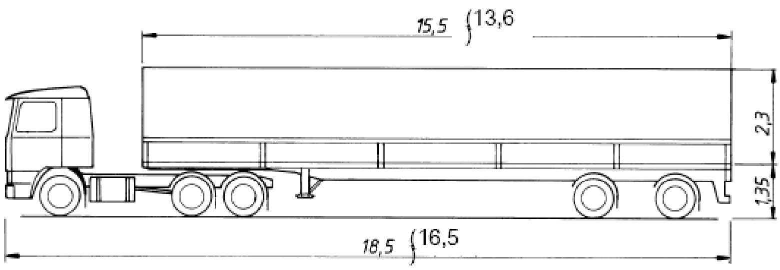



**Figure 6: Swedish / European semi-trailer combination. Source: Lumsden, 2006.**

**Table 2 Measures and weight for a Swedish/European semi-trailer combination. Source: Lumsden, 2006.**

| | Tractor | Semi-trailer | Combination |
|---|---|---|---|
| Total weight [tonnes] | 6.0-8.0 | 36.0 | 42.0-44.0 |
| Weight in working order [tonnes] | 8.5 | 8.5 | 17 |
| Loading capacity [tonnes] | | 25.0-27.0 | 25.0-27.0 |
| Pallet capacity [EUR-pallets] | | 36.0 | 36.0 |
| Volume [$m^3$] | | 84 | 84 |

In domestic long haul traffic another combination is common. The three-axle truck with a three- axle trailer has a total length of 24 metres. This combination cannot be used in an international context as it exceeds the longest length that is valid in most European countries, which is 18.75 metres. However, at the border it is possible to change the trailer to a shorter version, so the combination becomes legal. The trailer can be replaced by a semi-trailer with a dolly making the equipage 25,25 metres long. The dolly is attached below the front part of the semi-trailer giving it another pair of wheels and the drawbar needed for attaching it to the truck. See measures and weight information in figure 8 below.

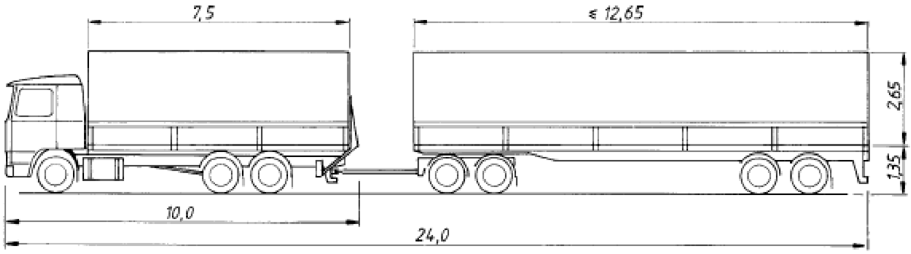



**Figure 7: Swedish long distance vehicle combination. Source: Lumsden, 2006.**

**Table 3: Measures and weight for a Swedish long distance vehicle combination. Source: Lumsden, 2006.**

| | Truck | Trailer | Combination |
|---|---|---|---|
| Total weight [tonnes] | 24.0 | 36.0 | 51.4-56.0-60.0 |
| Weight in working order [tonnes] | 10.5 | 9.2 | 19.7 |
| Loading capacity [tonnes] | 13.5 | 26.8 | 31.7-36.3-40.3 |
| Pallet capacity [EUR-pallets] | 18 | 30 | 48 |
| Volume [$m^3$] | 47 | 79 | 126 |

A tractor with one or two city trailers is not very common today. The city trailer is smaller than the semi-trailer making it possible to use it for distribution in cities. It is possible to attach another city trailer to the equipage using equipment similar to the dolly, but with a kingpin. This equipment is more technically advanced compared to the regular truck with trailer. One use of city trailers would be to use it for distribution is areas and towns located far from the terminal. At arrival the driver leaves one of the trailers in the outskirts while the other one is distributed. The driver then goes back and switch trailer and distributes the other one (Ehrling, 2006). This setup is in use by Coop Sweden which makes it possible for them to distribute their products directly to Stockholm from their warehouse in Västerås without the need or reloading in Stockholm (Sveriges Åkeriföretag ABC Åkarna, 2005).

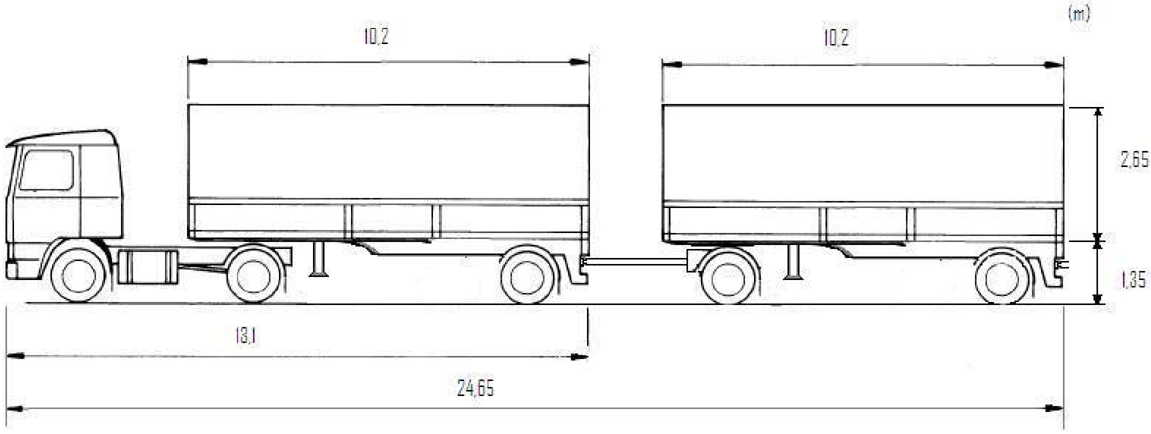



**Figure 8: City trailer combination.**

**Table 4: Measures and weight for a city trailer combination. Source: Krone, 2006.**

| | Tractor | City-trailer | Combination |
|---|---|---|---|
| Total weight [tonnes] | 6.0-8.0 | 22.0 | 50.0-52.0 |
| Weight in working order [tonnes] | 8.5 | 6.5 | 21,5 |
| Loading capacity [tonnes] | | 25.0-27.0 | 25.0-27.0 |
| Pallet capacity [EUR-pallets] | | 25.0 | 50.0 |
| Volume [$m^3$] | | 54 | 106 |

*Distribution truck*:

The distribution truck has a length of 7.5 floor meter and a volume of 40.5 $m^3$ (Lumsden, 2006). The distribution truck is lower in height compared to the regular trucks and trailers. The comparative floor area is therefore decreased by 14% ($40.5m^3/47m^3$), which results in a loading area of 6,46 floor meters for distribution trucks.

*Distribution truck with trailer*:

A trailer has a loading area of 12.65 floor meters (Lumsden, 2006). Distribution truck with trailer has 19.11 floor meters of loading area.

There may be troubles pulling a full size trailer with a distribution truck. The distribution truck needs to have an engine strong enough to handle the additional weight of the trailer.

*Line haul truck with trailer*:

The line haul truck with trailer is the norm to use in Sweden. The loading capacity of the truck with trailer is 20.15 floor meters.

*Tractor with semi-trailer*:

Tractor with semi-trailer is a quite common in Sweden and very common in other European countries. The loading capacity of a semi-trailer is 13.4 floor meters (Lumsden, 2006).

*Trailer, with a line haul truck driving part loads:*

The trailer is used for the terminal-to-terminal goods while the truck is used for line haul goods. This is a common setup for the Schenker hauliers.

## 2.3 Transportation Networks

In general there are many kinds of networks, for example; power supply systems, telecommunications networks and road systems. According to Bobzin (2006) the common denominator of a network discussed from this perspective is that some kind of transport process takes place within it. The focus of this research project is naturally pointed towards transportation networks. Networks can be described as –"the veins between all communicating activities scattered through space and time". The description is based on graph theory where the elementary features of a transport network are included. Fundamental ingredients of a network are nodes (*v*) and they are connected with branches (*e*). The first node is assumed to reflect the origin of the link at hand and the second node determines the destination. To describe the movements in the network introduction of $\varphi_e$ is representing the flow on link *e*, it describes the number of units going from origin α (e) to destination ω (e) with respect to a given period of time (Bobzin, 2006).

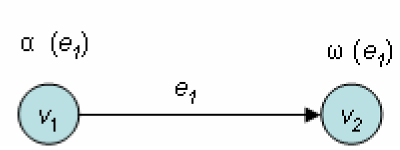



**Figure 9: Basic elements in a network. Source: Bobzin, 2006.**

In general each link (*e*) is able to manage a maximum flow that is assumed to be fixed, determined at a certain level of service delivered by the network. The corresponding vector of link capacities then restricts the link flow in such a capacitated network. Aside from the capacity constraints one of the most important flow restrictions in a network refer to the node flows instead of the link flows. Every flow starts at one vertex and runs through various nodes in the network and finishes its route at a node. As a result, each node is characterized by an inflow and an outflow, where the inflow is the sum of all link flows. Figure 11 illustrates the properties of the nodes:

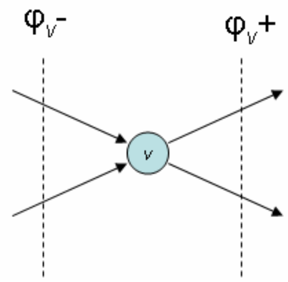



**Figure 10: Representation of inflows and outflows. Source: Bobzin, 2006.**

With help of the above figure one can distinguish between three types of nodes:

- Supply nodes, where $\varphi_v^- < \varphi_v^+$
- Demand nodes, where $\varphi_v^- > \varphi_v^+$
- Transit nodes, where $\varphi_v^- = \varphi_v^+$

Similarly, Lumsden (1998) is describing transports as something that can be ranged in a net structure with nodes and links. This structure represents the physical flow of resources and goods. A node is a place where the flow itself is stopped or can be stopped. For example, a node can represent a terminal or a warehouse. All transportation of goods is represented by the links. Figure 12 below represents a transportation network:

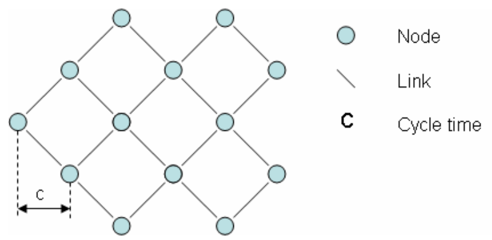



**Figure 11: A transport network. Source: Lumsden, 1998, p.28.**

To travel from one node to another can take a different amount of time. A general rule for a functioning transport network is that the links need to converge in some special node at a certain time or in a predetermined time interval or time window. Every link is then assigned a general amount of time representing the longest operational time in the network. The cycle time (c) can be split in two components, link time and node time.

Link time ($c_l$) is the actual time for performing the transport. It depends on a number of factors, such as, mode of transport and how it is performed and the character of the goods that is transported.

Node time ($c_n$) can be split into an active and a passive part. The active node time ($C_{na}$) is the time for internal handling the goods in the node. Passive node time ($c_{np}$) is when the goods are not on the move, i.e. is stored without any handling is being performed. To optimize a transportation network, the passive node time should be kept to a minimum and the link time should be as constant as possible to achieve high resource utilization (Lumsden, 1998). See figure 13 below:

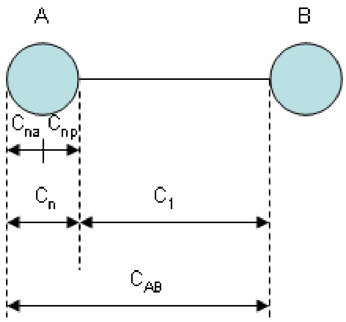



**Figure 12: The components of cycle time. Source: Lumsden, 1998.**

### 2.3.1 Different Types of Network Configurations

Woxenius (1998) suggests a framework of six different routing principles in a transport network: direct link, corridor, hub & spoke, connected hubs, static routes and dynamic routes. Each configuration has different qualities and therefore fulfils the prerequisites in different ways. See figure 14 below for possible configurations:

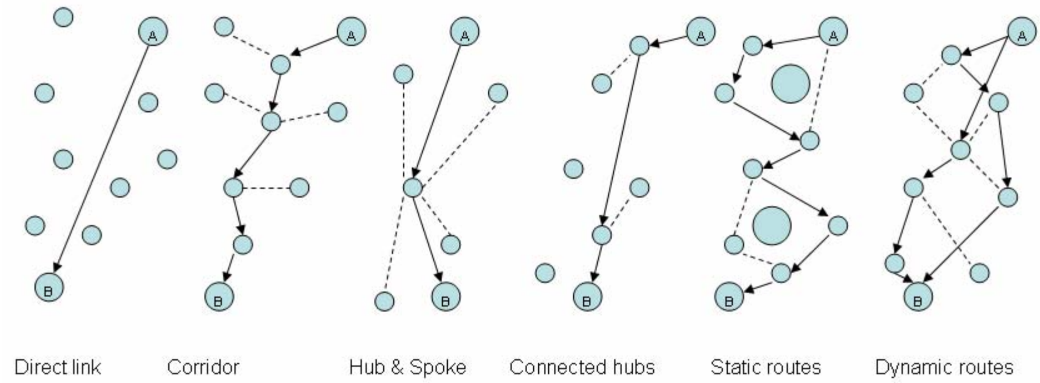



**Figure 13: Transport network configurations. Source: Woxenius, 1998.**

The *direct link* is only involving nodes from A to B. There is no coordination transport wise between the other nodes. A *corridor* design means you use a highly dense flow with short relations to nodes beside the main artery.

Regarding *hub and spoke* configuration there are goods arriving from the different distribution points to the central terminal. It can basically arrive any given time, but goods cannot leave the terminal before all the inbound goods have arrived. All inbound material is steered towards the same timeslot and the sorting process can then be initiated. As a result the outgoing process for all relations will start at the same time. In turn, this will increase and concentrate the demand for vehicles. In its nature, the usage of a hub and spoke network will be very resource intensive.

All goods must not wait until all relations are delivered into the central hub, from both producers and customer's point of view. By doing this lead time can be cut and frequency can be increased. Hub and spoke systems cannot be applied in all cases, as it requires an adaptation between producers and the customers. For example, imagine a traditional manufacturer that serves a few customers with a fairly small flow of goods, an application of a hub and spoke system, in this case, is generally impossible. The concept of reverse logistics (Wu & Dunn, 1995, p.34-5; Tibben-Lembke, 2002, p.223) can help increase the condition for using the system. The reverse flow helps to even out the imbalances in the system (Lumsden, 1998).

Lumsden *et al.* (1999) have listed and number of benefits and drawbacks with the hub and spoke solution. The benefits are:

- Fewer links to connect the same number of points
- Higher carrier filling rates (transportation flow is concentrated in fewer links)
- Possibility of higher frequencies between nodes

But, the system is also carrying some drawbacks compared to the direct system. These are:

- Increased average lead times
- Increased mean distances between each pair of nodes
- Increased operational costs due to handling activities and goods flow management
- Increased higher risk of damaging and loosing goods.

Lumsden *et al.* (1999) continues to suggest a number of improvements to the hub and spoke system. The first improvement includes direct deliveries through a direct shortcut. It means connecting two nodes in the system directly by not passing the way through the hub. The configuration can represent a combination of point-to-point and the hub and spoke system. The second improvement measure suggests allocating trucks on different routes. In a normal hub and spoke system each truck is travelling in its own route according to the delivery frequency back and forth between the node and the hub. The proposed approach means to use the trucks going directly between the nodes and then back to the hub in different designs.

*Connected hubs* are another configuration with hierarchical design where flows are gathered at hubs which are in turn connected to other hubs in a different region. Woxenius (1998) describes them as a direct link with regional consolidation. In turn, *static* links designates several links to be operated regularly. Many nodes are used as transfer points along the route. *Dynamic routes* maximise flexibility in a network configuration and demand is determining the links. The operator can choose between multiple links between A and B.

### Less-Than-Truckload Networks

Sommar (2006) describes Less-Than-Truckload networks as a segment of forwarders that consolidate transport consignments from many shippers in order to make efficient use of the vehicle's loading capacity. There are many customers involved in such a network that can be labelled as many to many network. The network consists of pick up and distribution, terminal activities and line haul between the actual terminals. Cost reduction is achieved by using terminals in many to many networks. Two functions distinct the kind of terminals in such a network; end-of line terminals and break-bulk terminals An E-O-L terminal is where unloading picked up consignments from consignors and load consignments that should be delivered to consignees. Normally the area served by one terminal (the catchment area) is called the terminal's region. The B-B terminal is typically used for consolidation traffic from several E-O-L terminals. They can be said serving as hubs in an L-T-L network. See figure 15 below describing the flows and relations between the two kinds of terminals.

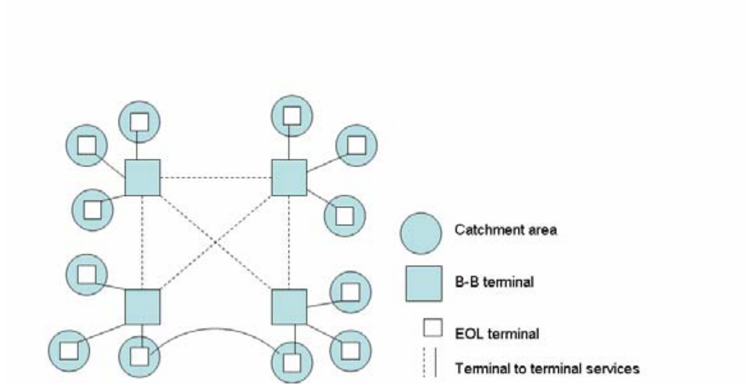



**Figure 14: LTL network using terminals as hubs. Source: Sommar, 2006.**

The LTL network is using the same principle as hub and spoke configuration above regarding earliest and latest departure time. Consignments in this type of network do not necessarily have to be transported between the terminals. The pick up and distribution can be done in so called milk rounds containing several stops which are connected by a long distance line-haul which governs for high utilisation of the main part of the distance whilst avoiding the terminals. This is appropriate when consignments are large (part loads) and lead time is an important factor (Sommar, 2006). This network configuration allows for handling the larger part loads in the direct link type of configuration while using terminals as hubs for the smaller terminal goods consignments under 1000 kilograms. The result is high resource utilisation with short lead time. Figure 16 below illustrates a network without terminals:

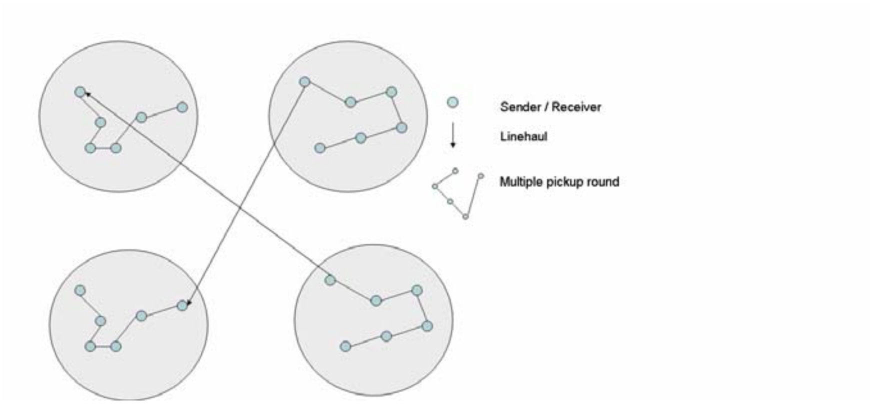



**Figure 15: LTL network without terminals. Source: Sommar, 2006.**

### 2.3.2 Transportation Network Problems

Bobzin (2006) describes the basic problems for transportation networks. He distinguishes between path related problems and flow related problems. The different problems are routing problems, flow problems, location problems, and cost of network related decisions.

