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**The Feasibility of Implementing High Capacity Transport
in Sweden**
-a market opportunity?

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Abstract

The White Paper of the European Commission states that transport is of great importance to a country and it envisions a future where transportation will be conducted in a more efficient manner. One way to achieve this in the road sector could be the usage of High Capacity Transport (HCT); thus the purpose of this study is to identify the feasibility of implementing HCT in the Swedish transport services market. To achieve this, a case study approach incorporating both qualitative and quantitative elements is applied. Previous studies within this area show that there are benefits as well as drawbacks from the usage of this type of transportation. The results from this study indicate that HCT offers a number of opportunities for market actors in terms of environmental and cost advantages. There are also some barriers to implementation, including the rebound effect, safety, network restrictions and infrastructure. Nevertheless, gains in transport efficiency generate a market for HCT in Sweden along routes where flows of goods are sufficient.

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Abbreviations

EMS	– European Modular System
FV	– Following Vehicle
HCT	– High Capacity Transport
JIT	– Just In Time
LV	– Lead Vehicle
Tkm	– Tonne-kilometer
SIKA	– Swedish Institute for Transport and Communications Analysis

1 Introduction

1.1 Background

“Transport is fundamental to our economy and society” (European Commission 2011 p.3). The White Paper of the European Commission clearly states that transport is of great importance to countries and it envisions a future where transportation will be conducted in a more efficient manner, lessening the impact on the environment while still being able to provide the necessities for society. Transport enables economic growth and job creation, which is important for any country and by focusing on transport issues there is much to be gained. Changes in infrastructure create new possibilities for mobility and that will lead to the emergence of new transport patterns. The burden on the environment can be lessened by promoting railways, inland waterways and short-sea shipping (European Commission 2011). Another important point is that the transport sector should make better use of resources and utilize new technology, thereby pointing towards options for increasing efficiency (Aronsson and Brodin 2006).

In the road transport segment, Sweden has a tradition of using High Capacity Transports (HCTs) (Vierth et al. 2008). Current regulation states that vehicles can have a maximum length of 25,25 meters and a maximum weight of 60 tonnes, compared to the situation in the majority of the European Union (exceptions being Finland, Denmark and the Netherlands) where vehicles are shorter and lighter (with a length of 18,75 meters and a weight of 44 tonnes). Trials with the Swedish dimensions are currently running in other EU countries and in Sweden tests are being performed with even heavier and longer combinations than today. These trials are searching for potential advantages to society and also to the industry such as economies of scale, increased transport efficiency and decreased emissions. One of the projects is the so-called “Duo2” trial undertaken by DB Schenker whereby a 32-meter vehicle is being tested on a route between Gothenburg and Malmö (DB Schenker 2011). Another project that is currently being conducted is the so called “ETT” or “One more stack” project where the Swedish forestry industry is trying out longer vehicles (30 meter compared to the regular 24 meter) and heavier vehicles (90 tonne compared to the regular 60 tonne) (Skogforsk 2012).

In recent years the modal split of freight transport in Sweden have changed from 35,1% rail and 64,9% road in 2008 to 38,2% rail and 61,8% road in 2011 (European Commission 2013b). The trend has thus been that transports are moving from road to rail in Sweden but road still has a dominant share of the total transport. The Swedish Transport Administration state that the Swedish railway suffers capacity problems on several lines, making them insufficient for goods traffic (Trafikverket 2012). If the long-term growth is taken into consideration there will without a doubt be a substantial increase in the transport volumes for all types of traffic modes. According to an investigation conducted by the Swedish Transport Administration (Trafikverket 2012) the industry hopes that the railway will be able to handle an increased share of the goods transport. However, the Swedish Transport Administration states that this cannot be achieved in reality, as the required investments by the railway in order to be able to accommodate this growth in goods transport cannot be justified from a socioeconomic point of view (Trafikverket 2012).

1.2 Freight Transport Trends

Within Europe the economy continues to grow, which is reflected in a 35% increase in GDP from 1995 to 2008 (see Figure 1). This means that people can afford to purchase more goods and services, which in turn need to be transported from the point of production to the point of consumption. As a result the freight transport sector within Europe is expanding steadily alongside GDP, as it plays an important role in helping to bridge the supply and demand gap (Coyle et al. 2011). This situation is depicted in the graph below:

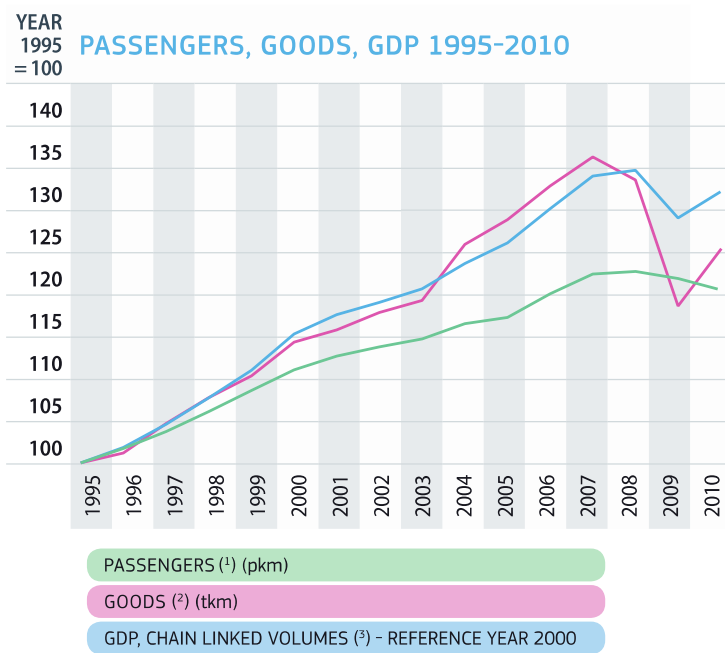


Figure 1: Transport Growth EU-27 (European Commission 2012)

Despite the onset of the recession in 2008, freight transport within the EU is expected to continue growing again as the economy recovers. This is indicated by a 5,3% increase in freight transport between 2009 and 2010 (OECD 2011). In Sweden alone it is estimated that goods transportation will increase by 61% between 2006 and 2050 (Trafikverket 2012).

However, the European Council states that a sustainable policy requires “*action to bring about a significant decoupling of transport growth and GDP growth*” (European Commission 2001a p.72). In other words, the economy should be able to recover without triggering a subsequent growth in transport. This is because the transport sector represented 31,7% of final energy consumption in the EU-27 in 2010 (European Commission 2012), as can be seen in Figure 2:

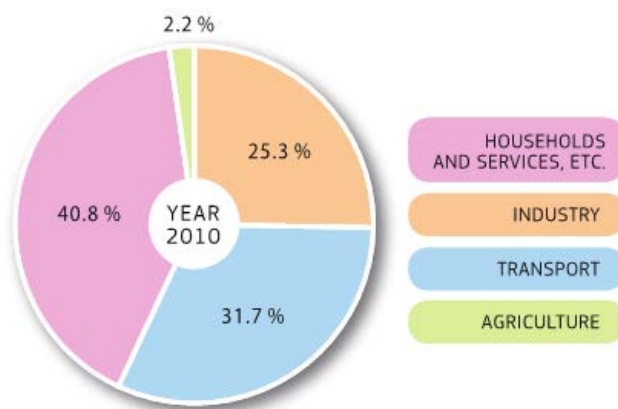


Figure 2: Final Energy Consumption by Sector in the EU-27 (European Commission 2012)

According to one report made by the European Environment Agency (2009) governments could limit the growth of the transport sector and the ensuing emissions by improving the transport efficiency of the economy. In this way it could cope with the increase in demand, while at the same time leading to positive effects on the environment and decreased costs for industry (Aronsson and Brodin 2006).

In 2010 road transport accounted for 45,8% of the total freight transport in the EU-27 (European Commission 2012) and is expected to carry much of the projected growth due to its timeliness and flexibility (OECD 2011). Similarly, within Sweden total freight transport has increased by 24% since 1975 (SIKA 2004), whereby trucks on road have the fastest growth rate (Lammgård 2007). According to a forecast for freight transport performance from the Swedish Institute for Transport and Communications Analysis (SIKA) this share of trucks on road is expected to increase further from 42% in 1997 to around 46% by the year 2010 (Lammgård 2007). This is because trucks carry much of the new and expanding transport flows in Sweden (Lammgård 2007). So although trains and ships continue to transport a stable flow of goods in Sweden, the relative importance of these modes is expected to decline over time (Lammgård 2007). Road being the most dominant mode of freight transportation in Sweden, now and in the foreseeable future, should be a major driving factor for improving its efficiency and adopting HCTs is one way of achieving this (McKinnon and Edwards 2010)

1.3 Target Group

The market for HCT from industry's perspective strongly depends on the goods to be shipped and the distance. According to De Ceuster et al. (2008) the usage of HCT would primarily be on longer distances (>500km); within Sweden this comprised on average 22% of road transport (tkm) between 2002 and 2011 (European Commission 2013a). While the average was 32% on distances less than 150km for the same period of time (European Commission 2013a). This means that the amount of road transport in Sweden on distances between 150 km and 499 km was on average 46% for this period of time and thus the majority of transports by road fall into this category. For more information regarding these calculations see appendix four. The table below outlines how the total tonnage of goods transported was distributed for the different distance categories.

Distance	>500km	150-499km	50-149km	<50km	Sum
Group of goods					
Products of agriculture, hunting, and forestry; fish and other fishing products	0,1%	2,6%	7,4%	5,6%	15,7%
Metal ores and other mining and quarrying products; peat; uranium and thorium	0,0%	0,4%	3,0%	26,8%	30,2%
Food products, beverages and tobacco	0,9%	3,2%	1,5%	1,9%	7,5%
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	0,3%	1,9%	2,3%	3,8%	8,3%
Other non-metallic mineral products	0,1%	0,9%	1,4%	2,4%	4,8%
Secondary raw materials; municipal wastes and other wastes	0,1%	0,8%	1,3%	2,8%	5,0%
Equipment and material utilized in the transport of goods	0,1%	0,4%	0,7%	4,6%	5,8%
Grouped goods: a mixture of types of goods which are transported together	1,2%	4,8%	1,8%	2,0%	9,8%
Other	0,6%	3,6%	3,5%	5,1%	12,8%
Sum	3,4%	18,6%	22,9%	55,0%	

Table 1: Total tonnage of goods transported in Sweden by road (European Commission 2013a)

From the table it can be concluded that the percentages of goods in terms of tonnage is mainly focused on the shorter distances. The reason for this is that heavier goods tend to be transported by other modes of transportation for longer hauls such as rail and shipping, which are better suited for these types of goods. Especially the group with metal ores impacts these numbers, as they are generally of high density and transported by truck only short distances from the mine to the long haul transport mode of choice. To find out what type of goods that would benefit from being transported by HCTs another measurement has to be used together with total tonnage. In the table below, total tonnage is thus compared with the total tkm for the different groups of goods.

Group of goods	Unit	Tonnes	tkm
Products of agriculture, hunting, and forestry; fish and other fishing products		15,6%	14,7%
Metal ores and other mining and quarrying products; peat; uranium and thorium		30,3%	7,5%
Food products, beverages and tobacco		7,5%	15,8%
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media		8,3%	10,3%
Other non-metallic mineral products		4,8%	5,1%
Secondary raw materials; municipal wastes and other wastes		4,9%	3,6%
Equipment and material utilized in the transport of goods		5,8%	2,9%
Grouped goods: a mixture of types of goods which are transported together		9,8%	22,8%
Other		13,0%	17,3%

Table 2: Total tkm for different groups of goods in Sweden transported by road (European Commission 2013a)

In this comparison the group of metal ores still stands for a major part of the total tonnage, but as mentioned before the tkm for this group of goods is comparatively low, indicating high-density goods being transported over short distances. Two groups of special interest in the above table are food products as well as grouped goods. Both of these groups have a significantly higher percentage of the total tkm than they have for total tonnage. This implies that these goods are transported longer distances when they are transported and that they thus could benefit from HCT. The reason for these goods being transported further by road based transportation is that they tend to be of higher value than bulk goods. High value goods are more sensitive to the time of delivery and a higher flexibility in the transports of such goods are thus important, a flexibility that can be provided by road based transports. Furthermore, McKinnon (2005) argues that loads now are rather volume constrained than weight constrained. In his words, this is due to the fact that weight limits have been raised by a greater margin than size limits in recent decades. Moreover, this has occurred over a period when the average density of freight has been declining, following a switch from heavier materials such as metal and wood to lighter, high value consumer goods (McKinnon and Edwards 2010). That food products are suited for road based transportation have also been concluded by Kille and Schmidt (2008) who state that the main reason for this is speed, relatively low costs and the existence of high-density networks. Bulk goods on the other

hand are not suited for road-based transportation due to their innate low value and their relatively low dependency on delivery times. Transport costs also stand for a high percentage of the total value of this type of good, making road based transportation a comparatively worse alternative for the transports of it. For these type of goods road based transportation is usually only used for shorter routes to a nearby port or railway station (Kille and Schmidt 2008), which is in line with the results in the above table.

1.4 Actors of the Transport System

The actors of the transport system can, according to Flodén (2007), be divided into four main groups; influencing actors, framework actors, system actors and system output receivers. In the group of influencing actors Flodén (2007) have included actors without direct influence to the system such as media and lobby groups. These actors in turn affect public opinion, something which Lamngård (2007) include as a market influencing factor. The framework actors include government and authorities which have the power to directly change the system (Flodén 2007). Direct influences include the power to change taxes or deciding what to do with the infrastructure (Lamngård 2007). Flodén (2007) includes road hauliers, terminal companies and freight forwarders in the system actors group. These actors are in a collective term usually referenced to as transport providers, a grouping which Arvidsson (2011) says comprises of actors that offer transport and logistics services. The system actors group has a high interest in changes to the market as that will directly influence their operations. The last group, system output receivers, consists of the transport customers (Flodén 2007). Shippers are thus included in this final group as they are *“responsible for arranging the transportation of the goods”* (David and Stewart 2010 p.210). Another actor included in this group are the transport buyers, which are actors that have a large goods flow and purchase the transport services they need from a third part, i.e. they do not own their own transport fleet (Arvidsson 2011). The model below depicted by Lamngård (2007) has the system actors and transport customers forming the core of the market while the influencing actors and the framework actors impact the market from the outside. The model also highlight that the market actors have their own individual goals and strategies within the companies.