The *routing problem* is basically to find the optimal routes between two geographically different points. The easiest problem can be described as the *shortest path problem*, which includes determining the path with minimum length, minimum travel time, minimum travel cost, or maximum reliability.

Flow problems have two aspects, the quantities of flows and their transport costs. *Maximum flow problem* deals with how much can be transported from one origin to a destination in the network. The *transportation problem* concerns the search for a cost minimal flow between origin and destination. In the *multi commodity flow problem* all nodes can be origins and destinations of different commodity flows at the same time. The task is to find a demand and supply feasible flow that ships from origin to destination at minimum transportation costs.

The *location problem* considers the many actors or network participant's need to concentrate their activities around certain areas. *The facility location* problem is to specify the location and sizing of facilities at some nodes in the network. The objective should be to minimize the sum of fixed charges and the transportation costs. Here, the decisions need to be taken with respect of the competitor's location pattern.

The costs of network related decisions constitute of several costs, namely; Variable costs directly related to the trip, such as, time needs and fuel consumption. Fixed travel costs, such as, vehicle ownership. Fixed costs related to the construction and maintenance of the infrastructure used in a transportation network, and finally the external costs which are related of the use of the infrastructure. External costs can be traffic noise, emissions and other types of pollution. These effects are discussed in more detail later in the report.

### 2.3.3 Network Imbalances

Network imbalance is referred to as imbalances in the material or goods and the resource flow. As previous described a network is a system of nodes connected together and connects the flow. In every node and link losses can be calculated as imbalances and distortion. The imbalance identifies the difference in the flow in different directions in a transport relation or link between the in and out flow of that particular geographical node (Lumsden, 1998). See also Bobzin (2006) referring to different types of nodes.

There are a number of factors that will lead to imbalances in the goods and resource flows. These are divided into five categories depending on the underlying reasons (Lumsden, 1995). To begin with, *structural imbalances* are referred to as imbalances created by different levels of demands for transportation at origin and destination. Second, *operational imbalances* are imbalances caused by the goods and resource flow from the hauler or any other actor is not adjusted to each other. The goods flow can be equal to and from a node in the network, but time restrictions (operational) might decrease the resource utilization. Third, *technical* *imbalances* means that the carrier units are not adapted to each other and to the different variants of goods that are transported in the network. Another type of imbalances is *chain imbalances.* They are caused from the network itself; one vehicle is delivering goods to a number of consignees during the distribution round. This means the resource utilization is strongly affected negatively during this round. The imbalance affects first of all the time for the transportation assignment. Finally, *security imbalances* are caused by big variances in the resource demand. Overcapacity in the transportation systems is fairly common because companies are not willing to reject any customers. This over capacity leads to low resource utilisation. The level in the security stock is also affecting the company's delivery security. Higher inventory levels in the security stock ensures higher customer service levels. The idea is to handle the insecurity and the demand variation so service levels are achieved and security stock and available resources is lowered (Lumsden, 1995).

All types of imbalances create, more or less, less utilisation of the resources. The empty running of trucks is an evidence for this according to Alan McKinnon (1996). Empty running trucks depend on five factors. These are: the lengthening of truck journeys, increasing drops per trip, expansion of load matching services, growth in the reverse flow of packaging material, and greater effort by shippers to obtain return loads. McKinnon's focus is on the UK market, but these factors can be generalised to be valid in all markets.

Big cities or areas where the consumption is greater than the production level can be a reason for structural imbalances and will generate greater resources arriving to the area and fewer resources which departure from it. This will generate empty running vehicles on the return trip. A factor affecting the return flow is the possibility for the companies to find the correct amount of goods and also the nature of the goods will have an impact of the utilization levels on the return trip. The back-loads can also be generated internally by the transportation company, or generated by taking external contacts with other businesses. McKinnon continues to mention the factors that are inhibiting return loading and these constraints are requirements for the outbound delivery service, internal management structure, incompatibility of the vehicles and products (referred to above as technical imbalances by Lumsden, 1995), need to recover handling equipment and packaging, unreliability of back loading operation, inadequate transport capacity, poor matching of locations and scheduling, and limitations in the route scheduling system (McKinnon, 1996).

Some of these factors are naturally a more restriction for the return loading than others, and some of them can be referred to as specific for the UK market. However it is useful to get an insight into the factors that are restrictive for return loading, and also in generating imbalances in the network transportation system as a whole. In McKinnon and Ge (2006) the results show that empty running trucks have declined but suitable return loads were only found in 2% of the total empty journey legs. This can serve as evidence that return loads in general is not very common in reality. However the potential to find return loads should increase with the development of reverse logistics and adoption of new management techniques.

### 2.3.4 Transportation Network Efficiency

According to Samuelsson & Tilanus (1997) the efficiencies can be assessed in various dimensions and by doing so, one can improve the understanding of the transportation process more deeply. If understanding the relationships between efficiency and the explanatory factors, the potential for improvement can be assessed. In their model they state that transportation efficiency is only a subset of supply chain efficiencies. This is of importance when looking at how transportation services are produced and assessing the potential to reducing the costs involved.

The overall efficiency in goods transportation can be expressed by the following formula:

$$E = T \; x \; D \; x \; S \; x \; C$$

**Overall efficiency (E)** is a product of the four-dimensional efficiencies *time, distance, speed and capacity*. These dimensional efficiencies are in turn a product of many different factors that will have to be addressed individually.

**Time efficiency (T)** is the percentage of the available time that the vehicle is used for transportation work. The theoretical maximum is 24 hours a day. It is broken down in four different factors; *business time efficiency*, which is the number of hours that a business operates per annum. *Availability*, which means the percentage of business time that vehicle is available for use. In this context, *utilization* means the percentage of time available that the vehicle is actually used. And finally, the *driving factor* is the percentage of driving time spent on the road actually performing a transportation work. Losses of driving time can depend on resting time restricted by law, unnecessary stops by the driver, loading/unloading time at the terminal etc.

**Distance efficiency (D)** is the percentage by which the maximum transportation output is reduced by not using the shortest route between point A and point B. This efficiency is broken down into five partial factors, namely; the infrastructure factor, backhaul factor, routing factor, detour factor and actual trip execution efficiency.

The *infrastructure factor* is the radial distance between origin and destination divided by the shortest route from origin and destination using the road network. The *backhaul factor* shows the loss of efficiency because of the lack of a return load. According to Samuelsson & Tilanus this factor has a substantial potential for improvement. Backhaul or return loads has a significant impact on the L-T-L (less than truckload) operations.

The *routing factor* is described as the inefficiency caused by not going to the customers in the optimal order on the route. It is the optimal length of the route (via all delivery points) divided through the actual route length. For optimising this factor routing or vehicle scheduling software can be used to help transport companies to make more efficient use of their vehicles. In recent years, some more serious restrictions regarding access to urban areas for certain types of vehicles i.e. Euro classification zones for minimizing the environmental impact and also equally important, restriction in time for distribution in city centres. Time windows restrictions are doubling the cost for distribution operations.

The *detour factor* is the result of the fact that goods are grouped and delivered in round trips rather than in F-T-L (Full-truck-loads) transported directly from terminal to the first delivery address, between the terminal and the second address and so on. It is defined as the single distance between the terminal and destination multiplied by the size of the shipment, summed over all shipments, divided by half of the total length of the roundtrip multiplied by the capacity of the vehicle. This factor is seriously reducing the efficiency. Due to the trend of smaller shipment sizes, the detour factor will have more impact on the total efficiency.

The *actual trip execution factor* is the ratio between planned trip length and actual trip length. This factor is most of the time below 1 because of detours, wrong directions taken and wrong addresses visited.

**Speed efficiency (S**) is the percentage by the maximum transportation output is reduced by not travelling by maximum speed. The optimum speed in practical circumstances is the maximum allowed speed restricted by law or technological aspects. Speed efficiency is a product of *speed limit factor* and the *congestion factor*. Speed limit factor is the actual average speed limit over the roundtrip route divided by the maximum speed allowed in the country. Congestion factor is the actual average speed driven on the roundtrip route divided by the average speed limit over the roundtrip route. The factor is fast declining when the road system approaches full utilization. It can also be mentioned that the factor is highly unstable and can vary a lot due to the traffic circumstances at different points in time and place.

**Capacity efficiency (C)** refers to the capacity of the vehicle and is measured in terms of weight or volume. It is broken down into as many as seven different partial capacity efficiencies. These are; *capacity factor, floor occupancy, height utilization, pallet load factor, box load factor, net product factor and actual loading execution efficiency*. No further thorough explanation will be presented about the partial capacity efficiencies.

To summarize the efficiency parameters, we can according to what Samuelsson and Tilanus previous mentioned, see the connection between the theoretical efficiency and the actual restricting parameters/factors find many areas to look into when the goal is to optimise the transportation network, reduce transportation lead time and transportation costs. In their work they also assessed the different efficiencies in an empirical study to decide the overall efficiency factor for regional L-T-L distribution to $E = 0{,}16 \times 0{,}24 \times 0{,}53 \times 0{,}021 = 0{,}00043$. This factor seems at first glance to be very small, but the theoretical position of the overall efficiency is considered to be extreme (Samuelsson & Tilanus, 1997).

## *2.4 Terminals*

A terminal is a node in a transport network between, for example, a producer or supplier and a customer. It binds together several means of transport with different characteristics to satisfy the demands from the actors in terms of frequency and capacity in the flow. The varied structure between suppliers and customers and the variances in means of transport is contributing to the question at issue in terminal operations (Hulten & Lumsden, 1995).

The queue problem at the terminals occurs when vehicles have to wait for loading or unloading their cargo. There is a direct connection between the queue problem and the arrival and departure allocation or dispersion over twenty-four hours. The seasonal aspect should also be taken into consideration. The layout and the capacity of the terminal depend on these factors mentioned above. Because of the variance and uncertainty in these factors it can be hard to decide the optimal size of a terminal (Lumsden, 1998). Often in reality, the terminals have expanded over time, where it is possible due to land restrictions. If a terminal is located in an urban area, it can be very difficult to adjust it to higher capacities by adding space to the terminal. To be able to handle peaks, the terminals are often over dimensioned from the beginning. This is because they need extra capacity in the most extreme cases of arrival and departure intensity. This phenomenon is most apparent in land transports because the number of customers with smaller shipments is big in the consolidation of the goods.

The cargo-carrying unit at the terminal must be placed at a predetermined gate or a loading platform. This is fairly easy in lorry transportation (land terminals) as the vehicles are pretty flexible. Every inbound mean of transportation must be adapted and put in order before the loading or unloading takes place. This, in turn will place some necessity demand for enough space for operating the vehicles on the terminal area.

### 2.4.1 The Functions of Terminals

Lumsden (1998) argues that the ideal transport is travelling as a unit from the supplier directly to the customer i.e. a door-to-door delivery. This ideal state of transport has not yet been realized in reality. The transport should either be in form of a standardized unit load or in form of terminal goods, either way there will occur problems because of the cargo quantity that seldom match the external mean of transports' cargo capacity in terms of volume and weight. A biased venture on direct transports (door-to-door) would lead to a low average utilization of the transportation vehicles and therefore increased costs as a result.

There are eight functions that can be performed at a terminal. These are *consolidation, transhipment, coordination, sorting, sequencing, kitting, commercialising* and *warehousing*. Of these the focus will be on consolidation, coordination, sorting and transhipment.

**Consolidation**

To minimize the problem with the direct transports one or two terminals is placed in the external materials flow. A terminal's catchment area is rather small. This means that consolidation and unitification takes place in the terminal. The goods is then moved in a larger cargo unit from this point in the transport chain. In a second terminal unloading of the goods is performed upon arrival and is then spread in smaller units to the consignee.

To look closer on consolidation, Higginson (1995) provides a good framework for analysing this concept. The timing of the despatch of the consolidated load is an important question to consider. If customers orders or shipments are arriving randomly, how long can they be held at the terminal with the purpose of accumulating a larger vehicle load? Larger loads on the vehicles will lower the transportation cost per shipment and ton kilometres. The negative sides of it will be longer cycle time (customer dissatisfaction) and larger inventory levels, which means higher costs.

Higginson (1995) argues that there are non-recurrent and recurrent approaches. In the former approach they set a target time or target weight prior to accumulating the shipments and after that despatch the consolidated load when the specific target is fulfilled. The latter approach re-evaluates the shipment release decision several times within an order (shipment) accumulation cycle.

**Transhipment**

In land-based terminals for truck transportation, transhipment is taking place between different means of transport. In this case between smaller distribution and pickup vehicles to larger long-haul vehicles, that can differ quite substantially in size and shape. The different vehicles put demand on the design of the terminal itself depending on the type of transhipment that occur on the terminal itself (Lumsden, 1998).

Stefansson (2006) is referring to transhipment when he is describing carriers as one of the many actors that can be third-party service providers. –"Carriers can provide a transhipment function in transportation setups where load units are shifted from one transport mode to another… Larger carriers can even run cross-docking terminals where load units, pallets or similar, are shifted from one truck lane to another".

**Coordination**

Different means of transportation are arriving to the terminal at different times. For realizing an effective node in the transportation network there has to be some kind of coordination of the vehicles going to and from the terminal. This coordination means primarily an adaptation of the arrival and departure times for long haul vehicles and distribution vehicles alike in terms of a tight scheduling. There are of vital importance that the different means of transports' capacity are coordinated to avoid goods to be left behind at the terminal. The other way around is not healthy either. If the inflow is small and the outbound capacity is big, it will mean low utilization of vehicles with higher costs as a result.

**Sorting**

For several reasons the flow of goods with different destinations can be stopped. If this happens, it is suitable to perform value added activities that are possible to perform on another place than the production site, such as sorting of the goods by different criteria (Lumsden, 1998). However, it is not necessary that sorting just take place because the flow is stopped. Destination sorting while loading goods onto a trailer or lorry is fairly common in a terminal, if the driver is going to deliver it to him/herself later on.

### 2.4.2 The Structure of Terminals

When looking at terminals it can be done from two points of view. First, from the internal flow inside the terminal and secondly from the flow between the terminals, defined as the external flow. The terminals are designed depending on the flow is planned to pass them. Below a more thorough description of these flows is presented.

**Internal flow**

When discussing the different structures of the goods flow inside terminals Lumsden (1998) states that they can be used to divide terminals into four types. These are throughput, circulation, circulation with a central flux client and flux warehousing. Most of the terminals are a combination of these types. It is first of all the flexibility to handle the many different types of goods and varied flows that is considered when type of flow design is chosen. The terminal's original function is to ease the connection between two modes of transport (transhipment). If this is the main function, it is of importance to minimize the movement between gate, loading platform and quay.

In a terminal one easily get crossing flows of goods with an expansion of the business over time. To avoid these crossing flows to occur in bigger terminals, one can create a circulated central flow in form of, for example, a conveyor belt system. The central flow can also be achieved by having a number of forklifts of different types circulating, moving the cargo back and forth between the gates. Goods can then be easily transferred from a gate to the circulation flow and from there to another gate within the terminal building. This means a greater flexibility, as one gate can be changed from arrival to departure gate almost instantly. The positive consequence of this is that the number of gates can be reduced, but a negative one is that the throughput time in the terminal is longer for the goods to pass from one gate to another. To minimize the cycle time in the circulation flow inside the terminal it is necessary to minimize the length of flow or increase the flow speed. This setup can then result in the queue problem to occur at the gates. The gates become bottlenecks in the terminal. See figure 17 below:

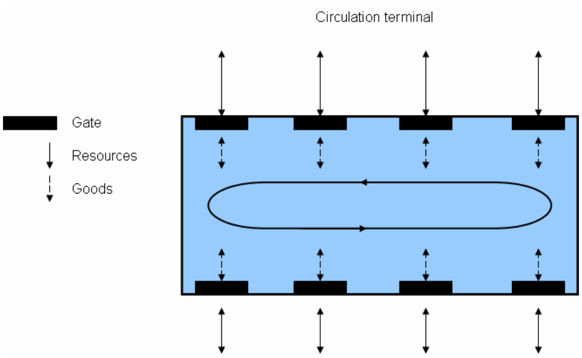



**Figure 16: Circulation terminal. Source : Lumsden, 1998.**

Many and different types of vehicles can be dealt with in the different types of terminals. When many goods flows are passing a terminal it can also be stored there. The terminal must then be designed for this purpose in a way to make it possible to achieve effective stock-keeping. Most probably this will lead to an installation of some kind of warehouse system in the terminal. The flow of goods to different gates is not rigid but can be moved between gates because of the varied inflow. One of the big issues with designing a terminal is the variation in capacity utilization. Normally peaks occur in the beginning and the end of a cycle. This can be in the beginning of a day or any cycle. This means that the terminal must be designed to bear these extreme flows of goods, which means it has over capacity most of the time. In a terminal with straight flow, each flow can be dimensioned separately, in a terminal with circular flow; you need to adapt it to the biggest flow passing the terminal (Lumsden, 1998).

### External Flow

The terminal's external flow should not be mixed with the theories about different network configurations, such as hub and spoke. The external flow is connected to the placement of the terminals in relation to the end customers and how the different flows are managed between terminals. The terminal can be used as a decentralized warehouse for the suppliers. There are much to gain from such a strategy. Closeness to the end customer means higher level of customer service by shortening the lead time. The deliveries can be perceived to be very fast from the customer's side. If the terminal is keeping many articles in stock, economies of scale can be achieved with a lower storage costs. To change the warehouse strategy from centralized to decentralized warehouses, or terminals, the total warehouse level is influenced (Lumsden, 1998).

## 2.5 Unification

Lumsden (1989) has formulated the concept of unitification from three aspects; transhipment, ergonomics, and cost and time reduction. - "If possible, one should combine several units of goods to a transport unit, transport carrier, adapted to available means of transportation and handling equipment. This current transportation unit should be created as early as possible in the material flow, preferably at the manufacturer, and be broken as late as possible, by preferably at the end consumer."

If the concept of unitification will be interesting to apply there are a number of prerequisites need to be realised: concentrated flow of goods should be present at some point in the system, the relations of goods flow must be of repeat character, the logistics chain must include more than one mean of transport.

The concept is much related to the increased mechanization of the handling of the goods. This means in reality an increased investment in handling equipment, either bound to the terminals or the external transportation vehicle. This means also additional costs in the form of pallets, platform bodies, containers and alike. There may also be extra costs for possible return transports of empty transport carriers. The possible cost reductions are the reduction in man-hours per ton-handled goods. It also means that the time at terminals is shortened and the external vehicles' grade of utilization is higher. If the cost reductions are realized and they are higher than the above-mentioned additional costs, is it profitable to switch to transport systems where the unification method is applied.

### Unit Load

The load carrier that will constitute the unit load must fulfil a number of criteria to support and facilitate the concept of unit loads. Keeping the goods together is of special importance and that it is carrying the goods with no affliction from other goods than the goods placed inside or on top of the carrier. It is also protecting the goods and as a consequence, the goods need to be secured inside it. When the goods are kept together, a new unit load has been created and it is easier to handle. A number of physical demand need to be fulfilled before the principle of unit loads can be realized (Lumsden, 1998).

Lumsden (1998) carries on pointing out these demands as size, time, form and handling. In terms of size, the unit loads ought to be as big as possible to create efficiency, but not as big as they create problems in the handling process because of too heavy weight. Regarding the time, the used units should be created as early as possible in the logistics chain, and be broken as late as possible, preferably at the place of consumption. This often affects the maximum size, because small units are preferably at the place of consumption. Space for storage is not often available there. Additionally, the unit load must be stable in its form so it can be mixed with unit loads of different character in terms of weight. Finally, in terms of handling, the load carriers must be able to be handled with all equipment available and present in the current transport system and thus at all handling points present in it.