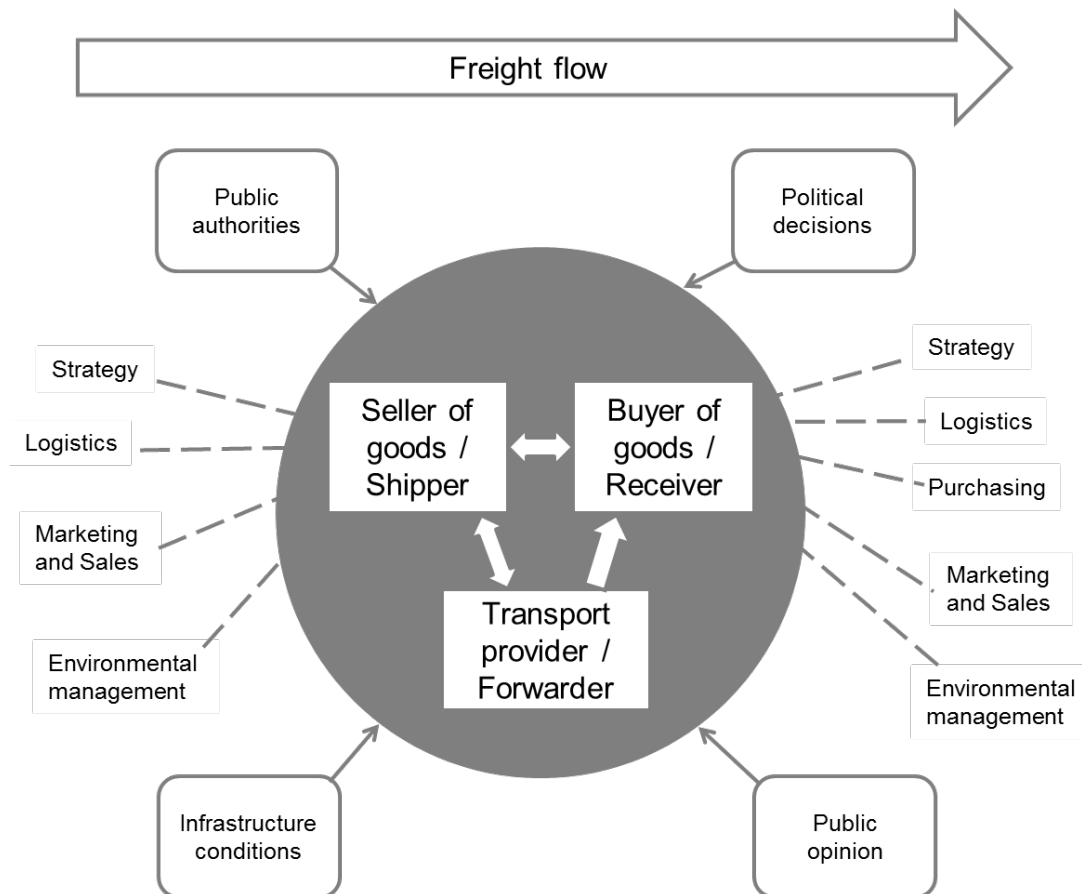


Figure 3: Conceptual model influencing the choice of transport solutions (Lammgård 2007 p.63)

1.5 Problem Discussion

Previous research regarding HCTs covers a number of different aspects, thus highlighting the complexity of the topic. The economic costs and benefits for society can be investigated to see if changes in regulations for heavier and longer vehicles are desirable from a public point of view. The environmental concerns related to road freight movement are continuously in focus of today's society and the main concern when it comes to introducing HCTs is that freight might shift from rail to road, which could be undesirable from an environmental perspective. It has been argued that HCTs can yield significant environmental benefits despite the fact that reduced road haulage costs resulting from economies of scale generate more road freight movement (McKinnon 2005), even though there is a higher fuel consumption for using larger vehicles (Lumsden 2004). Safety concerns for HCTs is a question which have previously been covered by Grislis (2010) and McCarthy (1995) who state that there is a connection between fleet size and road safety. Grislis (2010) also mentions that accidental rates are directly connected to the amount of truck kilometers and

proposes that HCTs can have a positive effect on safety. Concerns regarding the infrastructure are also something that has been covered in previous studies regarding HCTs. The wear and tear of roads as well as the effects on bridges has been highlighted as the main infrastructural issues (TS&W 2000; Maze et al. 1996; De Ceuster et al. 2008). The infrastructural effects of HCTs and the costs related to this are thus an issue that is of interest when deciding whether an implementation is feasibly or not.

From a business perspective it must be determined whether there is a potential market for HCT from both the demand and the supply side. The demand side is represented by the transport buyers, i.e. the shippers. Without sufficient demand from these parties to use road transportation for large volume flows, there is little to be gained from further investigating the issue at hand. According to Knight et al. (2008) transport buyers of low-density goods would appreciate any increase in available cube, as they are constrained by volume rather than weight restrictions. For higher density loads that reach the weight limit on trucks before they occupy all the available space, heavier trucks would enable load consolidation (Knight et al. 2008). In both cases, an increase in available volume/weight reduces the amount of vehicle movements required to distribute a given quantity of freight due to the higher load capacity per truck (McKinnon 2005). These efficiency gains result in decreased costs for transport buyers on longer distances with high volume flows (Lumsden 2004).

However, even if there is sufficient demand available from the transport buyer's side, it must still be determined whether it is feasible from a transport provider's standpoint, as these will be the actors responsible for providing the service and they will only be interested if there is an opportunity for generating profits. The introduction of HCTs will result in certain adjustments to be made on behalf of the transport providers. Nevertheless, in light of recent logistics developments towards outsourcing and centralized manufacturing, this has increased the demand for longer transport distances and higher volumes (Lumsden 2004). These changes will thus affect a shipper's entire logistics system and transport providers that adapt to these new patterns have the potential to enhance their competitiveness. However, prior to the introduction of HCT it is important to investigate the feasibility of implementation in order to investigate whether it is possible from the supply side.

1.6 Purpose

The purpose of this thesis is to analyze the feasibility of implementing High Capacity Transport (HCT) in the Swedish transport services market.

1.7 Research questions

1. What are the practical experiences of HCT in Sweden?
2. What are the enablers and barriers of implementing HCTs in the market for transport in Sweden?
3. What would be the target group of HCTs in Sweden?

1.8 Limitations

As the scope of the topic at hand is very broad there are certain limitations that will apply to it. An overarching limitation of this thesis is that it will be focused on Sweden and thus will not be in its entirety applicable to other countries. The focus of the thesis lies, as mentioned, within the business aspect of implementing HCTs; more specifically it will concentrate on the supply side, which means that the demand for HCT will only be covered to the extent of investigating the target group in terms of the type of goods flows. Furthermore, the costs and benefits for society, such as safety and the environment, are not covered in detail. They are rather an effect coming from the usage of HCTs and are thus topics to be covered in more depth as a continuation of this study. Similarly, infrastructure is only covered to a limited extent due to the technical features of the issue, which do not apply to the purpose of this study. For this reason road networks, bridges, effects on pavements etc. have only been covered in this study to the extent of how they will be affected by HCTs as previous studies have examined these issues in more detail.

1.9 Definitions

Efficiency – a complex concept with several definitions available that can be applied. For the purpose of this paper efficiency will be defined as the input used relative to the value/quantity of output (Arvidsson 2011). In other words, the emphasis of efficiency lays on reducing the amount of input required to produce a given amount of output. Productivity, on the other hand, focuses on maximizing the output with a given amount of input.

Externalities – a positive or negative effect on society from the production or consumption of a good or service that is not accounted for in the price.

HCT – is the abbreviation for High Capacity Transport and is used to describe vehicles that are longer and/or heavier than what the current regulations in Sweden allow. Other abbreviations commonly used to describe the same concept are LCV – Long Combination Vehicles, used in the US, and LHV – Longer and Heavier Vehicles, primarily used in the rest of Europe. However, as this study focuses on Sweden, the abbreviation HCT has been applied.

Tonne-kilometer (tkm) – is a unit of measurement for the demand of freight transportation. 1 tkm is one tonne transported over one kilometer. The problem with this measurement is that it is two-dimensional, i.e. it does not differentiate between weight and distance (Coyle et al. 2011). This can present some challenges for intermodal comparisons. For instance, 200 tkm could indicate 200 tonnes transported 1 kilometer, 100 tonnes transported 2 kilometers, or 1 tonne transported 200 kilometers.

1.10 Outlook on the Paper

Chapter two will begin with a presentation of the theoretical framework of the study; this part includes a discussion about the enablers and barriers of implementing HCT that are covered in literature and includes aspects related to transport efficiency, environment, costs, the rebound effect, road safety and infrastructure. There will also be a discussion of the shipper's preferences in this section. An outline of the methodology, as well as the methods used to gather data and analyze the results, comes thereafter in chapter three. This includes a discussion of the case study methodology as well as the literature review and interview methods. Aspects of reliability and validity will also be covered. This is followed by chapter four, which refers to previous reports regarding the implementation of HCTs and provides an examination of the topic with respect to current rules and legislations, previous usage of HCTs, vehicles and terminals, financial aspects and alternative methods. Chapter four also includes a model of analysis for the study. Chapter five then supplements this with the results from the interviews that have been conducted. This is followed by a comprehensive discussion in chapter six, which revisits the initial research questions and finally the paper will end with a conclusion in chapter seven. In chapter eight there is the list of sources that have been referenced throughout this study and in chapter nine is the appendix, which includes the interview guide, additional regulations and data regarding calculations that have been made.

2 Theoretical Framework

The following chapter presents the results of the literature review, which will constitute the theoretical framework of the study. The topics that have been covered include the enablers and barriers of implementing HCTs in Sweden from a business perspective. These refer to drivers and obstacles that can range from operational aspects, such as efficiency, environment and costs, to issues related to the rebound effect, road safety and infrastructure. This is followed by a presentation of the shipper's preferences in terms of modal choice and environmental concerns.

2.1 Enablers and Barriers

2.1.1 Efficiency

Efficiency is a complex concept with several definitions available in literature that can be applied. Generally though it can be argued that the emphasis of efficiency lies on the input used relative to the value/quantity of output (Arvidsson 2011). Therefore one must first define the inputs and outputs of an operation in order to establish gains in efficiency. With regard to transport efficiency, one view presented by Samuelsson and Tilanus (1997 p.141), states that the efficiency of goods transportation involves a *“non-stop movement from origin (A) to destination (B), and back, along a minimum distance route, at maximum speed, with a full load”*. Hence, it is the product of four dimensional inputs with respect to time (the percentage of available time that the vehicle is actually utilized), distance (the percentage by which maximum transportation output is reduced by not using the shortest route), speed (the percentage by which maximum transportation output is reduced by not travelling at maximum speed) and capacity (refers to the capacity of the vehicle and is measured in either weight or space) (Samuelsson and Tilanus 1997). According to this approach, transport efficiency is measured as a relation between the actual amount of input and the ideal amount of input, whereby HCT has the potential to influence the fourth dimension related to capacity.

Another interpretation of the inputs and outputs of transport efficiency is producing a service with less resource consumption without reducing the logistics performance (Aronsson and Brodin 2006). According to Clarke and Gourdin (1991) the inputs of a logistics system include people, vehicles, equipment, facilities, capital, information and product

offering. In order to be considered efficient, HCT must therefore be able to reduce the amount of these inputs required for a given amount of output. The output of a logistics system, on the other hand, can be linked to three types: Profit, Customer Service and Market Share (Clarke and Gourdin 1991). Whilst profit is connected to costs, the customer service of a transport covers aspects related to the quality of the delivery, such as frequency, transport time, regularity, transport safety, controllability and flexibility (Jensen 1987). Finally, market share refers to the road haulage network that can be captured by HCT, which is in this case only being discussed for Sweden; liberalization of vehicle size and weight limits elsewhere would simply open other road haulage markets to existing types of HCT (McKinnon et al. 2010).

The environment may be considered an additional output of the system that must be kept at a constant for a given amount of output (Dunn and Wu 1995). On the other hand, transport providers will not be interested in using HCT unless there is something to be gained in terms of costs. From this standpoint a transportation system is said to be efficient when it can reduce both the environmental effects and the total costs to transport a given amount of goods over a given distance without impacting the quality of the service. According to Aronsson and Brodin (2006) this is not necessarily a paradox, as costs and the environment have a common key for reaching high performance. This being that long-term cost effective transport must be resource efficient, which will also be positive for the environment in the long run. Nevertheless, there have been some studies that counter this argumentation and claim that optimizing transport efficiency might be at the expense of overall logistics costs (Arvidsson et al. 2013). According to Rodrigue et al. (2001) reducing logistics costs does not necessarily reduce the environmental impact due to the conflicting relations of green logistics with costs (cost-saving strategies are often at variance with the environment, as environmental costs are frequently externalized), time/speed (time constraints increase the use of air freight and trucking), reliability (the least polluting modes - railways and ships - are generally regarded as being the least reliable), warehousing (the desire to reduce inventories in a logistics system means that these have been transferred to the transport system, especially the roads) and e-commerce (resulting in a disaggregated retailing distribution). Arvidsson et al. (2013) thus argue that a road hauliers' ability to benefit from both energy

and cost reductions of an efficiency measure is affected by other actors within and outside the supply chain.

In order to achieve gains in efficiency a road haulier must therefore work in cooperation with these stakeholders, thus looking beyond merely operational measures and considering also the macro/strategic level. Consequently, Arvidsson et al. (2013) have divided transport efficiency measures of road hauliers' into three main groups: internal (to the haulier), joint with the customers (the forwarder or the shipper) and joint with the public sector. Internal measures include factors related to driver and vehicle efficiency, which is not directly related to HCT. Measures mentioned in cooperation with the customer, on the other hand, include, among others, the utilization efficiency and how it is affected by the backhaul effect and the load factor. Whereas the backhaul effect is related to empty running caused by unbalanced flows (McKinnon 1996), which cannot be resolved by increasing the size and weight of vehicles, HCTs could increase the load factor by enabling load consolidation. According to Blinge and Svensson (2006) the load factors, which measure the ratio of *"the actual goods moved to the maximum tonne-kilometers achievable if the vehicles, whenever loaded, were loaded to their maximum carrying capacity"* (OECD 2002 p.137), vary between 30% and 70% in Sweden. Theoretically speaking then, the emissions caused by road transport could be halved if more loads were consolidated (Arvidsson et al. 2013). This, however, is not so simple, as many vehicles today are full in terms of their volume capacity before they reach their maximum weight. These issues, concerning vehicle size and weight restrictions, are not easily adjusted, as they fall under the category of regulatory and incentive-based measures that are established in cooperation with the public sector (Arvidsson et al. 2013).

Similarly, McKinnon and Edwards (2010) state that the core inefficiencies of road transportation stem from truck capacity under-utilization. The constraints on vehicle loading can be classified into five broad categories (McKinnon 2007): market-related (associated with trade patterns and fluctuations on the volume of freight flow), regulatory (governing the size and weight of vehicles, the timing of deliveries and health and safety aspects), inter-functional (imposed on transport management by other departments within the business), infrastructural (related to the physical capacity of transport networks) and equipment-related (resulting from the incompatibility of vehicles, handling equipment and loads).

According to McKinnon and Edwards (2010), the regulatory constraints involving vehicle size and weight restrictions result in loads either “weighing-out” before all the vehicle space is filled or “cubing-out” before the vehicle reaches its maximum gross weight. In both cases this results in the weight/volume-carrying capacity of trucks being under-utilized, which is an issue that can be addressed by the use of HCT. The reason for this is, as argued by McKinnon and Edwards (2010), that increasing the carrying capacity of vehicles improves efficiency, because it allows companies to consolidate loads, thereby achieving a greater vehicle fill and cutting truck kilometers. In other words the amount of trucks/movements required for transporting a given amount of goods is reduced. This is due to the increased productivity per truck, meaning that the output (goods transported) is maximized with a given amount of input (number of trucks).

To summarize, efficiency will be defined in this study as the input used relative to the value/quantity of output (Arvidsson 2011). In other words, the emphasis of efficiency lays on reducing the amount of input required to produce a given amount of output. Within a logistics context it can be argued that HCT reduces the amount of inputs required in terms of vehicle movements to transport a given amount of goods, therefore increasing the efficiency of road transport.

2.1.2 Environment

According to Lumsden (2004) the environmental impact of trucks can mainly be related to fuel consumption, which causes CO₂ emissions. Despite the fact that larger trucks have greater fuel consumption per truck, the increased load factor reduces the fuel consumption per tkm (Lumsden 2004), as overall fewer trucks are being used for a given amount of goods. In other words, the fuel consumption per tonne of goods transported decreases with HCT. This is illustrated in Figure 4 (Lumsden 2004):

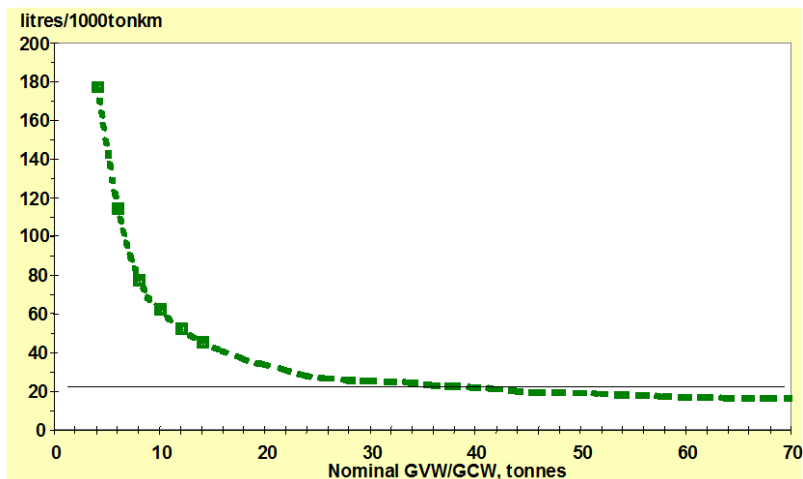


Figure 4: Fuel consumption per tkm (Lumsden 2004)

According to the European Federation for Transport and Environment this effect is greatest for very light loads and can represent a reduction of CO₂ emissions per tkm of up to 25% (T&E 2007). Considering McKinnon and Edwards' argument that loads today are becoming lighter (2010), this is advantageous. However, in terms of emissions, railway and shipping remain better suited for transporting heavier goods (T&E 2007). Furthermore, a study by the German Federal Environment Agency (Umweltbundesamt 2007) finds that the potential of HCT to reduce fuel consumption per tkm is highly dependent on the optimized use of the loading capacity.

A further positive externality to society resulting from having fewer trucks includes less utilized space on the road, in other words congestion. According to Knight et al. (2008) the most important factors determining the impact of HCT on congestion levels is its speed, lane take-up and the traffic volume. Although HCT reduces the overall traffic volume through more efficient use of road space in terms of load carried, this must be weighed against the localized congestion arising in their immediate environments, particularly on gradients and at junctions and intersections (Knight et al. 2008).

In terms of noise, larger trucks are generally louder due to more powerful engines and a greater number of axles (Umweltbundesamt 2007). However, on an aggregate level, the overall noise impact would be dependent on the change in the total number of trucks on the road (T&E 2007), which is meant to decrease with HCT. Also, it should be taken into consideration that HCT is not destined to operate in urban or densely populated areas.

Nevertheless, should HCT operate under urban conditions, Knight et al. (2008) argues that, because speeds are lower in these situations, propulsion noise will dominate the overall noise level and the effects of additional axles will be relatively small.

In summary, HCT vehicles have greater fuel consumption and thus higher CO₂ emissions per truck; however, on an aggregate level fewer vehicles are required for the same amount of goods due to gains in efficiency. This result in decreased overall emissions per tonne of goods transported.

2.1.3 Costs

The majority of operating costs related to truck transportation are related to fuel and labor. This is shown in Figure 5, which illustrates the total operating cost breakdown to EU hauliers for long distance freight transport (Larsson 2008):

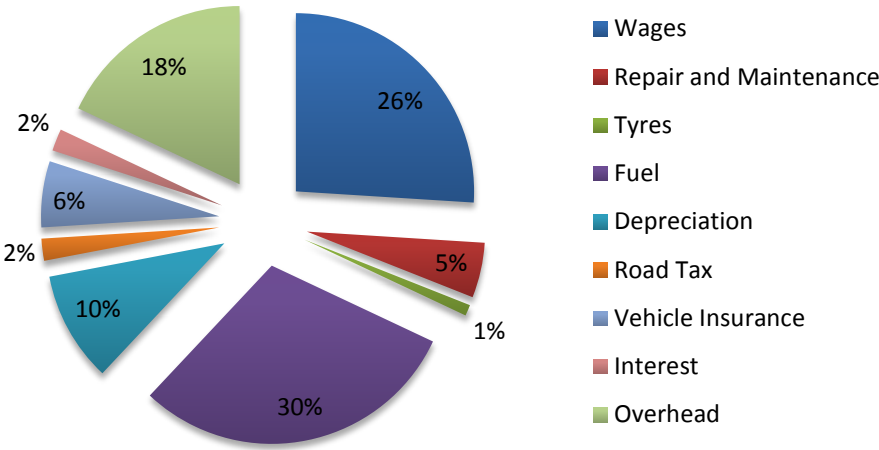


Figure 5: Total Operating Cost Breakdown to EU Hauliers (Larsson 2008)

Although these figures can vary slightly depending on the country, the distance travelled and the commodity type; fuel and wages generally account for more than half of the total operating cost (Christidis and Leduc 2009).

McKinnon (2005) reports that for the UK, when weight limits increased from 38 to 40 tonnes in 1999 and from 41 to 44 tonnes in 2001 this resulted in reduced road haulage costs of 7% and 11% respectively. Similarly, a study conducted by ISI Fraunhofer (2008) states that, because every third driver can be spared, this results in a 33% decrease in haulage related

labor costs, and a 25% decrease in fuel costs if fully loaded. Vierth et al. (2008) support this notion in their analysis, which compared the situation in Sweden, where it is possible to use longer and heavier vehicles than the rest of Europe, with a hypothetical situation in which EU rules are introduced in Sweden. Their findings conclude that the dominant effect of using smaller and lighter vehicles can be attributed to increased transport costs (Vierth et al. 2008). Thus, it can be argued that the increased loading capacity of HCT improves cost efficiency, because it reduces the amount of trucks/movements required and therefore also the associated fuel and labor costs for transporting a given amount of goods.

According to this view on cost efficiency, companies using HCT are able to produce the same amount of output with less input in terms of costs. As a result transport providers now have an abundance of resources available. The question then is whether they will save these resources or employ them in order to produce additional output. As a general rule companies will always choose to utilize resources when there is an opportunity to maximize profits (Arvidsson 2011). Numerically speaking, savings in terms of inputs are lower than the potential output increase, even when disregarding a profit margin. This can be explained using the efficiency ratio (Arvidsson 2011):

$$\text{Efficiency ratio} = \frac{1}{0,7} = \frac{\frac{1}{0,7}}{1} \approx \frac{1,43}{1}$$

Figure 6: Efficiency Ratio (Arvidsson 2011)

In the ratio above, the denominator represents efficiency and the nominator represents productivity. As such, when the input required to produce an output of 1 is 0,7 the spare capacity is 0,3. If this capacity is used to generate additional output then 1,43 units could be produced, which yields an overall greater outcome as 0,43 additional units of output is greater than the 0,3 units of input that would be saved (Arvidsson 2011).

However, it can be argued that it is not possible to simply increase the supply of freight transport merely on a cost basis, as the demand for it is derived. This means that the demand for freight transportation is dependent upon the demand for a product in another location (Coyle et al. 2011). In other words, when demand for goods decreases, so will the demand for the transportation of these goods and its individual parts; and vice versa, when

demand for goods increases so does the demand for transportation. However, this view on transportation as a purely derived demand has been challenged. Instead it is being argued that transportation is both a derived and induced demand, in which case a decrease in the cost of transportation will lead to an increase in the demand for it; this phenomenon is known as the rebound effect and would be undesirable from a public point of view.

To summarize then, the biggest affect of HCT on costs is related to fuel and labor, as fewer vehicles are required. As the majority of operating costs of truck transportation are related to these areas, HCT has potential to lower the costs and thus the price of road transportation. As prices decrease this might lead to a higher demand for road transportation, a phenomenon known as the rebound effect, which is discussed below.

2.1.4 The Rebound Effect

This concept is suggested by the fact that freight transport has grown faster than GDP between 1970 and 1998 (European Commission 2001a), and is expected to so again in the future in the industrialized world (Aronsson and Brodin 2006). As such, transport efficiency can be considered both a cure and a cause of increased demand for freight transportation (European Environment Agency 2009). On the one hand, a prospering economy requires efficient transportation in order to cope with the increase in demand for goods; on the other, gains in cost efficiency of transportation have led to increased mileage. In the words of Herring (2006) who presents a critical view on energy efficiency, this is because “the effect of improving the efficiency of a factor of production, like energy [or in this case transportation], is to lower its implicit price and hence make its use more affordable, thus leading to greater use”. This is known as the rebound effect and typically occurs in response to the introduction of a new technology that increases the efficiency in resource use. In this case the so-called “new technology” would imply HCTs and the primary resources saved are the associated fuel and labor costs. Although most of the literature on the topic focuses on the effect of technological improvements on energy consumption the theory can be applied to the consumption of all types of goods and services.

The rebound effect can be either direct or indirect in nature and occurs on both a micro and macro level. The direct effect simply means that as the price of commodity decreases due to

greater efficiency, so will the consumption of it based on the principle of the substitution effect. The indirect effect, on the other hand, is based on the income effect and suggests that as the cost of a commodity decreases, this enables increased household consumption of all other goods and services that entail other kinds of resource use (Greening and Greene 1997). Effects occurring on the macro level are called general equilibrium effects, because they involve both producers and consumers economy-wide and the impacts can only be estimated by countless adjustments of supply and demand in all sectors (Greene et al. 1999).

Although the direct effect of a new technology might be low, the indirect effect can be high, resulting in negative resource savings. Since environmental aspects related to indirect rebound effects are difficult to measure, this puts them at risk of becoming a future burden if they cannot be identified and quantified in the same manner as time and costs (Aronsson and Brodin 2006). Direct rebound effects, on the other hand, are slightly easier to detect and measure. With regard to transportation, two types can be identified: changing logistics structures and modal shift.

When looking at the efficiency of the transportation system as a whole, one can observe changing logistics structures as a direct rebound effect occurring on the macro level. The fact that transportation represents a decreasing cost factor, combined with low labor costs in some global locations, has made distant sources of supply more attractive (Coyle et al. 2011). The result is that the logistics structures of companies has been shifting towards trends such as outsourcing, offshoring and centralization, which has led to longer overall distances (Lumsden 2004). Therefore, the introduction of new technology is not sufficient to reduce the environmental impact of the transportation industry (Aronsson and Brodin 2006). Instead, companies must reevaluate their entire logistics structure, including where facilities are located and whom they cooperate with, particularly with regard to purchasing and distribution, as the mere trading of goods is one of the main reasons there is transport at all (Aronsson and Brodin 2006). Generally, it can be said that environmentally friendly logistics structures are characterized by larger and fewer shipments of goods, less handling, shorter transportation distances, more direct shipping routes and better utilization (McKinnon 1995; Dunn and Wu 1995; Cooper et al. 1991). So although fewer movements and larger vehicles are frequently mentioned as methods to reduce emissions, this must be combined with

structural changes, such as local sourcing and decentralized warehousing; otherwise the reduced operating costs of HCTs are at risk of offsetting the environmental benefits through increased mileage. However, this concept of employing fewer and larger vehicles is challenged by yet another contemporary logistics principle that has become the norm across many industrial sectors, namely Just In Time (JIT) deliveries. These aim to achieve a continuous flow of materials through the supply chain in an effort to keep inventory at a minimum (McKinnon and Edwards 2010). The idea is to synchronize transportation with the production process; however, this often results in deliveries occurring at short notice and in small quantities, something that is incompatible with HCT. Instead, efficient utilization of transport capacity is sacrificed for lower inventory and more flexible production (McKinnon and Edwards 2010).

The demand for freight transportation is said to be inelastic on an aggregate level, because it generally represents less than 4% of a product's landed cost and goods need to be transported from the point of production to the point of consumption (Coyle et al. 2011). However, among and between modes the demand is more elastic and changes in freight rates can affect a shipper's choice of mode. Therefore, modal shift away from railway and inland waterways towards roads is said to be another direct rebound effect of improved cost efficiency in the road sector and is one of the main arguments opposing the implementation of HCT within the EU. Opponents of HCT argue that the positive effects on the environment discussed previously from having "two larger trucks replace three smaller trucks" will be cancelled out over time if the cost reductions lead to a modal shift that increases the overall demand for road transportation, which would result in a net negative effect on both emissions and congestion (T&E 2007). Although the White Paper (European Commission 2011) also points towards options for increasing the efficiency in transport systems, such as improved vehicle utilization, that lead to both positive environmental effects and decreased costs for industry (Aronsson and Brodin 2006); modal shift remains a major concern when discussing HCTs and there have been a number of studies that have attempted to quantify the effect.

In the end it all comes down to the price elasticity of demand for road transport (Matos and Silva 2011). Despite the fact that demand for road freight transport is often assumed to be

price inelastic, Graham and Glaister (2004) found that the studies reviewed in their paper indicate the opposite. Instead, the price demand elasticity estimates are, almost without exception, negative and in many cases exceed unity. Similarly, a study in Germany that refers to previous experience in the road sector, states that a 1% price reduction in the cost for road transport leads to a 1,8% reduction in the demand for rail transport and a 0,8% reduction in the demand for inland waterways (Umweltbundesamt 2007). The same report estimates that a 20% cost reduction in road transportation following the implementation of HCT would lead to an overall loss of volume in the range of 38% for rail and 16% for inland waterways. However, according to Winebrake et al. (2012) who provide a critical review of the literature related to the HCT rebound effect, the size of the elasticities varies considerably across shipment-specific factors, including commodity types, shipping distances, region of activity and availability of competing modes/routes. For instance, a report from the Netherlands argues that if the weight of HCT was limited to 50 tonnes then the modal shift towards roads could be reduced (CE Delft 2000). This is because the portion of the intermodal market with which road transport could compete would be minimized, as competition among road and railways/inland waterways for relatively light loads is limited (T&E 2007); thus demonstrating the effect of commodity type on the price elasticity of demand for road freight transport.

Therefore, it should be taken into consideration that with operational freight transport efficiency measures, such as HCT, although likely to reduce emissions on the micro level, rebound effects occurring on the macro level should be taken into consideration, otherwise *“the cost reducing improvements will not lead to the desired and calculated total emissions-reducing effect in the long-term”* (Arvidsson 2011 p.43). Similarly, Herring (2006 p.15) argues that: *“resource efficiency alone leads to nothing, unless it goes hand in hand with an intelligent restraint of growth”*. One proposal to limit the scope of the rebound effect and to internalize externalities of road transportation to society is that user charges could be applied (T&E 2007). These would offset the cost savings accruing to road hauliers using HCT, thereby reducing the effect of the competitive advantage these may have triggered in comparison to other modes.

It can be summarized that a possible direct rebound effect of HCT is a modal shift away from railways and inland waterways towards road. However, the extent of the effect is difficult to predict and relies on the price elasticity of demand for road transportation. On the macro level the rebound effect is more difficult to measure. In general though an economy-wide rebound effect of decreased costs for transportation can be observed in a growing demand for it on a global level, which is reflected in changing logistics structures.

2.1.5 Road Safety

Theoretically, the number of accidents should decline when using HCT, because traffic accident occurrences increase with mileage and there is need for fewer road vehicles to transport the same amount of goods (Grislis 2010). Nevertheless, traffic safety problems do exist with these types of vehicles. These can be divided into three types: technical design features of the HCT vehicles, inapplicable road infrastructure and both car and lorry drivers' behavior on the road (Grislis 2010). Safety concerns regarding the technical design features of HCTs relate to the rollover tendency (associated with the stability of the vehicle), low speed off-tracking (when the rear axles of the vehicle are tracking towards the center of the swept path (Harkey et al. 1996)), high speed off-tracking (when a driver tries to avoid collision the end of a combination vehicle has the tendency to skid sideways into other traffic lanes), acceleration and speed maintenance (can cause safety problems when clearing intersections) and braking performance (a general concern affecting all trucks, but that is not particularly influenced by changes in truck size and weight if the requisite number of axles and brakes are added) (Grislis 2010). These safety issues related to the design features of HCT vehicles can be solved using more advanced technical solutions and high developed electronic devices, such as ABS brakes (Grislis 2010). With regard to road infrastructure, safety problems arise when HCTs block the width of more than one traffic lane at tight turns and corners. In some cases they may even go into traffic lanes of the opposite direction, which causes additional risk for other road users (Grislis 2010). This occurs because some elements of road infrastructure design are not intended for HCTs, which is reflected in the limited radius of curves and narrow traffic lanes. When it comes to car and lorry drivers' behavior, there is a general belief that the overtaking of HCT vehicles is more dangerous because of the increased amount of time it takes to pass them. Furthermore, Forkenbrock and Hanley (2003) found that HCTs were more likely to be involved in fatal accidents. This is

due to the increased dimensions of the trucks that impact the severity of the collision. So although statistically proven empirical evidence has not been found to show that HCTs are significantly more dangerous than typical truck-trailer and tractor-semitrailer combination vehicles (Grislis 2010), there is still a great amount of uncertainty and fear among the public concerning safety issues revolving around HCT.