## 2.6 Transport Economy

According to Lumsden (1995) transportation's primary goal is to move goods (or persons) from one point or another. A number of resources need to be added to create time utility (the service is available when it is needed) and place utility (goods are transported from the place of manufacturing to the place of consumption, where it has a bigger value) for the users. With this point of view, the prerequisites for transportation must be analysed separately. Motives for moving the goods and the cost components present in the transportation system needs to be defined and the transport systems economical characteristics needs to be described.

The economical characteristics of the transport can be described from a demand and supply-point of view. On the demand side, many authors have described the phenomena of derived demand, read, for instance Button (1982), Coyle *et al*. (2006), Engström (2004) or Hensher & Brewer (2001). Derived demand is a demand originating from consumers and companies, or other needs, as a demand for a certain product. It has no value of its own. The transport journey should be minimised because users see it as a cost in their total manufacturing function and therefore want to minimise it.

On the supply side the transportation industry is characterised by a division in a variable and a fixed component. The variable component can be wagons, trailers, trucks and similar. The fixed component can for example be ports, roads, bridges etc. They are normally lasting long time and will be very expensive to replace. The fixed components are characterised by economies of scale, long-lived and high costs. The variable components are short-lived and are replaced by economical, physical or technical obsolescence. They are also relatively cheap. There is also a chance for alternative use, when demand is decreasing on a market. Transport carriers that are handling the variable components have low sunk costs, another feature is that the variable costs is not characterised by economies of scale. The reason for this is that the movable components such as vehicles etc. has often been restricted in terms of size after the physical restrictions of breadth of roads, tunnel height and such measures. The capacity of the vehicles can be adapted to low volumes i.e. there are no minimum flows. The flexibility and the absence of economies of scale tend to stimulate competition on the market as new, smaller hauliers immediately can reach the average haulier's economical structure (Lumsden, 1995).

### 2.6.1 Types of Costs Involved in Consolidation

Transport costs can be described from a number of viewpoints. At a general level one should start from the producer of transport services, such as haulage contractors and forwarding agents, just because their costs are easy to define and track. Factor costs, costs for resources, and capital costs are covered in the calculations if they are considered to be direct costs. Some cost components for a road haulier can be:

- Vehicles
  - Fuel, repairs, service, maintenance, taxes, insurance and drivers costs.
- Administration and management.
- Garage and parade grounds.
- Rent for office space.
- Workshop.
- Terminal costs.

Apart from the direct costs there are also external costs. These will be covered in chapter 2.6.4. But worth mentioning is that there can be difficulties to separate these costs in a real situation. The whole idea with consolidation is to fill up a cargo unit with goods from different transports, in order to decrease the costs for the transport through transfer the goods via a point (terminal) between the origin and the destination. The costs for consolidation is determining if it is profitable or not, if you can find the optimal level of consolidation or if looking from the cargo unit side, to find the optimal size of the cargo unit (semi-trailer etc.). Bear in mind that it is restricted in size and weight by regulations from government and other legal institutions (Lumsden, 1995).

Lumsden (1995) continues to list four different kinds of costs that affect the size of the carrying units that will be the most optimal from an economical point of view:

*Direct line and delivery cost*. These costs always decrease when the load is increasing in the carrier unit to the maximum load size is achieved. The costs are wearing of the vehicles, wages and fuel.

*Terminal costs*. Terminal costs are increasing when the weight and size of the load is bigger because more work is needed to consolidate and organise the bigger cargo units.

*Time costs*. This is the capital tied up in the transported goods and the expanded storage space the transport buyer needs to maintain. Time costs are increasing with increasing cargo units because it means lower frequency of the transports (takes longer time).

*External cost and cost for society*. This cost constitutes of wear and tear of roads and pollution of the environment. These costs are considered to decrease as bigger carrier units mean fewer vehicles on the roads.

If only line and delivery costs exists the optimal load size would be infinitely large or as big as the resource's capacity allows as maximum cargo size. If the terminal costs will be included, the optimal size of the load for the transport producer will be a trade-off between these two costs. The time costs are especially of concern for the transport buyer and the optimal cargo unit size will be somewhat smaller than the one for the transport producer.

Optimal cargo load size is depending on whose perspective you take. Either you take the view from any of the actors: from the haulier, the carrier, the transport buyer, the transport producer, and the society's point of view.

### 2.6.2 Fixed and Variable Costs

The direct costs of a transport can be divided in many ways, one of the common ways are to see how they are varied over time. With the variation it is meant that in long- or short-term allocate costs on the activities that cause them. In long-term view all costs can be considered as variable, but the notion of long-term can be difficult to define. And the possibility to vary the cost over time is different for different means of transport. Many costs are considered to be fixed in a short-term period and variable over a long-term period. Even within the same transport mode the costs can have different length of levity. Within one year most of the costs are considered to be fixed, the only costs that are left are the ones with possibility for alteration. Such costs are often wages, fuel and maintenance. The difference between variable and fixed costs is a question of weighing in terms of actual time perspective and it requires sound judgement to determine if a cost is variable or fixed (Lumsden, 1995).

### 2.6.3 Economic Parameters

Fixed units with big fixed costs can within certain circumstances mean *economies of scale* for a haulier. These benefits exist in the transport industry due to a number of factors:

- *Bigger vehicles*, which means decreasing marginal energy-, production-, and wage cost.

- *Infrastructure.* Need of transportation often tend to be concentrated to certain parts of the infrastructure network. This allotment is possible through the scale benefits that lies in having the infrastructure between points or cities that generate a high number of transports.

- *Large fleets* of trucks. This can lead to decreasing maintenance costs, standardising benefits, easier solutions of optimisation problems etc. Be aware of that this is only valid in certain circumstances. Not all situations. For example, a small haulier can compete with a large transport organisation for a single transport mission.

Of course is it easier to adapt the size and capacity of the vehicle by, for example use bigger vehicles over longer distances than do the same thing for smaller vehicles and short distances. Often the physical restriction is a barrier in these situations.

*Economies of scope* is present when there are cost reductions to be made when several product types is going to be manufactured. Within many industries the discussion is going on whether one manufacturer shall produce all products or if there should be many manufacturers specialising in only producing one product (or service). This type of economy is present if the cost to produce two services in one single company is lower than the cost of produce the services/products separately.

*Economy of density* means that it can be benefits serving bigger markets. It allow for using the current resources more intensely. The density factor involve that the company's short-term average cost curve is sinking when the use of fixed assets, for example, terminals is used more extensively.
*Economy of experience* involves or is equal to the concept of learning-by-doing. You will get experience by operating in the marketplace and by doing so the cost per item will decrease when it is produced more than one product or when one haulier is present in a market for a long time.

*Economy of presence* involves that there is an economical value in only to be physically present in a transport relation. By being present in one relation, other transportation assignment will "pop up" from other relations from the same customer. At the same time, the existence of transportation services on certain relations will create a demand for transport there as the industry will exploit new possibilities where it is possible.

The use of these above mentioned economies are diverse for different kind of transport activities and are occurring in certain sectors of different extent. Some sectors have an element of economies of scale but others are more depending on economies of presence. The fixed and variable costs that are included in the different economies that can be utilised by the haulier are of crucial importance of conducting a transport service and indirectly the manufacturing of a product (Lumsden, 1995).

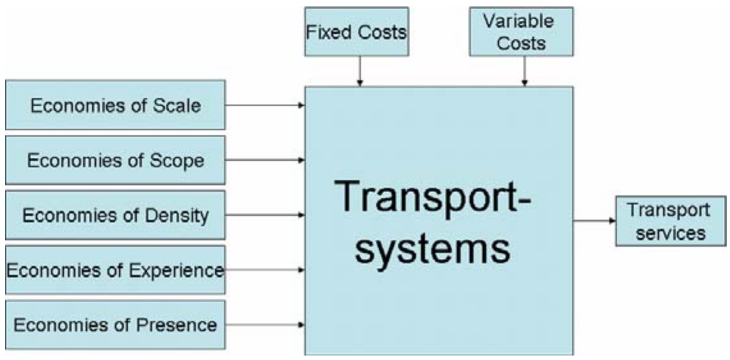



**Figure 17: Economical parameters affecting transport systems. Source: Lumsden, 1995, p.46.**

## 2.6.4 External Costs of Transportation

Transportation is not only causing costs for the carrier, one of the problems is that the society as a whole has to bear the external costs or effects of transportation. These can be general pollution, traffic jams, noise, barriers, accidents, vibrations, and atmospheric pollutions. External in this context means that the effects of the transportation is caused by vehicles like trucks etc. but it is the general public, or the pedestrians and cyclists that will be affected by the effects mentioned above caused by the transportation activities. The external effects of transportation has lately received increased attention by the society and the demand for increased environmental awareness such as eco driving, installation of fleet management systems has become industry standard or at least will be in a near future (Lumsden, 1995).

### 2.6.5 Performance Measurement in Transportation Operations

Starting with a broader perspective from a logistics point of view, Chow *et al*. (1994) identify the definitions of performance and performance measurement, as well as providing an extensive research in the literature regarding performance measurement.

Krajewski & Ritzman (1993) states that the competitive priorities in operation strategies are cost, quality, time, and flexibility. Similarly Coyle *et al*. (2003) lists a number of logistics productivity ratios, factors that they believe can be used to control different logistics elements, such as, warehousing, transportation, inventory, and customer service. In this section we are interested particularly about the productivity ratio for transportation. Andersson *et al*. (1989) goes further and states that in measuring logistics performance a comprehensive strategy of measurement is necessary for the successful planning, realization and control of the activities which are compose the business logistics function (Andersson *et al*. 1989).

Donsellar *et al*. (1998) states that the need for indicators is growing and especially the connection to the financial parameters need to be understood. One of the reasons of this is the companies' emphasis on continuous improvement (Steiner, 1997, de Wit & Meyer, 2005). To actually improve the economic performance of the firm, one need to know what indicators are influencing the same.

Two framework models have been developed to analyse the critical success factors behind transportation and distribution and has divided the transport and distribution sector in two segments: driving and (un)loading. These operations are quite different from each other and they continue to define transportation and distribution separately. Distribution is defined as a set of trips, which satisfy one of the following criteria:

- The loading plus unloading time is longer than the actual driving time.
- The distance between the first and the last stop of a trip is larger than 50 percent of the total distance per trip.

**General Transportation Model**

The remaining set of trips was defined as "transportation" by Donsellar *et al.* (1998) and in their evaluation model they classified different factors by choosing factors utilizing their model together with experts in the sector. The model for general transportation is presented in figure 19 below:

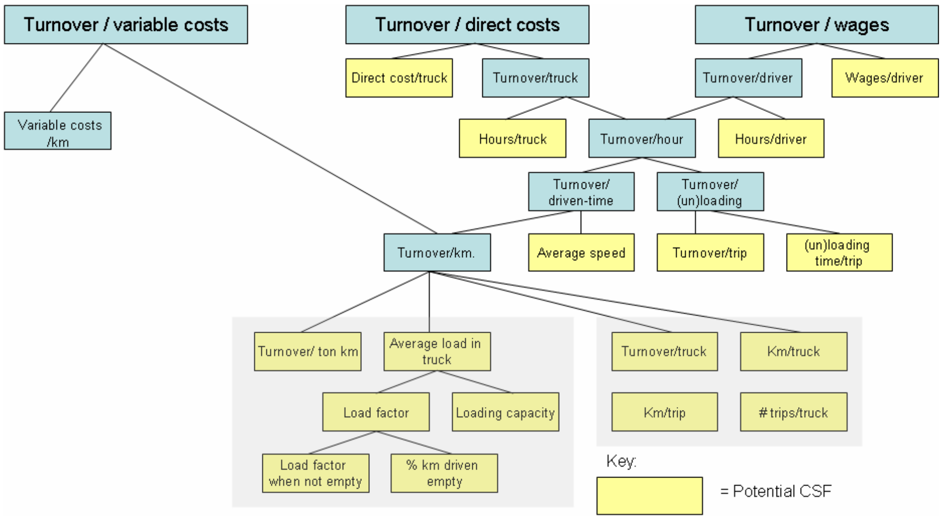



**Figure 18: Performance measurement model for general transportation. Adapted from Donsellar *et al.* 1998, p.440.**

A division of the general transport segment in two groups short and long distance (less than 500 km and over 500 km distance) was made. This was considered to be the longest distance per vehicle and driver where it is required to the driver to spend the night away from home. The result is that the transportation company needs to pay subsistence allowance to the driver meaning increasing wages for the driver. Other differences in operational performance between the segments are that average speed is higher, as is loading capacity. Even the kilometres driven empty with the vehicles is lower in the long distance segment.

To go back to the model one can see that two factors can be classified as CSFs; *the average wages paid per driver* and *the average load in a truck*. The average load in the truck can then be broken down in several factors, which can be found in the lower left corner of the model together with turnover per ton-kilometres. In the long distance segment, three factors can be found to serve as CSF's; *turnover per trip, turnover per ton-kilometres* and *turnover per truck*. The other CSF's identified in the model are *percentage of kilometres driven empty* and *distance per trip*. Improving all these factors will lead to substantial better operational performance.

## General Distribution Model

The classification for distribution can be found in the beginning of this chapter, and the model for this segment looks slightly different. In distribution focus is not on driving, but rather stopping, loading and unloading procedures. Therefore, the performance is determined by stopping operations such as factors like *the number of stops per trip* and *the stop time per stop.* The distribution model has also been divided in sub segments, this time under and over 2000 kilograms in drop weight. These segments require a different way of operation, but are about the same level in terms of performance. For example, in the low drop weight segment, have typically a low *turnover per hour* compared to the high drop weight per stop segment, but they also have a lower cost per hour, which gives approximately the same performance. Other factors that are different are *the number of stops*, which is larger in small drop weight per stop segment and the *stop-time per stop*, which is also shorter, and the *average loading capacity* is much smaller (Donsellar *et al.* 1998). The general distribution model is presented in figure 20 below:

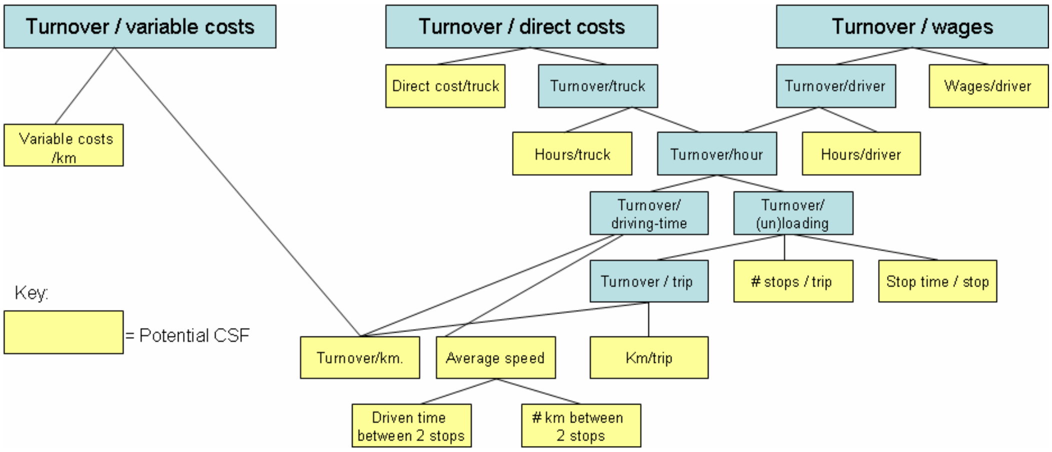



**Figure 19: Performance measurement model for general distribution. Source: Donsellar *et al.* 1998.**

### Summary of the performance measurement models

These two models address a number of important measures critical to the operational performance in a company, both for general transportation and distribution. In transportation a difference between long and short distances were made and in distribution a difference of small and large drop weight per stop was made. The critical factors are marked in the models as yellow boxes. However, reducing costs and lowering wages for example (compared to a successful company) is not the only solution in reality. Companies might be more successful if they, for example, have higher turnover per trip and appears to be as important as just reducing the costs involved. High turnover per trip can be reached by offering the customers more functionality. In this conducted study the operational performance is compared with a single critical success factor, in reality there can be several factors or a combination of them may express why certain companies are more successful than others (Donsellar *et al.* 1998).

## *2.7 Quasifirm Theory*

Luke *et al.* (1989) define the quasifirm as "a loosely coupled, enduring set of inter-organisational relationships that are designed to achieve purposes of substantial importance to the viability of participating members." The main characteristics of the quasifirm are the loose coupling between separate organisations and the high degree of shared purposes between these member organisations (Sommar, 2006).

Sommar (2006) states that in the transport industry the forwarder and the hauliers may work as a quasifirm. The hauliers sign contracts with the forwarder. The forwarder is the company within the quasifirm having the marketing function, they are the ones negotiating with the customers and signing the customer contracts. The result is that the hauliers have little influence over which future contracts are pursued by the forwarder.

## 2.8 Summary of Theory Chapter

To begin with road transportation is covered to gain some general insight in the truck transportation as one of the four modes of transportation. Road is the dominating mode of transport and is considered to be very flexible with good capacity. It is reliable and has great adaptability, these features is making it to the most used mode of transport. Furthermore, the most common vehicle combinations are described from a measures and weight perspective. There are three main types, distribution vehicles, tractor with semi-trailer and long haul truck with trailer.

The next section is covering the transport network itself. Here the focus is to describe the different parts constituting the whole network and the general construction and the parts in a network. Nodes, inflow, outflow and cycle time is explained and different kinds of network setups are discussed. Systems that apply direct deliveries, multiple terminals, single terminals and hub and spoke and a comparison between them. The next step is to look deeper into networks. Bobzin (2006) address a number of problems involved with networks, and McKinnon (1996) address the issue of imbalances that can be caused by structural, operational, technical or chain or security imbalances addressed by Lumsden (1998).

The overall efficiency in a network is important to look into because of the optimisation possibilities or improvement of the efficiencies. The overall efficiency is a product of time, distance, speed and capacity efficiencies. It gives a thorough insight in the transportation process and the potential for improvement can be assessed (Samuelsson & Tilanus (1997).

Terminals are a fundamental part of a transportation network. The functions of a terminal are consolidation, transhipment, coordination, sorting, sequencing, kitting, commercialising and warehousing (Lumsden, 1998). Moreover, the structure of terminals is discussed with focus on the internal and external flows. The very large flow of goods through the terminals is making it important to look at unit loads and the making of standardised units, unitification. Furthermore, Lumsden (1998) addresses demands that needs to be fulfilled before the principle of unit loads can be realized and these are size, time, form and handling.

Transport economy is included in the theory chapter to establish a general understanding of the costs that is involved when calculating of different transportation alternatives and the comparison between the same. The economical characteristics can be described from many points of views, from the transport carrier, the transport buyer or from the society's point of view. Furthermore, the interdependence of costs and consolidation is explained. It is very common to describe costs from a time perspective- to divide them in fixed and variable type of costs. The economical parameters economies of scale, scope, density, presence and experience are explained and put in the context of transport systems (Lumsden, 1995). Finally, the external effects or costs of transportation are covered. These are general pollution, traffic jams, noise, barriers, accidents, vibrations, and atmospheric pollutions.

Performance measurement of transportation systems is mapping the economical crucial success factors in transport systems. Donsellar *et al.* (1998) presents two models that address a number of important measures critical to the operational performance in a company, both for general transportation and distribution. The last chapter in the literature review is covering the quasi firm theory presented by Luke *et al.* (1997). The next chapter covers the methodology applied in the research project.

# 3 METHODOLOGY

*The chapter considers the types of research and strategy applied in the study, the sampling method, analysis method, the description of data, data collection strategy and how the literature review was conducted.*

## 3.1 Research Strategies and Approach

There are many types of research that can be conducted, for example Moore (1983) suggests a difference between applied and academic research, whilst Saunders *et al*. (2000) make a distinction of quantitative and qualitative research. These approaches have their roots in how the data are gathered and analysed. All research will involve some numerical data or data that could be usefully be quantified to help you answer your research questions and to meet the objectives of the study.