In summary, the number of accidents associated with road transportation should, theoretically speaking, decrease with HCT based on the rationale of fewer trucks on the road. However, there are other safety issues regarding the use of HCT that must be taken into consideration. These are related to technical design features of the HCT vehicles, inapplicable road infrastructure and both car and lorry drivers' behavior on the road.

2.1.6 Infrastructure

The physical infrastructure plays a major role in implementing a new system of larger vehicles. This may have an effect on roads, bridges, tunnels, roundabouts and road crossings. For the main purpose of this study the implications for roads and bridges will be discussed as those are the two main considerations, but it should be mentioned that the other aspects are by no means negligible even though not being covered in the following section.

Roads

The wear of roads is determined by a number of different factors, something that has been summarized by Leduc (2009) as can be seen below:

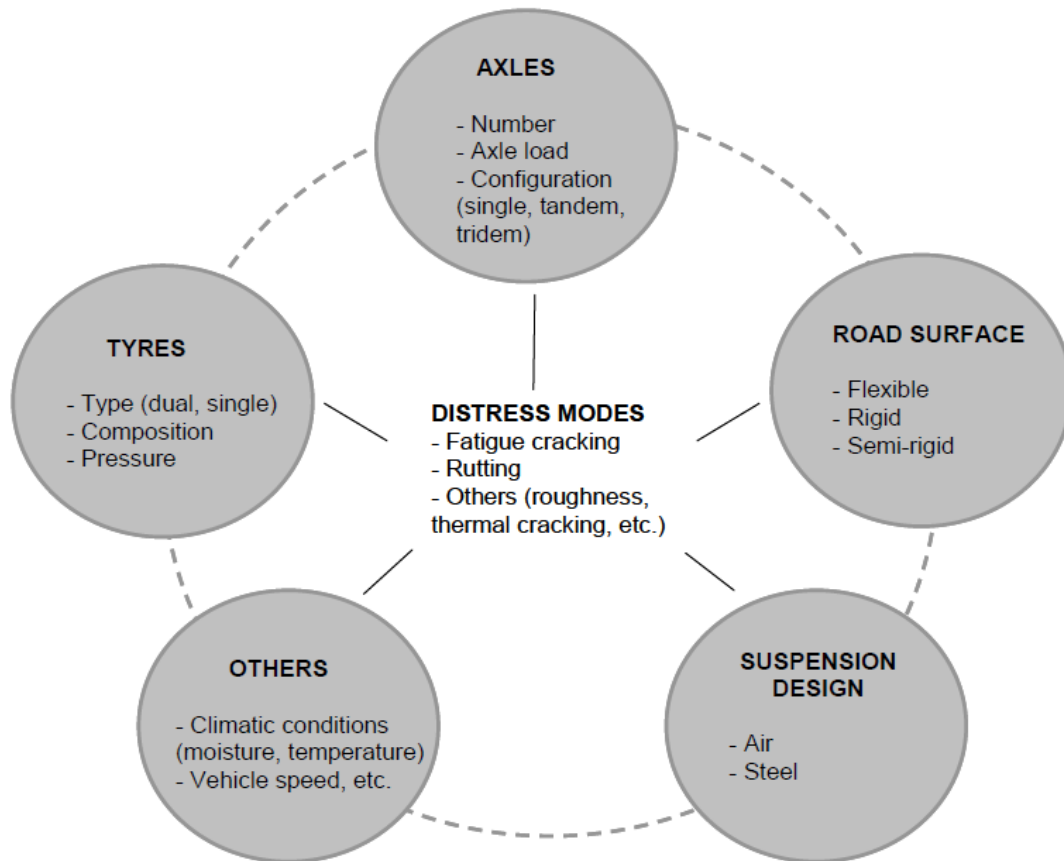


Figure 7: Factors affecting the wear and tear of roads (Leduc 2009)

Out of these factors several researchers have discussed which one is the most impactful and the general consensus is that the axle load is the most important factor to consider (Dodoo and Thorpe 2005; Gillespie et al. 1992; OECD 1998). According to Gillespie et al. (1992) the axle load has the greatest damage potential on roads and is mainly affected by the type of tires and load distribution among the axles. This view is shared by Atkinson et al. (2006) who state that including the axle load is fundamental when calculating the structural road wear from vehicles, whereas the other factors are not. The general rule used for calculating the wear on the road from a specific vehicle is the so called “fourth power law” (Atkinson et al. 2006; Knight et al. 2008; Vierth et al. 2008). The fourth power law is measured in terms of “standard axles” and states that the axle load creates a degradation of the road which is equivalent to axle weight divided by standard axle weight and raised to the power of four (Knight et al. 2008; Vierth et al. 2008). In relative terms that means, if the axle load is

doubled the degradation of the road is increased sixteen fold (Vierth et al. 2008). The fourth power rule has received criticism for not taking into consideration other aspects, such as type of pavement, type of tires, axle configuration and climate (OECD 1998; OECD 2011; Vierth et al. 2008), but even so it is still held as the general rule for calculating the road degradation due to the axle load being seen as the most important factor to consider. Continuing on the topic of axles there is the axle configuration to consider, as the effects from a single, tandem and tridem axle configuration differ. Due to the nature of how loads affect the roads the pavement will need some time to relax between axles, as some residue stress might remain if the axles are too closely together and thus pass by the same road section in too short an amount of time (Hjort et al. 2008). This means that one cannot simply summarize the effects of the single axles when using tandem and tridem configurations. The load limits for tandem and tridem configurations should thus be less than double or triple the single axle load limits to avoid unnecessary wear and tear of the roads (Hjort et al. 2008).

The Dynamic Interaction Between Vehicles and Infrastructure Experiment conducted by the OECD (1998) discussed among other things how the choice of suspension affected the wear and tear of roads. Their results show that by using an air suspension rather than a steel suspension the wear and tear will be lessened (OECD 1998). The reason for this is also stated in their report as they discovered that the important factors found in road-friendly suspensions are low levels of friction and spring stiffness, as well as an appropriate level of viscous damping (OECD 1998). All of these factors being superior in an air suspension compared to a steel suspension (OECD 1998). Furthermore the type of tires used on a specific vehicle also affects the roads. This was covered in the COST 334 report presented by the European Commission. The results concluded that there is a relative difference in how a dual tire setup and a wide single tire setup affect the roads, but that no more conclusions can be made at a general level (European Commission 2001b).

The specific characteristics of certain materials and designs used when constructing a road influences how it will react to different types of vehicles and loads (OECD 2011). The choice of pavement type especially decides how a road can cope with high levels of traffic and load factors, as there are clear differences between the pavement types. A road with a rigid surface distributes load in another way than a road with a flexible surface and the damage

they sustain can thus show differently. Rigid pavements tend to be more susceptible to longitudinal cracking, transverse cracking and corner cracking while flexible pavements tend to be more susceptible to fatigue cracking, thermal cracking and rutting (Ongel and Harvey 2004). In countries with cold climatic conditions such as Sweden, where roads are subject to seasonal freezing, the construction of the roads is even more important. The reason for this is the thawing of the frost that affects the roads during winter. During the period of thawing in spring the roads might, according to Isotalo (1993), sustain damage due to loss of bearing capacity and uneven frost penetration. The aspect regarding loss of bearing capacity is further highlighted by Simonsen and Isacsson (1999) who state that during this period of the year a single heavy vehicle can inflict significant damage to the road affected by thawing. Isotalo (1993) proposes that this type of damage can be limited by using frost-resistant structural layers with a higher bearing capacity than normal or by imposing seasonal weight restrictions for vehicles.

To offset the wear and tear of the roads there are a few alternatives that can be used. These methods can either focus on the vehicles or on the roads. Beginning with the vehicle focused alternatives, one way is to limit the access to certain roads for HCTs, meaning that these would only be allowed to traffic roads that are built in a way able to accommodate the strain from them. By using this method though, there can be a loss in efficiency as longer routes might have to be used depending on the layout of the road network (OECD 2011). Other types of regulations can also play a big part in keeping the roads in a good condition. More specifically this can include regulations regarding maximum weight, maximum axle load, axle groupings and suspension configurations (Vierth et al. 2008, OECD 2011). Switching to the road focused alternatives the first method that can be used to maintain the road condition is to design them with durability in mind. This means that the roads have to be built in a stronger and more durable way to begin with. This approach is of course only applicable when building new roads and does not affect current ones where another approach will have to be used. To keep current roads in good condition an increase in maintenance frequency or quality is one solution (OECD 2011), although this would increase socio-economic costs.

Bridges

In contrast to roads, where problems arising from the usage of HCTs can be counteracted by a number of different methods as mentioned previously, bridges have limitations that are much more fixed. The main limitation is the maximum load capacity that a bridge can withstand before it risks to collapse. This is commonly referred to as “extreme loads” and depends not only on the maximum weight traversing the bridge at the same time but also on how it is distributed across the bridge (De Ceuster et al. 2008). For HCTs this implies that the vehicles should be of a certain length if their weight increases, so as not to increase the strain on the bridges. An increase in only the weight allowance would severely increase the vehicles aggressiveness on bridges, all else being equal (De Ceuster et al. 2008). The second limitation of bridges is fatigue, which is the result of continuous use leading to degradation of the structure of the bridge (De Ceuster et al. 2008). The consequences for HCTs on fatigue is harder to track than the effects from extreme loads, the main reason being that fatigue consists of a combination of vehicles traversing bridges over a long period of time. An increase in the length of vehicles could for example mean that on average fewer vehicles will be on the bridge at the same time. This can lead to lessened fatigue as the average weight is either going down or is better distributed across the bridge. It can also lead to an increase in the fatigue if the weight increases more in proportion to the length, highlighting the complexity of foreseeing the effects of introducing HCTs.

The effects of extreme loads and fatigue also differ between different types of bridges. Bridges are usually divided into three main types, short span, medium span and long span. The span measures the length between two supports of a bridge and is thus not the same as the total length of the bridge (Encyclopædia Britannica 2013). De Ceuster et al. (2008) defines a short span being between 10 and 20 meters, a medium span being between 20 and 60 meters and a long span being above 60 meters. Furthermore De Ceuster et al. (2008) also state that the effects on short span bridges are primarily related to axle load and axle configuration, as long transport vehicles tend to exceed the span of the bridge. When it comes to medium and long span bridges the problems and ways of solving them are more or less the same for both types. An increase in vehicle gross weight coming from the usage of HCTs would increase the strain on the bridges, something that will have to be limited somehow. One way is to control the traffic on the bridge by, for example, enforcing

minimum distances between HCTs to avoid overloading (OECD 2011). Another way to avoid unnecessary strain on the bridges is to avoid overtaking and the meeting of two HCT vehicles at the weakest and thus most sensitive parts of the bridges (OECD 2011).

To summarize, the two main considerations for infrastructure impact from HCTs are on roads and bridges. For roads there are vehicle based considerations which include the number of axles, the axle load, the axle configuration as well as the chosen type of suspension and which tyres that are used. There are also considerations which are more related to outer factors and design such as climatic conditions and the choice of pavement type. Out of the mentioned factors the most important to consider for the wear and tear of roads is the axle load. For bridges the main considerations are extreme load and fatigue. The effects from HCT on these two things depend on the span of the bridge.

2.2 The Shipper's Preferences

There are many factors that come into play when deliberating the modal choice for a specific shipment. In chapter one the different actors of a logistics system and their influences have been described. According to Lammgård (2007) the direct decision when selecting transportation mode is in most cases made by the transport buyer, the shipper, or its forwarding agent. Therefore, this section will take the perspective of the shipper's and outline what determines their choice of mode. There are five modes of choice: air, motor, pipe, rail and water, whereby each mode offers specific inherent service and cost advantages, as well certain limitations (Coyle et al. 2011). For this reason there are two critical factors that play a key role in determining a shipper's modal choice: the customer value and the price offered by the transport provider Lammgård (2007).

Numerous research studies that have been conducted over the years commonly identify five main factors that determine the customer value of a transport service: accessibility, capacity, transit time, reliability and safety (Coyle et al. 2011). Accessibility refers to a modes ability to reach origin and destination facilities over a specified route, and can be geographically limited through infrastructure or network restrictions (Coyle et al. 2011). For instance, some routes will require air or ocean transport; hereby intermodal solutions can be applied to overcome accessibility problems. Furthermore, the amount and characteristics of a product being moved must be matched to the capacity of the mode, as some modes are better

suited for handling large volumes of goods whereas others are not. The next factor is the transit time; the total elapsed time that it takes to move goods from the point of origin to the point of destination, including pickup activities, terminal handling, line-haul movement and customer delivery (Coyle et al. 2011). As this affects inventory availability and stock out costs, it is directly related to customer satisfaction. Modal speed and handling of goods greatly determine the transit time. However, many companies feel that reliability is more important than the speed (Coyle et al. 2011). In other words, that the goods arrive within a specified time window, as this facilitates supply chain planning, such as forecasting inventory needs, scheduling production and determining safety stock levels. The final factor impacting the customer value of a transport is safety, as goods must arrive at the destination in a acceptable condition (Coyle et al. 2011). This, in turn, requires that proper precautions be taken to protect the goods from damage due to poor freight handling techniques, inferior ride quality, and accidents.

In addition to the above mentioned service aspects of a transport, price is another critical consideration in modal selection, as this has a direct impact upon the company's logistics costs (Coyle et al. 2011). Shippers must weigh the cost of the transport relative to the value of a product, in order to be able to sell the product at a competitive price. Generally, water, rail and pipeline are considered more suitable for low value commodities, while truck and air costs can be more easily absorbed by higher value finished goods (Coyle et al. 2011).

The table below provides a discussion of each mode selection factor:

Mode	Strengths	Limitation	Primary Role	Primary Product Characteristics
Truck	<ul style="list-style-type: none"> • Accessible • Fast and versatile • Customer service 	<ul style="list-style-type: none"> • Limited capacity • High cost 	Move smaller shipments in local, regional, and national markets	High value finished goods, low volume
Rail	<ul style="list-style-type: none"> • High capacity • Low cost 	<ul style="list-style-type: none"> • Accessibility • Inconsistent service • Damage rates 	Move large shipments of domestic freight long distances	Low value raw materials, high volume
Air	<ul style="list-style-type: none"> • Speed • Freight protection • Flexibility 	<ul style="list-style-type: none"> • Accessibility • High cost • Low capacity 	Move urgent shipments of domestic freight and smaller shipments of international freight	High value finished goods, low volume, time sensitive
Water	<ul style="list-style-type: none"> • High capacity • Low cost • International capabilities 	<ul style="list-style-type: none"> • Slow • Accessibility 	Move large domestic shipments via rivers, canals and large shipments of international freight	Low value raw materials, bulk commodities, containerized finished goods
Pipeline	<ul style="list-style-type: none"> • In-transit storage • Efficiency • Low-cost 	<ul style="list-style-type: none"> • Slow • Limited network 	Move large volumes of domestic freight long distances	Low value liquid commodities, not time sensitive

Table 3: Comparison of modal capabilities (Coyle et al. 2011 p.78)

According to Lammgård (2007) environmental concerns can be added as an additional factor influencing the decision process of transport services purchasing. Particularly as shippers have developed different levels of advancement in environmental management, which is reflected in customer transport service requirements towards the transport providers. For instance, some companies have implemented systems, such as EMS, to create additional environmental value. As different shippers have varying environmental needs, transport providers can apply customer segmentation in order to effectively use differentiated marketing to certain target groups (Lammgård 2007). For instance, intermodal road-rail solutions can be offered to those shippers with the highest environmental needs and relatively low priority regarding price. According to Lammgård (2007 p.213) in this way, “the shippers’ total transport service requirements can be satisfied and the transport providers

have created customer value for them". However, according to Rodrigue et al. (2001) the concept of green logistics creates a set of environmental paradoxes, as mentioned previously, which also affect the choice of transportation modes. For instance, when companies impose time constraints on deliveries this has significantly increased airfreight and trucking, which are considered to be the most reliable modes of transportation in terms of on-time delivery and safety, but are also the two least environmentally friendly. Ships and railways, on the other hand, have a reputation for poor customer satisfaction (Rodrigue et al. 2001), although they are the most environmentally efficient in terms of CO₂ emissions per unit of load.

In summary, modal choice is a complex process that entails an analysis of the best fit in terms of modal capabilities, product characteristics, supply chain requirements for speed and service, and transportation costs, in addition to environmental concerns.

3 Methodology and Methods

This chapter describes the methodology and methods that have been applied in this study to collect the data on which the results have been based; aspects related to the reliability and validity of the data has also been covered.

3.1 Case Study

Conducting a case study gives researchers the opportunity to incorporate exploratory, explanatory, and descriptive elements in the conducted research (Blumberg et al. 2008). Exploratory elements can be used to gather basic information regarding relatively uninvestigated topics, thus providing a basis for further research. Explanatory elements can be used for explaining the relationships between different variables that are included in a specific research, while the descriptive elements are mostly used to define and explain certain aspects. For this study, where some aspects are thoroughly investigated in previous research and others are not, the possibility of including different types of elements will help in creating a cohesive picture of the topic. The case study also has the advantage that several different sources can be used for the gathering of data, the main ones being interviews, documents and observations (Blumberg et al. 2008). This means that both qualitative as well as quantitative aspects can be covered, something which Creswell and Plano Clark (2011) call an embedded case study design. This comes with its own set of strengths and weaknesses. Johnson and Onwuegbuzie (2004) state that this approach can combine the strengths of both quantitative and qualitative research, such as the ability to test hypotheses (quantitative) and being able to provide in depth analysis of a limited number of cases (qualitative). Furthermore, they also state that the researchers can use numbers to complement the qualitative part of the research to strengthen the results (Johnson and Onwuegbuzie 2004). The downside of this is that the strain on the researchers will increase, as they have to understand and gain knowledge about a greater number of methods (Johnson and Onwuegbuzie 2004). As the topic at hand will rely on both data regarding freight transport (quantitative) and the views of the market actors (qualitative) the usage of this embedded case study design suits it well.

Compared to other types of research the case study also emphasizes that what is being researched is observed inside its own context rather than being isolated, something which

results in that it can be used to describe and investigate a theory while not being true for a whole population (Blumberg et al. 2008). In this thesis a multiple-case study approach has been used to be able to include the two trials of HCT usage in Sweden. The strength of the reliability within a case study is something that has been discussed by many researchers in the field of research design, with no real consensus among them (Bryman and Bell 2007), although a multiple-case approach is generally considered as the more reliable alternative (Blumberg et al. 2008). By using the multiple-case approach the researchers can study and examine the differences between the individual cases, finding things that they have in common as well as things that keeps them apart. This will, according to Bryman and Bell (2007), give the researchers an opportunity to reflect how different theories apply to the cases at hand.

3.2 Data Sources

In this thesis both primary and secondary data have been applied. Primary data is generally defined as data being collected by the researcher for the purpose of answering the specific research question at hand (Collis and Hussey 2009). This means that the data collected from the interviews in this study are considered primary data. Besides the primary data there is also secondary data, which is usually defined as data collected by someone else than the researcher and often for another purpose than the researcher will use it for (Collis and Hussey 2009). The results from the literature review are thus considered secondary data as well as the data from databases such as Eurostat.

Secondary data has been collected by means of a literature review that constitutes the theoretical framework of the paper. According to Collis and Hussey (2009 p.100) a literature review can be defined as *“a critical evaluation of the existing body of knowledge on a topic, which guides the research and demonstrates that the relevant literature has been located and analyzed”*. The aim is to give valuable insights into the topic and reveal previous research that has been conducted in the field. In order to obtain literature that is relevant to the research with regard to the topic, theory and methodology requires a systematic process. This in turn necessitates that the scope of the research be defined in terms of the time, geography, and single/multidisciplinary approach (Collis and Hussey 2009). Time refers to the date of publication of the sources to be used. The fact that the topic of HCTs can be

considered relatively recent means that it might not be covered in books; in which case journals and newspapers present suitable places to start looking. From there one can work back in time, using the references at the end of relevant publications to lead to previous studies (Collis and Hussey 2009). This technique is known as the snowball method and is advantageous in cases where it proves difficult to find initial sources (Raemdonck and Valcke 2003). In terms of geography the results of this study are restricted to the Swedish market, though the literature search may draw on examples from other countries for the sake of comparison. Finally, the literature review pursues a single disciplinary approach, as it reviews the topic of HCTs in Sweden from a purely economic perspective. In the next step key words associated with the research topic must be identified for the on-line searching of academic and other databases (Collis and Hussey 2009).

Knowledge extracted from the literature review can also include data, both qualitative (such as text or illustrations) and quantitative (such as tables or statistics) (Collis and Hussey 2009). In this thesis data from Eurostat has been incorporated in order to provide statistical information regarding the goods flow and truck mileage in Sweden. This can be used to compliment the theory and support argumentation. The data applied was the most recent available, from the years 2002 to 2011 (see appendix three). In some cases the data has also been used to make calculations that the researchers of this study deem relevant, which can be reviewed in more detail in appendix four and five.

3.3 Interview Study

3.3.1 The Interview Approach

Primary data has been collected through conducting a series of interviews, during which *“selected participants (the interviewees) are asked questions to find out what they do, think or feel”* (Collis and Hussey 2009 p.144). There are three types of interviews: structured, semi-structured and unstructured. For the purpose of this study semi-structured interviews have been chosen, which means that some of the questions are prepared, but the interviewers are able to add additional questions in order to obtain more detailed information about a particular answer or to explore new and relevant issues that arise from a particular answer (Collis and Hussey 2009). This allowed the researchers to adapt the questions of the interview according to the parties that have been interviewed. At the same

time the interviewers were not totally unprepared as is the case in unstructured interviews, which in turn require a high level of experience. Thus, this method of semi-structured interviews was well suited for the purpose of this study, because not much has been done yet on this topic and so the investigation is exploratory in nature, which calls for a more flexible approach.

However, the researchers are aware of the problems associated with semi-structured interviews resulting from the complexity of evaluating the outcomes, which is based on an interpretive paradigm (Collis and Hussey 2009). This means that the findings are not derived from the statistical analysis of quantitative data (Strauss and Corbin 1990), since there is no data available on the aspects being investigated in this study. Instead, the research involves an inductive process with a view to providing interpretive understanding of social phenomena within a particular context (Collis and Hussey 2009). Unlike structured interviews where answers are easy to compare because each interviewee is asked the same questions, in semi-structured interviews the issues discussed, the questions raised and the matters explored change from one interview to the next as different aspects of the topic are revealed (Collis and Hussey 2009). Although this process of discovery is the strength of such interviews, it may be difficult to keep a note of the questions and the answers, controlling the range of topics and later analyzing the data.

Nevertheless, the fact that the respondents interviewed varied greatly in their position, on the one hand public institutions, policy makers, research and development organizations and on the other a number of different business actors, meant that the interviews could not be identical but rather adapted to the individual situations. For instance, some interview respondents have already been running projects involving HCTs whereas others have not, and the researchers aimed to incorporate a wide range of different standpoints in order to get a comprehensive overview of the market's needs. Hence, semi-structured interviews meant that the feasibility of implementing HCTs could be investigated in a detailed manner, as it enabled the researchers to go there and ask specific and relevant questions including follow-ups that are in line with the requirements of the individual respondents. At the same time some basic questions have been retained and remained the same for all parties interviewed, which facilitated analysis and comparison.

3.3.2 Sample Selection

When it came to the actual conducting of the interviews, respondents with different relations to the topic have been interviewed, as mentioned above. These can be grouped into two types of stakeholders: interest groups and market actors (both with and without previous experience regarding the implementation of HCT). Although Skogforsk (The Forestry Research Institute of Sweden) is a research institute it has been grouped here together with Volvo and Bring Frigo due to its involvement in the ETT project, which provided valuable insights regarding the implementation of HCT from a supply-side market perspective.

The first group of interviewees consisted of Transportgruppen (The Transport Group), Skogsindustrierna (The Swedish Forest Industries Federation) and VTI (The Swedish National Road and Transport Research Institute). These institutions, though differing greatly in their roles, all have in common that they have an interest in the transport sector. For instance, the Transport Group represents eight member organizations, which altogether organize 11300 companies in the transportation sector in Sweden (Transportgruppen 2013). The Swedish Forest Industries Federation, on the other hand, aims to foster the competitiveness of its members consisting of nearly 100 companies in the paper, pulp and wood mechanical industries (Skogsindustrierna 2013). The third respondent in this group comes from The Swedish National Road and Transport Research Institute, which is a Swedish Government Agency that works together with all modes of transportation and is responsible for conducting research and development related to infrastructure, traffic and transport (VTI 2013). Although none of these organizations have any immediate relation to the usage of HCT, they represent a large segment of potential stakeholders, including shippers. Thus, by interviewing these organizations a rough mapping of the topic could be done of the different interests and arguments related to it, which provided a broader and more objective approach towards the subject.

The second group of interview respondents consisted of market actors both with and without previous experience regarding the implementation of HCT. Those with experience have gained it through related trial projects, namely ETT and Duo2, which will be described in more detail in chapter four. These interviews provided concrete outcomes related to the

benefits and challenges of implementing HCT from a market perspective and included results from their experiences. Other market actors without previous experience in the field were interviewed in order to investigate whether they would be interested in using HCTs or not and why. In this study this actor was represented by Bring Frigo, a transport providing company that specializes in temperature controlled road transportation.

Table 4 below summarizes the interview respondents in terms of their relation to the topic of the study, whereby the colors indicate the division between the two interview groups according to the type of stakeholders they are: either interest groups or market actors.

Respondent	Type of Organization	Name of Organization	Description	Type of Stakeholder
A	Representative Organization	The Transport Group	Organization representing the transport sector in Sweden	Interest group
B	Representative Organization	The Swedish Forest Industries Federation	The trade and employers' organization for the pulp, paper and wood mechanical industries	Interest group
C	Research Institute	The Swedish National Road and Transport Research Institute	An independent and internationally prominent research institute in the transport sector	Interest group
D	Research Institute	The Forestry Research Institute of Sweden	ETT (One More Stack): Aims to increase the gross weight of timber haulage vehicles in Sweden	Market actor with previous experience using HCT
E	Company	Volvo	Duo2: Two HCT vehicles run between Gothenburg and Malmö	Market actor with previous experience using HCT
F	Transport Provider	Bring Frigo	Logistics company offering temperature controlled transport solutions	Market actor without previous experience using HCT

Table 4: Description of the Interview Respondents

3.3.3 The Interview Guide

The preliminary interview guide (see appendix one) consisted of four types of questions: General, Institutional, Projects and Business. These were divided according to the different relations that the interview respondents have to the topic. The first set of questions that falls under the “General” criteria could be applied to all respondents from the institutional, project and business sector. For example: “Do you see any potential benefits from using HCTs in Sweden?” The fact that the initial questions were broad and open-ended was meant to give the interview a pleasant start, as they allowed the interviewee to get familiar with the topic and as the interview progressed the questions could become more specific. The second set of questions was targeted specifically towards the institutions. Only one question has been developed that was geared explicitly towards this group: “Would there be restrictions on the use of HCTs with regard to type of roads or times?” This question refers to any limitations that might be imposed on the use of HCTs in Sweden. The following set of questions was targeted at the projects that are being conducted, namely Duo2 and ETT, to acquire insights regarding these trials. The final set of questions is a continuation of this and was relevant for respondents stemming from both the project and the business category, as these questions incorporated aspects related to costs and operations. However, it should be noted that this interview guide merely acted as a support function. As such, it did not need to be strictly followed and further questions could be asked in accordance with the flow of the interview, as is the norm for semi-structured interviews.

3.3.4 The Interview Situation

There are a number of different approaches to conduct the interviews; either via telephone, video conferencing or face-to-face (Collis and Hussey 2009). Although all methods would be a feasible choice, face-to-face was judged to be the most effective for the purpose of this study. This is because telephone interviews do not give the visual impression of the person being interviewed, which makes it easier for the interviewee to deter from difficult questions. Face-to-face, on the other hand, incorporates an aspect of social interaction that enhances the flow of the interview, thus improving the accuracy and details one can obtain from the outcome (Collis and Hussey 2009). Furthermore, it enabled both researchers of this study to take part and be present during the interview, which helped to ensure that all of the issues were fully explored during the one-hour interview. Whenever it was not possible to

arrange a face-to-face interview, which was the case for the interview with Respondent D regarding the ETT project, then a viable alternative was to conduct the interview via Skype (a type of video conferencing), as this still incorporated a visual aspect. Furthermore, the interviews were recorded and transcribed, as this was permitted by all of the interviewees of this study. This enabled the researchers to go back, listen to what had been said and select the parts relevant to the study by means of coding the responses in accordance with the research questions.

3.3.5 Reliability and Validity

To measure the quality of the research it must be evaluated with regards to its reliability and validity. The reliability handles the issue of whether the results of the research can be obtained again by repeating it (LeCompte and Goetz 1982). Validity on the other hand focuses on whether the research measures what it is supposed to measure or not, in other words the accuracy of the research (LeCompte and Goetz 1982). To ensure that the reliability and validity is as high as possible there are several different methods that can be used. For the reliability of a case study the researchers should use a research design, which provides the needed features to investigate the topic at hand (Yin 1994). In this study the case study research design was deemed to be appropriate for the purpose, as mentioned previously. The theories used should also be properly presented and the records of observations should be concrete to the greatest possible extent (LeCompte and Goetz 1982). The theoretical framework of this study covered relevant theories relating to the topic and in addition the results of previous reports and trials covering the usage of HCT have been included. If there is any gathering of data by means of interviews or other similar methods it should be recorded (LeCompte and Goetz 1982) and if possible data should be collected from multiple sources (Yin 1994). Using data from multiple sources is also important for the validity of the research as it can help in protecting the research from biased results. Other methods that can be used to increase the validity of a multiple-case study is the usage of a sound replication logic when investigating the different cases (Eisenhardt 1989) and by comparing evidence from already existing research within the same area (Yin 1994).

With regard to reliability and validity when using interviews as a method for data collection, the former tends to be low and the latter high in the interpretive paradigm. Reliability refers

to the absence of differences in the results if the research is repeated (Collis and Hussey 2009). Qualitative measures do not need to be reliable in a positivist sense whereby a repeat study should produce the same result. Instead, emphasis is put on establishing protocols and procedures that establish the authenticity of the findings. According to Collis and Hussey (2009) there are three common ways of estimating the reliability of responses to questions in questionnaires or interviews: test re-test method, split-halves method and internal consistency method. The first method is not suitable for the study at hand due to the time constraints of interviewing respondents twice and the second method is rejected based on the fact that it is difficult to correlate answers from semi-structured interviews. Therefore reliability will be tested using the internal consistency method whereby every item is correlated with every other item across the sample and the average inter-item correlation is taken as the index of reliability (Collis and Hussey 2009). Validity is then the extent to which the research findings accurately reflect the phenomena under study (Collis and Hussey 2009). Therefore it is vital that the questions asked throughout the interviews correspond to the explanations given to the respondents regarding the purpose of the study.

4 Examination of High Capacity Transport

The content of this chapter refers to previous reports and studies relating to HCT. It covers the rules and legislations regarding HCT in Sweden as well as the overarching legislations of the European Union. Vehicle, terminal, financial and network related issues are mentioned. Previous usage of HCT in form of two trial projects being conducted in Sweden and what potential alternatives that exist to the usage of HCT are also included. At the end of the chapter a model of analysis is presented.