**Table 5: Distinctions between quantitative and qualitative data. Source: Saunders *et al*., 2000, p. 381.**

| Quantitative data | Qualitative data |
|---|---|
| Based on meanings derived from numbers | Based on meanings expressed through words |
| Collection results in numerical and standardized data | Collection results in non-standardized data requiring classification into categories |
| Analysis conducted through the use of diagrams and statistics | Analysis conducted through the use of conceptualisation |

A mixed strategy of both qualitative and quantitative is applied to this study. One could also claim that it fulfils the demand of being applied research as the topic suggests solving a profitability problem in the network concerning the terminal goods between relations shorter than 200 kilometres.

Saunders *et al*. (2000) continues to make a distinction between deductive and inductive research approaches. A deductive approach means the study is either based on a theory or you develop hypotheses to test the theory if it is valid in your chosen research context. If one instead collects data and through the data analysis develops a theory, the research approach is labelled as an inductive research approach.

The current research project has applied both a deductive and an inductive approach due to several reasons. First, the study hosts two parts that can be separated from each other. The deductive approach is applied in the usage of distribution trucks' calculation. In this part, tools as the SÅ Calc and SÅ Index (2006) software is used and the calculation is based on the theories and findings in the literature review, industry practise and the quantitative characteristics of the data. Getting access to this software was a great help in developing the calculation models used in the project. An inductive approach has been applied in the development of the different alternatives (of which usage of distribution trucks is one alternative). These alternatives originate from the empirical findings from collected data and information.

## *3.2 Literature Review*

The literature review includes reading known books in the logistics field. The theory chapter has been divided in road transportation, transportation networks, terminals, unification, and transport economy. Furthermore, a revision of transportation theory, physical distribution and logistics fields to see what factors are relevant to study and other interesting viewpoints found in the existing literature. The theory chapter is largely based on books and research articles found in the databases Emerald Insight and EBSCO. The books we have used to create the theoretical framework are for example, Logistikens Grunder (Lumsden, 1998) and Transport Economics (Lumsden, 1995) and Management of Transportation (Coyle *et al*. 2006). These books will serve as primary sources, as well as recent academic journal articles will contribute a great deal to the theoretical framework.

## *3.3 Data Collection Methods and Description of the Data*

Access to the necessary data and information for solving the research problems has been negotiated with the principal company in focus. The sources of the data are available in many business units and therefore assistance by the principal is crucial. In the initial stage of the project, a series of information meetings were held where students had possibility to ask questions and further their knowledge about Schenker as a company, but more important about the operations and network including the rules and all factors affecting the research project.

Data can be divided in two major categories: primary and secondary data. Primary data is new data collected for the purpose of solving the research objectives. On the other hand secondary data is classified as already collected data for other purposes, or research. Secondary data can provide a useful source from which to answer the research questions.

Advantages with using and collecting secondary data is that it normally realizes a big saving in resources, costs and effort compared to gather primary data. If there is a shortage of time, it is faster to analyse secondary data, meaning that larger sets of data can be analysed in the same time frame. This can especially be the case in longitudinal studies when analysing secondary data may be the only feasible opportunity to finish on time. Moreover, secondary data can provide comparative and contextual data, which can be used for comparing your own results, and help you to generalize the results to a larger context.

The type of data needed for the calculation of the usage of the distribution vehicles is decided by the parameters in the software SÅ Calc 2006 (Sveriges Åkeriförening). First, secondary data in form of compiled statistics over the ten different relations were collected from year 2005. Data connected to the flow of goods between terminals, such as, volumes of goods in tonnes, number of actual consignments for both part loads and terminal goods. This data can be classified as documentary written material according to Saunders *et al.* (2000).

Second, an investigation of the responsible hauliers on each relation was conducted. This information is needed for further collection of more specific secondary data. One aspect to consider is what kind of vehicles is used to produce the transportation services on each relation. Measures and available combinations of vehicles were obtained by field studies and structured interviews at the examined terminals. More specifically the vehicle data consists of, the cost price, capacity, and utilisation of the vehicles and the man hours needed to produce the transport services, mileage driven per vehicle, the length of the lifecycle of the vehicle, the depreciation and interest rates, insurance costs and repair and maintenance costs and fuel consumption. Moreover, structured interviews were conducted with the hauliers and with the truck drivers for two main purposes. To get more understanding about the process and obtain the data needed. Third, there are three major areas were costs needs to be calculated: direct costs for driving the vehicle, terminal costs and driver costs.

Fourth, the required time to produce and drive the distance between the terminals had to be calculated. Unloading and loading time statistics were obtained from interviews with Jesper Svensson and Thorleif Waldemarsson and revision of secondary data obtained from Görrel & Svensson (2001) investigation of a charter arrangement as an alternative to produce transport service. Assumptions needed for vehicle calculations were obtained by structured interview with Stefan Andersson, Mats Rasmusson and Svante Carlsson, they are all managers and experts working in Schenker's domestic traffic department.

Fifth, the qualitative input parameters and the alternatives presented in the multi criteria analysis model were obtained during the structured interviews mentioned above with many different people in the Schenker DB Logistics' organisation. The tool S.Å Calc 2006 was used for the quantitative analysis and calculations and an interview with the originator, Lars Aspholmer in Borås to get an insight in the functions and assumptions behind the calculation models present in the software. See reference list for detailed information.

Finally, the presentation of the findings will be shown as comparing graphs and / or figures of the different alternatives. Where example calculations have been made these will be presented both as graphs and in illustrative tables for easy comparison with each other.

## 3.4 Sampling Method

According to Saunders *et al.* (2000) sampling techniques can be divided in probability (representative) sampling and non-probability (judgemental) sampling. In order to decide the sample population, initial interviews with the principals and research of the Schenker homepage was conducted. From the register of terminals 26 districts with 28 terminals in the Swedish network were mapped. The distances were then calculated with help of the Schenker online tool and 62 relations less than 200 kilometres could be defined as the sample population in the research project. From the population a sample of 10 relations, constituting 16,1% of the total population, were picked out by the principals using their expert knowledge and judgement. The relations represent short distances where Schenker has profitability problems and other operational problems producing competitive and high quality truck transportation services to their customers.

It is important to be able to generalize the results of the analysis of the sample taken to the whole population. The choice of the size of the sample is a compromise governed by the confidence one need in the data, the margin of error one can tolerate, and the types of analyses undertaken. Determining the size of the sample is always a matter of judgment rather than a result from a calculation (Saunders *et al.* 2000). The use of judgemental non-probability sampling method had to be applied in choosing the sample for this study because using a random sampling method would include relations not relevant for the problem definition. However, the sample can be seen as representative for the population as experts in the field state so.

## 3.5 Data Analysis Method

The weight criteria method is developed for being useful when carrying out an evaluation of alternative solutions according to several criteria. The method forces the analyst to perform a thorough comparison using several different criteria in order to analyse and evaluate different alternatives. The method is especially suited for evaluations with a large number of criteria that cannot be ranked trivially. The evaluation method was originally developed for evaluating alternative solutions in the machine design process (Bjaernemo, 1983), but it is rather general. Lindau et al. 1993; Woxenius, 1998; Bask and Vepsäläinen, 1998, have used the model for the transport sector. The method is described step by step below.

### Define the Conditions of the Evaluation Situation

Woxenius (1998) describes the evaluation method as: "The first step is to define the conditions of the evaluation situation. This should be carried out thoroughly every time, since it is a common mistake to use the old references that do not fit the actual problem."

### Make a List of Demands and Criteria

The next thing to do is to make a list of requirements that are specified as criteria and demands. The demands are necessary for the different alternatives to fulfil, to even qualify for the evaluation. The different criteria are more like wishes of what the different alternatives could contribute with when implemented. Cost of implementation is not for the different alternatives are not part of the evaluation (Woxenius, 1998).

### List the Alternative Solutions

"A list of alternative solutions that satisfy the demands is generated. These are evaluated against the demands. Those solutions that satisfy the demands are listed for further evaluation." (Woxenius, 1998).

### Weight the Criteria against Each Other

This step is where the criteria are weighted against the other criteria in order to decide how important the different criteria are. The criteria are coded with letters and are compared in pairs. The method uses a matrix where the criteria are listed. The criteria are called "C1...CX." (Woxenius, 1998).

**Table 6: Example of evaluation criteria matrix.**

| | Criterias | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | Corr | pi | ki (pi/∑pi) |
| C1 | 0 | 0 | 1 | 1 | 0 | 2 | 2 | 1 | 7 | 0,14 |
| | C2 | 0 | 1 | 0 | 2 | 0 | 2 | 3 | 8 | 0,16 |
| | | C3 | -2 | 2 | 0 | 1 | 1 | 5 | 7 | 0,14 |
| | | | C4 | -3 | 2 | 0 | 1 | 7 | 7 | 0,14 |
| | | | | C5 | -4 | 2 | 0 | 9 | 7 | 0,14 |
| | | | | | C6 | -5 | 2 | 11 | 8 | 0,16 |
| | | | | | | C7 | -8 | 13 | 5 | 0,10 |
| | | | | | | | | ∑: | 49 | 1,00 |

"As is indicated by the name of the evaluation method, weighting the criteria against each other is a crucial step in the method. The criteria are weighted in order to decide how important the different criteria are. The criteria are coded and then compared in pairs in a matrix. For instance, if criterion A is more important than B, the number 2 is put in the cell AB. If they are equal in importance, the number 1 is put in the cell. If B is more important than A, the number 0 is put in the cell. All cells in the matrix are filled out using the same procedure. As is shown in table 1, the criteria are here coded C1 to C7. Criteria C1 is found less important than all other criteria, C2 is found equally important as C3 while C2 is found more important than C4. A correlation factor, **corr**, with odd numbers is put in a column.

Every column is then summed up and the plus sign of the sum is changed to a minus sign. The rows, including **corr**, are then summed up with their proper signs giving the row sums. The $P_i$-column is added up and the sum shall equal the squared number of criteria. The weight factor, $k_i$, can now be calculated as $k_i = P_i / \Sigma P_i$. The sum of all $k_i$:s, $\Sigma k_i$, will equal 1.00 if the matrix is properly filled out." (Bask & Vepsäläinen, 1998).

## Evaluate the Alternatives According to the Defined Criteria

The different alternative solutions are evaluated using a new matrix. The evaluator scores the alternatives according to the degree of fulfilment against each criterion. The scoring scale used is:

3 The alternative fulfils the criterion well
2 The alternative is likely to fulfil the criterion
1 The alternative is not likely to fulfil the criterion
0 The alternative cannot fulfil the criterion at all

**Table 7: The alternative evaluation matrix, ki fulfilment ranking.**

| | Criteria | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | | |
| | 0,14 | 0,16 | 0,14 | 0,14 | 0,14 | 0,16 | 0,10 | :poin | ki fulfilment |
| Alt 1 | 1 | 1 | 0 | 2 | 2 | 1 | 2 | 9 | 1,24 |
| Alt 2 | 2 | 3 | 1 | 3 | 0 | 0 | 3 | 12 | 1,65 |
| Alt 3 | 2 | 1 | 2 | 3 | 1 | 2 | 3 | 14 | 1,94 |
| Alt 4 | 3 | 2 | 3 | 1 | 0 | 0 | 2 | 11 | 1,53 |
| Alt 5 | 3 | 2 | 2 | 1 | 3 | 2 | 2 | 15 | 2,14 |
| Alt 6 | 2 | 1 | 0 | 2 | 0 | 3 | 2 | 10 | 1,43 |
| Alt 7 | 1 | 1 | 0 | 2 | 2 | 0 | 1 | 7 | 0,98 |

**Final Evaluation**

The ki fulfilment column shows which project fulfils the different criteria best. The last step is to investigate the cost of the different alternatives. The final decision should then be based upon the ki fulfilment-rate and the cost of the different solutions. A ratio between cost and fulfilment can then be calculated, but the decision is not necessarily the most cost-efficient one (Woxenius, 1998).

## 3.6 Validity

Saunders *et al*. (2000) states that validity is defined as the ability of the conducted research to measure what it is indented to measure. Similarly, Golafshani (2003) states that validity is the truth of the conducted research in relation what it is supposed to measure, the strengths of conclusions, interference or propositions. Interviews are a great threat to validity. Interviewers can affect the respondents and cause bias to the results. The questions can be interpreted in many ways if not clearly stated. Therefore, it is of importance to have enough respondents and statistical evidence to present valid results.

Svenning (1996) makes a difference between internal and external validity. Internal validity is a measure how well the theoretical and the empirical results are matching in the research project and how its different parts are designed. External validity is a measure of the relation between the conducted research and the scientific context. Is the result possible to be generalized to a wider context? In a quantitative research study it is important that the empirical base is correct. If the internal parts of the research project cannot achieve validity status, the whole project's validity can be questioned. Internal validity is to ask the right people the right questions.

## 3.7 Reliability

Reliability means consistency of measurement and refers to how trustworthy the sources are. Reliability is determined by repeatability (can the study be conducted again with the same results under same conditions?), credibility, and dependability. Important to stress is that reliability is not measured but instead estimated and is required to make statements about how valid the results of the research project are (Golafshani, 2003). Low reliability can be a result of faulty samples, wrong sample techniques, the affect of the interviewer and interpretation problems. By approaching the subject from many directions is giving a higher chance of achieving reliable results (Svenning, 1996).

# 4 EMPIRICAL STUDY

*In the fourth chapter the empirical findings of the study is presented. First, an introduction to Schenker DB Logistics is presented and an overview of their services follows. The chapter then continues to focus more on the present situation, in fields that are relevant of the current research project.*

## 4.1 Schenker DB Logistics

Schenker & Co. was found in 1872 in Austria. The company developed and merged with companies during the 20$^{th}$ century. In 1991 was a majority of shares in Schenker acquired by the company Stinnes AG from Deutsche Bahn. In 1998 BTL Sweden and Schenker Transport merged to one company. BTL Sweden then consisted of Bilspedition Inrikes and Scansped. So, BTL Sweden AB and Schenker coordinated using the Schenker BTL brand name. BTL AB was fully acquired by Schenker in year 1999. Stinnes, the owner of Schenker, was then taken over by Deutsche Bahn in 2002 and the current name is Schenker DB Logistics. The most recent corporate change is the acquisition of BAX Global that will result in a new organisation structure (Schenker Company History, 2006).

Globally, Schenker has 39 000 employees at 1 100 different locations and a turnover of more than 8 billion Euro. Schenker handles 16 million tonnes of freight in 18 million shipments every year (Schenker AB Infoblad, 2005). Schenker's division north consists of the operations in Ireland, Great Britain, Norway, Denmark and Sweden. Schenker Sweden has a domestic and an international unit. Sweden is one of the largest markets for Schenker. It has 4200 employees in Sweden with a turnover of 10 billion SEK (2004). The Swedish network consists of ten different logistics centres, 29 terminals and 145.000 m$^2$ warehouse areas. The division Coldsped has access to ten cold storages in the network for transporting and distributing chilled and frozen goods (Schenker corporate communications, 2004).

Schenker is one of the largest forwarders in Sweden and they offer their services to/from domestic as well as international destinations. Their main transport service services within the land transport division are consolidated cargo, less-than-truck load, and truck load of both tempered and non-tempered unitised goods. The terminals within the network are mainly operated by Schenker while transport services are either performed by a hauling division or bought from external suppliers (Sommar, 2006).

Schenker Sweden's business model is to have contracted hauliers working together with Schenker as a quasifirm. Most of Schenker's hauliers are solely or mainly performing transport services for Schenker. Schenker primarily contracts one haulier for each terminal to terminal relation or distribution area. It is up to the haulier how to organize the transport. A secondary haulier is contracted by Schenker if the primary haulier is not able to take on additional goods (Sommar, 2006). It is Schenker's responsibility to try to get good freight balances on their different relations.

## 4.2 Products

The products offered by Schenker land transports are parcel services, less-than-truckload shipments, direct shipments, coldsped and concepts (Schenker-Products-Land transports, 2006). These different products offer customers the availability to ship different types of products with different sizes and requirements to most destinations within Sweden or internationally.

## 4.3 The Transportation Network

The Schenker Sweden domestic transport network consists of 26 different geographical areas with in total 29 different terminals. The network is a multiple terminal direct relation network where each terminal has a direct relation with all other terminals. Goods going to terminals located far north or relations with small freight volumes have consolidation terminals within the network where the goods is consolidated with other goods going to the same terminal.

The relations are divided into two categories at Schenker, "near" and "far" relations. The "near" relations are defined as relations located less than 150 km apart, whereas the "far" relations are defined as being more than 150 km apart.

Each terminal has a distribution area around the terminal. The size of the area differs for different regions. The most common procedure for terminal to terminal goods is that it is picked up in one region by the distribution trucks in the afternoon. The goods is sorted and transferred through the terminal to the outgoing area of the terminal. The goods are then transported over night to the receiving terminal. The receiving terminal sorts the incoming goods to the right distribution truck according to the receiver's location within the district. The goods are finally delivered to the end customer, often before noon the day after the goods was shipped. Relations located far north in Sweden have extra long delivery time because of the long transports needed.

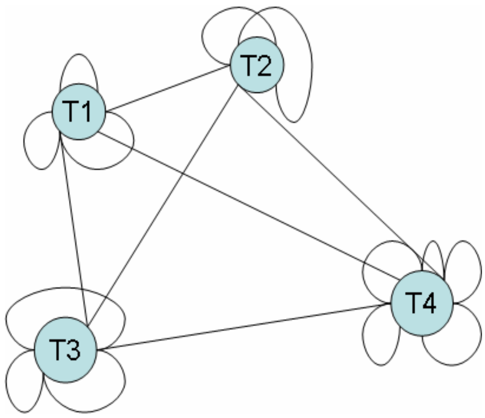



**Figure 20: Multi node network structure.**

### 4.4 The Terminals

Each terminal has shipping and receiving areas for each terminal-to-terminal relation in the network. This area works as the outgoing shipping area in the afternoon and the incoming receiving area in the early morning. The haulier is responsible for loading the goods from the shipping area of the terminal into the truck/trailer and unloading it at the receiving terminal whereas the terminal personnel are responsible of sorting the goods within the terminal.

Each terminal has one or more contracts with hauliers supplying the distribution service in the area surrounding the terminal. There are separate gates in the terminals for the distribution trucks. The distribution trucks pick up goods in the morning to distribute during the day. The distribution trucks pick up goods that are to be sent from customers during the afternoon and they return to the terminal around 15.00 or later in the afternoon.

The terminal handles the goods every time it passes through the terminal. The service in the afternoon and the morning is to redistribute the goods from the incoming receiving area of the terminal to the outgoing destination area of the terminal. During the afternoon the goods come in to the terminal from the distribution trucks and are sorted into the line haul destination areas. The morning procedure is vice versa when the incoming goods come from the line hauls and are redistributed to the distribution trucks. The process direction at the terminal is different in the morning compared to the afternoon. The gates used for incoming goods in the morning are used for outgoing goods in the afternoon, and vice versa.