4.1 Rules and Legislations

When Sweden and Finland joined the European Union both countries already used vehicles on their national networks exceeding the European dimensions and limitations. Due to this it was impossible for them to apply the rules of the European Union for competitive and environmental reasons (EMS 2013). The solution to this problem is a part of the 96/53/EC directive (European Council 1996), which regulates the allowed dimensions of vehicles in international traffic within the European Union.

The 96/53/EC directive states that the maximum length of a so-called road train is 18,75 meters and the maximum width is 2,55 meters (European Council 1996). Furthermore an articulated vehicle may not exceed 16,5 meters. In Sweden, on the other hand, the regulations for vehicles are governed by Trafikförordning (1998:1276). In chapter 4 § 17 of these rules it is stated that the maximum allowed length of a vehicle is 25,25 meters and that maximum width is 2,55 meters.

The solution to this difference in legislations is written in article 4 § 4 of the 96/53/EC directive where it is stated that (European Council 1996):

“The Member State which permits transport operations to be carried out in its territory by vehicles or vehicle combinations with dimensions deviating from those laid down in Annex I also permits motor vehicles, trailers and semi-trailers which comply with the dimensions laid down in Annex I to be used in such combinations as to achieve at least the loading length authorized in that Member State, so that every operator may benefit from equal conditions of competition (modular concept)”

The “modular concept” mentioned in that paragraph is more commonly referred to as the European Modular System (EMS). By including the above paragraph in the directive, countries that so wish can allow vehicles on their national road network which exceed the standard European dimensions, as long as the individual modules adhere to the regulations of the 96/53/EC directive so that all operators can benefit from the differences in national legislations and be equally competitive.

4.2 Vehicles and Terminals

For vehicles to adhere to the EMS mentioned in the previous section they must be configured from a number of standardized modules. The modules that are primarily used in the EMS system are:

- Truck
- Tractor
- Dolly
- Link
- Maximum 7,82 m swap body
- Maximum 13,6 m semitrailer

(Transportstyrelsen 2013a)

Both trucks and tractors have the ability to tow trailers and dollies. The difference between them is that whilst the truck has a load carrier the tractor does not have one. A dolly is used for connecting a semitrailer to a drag unit and function as the steering axle for the semitrailer. The link fill a similar function as the dolly but have a load area where a swap body can be loaded. A swap body is a standardized container used for both road and rail carriage while semitrailers are designed to have their front end resting on a tractor, link or dolly. In Sweden these modules can be connected in three main configurations as can be seen below:

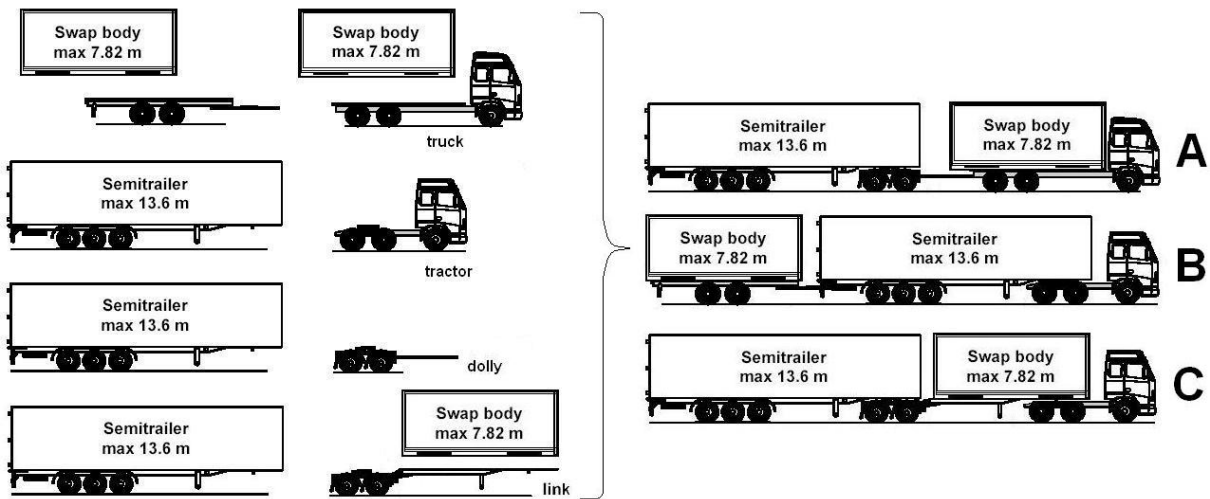


Figure 8: EMS Configurations (Åkerman and Jonsson 2007)

The above combinations adhere to the 96/53/EC directive as well as the Swedish rules regarding the length of the vehicle, but there are a number of additional limitations and rules that must be followed for these combinations to be allowed on the Swedish road network (Transportstyrelsen 2013b). For more details about these rules see appendix two.

With regard to terminal infrastructure, the ability to accommodate longer and heavier trucks at collection and delivery points plays a crucial role in assessing the feasibility of using HCT for transport providers. An increase of the vehicle dimensions would pose a challenge for current terminals, as they would have to be adapted to accommodate the new vehicles (OECD 2011). The terminals would have to be modified to cope with the increased physical space needed for the new vehicles and also to be able to handle the increased quantity of goods transported by them (OECD 2011). When terminals are not suited to handle HCTs this will cause problems in their everyday use (Grislis 2010).

A study conducted by Knight et al. (2008) have covered many of the aspects that should be taken into consideration for assessing the feasibility of High Capacity Transports. The research in the Knight et al. (2008) study is based on a combination of scientific literature review, freight data analysis, information gathering from stakeholders, modeling of freight flows and computer simulations. In a survey in the study by Knight et al. (2008), where delegates from the road freight industry were questioned about their terminals, the response was usually that the terminals of their own companies were sufficient to

accommodate HCTs, but that the terminals at some of the companies they trade with were insufficient. Furthermore, the survey showed that while the general view of the delegates was that a 25,25m truck capable of meeting current turning circle restrictions would present little problems to their terminals; they recognized that it would be more difficult to maneuver a 34m HCT vehicle at many industrial and commercial sites (Knight et al. 2008). Space limitations at truck stops, motorway service areas and lay-bys present a further challenge in the survey. The results showed that *“there was a general consensus that these facilities are currently inadequate and that substantial investments would be required to upgrade them for LHVs, especially if coupling/decoupling of LHV units became a common practice”* (Knight et al. 2008 p.48). Similarly, Grislis (2010) states that most of the rest areas and truck stops in Europe are not designed to accommodate HCTs and although these could be parked in designated slots intended for oversized cargo transports, there is only a limited number these special parking places available.

According to a market analysis conducted in the Netherlands by the Ministry of Infrastructure and Development (MIE 2011), 75% of the terminals surveyed were able to receive HCTs. Out of the terminals that could receive HCTs most of them were either based in a port area or were inland terminals whose operators also operated road vehicles and HCTs (MIE 2011). The 25% of the terminals that did not receive HCTs had different reasons for this. For instance, some of them specialized in bulk goods which are normally processed via inland shipping or rail, whereby the 60-tonne weight restriction constitutes a barrier to using current sized trucks (MIE 2011). Another reason was that they did not consider road transport to be their core business, and that they tried to make maximum use of vessels and trains (MIE 2011). In these cases road transport is only used for transport to and from the terminal, or for urgent shipments (MIE 2011).

4.3 Financial

A study conducted by the Dutch Ministry of Transport, Public Works and Water Management on the effects of the introduction of longer and heavier vehicles on the national roads in the Netherlands showed that large investments was placed in new equipment (MTPW 2011). The study included 153 companies that were either hauliers or companies having their own transportation, out of these companies 118 used the new type

of vehicles whilst the remaining did not. That there would be higher capital costs and investments with the usage of HCT is also mentioned in the study by Knight et al. (2008) which states that HCT vehicles would have a significantly higher capital cost. Most of this additional cost would be in the purchase of the trailer, dollies and linking equipment, as there is little need to acquire new tractive units with higher power ratings (Knight et al. 2008). The study by the Dutch Ministry of Transport, Public Works and Water Management (MTPW 2011) also highlights the respondent's view that savings can be made mainly in the cost of drivers and the cost of fuel. The stated reason for this is that HCTs can transport more volume than a regular transport vehicle, so the fuel used will increase but the increase in capacity will be relatively higher resulting in a net reduction of costs (MTPW 2011). At the same time fewer vehicles will be used reducing the required number of drivers and thus the cost (MTPW 2011). Another possible cost reduction was expressed by the respondents of the report by Knight et al. (2008); their general view was that, due to the higher capital cost of HCT vehicles, these would primarily be used on routes offering good loading potential in both directions, thus resulting in higher load factors and a lower level of empty running compared to regular sized trucks.

4.4 Network Restrictions

From a socio-economic perspective it would be undesirable to permit all types of HCT vehicles on all road types (Knight et al. 2008). This is because the dimensions and weight of HCTs put certain demands on the road network, which leads to a situation where restrictions come into action. These are meant to limit their influence on the infrastructure, as well as keeping them away from locations where they should not be for safety reasons. To limit the damage on infrastructure HCTs will have to follow rules considering bearing capacity. This will ensure that HCTs only traffic parts of the road network that are properly prepared to handle them. In Sweden, however, the road bearing capacity would be a minor problem as about 94% of the Swedish road network has been appointed the highest existing bearing capacity (Transportstyrelsen 2013b).

Nevertheless, HCTs would without doubt be prohibited inside urban areas, as this is already the case with 25,25m trucks in Sweden. This is because the road network in these areas is generally too narrow for them, which presents a number of physical risks related to

maneuvering around tight corners, roundabouts etc. Furthermore, analysis of accident data suggested that larger vehicles had disproportionately higher casualty rates on minor roads (Knight et al. 2008), indicating the HCT should be restricted to motorways and rural trunk roads. However, as HCTs are mainly focused on main routes with high capacity flows this does not present a major problem; the vehicles would rather be intended for deliveries to distribution centers where loads can then be split into smaller shipments for regional or local distribution (T&E 2007). A greater challenge stems from the regulations in the rest of Europe, which would prohibit HCTs from operating across borders; thus excluding the Trans-European Road Network, which is planned to cover routes considered essential to international movements, for example between ports and airports (Knight et al. 2008). HCT would therefore be used primarily for national transports within Sweden.

4.5 Previous usage of High Capacity Transport

4.5.1 ETT

The ETT (En Trave Till; One More Stack) project was first proposed by Skogforsk (The Forestry Research Institute of Sweden) in the year of 2006 (Andersson and Frisk 2013). The purpose of the project was to develop the existing transport technology and to increase the gross weight of the timber haulage vehicles (Andersson and Frisk 2013). By doing so the aim was to decrease the number of timber haulage vehicles on the roads of Sweden and thus also decrease the total fuel consumption and emissions (Andersson and Frisk 2013). The first ETT vehicle went on the road in early 2009, transporting roundwood from a terminal to a sawmill on a route in northern Sweden (Löfroth and Svenson 2011). By now about 30 organizations are in one way or the other involved in the project, including the Swedish Transport Administration, the Swedish Transport Agency, Volvo Trucks and many other (Löfroth and Svenson 2011). The vehicle used in the project, the ETT rig, differs from the regular trucks used for timber transports in several ways. As can be seen below, the ETT rig is based on modules from the EMS and the combination is 30 meters in length compared to the 24 meters of the regular timber trucks (Löfroth and Svenson 2011).

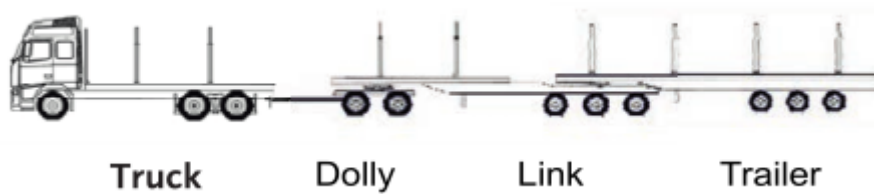


Figure 9: ETT Modular System (Löfroth and Svenson 2012)

Due to the increased length of the ETT rig it has 11 axles instead of 7, something which allows the axle load to stay the same or even decrease in comparison (Löfroth and Svenson 2011). Besides being longer than the regular timber transports it is also constructed to allow a heavier weight, 90 tonnes compared to 60 tonnes (Löfroth and Svenson 2011). Alongside the ETT project a secondary project was added in mid-2009, this project was called the ST (Större Travar; Bigger Piles) project (Lövroth and Svenson 2012). Being 24 meters long, the ST rig follows the current regulations in Sweden when it comes to length, but is heavier weighing in at 74 tonnes (Lövroth and Svenson 2012). To keep the axle load within the regulations the ST rig was equipped with more axles than the standard vehicles (Lövroth 2012).

The resulting increase in transport efficiency from using the ETT rig was substantial, as two vehicles of that type were able to transport as much as three conventional rigs, effectively increasing transport efficiency by 50% (Lövroth and Svenson 2012). This means that the number of vehicles needed to transport the same amount of goods would be lowered by a third. The results from the project also show that the fuel consumption per vehicle went up, but that the increase in loading capacity more than compensated for this. In total the fuel consumption per unit transported went down by 21% (Lövroth and Svenson 2012). This also led to a similar decrease in carbon dioxide emissions, as that is directly linked to the amount of fuel used (Lövroth and Svenson 2012). The increase in transport efficiency and decrease in fuel consumption also affected the transport costs. After taking into account the increased time for loading and unloading the larger ETT rig, the decrease in transportation costs were calculated to be about 23% (Lövroth and Svenson 2012). It was also mentioned in the results that there was no increase in road wear due to that the axle load did not differ from the regular vehicles, although the strain on long bridges increased (Lövroth and Svenson 2012).

In connection to the road tests of the ETT rig a behavioral study of other drivers overtaking of the ETT rig was conducted. The study noticed no negative observations from the overtaking drivers (Lövroth and Svenson 2012).

The results from the usage of the ST rig were similar to the results from the ETT rig, but as the vehicles themselves differed less from the regular ones the benefits were also not as extensive. Fuel consumption and carbon dioxide emissions went down with about 8%, transportation costs decreased by approximately 5-10 % and no increase in road wear was noticed, although the strain on long bridges increased (Lövroth and Svenson 2012).

4.5.2 Duo2

The Duo2 project was started in 2010 (Vinnova 2013) and is run by the Volvo Group, the Swedish Government Agency for Innovation Systems, DB Schenker and several other actors from both industry and society (Volvo 2012; Duo2 2012). One reason for starting the project was to find a way to meet the goals set by the Swedish government. These goals aim to greatly reduce the carbon dioxide emissions for land based transports as well as reducing congestion and increasing the possibilities for co-modality (Vinnova 2013). The initial goals of the projects were set to reduce carbon dioxide emissions by 15-30%, increase efficiency by 50-100%, maintain or increase traffic safety as well as maintaining the traffic rhythm (Duo2 2012). As for the vehicle used for this trial it has a length of 32 meters and a weight allowance of 80 tonnes (Volvo 2012), furthermore the vehicle is based on modules from the EMS system (Duo2 2012). Initial results show that the Duo2 vehicle has achieved fuel savings amounting to over 30%, although the first official report will only be published when the projects first trial period nears its end in 2013 (Volvo 2012). The decrease in fuel consumption will also result in a similar decrease in carbon dioxide emissions (Duo2 2012). Other potential conclusions that can be drawn from the project have been proposed to be an increase in transport efficiency and road safety (Duo2 2012), but this will not be determined until the first results are published.

4.6 Alternatives to High Capacity Transport

Aside from increasing the weight and length of vehicles there are a number of alternatives available in literature for achieving one or several of the benefits which have been mentioned with HCT. This includes aspects such as improved transport efficiency of the road sector, environmental impact and cost reductions. In order to discuss the full potential of HCT and the feasibility of introducing it, evaluating and considering the alternatives should therefore be done.

4.6.1 Platooning

One of the alternatives to the use of HCTs is something called platooning, which is a system where several vehicles are linked together electronically via wireless communication. The European Union's Seventh Framework Program for Research and Technical Development has funded the Safe Road Trains for the Environment project, which has been developing a platooning system intended to function on existing public highways. According to the Safe Road Trains for the Environment project a platoon consists of a lead vehicle (LV), which is controlled by an approved driver and one or more following vehicles (FV) (Bergenheim et al. 2010). The technical equipment in the FVs connects them to the LV, which gains control over them. The FVs are thus set on autonomous driving, which includes both lateral and longitudinal control. By doing this connection the FVs are driven without direct driver involvement, as all the driving is done by the driver of the LV and the FVs are being controlled by their technical devices instead of their drivers (Bergenheim et al. 2010).

By using platooning there are potential benefits in several different aspects. Traffic flow benefits have been recognized by Dávila and Nombela (2010). Benefits to safety have also been highlighted, as the platoon is driven by a certified and trained professional driver, who is expected to handle most situations better than the average. There are also potential downsides to using platoons in aspects of safety when it comes to extraordinary events, as those situations must be handled on a case to case basis, which puts a lot of emphasis on the lead driver's skills and adaptability (Dávila and Nombela 2010).

4.6.2 Electrified roads

The concept of electrified roads is not new but it has started to re-emerge in recent years as companies have started to look for environmentally friendly solutions to cope with the expected future growth in freight transport. Electrified roads operate much like a conventional railway as overhead contact lines provide electricity to the vehicles through a pantograph. Vehicles used in an electrified road system could utilize hybrid technology. This technology consists of an electric motor that provides power to the driveshaft as well as a diesel powered combustion engine (Siemens 2012). When the vehicle is connected to the overhead contact lines the pantograph provides the needed electricity to drive the vehicle via the electric motor and when the vehicle is disconnected from the overhead contact lines the combustion engine starts to provide electricity to the electric motor (Siemens 2012). This system allows the vehicles to travel on roads that lack the overhead contact lines and the flexibility from using road based transportation is thus maintained. This also means that the operational aspects of vehicles used on electrified roads would not differ from regular vehicles as long as some type of hybrid system is used. This applies as long as the vehicles are not only depending on the availability of electric supply.

Another component that can be used is regenerative braking which means that the energy generated when braking a vehicle is collected and sent back to the energy grid (Siemens 2012). By utilizing regenerative braking the energy efficiency is thus increased (Clarke et al. 2010). The increase in energy efficiency leads to decreased costs for the truck operators as their used amount of fossil fuel would go down, effectively reducing their costs as fuel stands for a major part of the total costs (Larsson 2008).

A potential problem with using electrified roads is the infrastructure. While the road network already exists there is a need for investments to create a big enough network with overhead cables to make it a feasible alternative to regular road based transports. The needed investment would have to be compared with how much other modes of transportation could be improved with the same amount of investments.

4.6.3 Alternative fuels

Although not being a pure alternative in general terms, the usage of alternative fuels can provide one of the positive effects associated with the usage of HCTs. The reason for using alternative fuels is to lessen the environmental impact from freight transportation by decreasing the total amount of greenhouse gas emissions. There are several alternative fuels with various benefits and drawbacks associated with them. Electricity is one alternative that has been used for a long time. The drawback of electric vehicles is that they are limited in terms of the distance they can cover before they have to recharge the batteries (Cullinane and Edwards 2010). The biggest issue with using electricity to power vehicles is that the production of the electricity effectively determines how much the total greenhouse gas emissions actually decrease. If the energy is produced in an environmentally friendly manner the total emissions will decrease, but if this is not the case then they will remain the same and only the geographical location of the emissions will change (Cullinane and Edwards 2010).

Hydrogen is also an alternative fuel that have been looked into as it has the potential of powering a type of fuel cell where hydrogen react with oxygen and only produce water vapor as a byproduct coming out of the tailpipe (Cullinane and Edwards 2010). This is of course viewed as very favorable but the technology still has to improve to be a commercially feasible alternative. There are also several downsides with using hydrogen. First and foremost it suffers from the same problem as electricity, hydrogen also have to be produced and thus the source of the energy used for the production will determine how much it affects the total greenhouse gas emissions (Cullinane and Edwards 2010). Furthermore Eyre et al. (2002) state that for hydrogen to be commercially feasible it needs to have the appropriate infrastructure with filling stations and fuel distribution, something, which would require significant investments.

Another type of alternative fuels that can be used to reduce greenhouse gas emissions is biofuels which are fuels produced from biomass (Bomb et al. 2007). The benefit from using biofuels is that they can be used in most of the current vehicles with only minor alterations to them (IEA 2011), reducing the needed investment in new equipment. Biofuels can also utilize much of the current distribution infrastructure for fuels (IEA 2011) which further

lessens the investments needed for a large scale introduction of these types of fuels. While biofuels would mean a decrease in greenhouse gas emissions there are potential issues related to their usage, one of them being the so-called “land-take” issue (Cullinane and Edwards 2010). This issue covers the side effects from an increased demand for biofuels on a macro level and how it effects biodiversity and socio-economic conditions (van Stappen et al. 2011) as well as causing changes to the agricultural production (Cullinane and Edwards 2010).

4.7 Summary

Previous reports and studies related to the usage of HCT have showed that the challenges for terminals related to an introduction of HCT, such as size restrictions and increased flow of goods, would not be applicable for a majority of the current terminals. When introducing HCT investments would be high, as new equipment would be needed, although a net reduction in cost is expected. Most parts of the current road network in Sweden are able to handle heavier vehicles than the current regulations allow. Trial projects conducted with HCTs show that there are considerable gains in transport efficiency and that there is a decrease in fuel consumption and emissions per unit loaded resulting in that costs are going down. Platooning, electrified roads and the use of alternative fuels were proposed to achieve some of the benefits from the usage of HCT but they all come with their own set of strengths and weaknesses.

4.8 Model of Analysis

The literature review and the examination of HCT have revealed that there are nine main areas to consider for implementation of HCT in Sweden, these include; rules and legislations, ETT, Duo2, freight transport trends, financial, operational, infrastructure, target group and alternatives. These in turn can be divided into four groups, namely: practical experience, enablers and barriers, target group and alternatives, as can be seen in the model below.

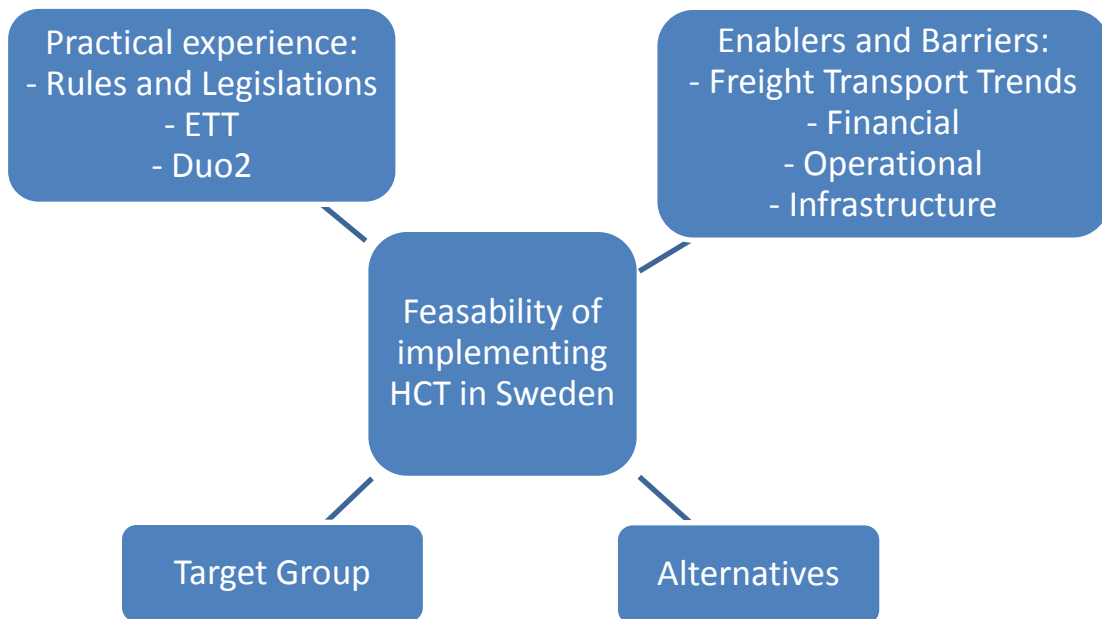


Figure 10: Model of Analysis

Both the results from the interviews and the analysis will be structured according to this model, as that will provide a good overview of the topic.

5 Results from the Interviews

This section outlines the results from the six interviews that have been conducted. It has been noted what each respondent has contributed to the topics included in the model of analysis, starting with the previous usage of HCT (rules and legislations, ETT and Duo2), followed by enablers and barriers (freight transport trends, financial, operational and infrastructure), and ending with the target group and alternatives. The table below summarizes the contribution of each respondent to the different topic areas:

Respondent	A	B	C	D	E	F
Rules and Legislations	X	X	X			
ETT		X		X		
Duo2					X	
Freight Transport Trends	X		X			
Financial	X				X	X
Operational	X	X	X	X	X	X
Infrastructure	X	X	X	X		
Target Group	X	X				X
Alternatives	X	X	X			X

Table 5: Contributions of the respondents to different topic areas

5.1 Previous Usage of High Capacity Transport

5.1.1 Rules and Legislations

From a policy perspective HCT is, in the words of Respondent A from the Transport Group, “problematic but should not be problematic”, as all other modes of transportation, including trains, ships and aircrafts, are getting bigger. According to this Respondent HCTs should have a bigger role to play; however, this proves difficult in light of the many feelings involved, which makes it hard to discuss the topic in logical terms. Particularly the interest of the railway, which is very prominent in the EU, makes it difficult to promote anything that is regarded as a threat.

In terms of the rules and legislations regarding the use of HCTs the importance of the EMS is frequently mentioned. For instance, Respondent A states that: “it would probably be easier to argue for an increase in the length of the Swedish vehicles if they continue to use standardized modules that are a part of the EMS”. Similarly, Respondent C from the Swedish National Road and Transport Research Institute agrees that there would be a lot of advantages if HCTs would build on the modules of the EMS; it would, for example, increase

flexibility when crossing borders. Nevertheless, there is an overarching agreement that cross-border regulations would limit HCTs international use and to have longer trucks in Sweden would probably require some changes in the legislations of the European Union (Respondent B, The Swedish Forest Industries Federation).

5.1.2 ETT

Regarding the ETT project that has been running in Sweden to test the use of HCTs, Respondent B mentions that HCTs in the forest industry would primarily be used to transport the timber from the forests to the rail terminals for the trunk leg of the transport, as is currently the case with the trucks of the ETT trial. According to this Respondent not only the capacity of trucks should be increased, but also that of the railway, as they complement each other. Also, it is easier to focus HCT on the initial leg of the transport, as politicians would otherwise be against it and questions regarding modal choice would arise.

Experience from the ETT project to date has shown that increasing the size and weight of trucks has had a positive effect on both costs and the environment. According to Respondent D from the ETT project, increasing the size and weight of timber vehicles has resulted in a decrease of transport costs by 8-10% for the 74-tonne trucks and 20% for the 90-tonne trucks. In terms of emissions the figures are similar; they show a decrease of 10% for the 74-tonne trucks and 20% for the 90-tonne trucks, resulting from less fuel consumption per tonne.

Despite the benefits that have been measured from testing these HCTs, Respondent D is also aware of the public concerns involved with this topic and mentions fear and feeling as the major burdens to implementation. These are mainly related to the rebound effect, though Respondent D states that the magnitude of this effect depends on the type of goods and recons the amount transported will not increase in the forest industry. In terms of infrastructure HCT tested during the ETT project is not said to have impacted the roads. This is due to the increased number of axles, 9 for the 74-tonne truck and 11 for the 90-tonne truck instead of the regular 7 axles, which results in less weight per axel. However, the Respondent does acknowledge that the uptake area of terminals might increase if HCT were

to be implemented on a larger scale, though these then might also be able to handle more railway traffic.

5.1.3 Duo2

According to Respondent E the Duo2 trial, which has been operating two HCT vehicles between Gothenburg and Malmo, was launched primarily in support of Volvo's core value "Care for the Environment". Moreover, it is part of Volvo's effort to work with improving driver productivity, which is said by the Respondent to improve with HCT as the costs per tkm are lowered. The timing of the project was brought about by the government's focus on both the environment and better utilizing infrastructure. Furthermore, the work that has been done in other European countries regarding this topic makes it very contemporary and it has become of great interest to several different parties. Particularly following the positive results from the ETT project, this has raised the desire to pursue a similar HCT trial in Sweden with general cargo (Respondent E). However, this required a route with only separated lanes, which made the stretch between Gothenburg and Malmö appropriate and because DB Schenker has suitable terminals in these locations, they were asked to run the trial. According to Respondent E the results of the trial to date have fulfilled most of the expectations, the exception being the weight of the vehicle; with an average of 60 tonnes this was found to be lower than expected. Due to weight restrictions on some of the bridges along the route the weight of the trial HCT vehicle was limited to 80 tonnes, but it typically ranged from 42 to 78 tonnes. This leads to the conclusion that volume is the important factor along this route, which indicates that it is primarily high value goods being transported (Respondent E).

5.2 Enablers and Barriers

5.2.1 Freight Transport Trends

According to Respondent A there will be an increase of freight transported in Europe, which the White Paper aims to avoid getting on the road. Instead, to accommodate the increase and rebalance the freight (in terms of percentage), other modes must be made more competitive in comparison to road. However, at some point the commission should come to the conclusion that the shift to inland waterways and rail will not be fast enough due to infrastructure capacity problems. In line with this, Respondent C also states that they are

capacity restrictions in the rail network on certain routes in Sweden. For this reason one should, according to Respondent A, use what is available in the short-run and increasing the capacity of trucks is one option, as this is achieved more easily. From this perspective, it was proposed that Sweden could act more as a role model and show the path. In Respondent A's words, "in transport policy using rail freight is not a tool but seems to be a goal" and to enhance competitiveness in intermodal solutions, "the solution is not to limit the road market, but to have the railway shape up".

5.2.2 Financial

From a socio-economic perspective HCT is the most viable solution due to the lower infrastructure costs required for implementation (Respondent A). Furthermore, according to Respondent F from Bring Frigo, required investments for the implementation of HCT would be minor for road transport providers, as the required equipment is readily available within the company, with the exception of only some more dollies that would have to be acquired. In fact, HCT could be implemented within days; if the new regulations would be based on the current modules then it would only be a matter of changing to more trailers. Moreover, Respondent F argues that the introduction of HCT would allow for divestments of old equipment, such as tractors; because one tractor can pull more trailers with HCT, less of them are needed. Contrary to this, Respondent E argues that haulage companies would indeed be required to invest in new equipment and as these are often small businesses that operate on low margins, this investment presents a substantial risk. Particularly in light of the fact that they only have limited bargaining power towards the logistics companies, which have the power to lower the rates and reap the profits in this situation.

5.2.3 Operational

In the interviews the most frequently cited operational potential in connection with HCT is efficiency, both in terms of the environment and costs. This is reflected in the results of the ETT project mentioned previously, which indicate a reduction in both factors (Respondent D). According to Respondent B this is due to 50% more loading capacity on each ETT truck compared to a regular one. In the words of Respondent A more freight on each lorry means "more freight to each motor", which leads to "more energy efficiency and lessened emissions, something that is a goal in transport policy". Similarly, Respondent F claims that

the diesel consumption would increase slightly per truck, but per unit of load it would decrease.

In terms of costs, Respondent F further states that companies can save money if they can reduce the number of trucks by consolidating loads onto HCTs. However, the customers would of course notice this and so the margins of the carriers would not increase in the long run; rather, the decreased costs for transport providers would be transferred to the shippers in the form of lower prices. Respondent C agrees to this notion by stating that the greatest benefit of HCT is on transport cost. However, this is only true if the capacity is used, so the incentive to fill the trucks is increased.