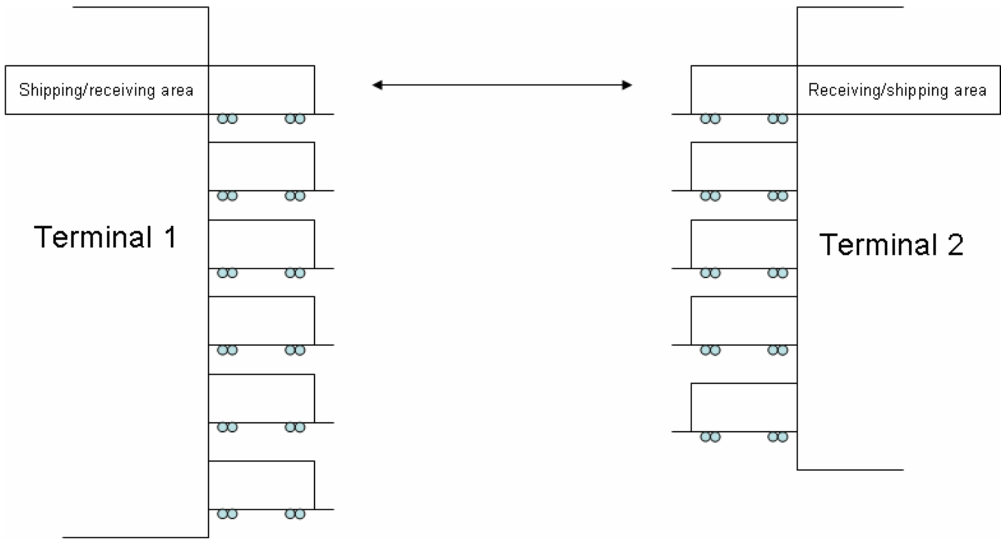



**Figure 21: Terminal to terminal relation.**

## 4.5 Transport Organisation

All goods weighing less than 1 000 kg are less-than-truckload shipments (LTL). The weight definition differs slightly in some areas. These shipments are transported through terminals. Goods weighing more than 1 000 kg are called part loads or full loads. The haulier having the contract between two relations is responsible for both the terminal to terminal LTL shipments as well as the part loads between the two areas.

The part loads are picked up by the line haul truck from the sending area and are delivered directly to the end customer without going through any terminal. The contracted haulier picks up the LTL goods at the terminal and drops it off at the receiving terminal. One common way for the hauliers is to use the truck for part loads and to have a trailer with the terminal LTL goods. The trailer is picked up at the sending terminal when it's loaded. The haulier lets the trailer of at the receiving terminal and the line haul truck goes on to deliver the part loads to the end customers. When capacity problems occur the haulier must prioritize to transport the terminal to terminal goods instead of additional part loads.

The line haul truck does not need to drop off all the LTL goods from the sending terminal at the receiving terminal. Line haul trucks can deliver LTL goods directly to the end customer if the consignment weighs more than 350 kg. This restriction is only valid for "far" relations whereas LTL goods on "near" relations may always be dropt off at the end customer directly by the line haul truck. Some terminals have altered the weight limit in collaboration with their contracted hauliers.

## 4.6 Charter

Charter is a different way to organize the terminal to terminal transports. A charter relation is a relation where Schenker takes the responsibility for transporting the goods from the outgoing terminal to the receiving terminal, instead of having a contracted haulier being responsible for the route. The Schenker terminal uses its own terminal personnel to load and unload the truck. A haulier is contacted and paid for supplying Schenker with a driver and a vehicle that drives between the two terminals.

The charter setup is often the result of Schenker having difficulties contracting a haulier for the route, perhaps due to difficulties to get the relation profitable.

Some relations may have exceptions in the charter setup organisation. Schenker can sometimes buy services for loading or unloading from the hauliers as well as the truck driving services.

## 4.7 NAV

Five different actors in the transport chain handle the consignments. These are distribution, terminal, line haul, terminal and distribution. The revenue generated by each package is split between the actors according to a system called NAV (New revenue division model) developed in 1996. This system is used to split revenues and risks between the actors involved in the transport chain.

There are many different factors that are taken into consideration in NAV. These factors are such as the number of actors involved in the transport chain and if the shipping or receiving area is in a more expensive area for the distribution trucks NAV compensates for that. It is therefore feasible for the haulier to deliver some goods directly to the end customer in order to increase its share of the NAV distribution. The rule is still that all goods on “far” relations weighing less than 350 kg must be transported to the terminal. However, many hauliers drop off all the LTL goods at the receiving terminal without doing further calculations whether it would be beneficial to distribute them selves.

## 4.8 Hauliers

Schenker have many different contracted hauliers. These hauliers are collaborating and negotiating with Schenker through the association BTF. The Schenker-haulier relations are usually lasting over long periods of time. The hauliers are satisfied with Schenker as a long-term partner compared to some of their competitors, which are more into transport bidding for their routes.

The size of the different contracted hauliers differs. Some hauliers consist of a single truck and driver. Other firms have many trucks on different routes and an extensive planning system for the drivers and the trucks. Since the hauliers have exclusive contracts on their respective routes Schenker can’t do any route planning them selves. The hauliers can do route planning and transport optimization within their own fleet and between its different contracted routes. Schenker encourage their hauliers to consolidate and optimize as much as possible in order to decrease overall costs.

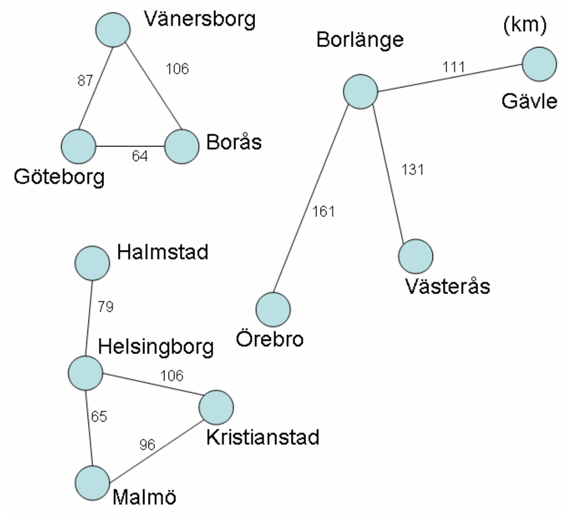
## 4.9 Investigated Relations

All Schenker’s terminals were listed with the distance between them in a table available in Appendix I. The terminals located less than 200 km apart were marked green and terminals located more than 200 km were marked red. There are 62 terminal relations within 200km. A meeting with Stefan Andersson (2006) resulted in finding 29 relations that were labelled as problem areas. 10 out of these 29 relations were chosen for further investigation based on Stefan’s recommendations regarding relations that would be the most representative for the study.

The relations being more thoroughly investigated are:

**Table 8: Investigated relations in Schenker's network.**

| Relations | Distance (km) |
|---|---|
| Borlänge-Gävle | 111 |
| Borlänge-Västerås | 133 |
| Borlänge-Örebro | 161 |
| Göteborg-Borås | 64 |
| Göteborg-Vänersborg | 87 |
| Vänersborg-Borås | 106 |
| Helsingborg-Halmstad | 79 |
| Helsingborg-Kristianstad | 106 |
| Helsingborg-Malmö | 65 |
| Malmö-Kristianstad | 96 |




The number of relations was further decreased in the calculation model. The three relations focused on where Vänersborg, Borås and Göteborg located in west Sweden. These were also the terminals visited during the project.

## 4.10 Imbalances in the Network

When analysis of the collected secondary data for the ten relations included in this study was done, one could clearly see that quite substantial imbalances in the goods flow are occurring. These can be explained as structural and operational imbalances as pointed out earlier by Lumsden (1995). McKinnon (1996) states that imbalances create less utilisation of the resources utilised. However when looking at Schenker's network one can see that the contracted hauliers can coordinate their efforts between the relations and pickup other material from external line haul customers to fill up the vehicles so that it is economically acceptable to operate the relation. As Schenker wants their hauliers to be profitable, they encourage their hauliers to take such actions to achieve a sustainable solution. This factor is disregarded when calculating the capacity needed on each relation, which is one of the underlying factors making assumptions about when conducting the calculations on the extensive use of the distribution trucks.

To illustrate the imbalances a balance index has been calculated where a balance of 1.0 is showing a balance on the relation. An index lower than 1.0 means less goods are transported from or to that terminal, and a index higher than 1.0 means that more goods are transported to that relation. To look closer on the imbalances one can clearly see that there are substantial differences in the flows. The table 27 below is showing the imbalances for above mentioned relations.

**Table 9: Imbalances on three of the investigated relations.**

| Network relations | Balance index (Balance = 1.0) |
|---|---|
| 2 → 3 | 1,20 |
| 3 → 2 | 0,83 |
| 1 → 3 | 0,34 |
| 3 → 1 | 2,90 |
| 2 → 1 | 1,55 |
| 1 → 2 | 0,65 |

Between 2 and 3 the imbalance is not so severe according to the calculation. However to look at the relation 3 – 1 one can see an exceptional difference in the flow. It is a much bigger from 3 to 1. This can be described as a typical structural imbalance since a large customer is located in 3 and their post order business generates great volumes out from 3.

# 5 TRANSPORT OPTIMISATION ALTERNATIVES

*In this chapter the different optimisation alternatives are presented. The reason for presenting this in a new chapter is to distinguish it from the first part of the empirical study. This second part focus on the research problem and the optimisation alternatives, while the first part is focusing on Schenker in general terms.*

Schenker has a problem of low efficiency and profits on short distances in their network. In order to increase efficiency and profitability on these short problematic routes are there several different approaches. The first step is to investigate which cost drivers are the most relevant ones for usage of different types of trucks. The table below shows the allocated cost drivers for four different types of trucks. The trucks are assumed to be used normally with associated costs related to distribution for the distribution trucks and for long haul for the long haul truck and the tractor.

**Table 10: Cost driver allocation based on different factors and vehicles, Adapted from SÅ Index, 2006.**

| | Truck type | Truck type | Truck type | Truck type |
|---|---|---|---|---|
| | Distribution 2 axles | Distribution 3 axles | Longhaul terminalgoods 3+4 axles | Tractor 2-axles |
| | Year Month | Year Month | Year Month | Year Month |
| | Data period 2006 1 | Data period 2006 1 | Data period 2006 1 | Data period 2006 1 |
| Costs | Share | Share | Share | Share |
| Depreciation | 11,8% | 12,1% | 10,2% | 5,8% |
| Interest | 3,4% | 3,8% | 3,4% | 1,8% |
| Tax | 1,8% | 2,5% | 2,0% | 1,6% |
| Insurance | 4,9% | 5,1% | 5,3% | 5,9% |
| Drivers wage | 45,4% | 38,8% | 34,0% | 39,6% |
| Administration | 12,3% | 13,3% | 7,2% | 5,3% |
| Tires | 1,2% | 2,0% | 2,6% | 1,7% |
| Diesel HSK | 12,5% | 14,6% | 26,4% | 31,5% |
| Repairs | 6,7% | 7,9% | 8,9% | 6,9% |
| | 100% | 100% | 100% | 100% |

One can see that the largest costs for the trucks are the driver wage and the diesel costs. The driver wage is somewhere between 34% and 45% of the total cost of using the trucks. Optimising the working hours for the drivers is therefore where the largest potential for cost savings is.

The cost for diesel is around 26% to 31% of the long haul trips using large trucks, whereas it is only around 12-15% for distribution traffic. The diesel costs can be minimized by more effective and newer trucks as well as a more efficient driving behaviour.

Administration is more costly for distribution trucks than it is for long haul trucks. One probable reason for increased administration costs using distribution trucks is that they serve more customers and relations than long haul trucks do.

Tires and to some extent repairs, insurance and tax are proportional to the mileage driven with the truck. Increased utilisation of existing vehicles may have some effects on these costs, but these are probably quite small.

Depreciation and interest are two costs that are more fixed. Interest is fixed as it is not proportional to the number of kilometres driven with the truck. The deprecation cost is a mix of age and mileage. These two costs are the main advantages of increasing utilisation of the trucks. However, the fixed costs are only around 5-12% of the total cost of the truck.

## *5.1 Criteria*

The criteria used to evaluate the different alternatives were chosen based on the authors' own ideas and thoughts formed during the thesis process in combination with the interviewed people. The chosen criteria were also inspired by external literature and articles using the weight criteria method as an evaluation tool.

### 5.1.1 Increased Vehicle Utilisation

Increased vehicle utilisation is a positive goal to achieve. By increasing vehicle utilisation overall costs may decrease as a result of the fixed cost per kilometre driven by the vehicles decreases.

### 5.1.2 Potential of Decreased Operational Costs

One can argue that decreased costs are such a dominant criterion that it should not be included in the weight criteria method. The authors decided to include criterion of measuring the potential of decreasing the operational costs, which not necessarily means that the overall costs will be decreased.

### 5.1.3 Increased Vehicle Flexibility

Having more flexible vehicles has the potential of increasing utilisation and effectiveness of the vehicle fleet. Vehicles are more adaptable to the different tasks needed and flexible loading units give the opportunity of just dropping off or picking up load units at the terminals. The truck or tractor can be used more of the time in transport with flexible loading units.

### 5.1.4 Working Time Optimisation

The largest cost of the transport service is the wages, especially on short distances. Alternatives requiring decreased working time are therefore a good alternative if costs for the company are to be decreased.

### 5.1.5 Possibility to Even Out Imbalances

Some suggested alternatives may give a possibility to better cope with imbalances in the network. New ways of working with the goods may lead to better ways of handling these imbalances as well as using alternative routes for some of the goods.

### 5.1.6 Increased Network Flexibility

Schenker's network with its current setup is not very flexible, at least not on paper. There may be ways to better utilise the existing resources and new ways to handle the goods within the network. An optimisation of existing resources may lead to decreased costs.

### 5.1.7 Possibility to Handle Large Freight Peaks

The Schenker network sometimes has difficulties handling large freight peaks. Customers will not be satisfied with Schenker if goods are not delivered as scheduled and revenues may be lost to competitors. An increased possibility of handling these freight peaks would be of interest to Schenker.

## *5.2 Alternatives*

All in all seven different alternatives have been suggested through the project. Some of these alternatives have been discussed from the very beginning of the project; some have been added throughout the project. The usage of distribution trucks, unification and technical load and unload assistance have all been discussed from the beginning. Interviews with Andersson (2006) have resulted in the alternative to separate part loads and terminal loads and findings from Görrel and Svensson (2001) resulted in the Charter alternative. Increased flexibility by using swap bodies was discussed during the interview with Johansson (2006) and increased flexibility using city trailers was suggested by Ehrning (2006). Discussions with Finn (2006) regarding Schenker's competitors resulted in an alternative to have Inter-district distribution, preferably over day (day zero).

### 5.2.1 Usage of Distribution Trucks in Terminal to Terminal Traffic

The current relations are served by different configurations of long haul trucks. These trucks may not always be the optimal ones to use for the goods flow required. There may also be other configurations that may decrease the overall transport costs, for instance usage of distribution trucks. These may be used exclusively for goods and parcels between terminals. They may also be used in freight peaks in order to increase overall capacity.

Distribution trucks used during the night would not need to accommodate some of the fixed costs that are not related to the distance driven. The capacity of the distribution truck is lower than that of the ordinary long haul truck combinations that are currently used. There are possibilities to attach a trailer or a semi-trailer with dolly to the distribution truck, if the truck engine can handle the total weight. When discussing terminal-to-terminal goods characteristics, this is not a problem, as the restrictions will be connected to the volume of the goods, not the weight. Increased use of distribution vehicles will increase the turnover per truck and per driven hours and by this decrease the fixed cost per kilometres. This is according to Donsellar *et al.* (1998) one of the critical success factors that will, if improved, lead to potentially better operational performance presented in their general transportation model.

### 5.2.2 City Trailers / More Flexible Loading Units

Efficiency may be increased by introducing more flexible loading units such as city trailers or perhaps swap bodies for the trucks. Benefits when using city trailers are that the tractor can pull two city trailers for long haul distances or to use only one for city distribution. City trailers can also be used in pairs for distribution. Both city trailers are driven to a parking lot in the area of the distribution. The truck then takes one of them and distributes. The driver then changes and distributes the goods from the other one.

This setup can be used to improve the overall network efficiency but in particular the time and distance efficiency discussed by Samuelsson & Tilanus (1997). Use of city trailers would increase the driving factor because of the fact that they do not need to unload their cargo at the terminals as well as they can deliver the bigger pallets and units first and still use the same vehicle for distributing the smaller consignments. The vehicle itself is flexible and is not restricted for city distribution. Other efficiencies that can be improved by the use of city trailers are the infrastructure factor, the routing factor and the detour factor.

A regular truck with trailer has the flexibility to leave the trailer at the terminal. The truck itself is not flexible since the whole truck has to be stationed at the terminal when loading or unloading, which makes the truck with trailer setup less flexible compared to a fleet with tractors and semi-trailers or city trailers. Usage of swap bodies is a possibility to increase the flexibility of the truck in a truck with trailer alternative.

### 5.2.3 Technical Load and Unload Assistance

Loading and unloading are time-consuming and thereby costly activities. There are technical solutions such as rolling floor or walking floor that can be implemented at the terminals and in the vehicles. Usage of these may increase the loading efficiency and decrease overall costs by being able to load and unload faster. When the goods flow is passing a node (or terminal) one should minimise the passive node time and aim at speeding up the active node time as much as possible according to Lumsden (1998). Using technical loading assistance is an attempt to decrease the time spent on unloading or loading the goods on the vehicles. Often the type of goods is a clear restriction when to use technical loading equipment. With large homogenised type of goods flow (Stora Enso, for example) this is a more suitable solution, but with a mixture of various kinds of goods the efficiency of such solution is not adding up the initially large investments and the adaptation of the terminals.

### 5.2.4 Unification

The theory behind making better and larger units states clearly that savings in time and effort at the terminals can be realized, as well as better utilization on the vehicles. The concept of unitification is formulated from the three aspects, transhipment, ergonomics, and cost/time reduction (Lumsden, 1989). The units should be created as early as possible and be broken up as late as possible in the freight flow.

In practise not all of the goods collected at the customers are arranged in good and easily stacked cargo units. This is instead often performed by the truck driver when loading the vehicles. By consolidation of the goods and the units, s/he is by experience and sound judgement making suitable units that is loaded in the vehicle. The possibility of making better units is largely depending of the nature of the cargo/goods. There may be possibilities to increase loading speed and utilization of the vehicles, if there would be a better way of making cargo units, either by external help from the terminal employees or increased requirements of the sender of the goods.

### 5.2.5 Load and Unload Assistance at Terminals

There may be ways to increase overall efficiency by implementing a system where the terminals handle all or parts of the loading and unload procedures. This setup is inspired by the charter (see Görrel & Svensson, 2001), where Schenker is responsible for unloading and loading the vehicles and just hire the space of the truck and the driver to perform the transport work. The main benefit is increased working efficiency per worker since they can load and unload the trucks in a more efficient order. The allocation of the terminal workforce can easily be adapted to the current departing schedule so trucks that need to leave early can be prioritized while the ones leaving later can be loaded later during the evening. This is not easy to achieve in a terminal where many extra functions such as kitting, sorting, coordination, consolidation, transhipment, sequencing, commercialising and warehousing are performed. Another factor is the dispersion of the truck traffic over the day that has an impact on how the terminal work should be performed (Lumsden, 1998).

According to Källström (2006) terminals have unused resources during the night shift. A less controversial alternative to a complete “Charter” implementation would be to let the terminals offer loading or unloading services to the hauliers for trucks leaving or arriving during time windows where they have unused resources. These services could be offered at comparatively good prices decreasing the overall cost for companies.

### 5.2.6 Separate the Flows of Part Loads and Terminal Goods

Separated part load flow and terminal goods flow may increase capacity and decrease costs in the Schenker network. The terminal-to-terminal traffic would be independent of the bulk loads flow. The trucks would have more capacity in terms of time to transport bulk loads before they pickup the consignments from the terminal. This would help Schenker and its hauliers to better cope with the increasing flow of goods. This proposed solution should be combined with more flexible loading units or increased usage of trailers.

### 5.2.7 Inter-district Day-Zero Distribution

There is a service called “Schenker near, day 0-distribution” (day-zero distribution) that Schenker offer the customers. The service means that pick up and delivery of the goods are made in the same day. The trucks are used to pick up goods from several customers and then transport it directly to next district for distribution. The main advantage is that only one operator handles the goods in the same way as the more heavy part load goods is handled. The short driving distance may make it feasible with zero-day distribution between closely related districts. According to Finn (2006) there is a competitor to Schenker in the Vänersborg area that uses a service similar to day-zero distribution between the Vänersborg region and Göteborg successfully. However, this service is not sold actively by Schenker’s sales force.

## *5.3 Transport Calculation Model*

The different transport setups will be calculated on using a developed model. This model will be based on costs for drivers and vehicles from SÅCalc 2006, loading, unloading and other data for Schenker and its terminals, goods volume and goods weight for the investigated relations, data for the relation between the typical size and weight of the goods and data for the capacity of the different types of trucks and transport setups possible as well as assumptions made based on information and data acquired through the thesis processes.

# 6 RESULTS

*The current chapter is presenting the results of the conducted investigations and research models that have been used to analyse the collected information and primary as well as secondary data.*

## 6.1 Transport Evaluation Alternatives and Criteria

The different evaluation criteria and the alternatives for improvement have been described in chapter five. These seven alternatives have been evaluated using the weight criteria method. The alternatives are:

1. Usage of distribution trucks in terminal to terminal traffic
2. City trailers/More flexible loading units
3. Technical load/unload assistance
4. Unit unification help at terminal
5. Terminal personnel handles loading/unloading ("Charter")
6. Separate part loads and terminal goods in the flow
7. Day-zero distribution between districts

These alternatives have been weighed against each other based on a number of criteria. The criteria have been evaluated against each other regarding which are the most important ones. The seven criteria evaluated are:

C1: Increased vehicle utilisation
C2: Potential of decreased operational costs
C3: Increased vehicle flexibility
C4: Working time optimisation
C5: Possibility to even out imbalances
C6: Increased network flexibility (line rights)
C7: Possibility to handle large freight peaks

## 6.2 Evaluation

Two independent evaluations using the evaluation method criteria have been done. One evaluation was performed by authors and another one by experts within the principal organisation.

**Table 11: Authors weighted criteria.**

| | Criteria | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | Corr | pi | ki (pi/∑pi) |
| C1 | 0 | 0 | 1 | 2 | 2 | 0 | 1 | 1 | 7 | 0,14 |
| C2 | | 0 | 2 | 2 | 1 | 1 | 2 | 3 | 11 | 0,22 |
| C3 | | | -3 | 1 | 0 | 0 | 0 | 5 | 3 | 0,06 |
| C4 | | | | -5 | 0 | 0 | 0 | 7 | 2 | 0,04 |
| C5 | | | | | -3 | 1 | 1 | 9 | 8 | 0,16 |
| C6 | | | | | | -2 | 1 | 11 | 10 | 0,20 |
| C7 | | | | | | | -5 | 13 | 8 | 0,16 |
| | | | | | | | | ∑: | 49 | 1,00 |

The authors rated the seven criteria according to the table above. The most important criteria were the potential of decreasing operational costs, increasing network flexibility, the possibility to handle large freight peaks and to even out imbalances.

**Table 12: Schenker weighted criteria.**

| | Criteria | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | Corr | pi | ki (pi/∑pi) |
| C1 | 0 | 2 | 2 | 0 | 2 | 2 | 2 | 1 | 11 | 0,22 |
| C2 | | -2 | 2 | 1 | 2 | 2 | 2 | 3 | 10 | 0,20 |
| C3 | | | -4 | 0 | 2 | 2 | 1 | 5 | 6 | 0,12 |
| C4 | | | | -1 | 2 | 2 | 1 | 7 | 11 | 0,22 |
| C5 | | | | | -8 | 1 | 0 | 9 | 2 | 0,04 |
| C6 | | | | | | -9 | 0 | 11 | 2 | 0,04 |
| C7 | | | | | | | -6 | 13 | 7 | 0,14 |
| | | | | | | | | ∑: | 49 | 1,00 |

Schenker rated their criteria differently. The potential of decreased operational costs was still important, but even more important was to increase the vehicle utilisation and to optimize working hours.

**Table 13: Alternatives by authors.**

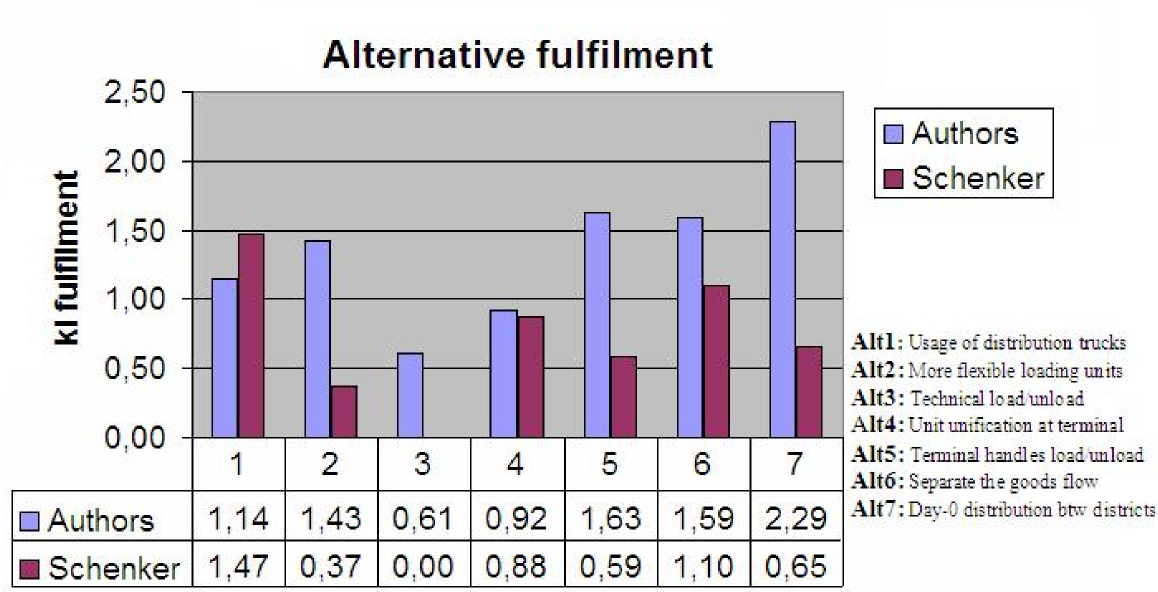
| | Criteria | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | ∑:fulfilment | ki fulfilment |
| | 14% | 22% | 6% | 4% | 16% | 20% | 16% | | |
| Alt1 | 3 | 1 | 2 | 1 | 0 | 0 | 2 | 9 | 1,143 |
| Alt2 | 3 | 2 | 3 | 1 | 0 | 0 | 2 | 11 | 1,429 |
| Alt3 | 1 | 1 | 0 | 2 | 0 | 0 | 1 | 5 | 0,612 |
| Alt4 | 2 | 1 | 0 | 2 | 0 | 0 | 2 | 7 | 0,918 |
| Alt5 | 2 | 3 | 1 | 3 | 0 | 0 | 3 | 12 | 1,633 |
| Alt6 | 2 | 1 | 1 | 3 | 0 | 2 | 3 | 12 | 1,592 |
| Alt7 | 1 | 3 | 2 | 2 | 2 | 3 | 2 | 15 | 2,286 |

The authors suggests inter-district day zero distribution as the most beneficial alternative to investigate and implement. The authors also suggest implementing more flexible loading units, having terminal personnel doing loading and unloading, to use distribution trucks in terminal to terminal traffic and to separate the flows as alternative solution.

**Table 14: Alternatives by Schenker.**

| | Criteria | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | ∑:fulfilment | ki fulfilment |
| | 22% | 20% | 12% | 22% | 4% | 4% | 14% | | |
| Alt1 | 3 | 1 | 1 | 0 | 0 | 1 | 3 | 9 | 1,469 |
| Alt2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0,367 |
| Alt3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,000 |
| Alt4 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 4 | 0,878 |
| Alt5 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 3 | 0,592 |
| Alt6 | 1 | 1 | 1 | 1 | 1 | 0 | 2 | 7 | 1,102 |
| Alt7 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 3 | 0,653 |

Schenker believes that usage of distribution trucks is the alternative that best fulfils the requirements. Separated flows and terminal unit unification may also be of interest in the future.




**Graph 2: Comparison between the two evaluations of alternative fulfilment.**

There are major differences between the two compared evaluations. One major reason may be that the authors have taken a wider and more general approach towards the criteria and the alternatives evaluated compared to the personnel at Schenker. Schenker's evaluation was to a larger extent based on their thoughts regarding the restrictions that the different alternatives have and which ones they personally believed were the best ones to investigate further and to implement.

When the evaluation is compared with the sources of the seven alternatives one can find that Schenker have given the alternatives that were not suggested by them a low score. The alternatives suggested by Schenker got a relatively high score.

The authors have given their best score to an alternative not suggested by Schenker. This alternative as well as other alternatives that scored better in the author's evaluation compared to Schenker's evaluation requires more fundamental changes to the organisation and the transport setup. These changes may either be very difficult to implement into a complex system such as Schenker's network, which Schenker's personnel know, or that they are controversial within the company.

## 6.3 Truck Transport Model

Different types of trucks and trailers can produce the transport work. The relations are different regarding type of goods, amount of goods and driving distance. The main focus of this model is to evaluate the costs generated by using different types of trucks in terminal-to-terminal transports.

The ten different relations being investigated give similar results in the calculation model. The number of relations was therefore decreased to three. The three relations chosen were the three relations between Göteborg, Borås and Vänersborg since these terminals have been visited.

### 6.3.1 Distribution Trucks

One of the main focuses of the report is to investigate distribution trucks as an alternative to the current transport setup. The main focus has been to create a model describing the different costs of using distribution trucks compared to traditional long haul trucks. The model has been developed using SÅCalc, SÅ Index, transport data from Schenker (2005) and information from Volvo 3P, Schenker and hauliers in order to find representative values for different aspects and costs for the trucks.

The data gathered shows the total freight volume of 2005. This data has been used to calculate the average freight volume per month and day. The year has been assumed to have 240 working days.

**Calculation Data**

The data used in the calculation is for 2005 and 240 working days. According to Andersson (2006) the goods are 1100 kg/floor meter. Loading speed at the Schenker terminals is 4 floor meters per hour, unloading speed is 6 floor meters per hour (Waldermarsson, 2006). Average speed for the Schenker line haul trucks are 72 km/h (Andersson, 2006). An additional 20 minute's driving time is added for each trip. Using SÅ Calc, combined day and night working hours, overhead and values for wages supplied by Carlsson (2006) were drivers' costs set at 254 SEK/hour. The goods volume from Vänersborg to Göteborg was decreased by 15% because of the goods not having Göteborg as the final destination (Andersson, 2006). Goods from Borås to Vänersborg and back are decreased by 20% because of the goods not receiving the terminal (Andersson, 2006). All loading and unloading are assumed to be done by the driver and costs associated with damaged goods are not included.

The mileage cost of the different truck types have been calculated using altered numbers from the SÅCalc standard examples, see Appendix II. The vehicles mileage and driving time per year have been altered to better fit into the short relations that the vehicles are used for.

The distribution truck data has been modified regarding the mileage, insurance, maintenance and other costs. One distribution truck has been calculated in day traffic with extra mileage driven. Another one has been calculated based on the same assumptions, but when it is pulling a trailer. These two costs have been combined in a new fixed total cost for the vehicle. The new vehicle has then been calculated using the increased fuel consumption generated when pulling a trailer. This calculated vehicle cost is used when calculating the cost of using distribution trucks with trailer in terminal to terminal traffic during the night. The calculated cost per kilometre for the distribution trucks used is only valid on short terminal to terminal relations. See Appendix III for calculated values.

The distribution trucks used in nightly terminal to terminal traffic have higher variable costs and lower fixed costs compared to line haul trucks. The distribution trucks would therefore become more expensive compared to the long haul trucks on longer distances.

The number of vehicle combinations needed is rounded upwards meaning that there is always spare capacity in the system, even though it may be very small. The spare capacity in floor meters is presented in a graph below the costs for each relation.

Imbalances in the relations have not been taken into account in the model regarding number of trucks. If one of the relations require more trucks in one direction than the relation requires back again is it assumed, on these short distances, that the haulier can use the truck in some other transport or terminal relation.

The model calculates the freight transported for each relation for every working day. The freight is recalculated into floor metres using the value presented above. The time to load and unload this freight is calculated as well as the number of vehicle combinations needed to handle the freight, rounded upwards. The driving time is calculated based on the distance, the average speed and additional time for entering and leaving the terminal. The cost for the different vehicle combinations is calculated based on the number of vehicles needed, the time required to load and unload the freight, the driving time per vehicle, the drivers wage and the cost for driving the vehicle.

### Evaluated Truck Combinations

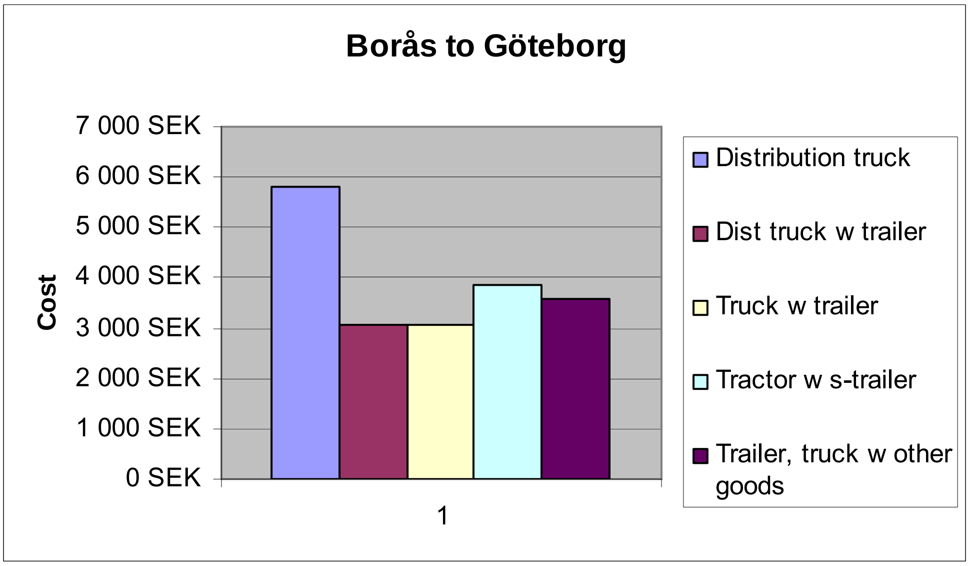
The different vehicle combinations and their loading area in floor meters used in the calculations are shown in the table 34 below.

**Table 15: Vehicle combinations.**

| Vehicle combinations | Loading area (fl m) |
|---|---|
| Distribution truck | 6.46 |
| Distribution truck with trailer | 19.11 |
| Line haul truck with trailer | 20.15 |
| Tractor with semi-trailer | 13.4 |
| Trailer, with line haul truck driving part loads | 12.65 |

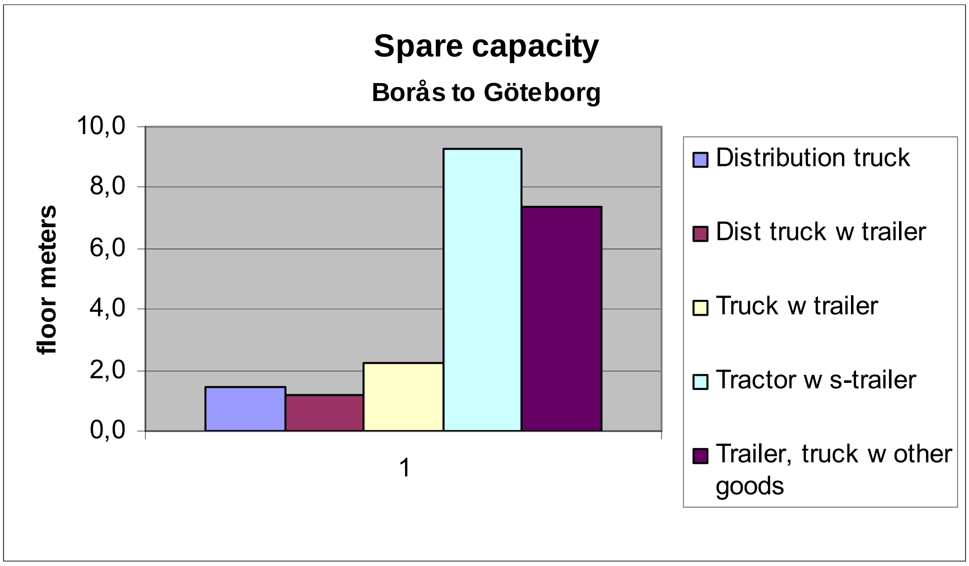
### 6.3.2 Results of Truck Calculations

The results presented in the graphs below show the total cost for producing the transport service required between origin and destination per day using the different types of vehicles. The results for the different relations are similar, therefore only the most interesting and representative results are presented below.



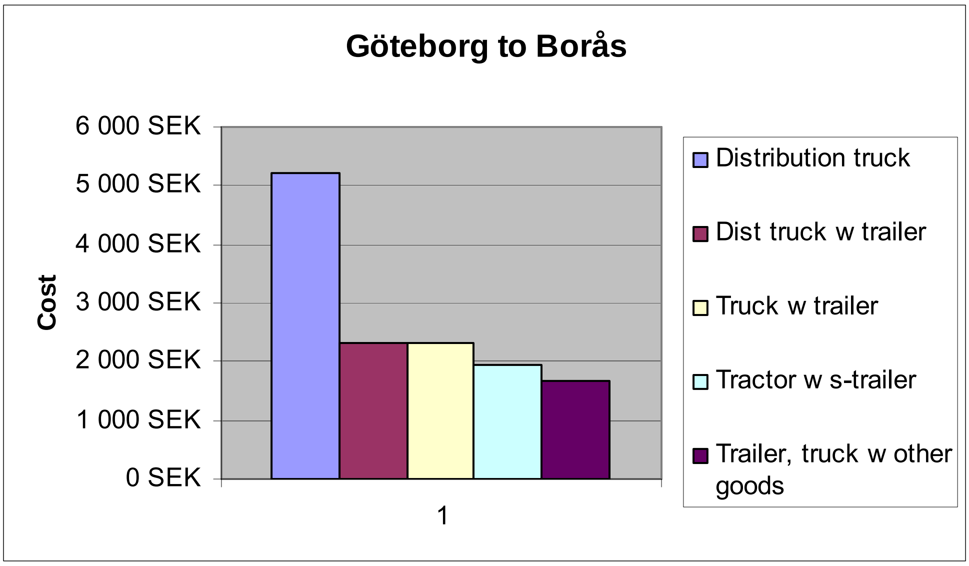

**Graph 3: Cost for Borås → Göteborg.**

Graph 35 showing Borås to Göteborg traffic is representative for the typical terminal to terminal relation. The truck with trailer and the distribution truck with trailer have similar costs. The main difference between truck with trailer and distribution truck with trailer is the capacity that differs slightly between the two combinations.



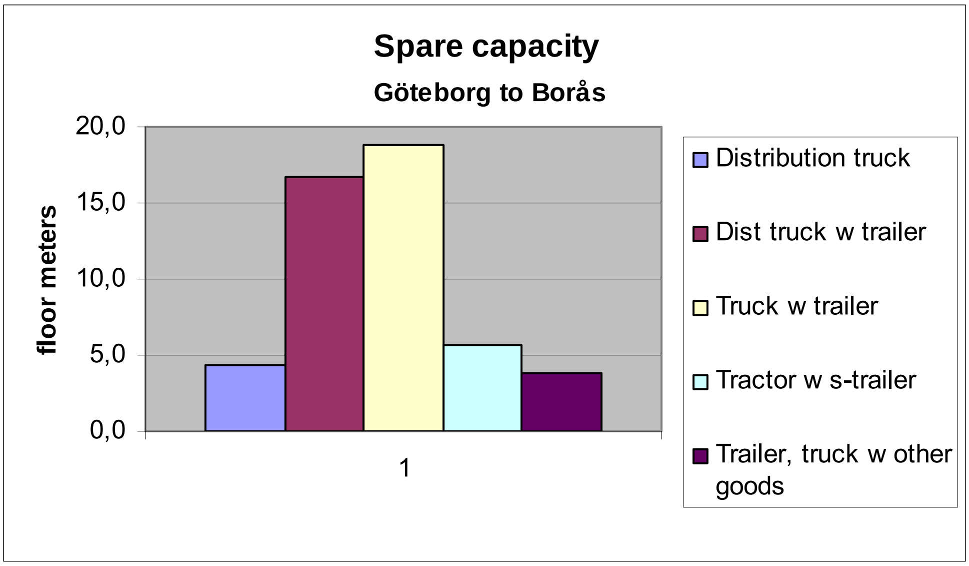

**Graph 4: Spare capacity for Borås → Göteborg.**

One can see the difference in spare capacity. The difference between a distribution truck with trailer and a regular truck with trailer is relatively small. There is a marginal effect regarding the spare capacity and the overall costs since one solution needs another vehicle combination while the one comparing it with doesn't.



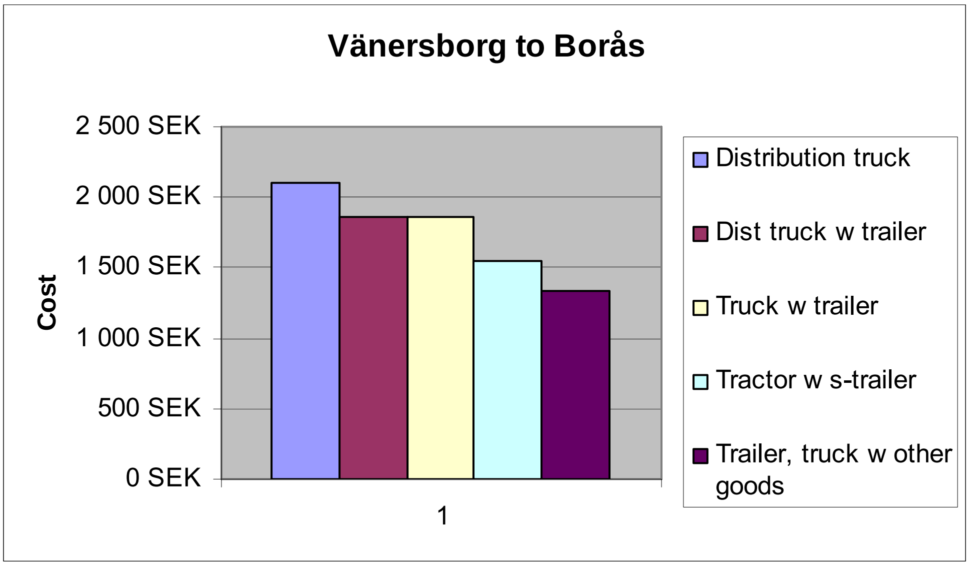

**Graph 5: Cost for Göteborg → Borås.**

When comparing the costs associated with the Göteborg to Borås and back again relation one can see that truck with trailer is cheaper on one way while tractor with semi-trailer is cheaper on the way back. This is typically a result of the marginal effect. Using the truck with trailer, where only the trailer is used for terminal goods is often a cost efficient way to handle the terminal goods.



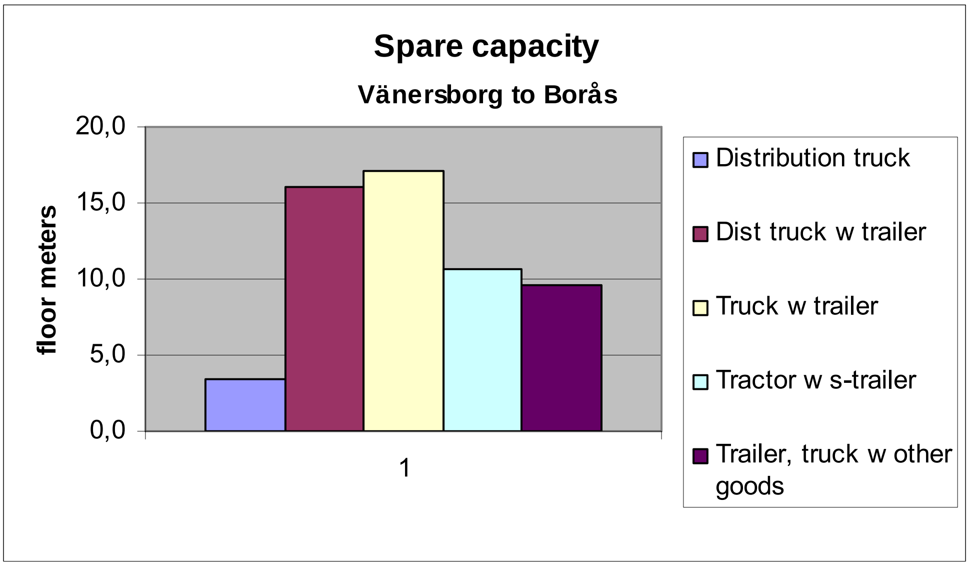

**Graph 6: Spare capacity for Göteborg → Borås.**

Here one can see the reason why distribution truck with trailer and truck with trailer are more expensive than the tractor and the trailer setups. The reason is the spare capacity generated with those setups compared to tractor with semi-trailer.




**Graph 7: Cost for Vänersborg → Borås.**

The Vänersborg to Borås graph was included to show that there may be situations where single distribution trucks are not that much more expensive than in other ways of producing the transport service. The reason is that the larger vehicle combinations are not as flexible regarding small freight volumes as distribution trucks. The best alternative would be to use a larger vehicle combination combined with an extra distribution truck handling the extra capacity needed.

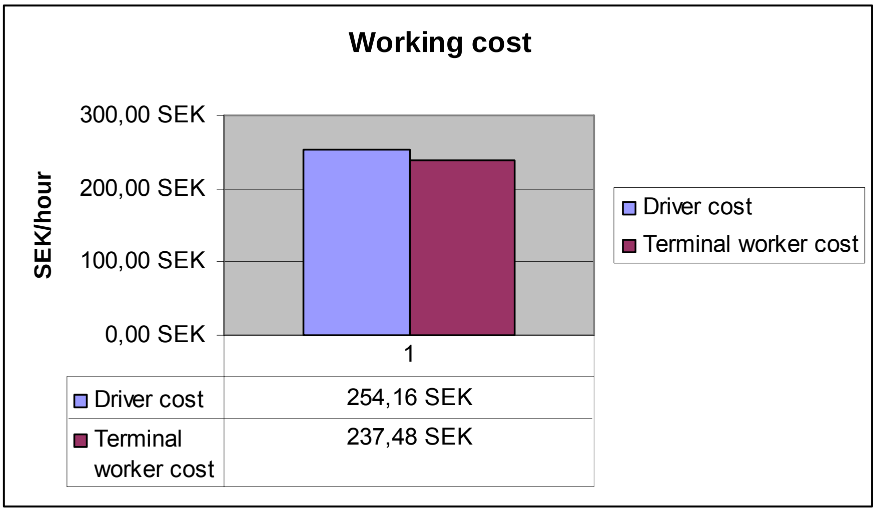



**Graph 8: Spare capacity for Vänersborg → Borås.**

The spare capacity is huge on the all alternatives except the small distribution truck. One alternative would, as mentioned above, be to combine a larger vehicle with a small distribution truck.

### 6.3.3 Load and Unload Costs

The cost associated with loading and unloading is mainly because of the worker wage. The overall cost of the driver and the terminal worker with overhead costs is presented in the table below. The costs are from SÅCalc 2006 and modified in collaboration with Carlsson (2006). The costs for a terminal worker are in line with the costs presented by Nilssen (2006).

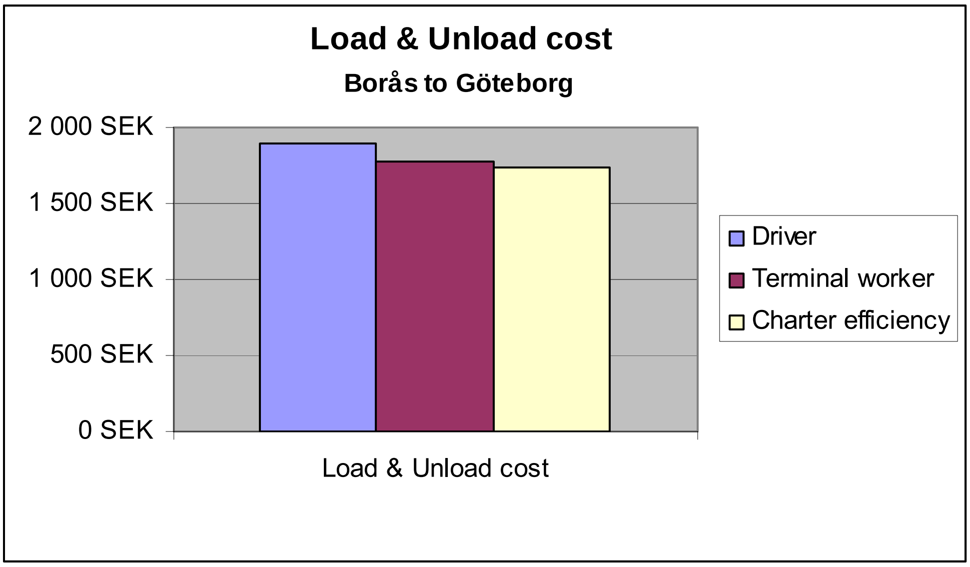



**Graph 9: Comparison between costs associated with drivers and terminal workers.**

One can clearly see that the cost of having a driver is slightly higher than it is for a terminal worker. The terminal worker needs experience of the process of loading a truck efficiently before he or she can do it as efficient as a truck driver.

Görrel & Svensson (2001) measured and presented decreased average loading time and increased efficiency when having terminal workers doing the loading process. Their findings show that the average time spent on loading decreases from 2.42 minutes per shipment to 2.36 minutes per shipment. Terminal personnel are on average 2,6% more efficient than truck drivers regarding loading.

The graph below compares the loading and unloading cost for Borås to Göteborg when using the driver’s cost of doing it, a terminal worker doing it or terminal workers doing it in a Charter organisation.




**Graph 10: Different load and unload costs.**

The graph 42 shows that there is a potential of decreasing the overall loading and unloading cost in the network. This can be done by changing the organisation into a more "charter" like system for the loading and unloading procedure.

# 7 DISCUSSION & CONCLUSION

*In the chapter the conclusions of the undertaken research are presented in a logical and structured way.*

The use of distribution trucks is a valid alternative to the use of line-haul trucks on short terminal to terminal relations. The calculations show that the cost for operating this part of the network with distribution trucks is almost the same as to use line-haul trucks. The capacity of the distribution truck with trailer is slightly lower than using line-haul trucks. Significant cost reductions are hard to realise due to the fact that a distribution vehicle with trailer has higher mileage cost and increased fuel consumption compared to a line-haul truck. The savings from the decreased fixed cost per kilometre can almost make up for the increased variable cost per kilometre, but no further cost savings can be achieved.

In terms of validity and reliability of the results, the empirical parts of the quantitative research, i.e. the distribution truck usage calculations can be seen as representative and reliable because they are based on industry standard, and tuned to fit the organisations' situation in terms of the chosen relations and vehicle technicalities. The calculations can easily be conducted for other relations in the network, by alter the distances and certain special exceptions related to the network and the relations.

The use of distribution trucks could work as an ad hoc solution for temporary freight peaks. This alternative can serve as a flexible solution for the hauliers when having capacity problems for the part loads. Instead of always having to prioritize the terminal goods first the haulier can call Schenker or the haulier responsible for distribution in the area for help. An extra distribution truck with or without trailer can solve the terminal goods that day. Revenues, service and customer satisfaction would likely increase from such a configuration.

This can be combined with, for example, a modification in the transport operations schedule. The distribution trucks can be loaded late in the evening and leaving early in the morning so they can start their distribution operations directly when arriving to the destination district. The savings of doing this would be of more significant nature as the cost of the destination terminal activities are kept to a minimum or zero. This can be combined with a solution where the part loads and the terminal-to-terminal goods flows are separated, if possible, depending on the freight volumes.

Increased efficiency and the flexibility in the network can be achieved by using swap bodies as a supplement cargo bearer. They would increase the flexibility in the terminal loading process and thus lower the costs. This is something that Schenker can utilise better than they are doing today according to several conducted interviews. Another way of increasing flexibility in the network is to use the city trailer in the transport and distribution operations. The advantage is the flexible use of the vehicle combination using a tractor with double city trailer equipage. This combination allows for using the tractor with single trailer for district distribution during the daytime, either by only using one city trailer or by bringing two city trailers to the destination area. One city trailer can be parked while the other one is distributed; the driver then switch city trailer and distribute the other one. The same equipage (tractor with double city trailers) can be better utilised during night on short terminal-to-terminal relations.

In a long-term perspective Schenker ought to review if there are possibilities to implement the more controversial alternatives presented in this report, such as the question of line-rights, inter district day zero distribution and the implementation of using the charter setup. Maybe the creation of a sub network on short relations where sufficient freight flows exist could be considered as a solution for the future. These solutions require big bold changes in the present organisation and can therefore be labelled as “controversial” and difficult to implement within the company.

The alternative of implementing a technical loading assistance solution is not seen as fulfilling the criteria of making the loading process faster or more flexible. Due to the small savings with rather high initial investments this alternative is rejected by the conducted research. Technical loading assistance suits large homogeneous goods flows. As the goods flow is ranging from consignments from one kilo to massive pallets up to several tonnes, Schenker’s network is too dispersed to be convenient for technical loading devices as walking floors.

Unification of the goods at terminals is not likely a viable option for decreasing costs. Time spent on stacking different types of goods on top of each other is the same regardless of when the process takes place. Total loading time would likely increase if unification takes place before loading instead of doing the processes at the same time. The only benefit of having a separate unification processes at the terminal would be to decrease the space required at the terminal. Overall cost saving activities should instead be focused on increasing the speed at which the workers can load and unload the trucks. The workers wage is the most costly part of these short distance terminal to terminal relations. Further work should focus on increasing the speed of loading and unloading the trucks. Usage of new and better information systems can make it possible for the person loading to know how much goods there is that day. If the entire truck capacity is not needed, the loading speed can likely be increased as less time has to be spent on unification of the goods.

The terminal can easily help the hauliers without major changes of the operation organisation. Already today assistance to certain small hauliers can be given. Regarding the coordination of resources on the terminal this is easier in times of low workload. At peaks coordination will be harder to handle and an increase in resources might be difficult to avoid. However, late at night, when utilisation of resources at the terminal is low, there are good possibilities to help with the unload process for arriving trucks. Utilising these resources better will decrease overall costs for the companies involved in the transport chains. This solution would not only decrease costs but also strengthen the bonds between the hauliers and the terminals, which can be used as a first step towards a possible future charter setup.

## 7.1 Recommendations

We recommended Schenker to use distribution trucks with trailers as an alternative to long haul trucks on short terminal to terminal relations. These trucks can also be used to increase the capacity when needed within the network. Schenker can then offer their hauliers to concentrate on the bulk goods while they arrange an extra shipment with terminal goods using a distribution vehicle. Schenker should further investigate when and how much unused resources they have at their terminals. Trucks leaving or arriving at the terminal at these times should be offered load and unload assistance at a good price. This measure would decrease the total cost for the companies involved in the transport chain. If the hauliers are satisfied with the terminals doing some loading or unloading, it might be easier to implement a charter-based network in the future. Future plans should involve new and more flexible carrier units in an effort to implement a more cost efficient setup. One such measure would be to use tractors with one or two city trailers attached, depending on whether they are doing a long haul transport or distribution. Swap bodies is another alternative way to increase flexibility.

Line haul rights should be reviewed in order to decrease problems and costs associated with the strict rules. Increased consolidation on routes overlapping where there is more than one haulier operating would decrease costs. One such route is along the West coast from Malmö passing Helsingborg, Halmstad, Göteborg to Vänersborg.

The inter district day zero distribution product should be marketed further to support growth between districts. This would probably gain Schenker in many aspects, more cross selling in this service at already existing customers, but also attract new customers with certain needs. In addition, it would decrease overall costs. One way to start would be to decrease the weight limit for when goods is picked up by the line haul trucks instead of the distribution trucks.

## 7.2 Future Research Opportunities

During the numerous interviews and the research process writing the present masters thesis, a number of areas has been touched upon where it is interesting to conduct further more in-dept analysis and research. These are outside the scope of this project, whereas they are presented here, so they can be served as potential research topics for the future. A division between economical, operational and human resource management subjects has been done.

**Economical**

Further investigate the NAV system (New revenue division model) how to change the allocation of monetary flow within the NAV-system to better represent the real incomes and costs in Schenker's business model and network.

**Operational**

How can Schenker use swap-bodies in the operational process to increase efficiency and effectiveness as well as network flexibility? Investigation should include the cost of investments of existing or new technology versus the gains in efficiency & effectiveness. Another area is the line haul right. Is it really effective to let certain hauliers drive certain areas within pickup-, distribution-, and long haul relations? Evaluate the long-term relationship system of today's contracted hauliers and the more effective use of resources in Schenker's network system tomorrow.

**Human Resource Management**

From a personnel perspective, study how to involve truck drivers more in decision making around the transport process by involving them in economical statistics. Around 40% of the costs are related to the truck driver's wage. What can be done to produce the transportation services more effectively when focusing on driver time optimization?

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# APPENDIX A: TABLE OF DISTANCES IN SCHENKER'S SWEDISH NETWORK

| Distance (km) | Borlänge | Borås | Gävle | Göteborg | Halmstad | Helsingborg | Hultsfred | Jönköping | Kalmar | Karlstad | Kristianstad | Linköping | Luleå | Malmö | Skara | Skellefteå | Stockholm | Sundsvall | Umeå | Vänersborg | Värnamo | Västerås | Växjö | Örebro | Örnsköldsvik | Östersund |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Borlänge | | 408 | 111 | 443 | 520 | 609 | 389 | 374 | 506 | 209 | 601 | 275 | 851 | 665 | 315 | 714 | 216 | 315 | 579 | 366 | 444 | 133 | 492 | 161 | 469 | 383 |
| Borås | 408 | | 485 | 64 | 152 | 229 | 207 | 83 | 280 | 261 | 274 | 212 | 1225 | 285 | 95 | 1088 | 406 | 689 | 953 | 106 | 105 | 345 | 171 | 248 | 843 | 760 |
| Gävle | 111 | 485 | | 520 | 597 | 686 | 442 | 451 | 537 | 321 | 678 | 327 | 745 | 742 | 392 | 608 | 174 | 210 | 473 | 463 | 521 | 146 | 569 | 239 | 364 | 388 |
| Göteborg | 443 | 64 | 520 | | 140 | 217 | 270 | 147 | 343 | 256 | 262 | 276 | 1259 | 273 | 128 | 1122 | 469 | 724 | 987 | 87 | 169 | 379 | 235 | 283 | 878 | 794 |
| Halmstad | 520 | 152 | 597 | 140 | | 79 | 234 | 164 | 240 | 393 | 124 | 308 | 1336 | 135 | 265 | 1199 | 502 | 801 | 1064 | 225 | 111 | 456 | 131 | 360 | 955 | 883 |
| Helsingborg | 609 | 229 | 686 | 217 | 79 | | 288 | 235 | 294 | 470 | 106 | 362 | 1425 | 65 | 341 | 1288 | 556 | 889 | 1153 | 301 | 169 | 545 | 185 | 448 | 1043 | 976 |
| Hultsfred | 389 | 207 | 442 | 270 | 234 | 288 | | 123 | 115 | 323 | 230 | 116 | 1182 | 300 | 219 | 1045 | 313 | 646 | 910 | 280 | 138 | 302 | 105 | 229 | 800 | 824 |
| Jönköping | 374 | 83 | 451 | 147 | 164 | 235 | 123 | | 212 | 243 | 228 | 128 | 1191 | 292 | 95 | 1054 | 322 | 655 | 919 | 156 | 71 | 311 | 119 | 214 | 809 | 742 |
| Kalmar | 506 | 280 | 537 | 343 | 240 | 294 | 115 | 212 | | 437 | 191 | 230 | 1279 | 285 | 310 | 1142 | 410 | 743 | 1007 | 371 | 177 | 399 | 109 | 343 | 897 | 922 |
| Karlstad | 209 | 261 | 321 | 256 | 393 | 470 | 323 | 243 | 437 | | 469 | 217 | 1060 | 527 | 167 | 923 | 314 | 525 | 788 | 160 | 312 | 209 | 361 | 112 | 679 | 557 |
| Kristianstad | 601 | 274 | 678 | 262 | 124 | 106 | 230 | 228 | 191 | 469 | | 354 | 1417 | 96 | 321 | 1279 | 548 | 881 | 1144 | 346 | 161 | 536 | 127 | 440 | 1035 | 968 |
| Linköping | 275 | 212 | 327 | 276 | 308 | 362 | 116 | 128 | 230 | 217 | 354 | | 1067 | 420 | 224 | 930 | 198 | 531 | 795 | 285 | 199 | 187 | 220 | 116 | 685 | 710 |
| Luleå | 851 | 1225 | 745 | 1259 | 1336 | 1425 | 1182 | 1191 | 1279 | 1060 | 1417 | 1067 | | 1482 | 1132 | 138 | 913 | 536 | 273 | 1203 | 1261 | 886 | 1309 | 979 | 383 | 585 |
| Malmö | 665 | 285 | 742 | 273 | 135 | 65 | 300 | 292 | 285 | 527 | 96 | 420 | 1482 | | 398 | 1344 | 613 | 946 | 1210 | 358 | 226 | 601 | 198 | 505 | 1100 | 1033 |
| Skara | 315 | 95 | 392 | 128 | 265 | 341 | 219 | 95 | 310 | 167 | 321 | 224 | 1132 | 398 | | 995 | 357 | 596 | 860 | 84 | 165 | 252 | 213 | 155 | 750 | 667 |
| Skellefteå | 714 | 1088 | 608 | 1122 | 1199 | 1288 | 1045 | 1054 | 1142 | 923 | 1279 | 930 | 138 | 1344 | 995 | | 776 | 398 | 135 | 1065 | 1123 | 748 | 1171 | 841 | 245 | 463 |
| Stockholm | 216 | 406 | 174 | 469 | 502 | 556 | 313 | 322 | 410 | 314 | 548 | 198 | 913 | 613 | 357 | 776 | | 377 | 641 | 429 | 391 | 108 | 439 | 204 | 531 | 556 |
| Sundsvall | 315 | 689 | 210 | 724 | 801 | 889 | 646 | 655 | 743 | 525 | 881 | 531 | 536 | 946 | 596 | 398 | 377 | | 263 | 667 | 724 | 349 | 773 | 442 | 154 | 189 |
| Umeå | 579 | 953 | 473 | 987 | 1064 | 1153 | 910 | 919 | 1007 | 788 | 1144 | 795 | 273 | 1210 | 860 | 135 | 641 | 263 | | 930 | 988 | 613 | 1037 | 706 | 110 | 384 |
| Vänersborg | 366 | 106 | 463 | 87 | 225 | 301 | 280 | 156 | 371 | 160 | 346 | 285 | 1203 | 358 | 84 | 1065 | 429 | 667 | 930 | | 226 | 323 | 274 | 226 | 821 | 704 |
| Värnamo | 444 | 105 | 521 | 169 | 111 | 169 | 138 | 71 | 177 | 312 | 161 | 199 | 1261 | 226 | 165 | 1123 | 391 | 724 | 988 | 226 | | 381 | 68 | 284 | 879 | 812 |
| Västerås | 133 | 345 | 146 | 379 | 456 | 545 | 302 | 311 | 399 | 209 | 536 | 187 | 886 | 601 | 252 | 748 | 108 | 349 | 613 | 323 | 381 | | 429 | 99 | 504 | 528 |
| Växjö | 492 | 171 | 569 | 235 | 131 | 185 | 105 | 119 | 109 | 361 | 127 | 220 | 1309 | 198 | 213 | 1171 | 439 | 773 | 1037 | 274 | 68 | 429 | | 331 | 927 | 860 |
| Örebro | 161 | 248 | 239 | 283 | 360 | 448 | 229 | 214 | 343 | 112 | 440 | 116 | 979 | 505 | 155 | 841 | 204 | 442 | 706 | 226 | 284 | 99 | 331 | | 594 | 549 |
| Örnsköldsvik | 469 | 843 | 364 | 878 | 955 | 1043 | 800 | 809 | 897 | 679 | 1035 | 685 | 383 | 1100 | 750 | 245 | 531 | 154 | 110 | 821 | 879 | 504 | 927 | 594 | | 257 |
| Östersund | 383 | 760 | 388 | 794 | 883 | 976 | 824 | 742 | 922 | 557 | 968 | 710 | 585 | 1033 | 667 | 463 | 556 | 189 | 384 | 704 | 812 | 528 | 860 | 549 | 257 | |
| Green = <200km | 3 | 7 | 3 | 6 | 8 | 5 | 5 | 9 | 4 | 3 | 6 | 6 | 1 | 4 | 7 | 2 | 3 | 2 | 2 | 5 | 11 | 5 | 9 | 5 | 2 | 1 |
| Red = >=200km | 22 | 18 | 22 | 19 | 17 | 20 | 20 | 16 | 21 | 22 | 19 | 19 | 24 | 21 | 18 | 23 | 22 | 23 | 23 | 20 | 14 | 20 | 16 | 20 | 23 | 24 |
| Green relations | 62 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Red relations | 263 | | | | | | | | | | | | | | | | | | | | | | | | | |

Green relations are < 200 km apart, red relations are > 200 km apart.

# APPENDIX B: SÅ CALC VEHICLE CALCULATIONS 1-4

**GRUNDUPPGIFTER**

Developed short distance distribution truck

| Användning per år | | Spec |
|---|---|---|
| Timmar | | 3 500 |
| Mil | | 4 500 |

| Investeringen | | ☑ Spec |
|---|---|---|
| Nuanskaffningskostnad | | 1 127 400 |
| Livslängd, år | | 6,78 |
| Restvärde, kr | | 100 000 |
| Andel fast avskrivning % | | 85% |
| Ränta % | | 5,00% |

| Drivmedel | | Spec |
|---|---|---|
| Förbrukning liter per mil | | 3,50 |
| Pris per liter | | 8,00 |

| Övrig fasta kostnader per år | Spec | kr/år |
|---|---|---|
| Fordonskatt och vägavg | ☑ | 32 343 |
| Försäkringar, skador | ☑ | 40 000 |
| Övriga fasta kostnader | ☑ | 26 000 |

| Sträckberoende rörliga kostnader | Spec | kr/mil |
|---|---|---|
| Däck | ☑ | 4,30 |
| Reparation och service | ☑ | 18,12 |
| Övriga rörliga kostnader | ☐ | |

| Tidsberoende rörliga kostnader | Spec | kr/tim |
|---|---|---|
| | ☐ | |

Infoga sammandrag från SÅcalcs meny

**KALKYL**

| Fasta Fordonskostnader | kr/år |
|---|---|
| Avskrivning, fast del | 128 425 |
| Räntekostnad | 30 685 |
| Fordonskatt | 32 343 |
| Försäkringar, skador | 40 000 |
| Övriga fasta kostnader | 26 000 |
| Leasing | |
| Totala fastakostnader | 257 453 |
| Fast kostnad per anv tim | 73,56 |

| Sträckberoende rörliga kostn. | kr/mil |
|---|---|
| Avskrivning | 5,13 |
| Däck | 4,30 |
| Reparation och service | 18,12 |
| Drivmedel | 28,00 |
| Övriga rörliga kostnader | 0,00 |
| Summa rörliga kostnader | 55,55 |

| Tidsberoende rörliga kostn. | kr/tim |
|---|---|
| | 0,00 |

| Kostnad per år | kr |
|---|---|
| Fasta Fordonkostnader | 257 453 |
| Rörliga milberoende kost. | 249 993 |
| Rörliga tidberoende kost. | 0 |
| Total årskostnad | 507 446 |

*Totalt per mil 112,76 kr, per tim 144,98 kr.*

Calculation I: Developed short distance distribution truck

**GRUNDUPPGIFTER**

Developed short distance distribution truck w trailer

| Användning per år | | Spec |
|---|---|---|
| Timmar | | 3 500 |
| Mil | | 4 500 |

| Investeringen | | ☑ Spec |
|---|---|---|
| Nuanskaffningskostnad | | 1 663 000 |
| Livslängd, år | | 6,78 |
| Restvärde, kr | | 100 000 |
| Andel fast avskrivning % | | 85% |
| Ränta % | | 5,00% |

| Drivmedel | | Spec |
|---|---|---|
| Förbrukning liter per mil | | 5,00 |
| Pris per liter | | 8,00 |

| Övrig fasta kostnader per år | Spec | kr/år |
|---|---|---|
| Fordonskatt och vägavg | ☑ | 46 713 |
| Försäkringar, skador | ☑ | 52 500 |
| Övriga fasta kostnader | ☑ | 31 500 |

| Sträckberoende rörliga kostnader | Spec | kr/mil |
|---|---|---|
| Däck | ☑ | 6,06 |
| Reparation och service | ☑ | 22,39 |
| Övriga rörliga kostnader | ☐ | |

| Tidsberoende rörliga kostnader | Spec | kr/tim |
|---|---|---|
| | ☐ | |

Infoga sammandrag från SÅcalcs meny

**KALKYL**

| Fasta Fordonskostnader | kr/år |
|---|---|
| Avskrivning, fast del | 195 375 |
| Räntekostnad | 44 075 |
| Fordonskatt | 46 713 |
| Försäkringar, skador | 52 500 |
| Övriga fasta kostnader | 31 500 |
| Leasing | |
| Totala fastakostnader | 370 163 |
| Fast kostnad per anv tim | 105,76 |

| Sträckberoende rörliga kostn. | kr/mil |
|---|---|
| Avskrivning | 7,81 |
| Däck | 6,06 |
| Reparation och service | 22,39 |
| Drivmedel | 40,00 |
| Övriga rörliga kostnader | 0,00 |
| Summa rörliga kostnader | 76,26 |

| Tidsberoende rörliga kostn. | kr/tim |
|---|---|
| | 0,00 |

| Kostnad per år | kr |
|---|---|
| Fasta Fordonkostnader | 370 163 |
| Rörliga milberoende kost. | 343 152 |
| Rörliga tidberoende kost. | 0 |
| Total årskostnad | 713 315 |

*Totalt per mil 158,51 kr, per tim 203,8 kr.*

Calculation 2: Developed distribution truck with trailer

## GRUNDUPPGIFTER

Developed long haul truck

| Användning per år | Spec | |
|---|---|---|
| Timmar | | 3 000 |
| Mil | | 5 000 |

| Investeringen | Spec ☑ | |
|---|---|---|
| Nuanskaffningskostnad | | 1 730 000 |
| Livslängd, år | | 8,00 |
| Restvärde, kr | | 120 000 |
| Andel fast avskrivning % | | 80% |
| Ränta % | | 5,00% |

| Drivmedel | Spec | |
|---|---|---|
| Förbrukning liter per mil | | 4,40 |
| Pris per liter | | 8,00 |

| Övrig fasta kostnader per år | Spec | kr/år |
|---|---|---|
| Fordonskatt och vägavg | ☑ | 38 434 |
| Försäkringar, skador | ☑ | 57 500 |
| Övriga fasta kostnader | ☑ | 34 750 |

| Sträckberoende rörliga kostnader | Spec | kr/mil |
|---|---|---|
| Däck | ☑ | 4,24 |
| Reparation och service | ☑ | 17,40 |
| Övriga rörliga kostnader | ☐ | |

| Tidsberoende rörliga kostnader | Spec | kr/tim |
|---|---|---|
| | ☐ | |

*Infoga sammandrag från SÅcalcs meny*

## KALKYL

| Fasta Fordonskostnader | kr/år |
|---|---|
| Avskrivning, fast del | 161 000 |
| Räntekostnad | 46 250 |
| Fordonskatt | 38 434 |
| Försäkringar, skador | 57 500 |
| Övriga fasta kostnader | 34 750 |
| Leasing | |
| Totala fastakostnader | 337 934 |
| Fast kostnad per anv tim | 112,64 |

| Sträckberoende rörliga kostn. | kr/mil |
|---|---|
| Avskrivning | 8,04 |
| Däck | 4,24 |
| Reparation och service | 17,40 |
| Drivmedel | 35,20 |
| Övriga rörliga kostnader | 0,00 |
| Summa rörliga kostnader | 64,88 |

| Tidsberoende rörliga kostn. | kr/tim |
|---|---|
| | 0,00 |

| Kostnad per år | kr |
|---|---|
| Fasta Fordonkostnader | 337 934 |
| Rörliga milberoende kost. | 324 402 |
| Rörliga tidberoende kost. | 0 |
| Total årskostnad | 662 336 |

*Totalt per mil 132,46 kr, per tim 220,77 kr.*

Calculation 3: Developed long haul truck

## GRUNDUPPGIFTER

Developed 3 axl tractor w semi-trailer

| Användning per år | Spec | |
|---|---|---|
| Timmar | | 3 000 |
| Mil | | 5 000 |

| Investeringen | Spec ☑ | |
|---|---|---|
| Nuanskaffningskostnad | | 1 149 800 |
| Livslängd, år | | 8,00 |
| Restvärde, kr | | 140 000 |
| Andel fast avskrivning % | | 75% |
| Ränta % | | 5,00% |

| Drivmedel | Spec | |
|---|---|---|
| Förbrukning liter per mil | | 3,70 |
| Pris per liter | | 8,00 |

| Övrig fasta kostnader per år | Spec | kr/år |
|---|---|---|
| Fordonskatt och vägavg | ☑ | 32 343 |
| Försäkringar, skador | ☑ | 50 000 |
| Övriga fasta kostnader | ☑ | 32 250 |

| Sträckberoende rörliga kostnader | Spec | kr/mil |
|---|---|---|
| Däck | ☑ | 3,82 |
| Reparation och service | ☑ | 15,30 |
| Övriga rörliga kostnader | ☐ | |

| Tidsberoende rörliga kostnader | Spec | kr/tim |
|---|---|---|
| | ☐ | |

*Infoga sammandrag från SÅcalcs meny*

## KALKYL

| Fasta Fordonskostnader | kr/år |
|---|---|
| Avskrivning, fast del | 94 669 |
| Räntekostnad | 32 245 |
| Fordonskatt | 32 343 |
| Försäkringar, skador | 50 000 |
| Övriga fasta kostnader | 32 250 |
| Leasing | |
| Totala fastakostnader | 241 507 |
| Fast kostnad per anv tim | 80,50 |

| Sträckberoende rörliga kostn. | kr/mil |
|---|---|
| Avskrivning | 6,31 |
| Däck | 3,82 |
| Reparation och service | 15,30 |
| Drivmedel | 29,60 |
| Övriga rörliga kostnader | 0,00 |
| Summa rörliga kostnader | 55,03 |

| Tidsberoende rörliga kostn. | kr/tim |
|---|---|
| | 0,00 |

| Kostnad per år | kr |
|---|---|
| Fasta Fordonkostnader | 241 507 |
| Rörliga milberoende kost. | 275 156 |
| Rörliga tidberoende kost. | 0 |
| Total årskostnad | 516 663 |

*Totalt per mil 103,33 kr, per tim 172,22 kr.*

Calculation 4 Developed – 3 axle tractor with semi-trailer

# APPENDIX C: ADDITIONAL TABLES SHOWING TRUCK MEASURES

| | Usage | | Maximum | | Cost | | |
|---|---|---|---|---|---|---|---|
| Truck type | Hours | Mil (10km) | Milage | Age when too old | Total/year | Total/10km | Total/hour |
| **SÅCalc examples** | | | | | | | |
| Long-haul truck with trailer | 3 432 | 12 348 | 100 000 | 6,18 | 1 120 378 SEK | **90,73 SEK** | **326,45 SEK** |
| Distribution truck | 1 800 | 5 000 | | 8 | 469 724 SEK | **93,94 SEK** | **260,96 SEK** |
| 3-axel Tractor w trailer | | | | | | | |
| **SÅCalc examples, with Schenker short distance milage** | | | | | | | |
| Long-haul truck with trailer | 3 000 | 5 000 | | | 686 336 SEK | **137,27 SEK** | **228,78 SEK** |
| Distribution truck | 2 000 | 2 500 | | | 388 974 SEK | **155,59 SEK** | **194,49 SEK** |
| **Estimated for short terminal-terminal traffic** | | | | | | | |
| Long-haul truck with trailer | 3 000 | 5 000 | 100 000 | 6,67 | 662 336 SEK | **132,47 SEK** | **220,78 SEK** |
| 3-axel Tractor w trailer | 3 000 | 5 000 | 10 000 | 8 | 516 663 SEK | **103,33 SEK** | **172,22 SEK** |
| Combined distribution day & night with trailer | 3 500 | 4 500 | | | 595 676 SEK | **132,37 SEK** | **170,19 SEK** |
| **Estimations for the combined distribution truck** | | | | | | | |
| Distribution truck with trailer | 3 500 | 4 500 | | | 713 315 SEK | **158,51 SEK** | **203,80 SEK** |
| Distribution truck, day traffic without trailer | 3 500 | 4 500 | | | 507 446 SEK | **112,77 SEK** | **144,98 SEK** |

Cost for combined distribution day and night, Total/year, was calculated using a combination of the estimations for the combined distribution truck. 1500 swedish miles with night traffic and 2000 swedish miles with day traffic:
713315*(1500/3500) + 507446 * (2000/3500) = 595676 SEK.

| Trucks | Load capacity (tons) | Load capacity (floor m) | Volume capacity (m^3) | EUR Pallets | Cost/10km | Cost/hour |
|---|---|---|---|---|---|---|
| 3 axel distribution truck | 6,4 | 6,46 | 40,5 | 18 | 155,6 SEK | 194,5 SEK |
| 3 axel distribution truck with trailer | 33,2 | 19,11 | 119,5 | 48 | 132,4 SEK | 170,2 SEK |
| Truck with trailer | 40,3 | 20,15 | 126 | 48 | 132,5 SEK | 220,8 SEK |
| Semi-trailer | 26 | 13,60 | 84 | 36 | 103,3 SEK | 172,2 SEK |
| Trailer (Truck w trailer - Truck) | 26,8 | 12,65 | 79 | 30 | 83,2 SEK | 138,4 SEK |

| | Load capacity (ton) | Load capacity (floor m), length | Volume capacity (m^3) | EUR Pallets | Width (m) | Loading height (m) |
|---|---|---|---|---|---|---|
| **2-3 axel distribution truck** | **6,4** | **6,46** | **40,5** | **18** | **2,48** | **2,3** |
| **3 axl truck** | **13,5** | **7,50** | **47** | **18** | **2,55** | **2,65** |
| **trailer** | **26,8** | **12,65** | **79** | **30** | **2,55** | **2,65** |
| **semi-trailer** | **26** | **13,60** | **84** | **36** | **2,55** | **2,3-2,65 (3)** |