Although this raises concerns regarding a possible modal shift from rail to road, Respondent A claims that road and rail are not the biggest competitors in freight transport; rather, rail competes with inland waterways due to the types of goods that they carry, and if there is no option to shift freight then road should be made as efficient and sustainable as possible, for example by implementing HCT. This notion is supported by Respondent F who states that rail is not a viable option for the type of goods transported by Bring Frigo. This is because their business focuses on temperature controlled food products, which require the flexibility and timing that can only be offered by road transport, as trucks can “be sent where they are needed every day”. This degree of flexibility is why trucks are so successful, whereas the railway needs stable, industrial flows of goods to get good results due to the effects of time slots. As such, there is no real alternative to trucks in this industry, because it is important to the customer that the level of service quality is kept high, something that is currently not possible with other modes of transportation. Therefore, in order to change mode the customer’s demands must first adjust so that larger windows of delivery are introduced. For this reason, HCT would be an efficient way to lower the cost and the environmental load, while at the same time maintaining the flexibility and service level required in this industry (Respondent F). Similarly, Respondent E states that there would be no significant change from rail to road following a nationwide introduction of HCT. According to this Respondent, when the rail is working then there is nothing that can compete with it in terms of price. For instance, Respondent B states that even if the trucks were allowed in the whole country; they would continue using rail for the trunk leg of timber transports and HCT would only be

used from the inland forests to the rail terminals along the coast, as this is the cheapest option for transporting raw materials. This is particularly important for low cost goods where transport costs stand for a high percentage of the total value. However, the problem is that the railway is very sensitive to interruptions whereas trucks are able to avoid disruptions by taking alternative routes (Respondent E). This makes them very dependable and flexible, something that is essential for high value goods where the transport cost only represents a small percentage of the total value. Therefore road and rail do not compete for the same type of goods. However, in the words of Respondent C, the outcome of the rebound effect is unclear and although transfers between the modes are case specific, HCT will in any case pose a challenge to the railway.

Furthermore, the impact of HCT on traffic safety was frequently mentioned as a burden for implementation and was taken into consideration by the majority of the participants of the study. According to Respondent C, HCT should in theory mean fewer trucks on the road, which in turn means fewer accidents in total; this notion is supported by Respondent E. However, according to Respondent C there are several types of accidents that can be influenced by a number of factors, such as the vehicle length, over-taking, stability and type of roads (minor roads are more dangerous for HCT usage). This makes traffic analysis quite complicated to carry out and as a result there is not enough empirical data available, which makes the topic controversial (Respondent C). Although the ETT trial running in the north of Sweden has so far not experienced any issues related to safety (Respondent B); questions of safety remain important for road transport operators. For instance, Respondent F voices the concern that there might be a tradeoff between road safety and transport efficiency, though the effects are unclear. According to Respondent E the biggest safety issue is presented by the truck itself and whether it is well maintained or not; ultimately the driver takes the biggest risk. Nevertheless, neither Respondent E nor Respondent F reckon that it will be difficult to find sufficient drivers able and willing to drive the larger and heavier vehicles, despite the increased level of difficulty.

For safety reasons there would also be a number of network restrictions imposed on the use of HCT, which might create a burden on a company's operations. According to Respondent C, the type of roads that will be included is something that should be discussed before a

possible implementation. However, according to Respondent F, network restrictions applying to cities would not present a major challenge, as this is no different from the current situation for the 25,25 meter trucks. Furthermore, HCTs would primarily be used for long-haul transports on main routes where the amount of goods is sufficient and not for maneuvering through urban areas; for the final delivery to the customer distribution centers would be used, as is currently the case in big cities.

According to both Respondent E and F, these terminals would generally be able to handle the increased size of HCT vehicles, though they will need to become more productive. According to Respondent F, there could be some minor problems to and from certain terminals depending on the condition of the road between the terminal and the main route. However, it should be possible to work around this; for example, the trailers could be decoupled by the roadside and then be picked up one by one to the terminal. In such cases it is only a matter of planning, which might come at the cost of time. However, Respondent E states that the new configurations of the HCT vehicles would actually enable more efficient distribution to the cities, as the truck can be reconfigured in a more convenient way, which then again saves time.

In terms of time restrictions, for instance if HCT could only be used during the night, as is currently the case with the Duo2 trial, this will inflict some limitations on flexibility, as it requires loads with more specific delivery times (Respondent E). According to Respondent E, DB Schenker has said that they would consider changing all of their trucks to the new types of configurations if they could run them during the day; however, when this is not possible it restricts them and it also bears increased risks for traffic safety if the drivers are tired. Nevertheless, Respondent F states that it would still be possible to use HCT for long distance transports during the night.

5.2.4 Infrastructure

Network restrictions resulting from infrastructural capacity limitations, for example on roads and bridges, will present a more challenging situation. According to Respondent C, assumptions regarding axle load are important when calculating costs for road wear. For example, during the ETT project the weight per axel has been decreased in order to lessen

the strain on the roads (Respondent D). For the ETT project this was said to be important for two reasons: on the one hand, they do not want the trucks to get stuck on muddy roads and on the other, they do not want to put more strain than necessary on the roads as that would increase their costs, because they usually own and build the roads in the forests themselves (Respondent B). However, in terms of bridges, simply increasing the number of axles will not solve the problem, as it is the total maximum weight that is most important in this case (Respondent C). Due to weight limits these will need to be checked and in some cases reinforced in order to avoid accidents (Respondent B). For this reason full HCTs might not be able to take certain routes and will need to take detours to avoid some bridges. However, Respondent B also points out the fact that trucks might be able to use shorter routes when going back empty to the forest because their weight is reduced when not laden, which means they could cross the bridges. Effects on margins from strengthening bridges and/or taking detours are not clear (Respondent C). Nevertheless, minor adjustments on bridges will probably be cheaper than increasing rail capacity (Respondent A).

5.3 Target Group

In the words of Respondent F: “big capacity is good where you need it” and for HCT this is most commonly the case on long haul routes where the amount of goods is sufficient. According to Respondent A Scandinavia traditionally has a stable flow of containers on stable routes, which is something that speaks for the usage of HCTs in those corridors. Also in the words of Respondent A, it is high value consumer goods that tend to “run on rubber” and if the amount of goods continues to increase as predicted then there will eventually be stable high volume flows even for this type of good, which will open up for new ways of transport combinations to be used. This is because the transport cost is a low percentage of the total for high value products like fashion etc., and if the products are not in the shop at the right time it will be more expensive than the transport cost for the retailer. For this reason the deliveries are very important and having a train once a week is not an option, which is why trucks are used (Respondent A). In the forest industry, on the other hand, which represents a very different kind of product, HCT is mostly used on shorter distances (from the forests to the rail terminal) (Respondent B). Furthermore, unlike high value consumer goods that are rather volume constrained, it is the weight that is most important for the forest industry as opposed to length (Respondent B).

5.4 Alternatives to High Capacity Transport

In addition to increasing the weight and length of trucks, a number of alternatives have been suggested for improving the efficiency of road transportation. Among the proposals that have been brought up was the use of a “duck-tail” to improve the aerodynamic profiling of the trucks (Respondent B). However, in order for this to be applicable the tail would have to be outside of the permitted length, which is so far not the case in current regulations; otherwise it lessens the loading space, thus increasing the cost per load. Another suggestion was electrified roads using overhead wires or something beneath the roads (Respondent A). This concept has been tested by Siemens, but according to Respondent C it is not possible to implement in the short-run as it would require vast amounts of infrastructure investments, which are currently not available because the money is needed elsewhere (Respondent A). To solve this lack of funding for infrastructure development, new methods must be found and used to improve the transportation system. This, in turn, makes it difficult for those opposing HCT, as longer and heavier vehicles could utilize infrastructure that is currently already in place (Respondent A). If one were to take this concept one step further then road trains could use highways in a similar fashion to the railway, i.e. through platooning. In terms of infrastructure costs, this option would be cheaper than electrified roads and still be good for the environment (Respondent A). The use of alternative fuels was also mentioned as an alternative to HCT. However, finding a source of energy that is not fossil fuels and not emitting carbon dioxide is not so easy. Furthermore, it is not possible to shift from oils to biofuels in Europe (Respondent A). A more practical solution was offered by Respondent F, who had installed bars inside some of the trucks, which enable double or even triple stacking of pallets in order to use the height of the truck to its fullest.

6 Analysis

This study has investigated the market potential of using HCTs in Sweden based on the case study methodology. Both the literature review and interviews have revealed interesting results that will be analyzed in this section according to the model developed in chapter four.

6.1 Previous usage of High Capacity Transport

The results in this study bring up that HCTs should have a bigger role to play but that it is difficult due to the many feelings involved, making it hard to discuss in logical terms. As a member of the European Union Sweden also has to follow the legislations set by it, which results in limitations in what can and cannot be done even within the borders of Sweden. For large scale changes the EU legislations would have to change and the possibilities to do this are hard to determine. Currently the EMS makes it possible to use longer and also heavier vehicles on national road networks within the EU as long as the vehicles consist of modules following the standards of the system (European Council 1996). By building on these modules there would also be an increase in flexibility when crossing borders as the vehicles can be reconfigured for the regulations used in the country they are entering. That is of course if cross-border transportation is allowed as it was said that cross-border regulations could greatly limit the international usage of HCT. From the interviews it was suggested that if proposals of HCTs within Sweden build upon the modules of the EMS the discussion with the EU about the possibility of changing legislations would probably be easier to conduct. One thing that was brought up during the interviews that would make the discussions harder was that the railway, which has a very prominent position in the EU, sees HCT as a threat and would therefore argue against it.

When the ETT project started it aimed to develop technology to increase the gross weight of vehicles in order to decrease the number of vehicles used as well as decreasing the fuel consumption and the emissions (Andersson and Frisk 2013). The results of the trial showed that there were positive effects in terms of decreased transport costs, reduced fuel consumption and lowered emissions (Lövroth and Svenson 2012). They also showed an increase in transport efficiency resulting in a reduction in the number of vehicles that had to be used if HCT was implemented. These things were also mentioned in the interviews.

Furthermore, there was not considered to be an increase in the wear of the roads as the increase in the number of axles for the vehicles led to a decrease in axle load. The ETT vehicles would primarily be used for transports from the forest to terminals in northern Sweden where the goods would be reloaded onto trains. Thus, the new vehicles would increase the efficiency and lower the costs of the current operations, but no modal shift would come into question. A modal shift will not occur, as the goods of the forest industry are low value raw materials with a high percentage of the total value being transport costs. For the longer hauls the option of railway would still be the most lucrative alternative for companies in this sector. During the interviews it was mentioned that the forest industry would like to see an increase in the allowed length of trains so that they could achieve the same positive effects there as from the ETT vehicles. By also increasing the length of the trains, the total efficiency of the whole chain of transportation would be increased, something which can hardly be seen as something negative.

The forest industry was said to be aware of the public concerns regarding the new vehicles, which is something that will not necessarily be a major issue in the long-run, as new technology is rather quickly accepted when the advantages are made clear. When the transport costs goes down there is a possibility that a rebound effect will occur (Herring 2006). However, for the forest industry there will not be major changes in the amount of goods being transported and thus there will also be little to no possibility of a rebound effect occurring.

As the ETT project showed promising results, the foundation for transferring the efficiency improvements from forestry products to general goods was laid; thus the Duo2 project was initialized. This project also aimed for the same things as the ETT project. The vehicle used in Duo2 was designed to build upon modules from the EMS. This will simplify a potential future introduction if the end results are promising. So far there are only initial results available, but these show that the expectations are mostly fulfilled and that the Duo2 vehicle seems to achieve the same positive results as was seen in the ETT project. An interesting aspect that has so far been noticed in the Duo2 project is that the average load has been lower than expected, the average has only been 60 tonnes, which is clearly below the 80 tonne

allowance of the Duo2 vehicle. This means that the general goods transported in this project is more sensitive to volume than weight, which in turn indicates high value goods.

6.2 Enablers and Barriers

The results from the literature review and interviews have revealed a number of enablers barriers related to the implementation of HCT in Sweden. Business actors must take into consideration future freight transport trends, financial, operational and infrastructural factors.

Despite the economic crisis of 2008, which caused a dip in the total amount of freight flows in Europe (OECD 2011); both the results from theory and the interviews agree that these have started picking up again in recent years and are expected to continue growing in the future as the economy recovers. As transportation represents a significant portion of energy consumption in Europe, this sector is attracting an increasing amount of attention from EU politicians who wish to decouple transport from economic growth. This is reflected in the White Paper (European Commission 2011) that aims to divert the expected growth in transport away from road, which accounted for nearly half of the total freight transport in 2010, to more environmentally friendly modes of transportation, such as railway and inland waterways. However, this will require vast amounts of infrastructure investments to be made, which will be both costly and timely, as these modes of transportation are currently faced with capacity constraints. This, in turn, implies that the efficiency of the transportation sector must be improved elsewhere, at least in the short-run, and HCT is one option for doing so.

This is because HCT utilizes resources that are readily available; in terms of infrastructure the required investments and time to reinforce bridges and repair roads from wear and tear are minimal compared to expanding the railway/inland waterway network. Thus, from a socio-economic perspective this makes it quite a feasible solution. With respect to investments that companies will need to deploy for the switch to HCT there are some disagreements among the results of this study. In theory, HCT vehicles are considered to have a relatively high capital cost. However, the respondents that have been interviewed disagree upon this point. Whereas one has stated that the required investments for new equipment would be

marginal, another has stated that it would be a significant investment for small haulage companies to acquire the equipment needed for HCT. Furthermore, their bargaining power towards the logistics companies is limited, which makes the investment questionable. Therefore it must be investigated whether there are sufficient flows prior to making the investment. Nevertheless, should transport providers decide to forego the opportunity when it arises, then they risk having higher transportation costs compared to their competitors.

This is due to the fact that HCT is said to have the highest impact on transport efficiency in terms of operating costs; this was a result of both the literature review and the interviews. The increased carrying capacity of HCT vehicles means that the amount of trucks/movements required for transporting a given amount of goods is reduced (McKinnon and Edwards 2010). As fewer trucks are required this reduces both fuel and labor costs, which represent the greatest cost factors related to road transportation (Larsson 2008). However, this only holds true if the capacity is utilized, which should, in theory, also decrease the amount of empty running, because the increased cost of operating HCTs means that these will only be employed on routes with sufficient capacity and where loads can be consolidated (Knight et al. 2008). Proponents of HCT therefore argue that there is also a positive effect on the environment; despite the increased fuel consumption per HCT vehicle, load consolidation means fewer truck movements and lessened emissions per tonne of goods transported.

However, according to theory it could be argued that decreased costs for transportation are partly responsible for globalization and the subsequent changing logistics structures of companies towards trends such as offshoring, outsourcing and centralization (Lumsden 2004); something that has been referred to in this study as the rebound effect. This is suggested by the fact that transportation has grown faster than GDP in some years, which in turn results in overall longer transport distances and a net negative effect on the environment (European Commission 2001a). Furthermore, it was mentioned in the interviews that some politicians fear that the cost reductions in road transportation following an implementation of HCT will lead to a modal shift away from railways to roads. This would be in contrast to the goals of the White Paper and is probably the strongest argument opposing HCT. Nevertheless, the review of the shipper's preferences in chapter

two showed that there are several factors influencing modal choice, including accessibility, capacity, transit time, reliability and safety (Coyle et al. 2011), as well as environmental concerns (Lammgård 2007). Furthermore, rail and trucking differ significantly in terms of their modal capabilities. Therefore, it can be claimed that price only plays a minor role in this aspect. In line with this argumentation, HCT was not considered by the interview respondents to increase the total amount of truck mileage nor lead to a modal shift. This is because road freight does not in all instances compete with rail freight due to differences in the type of goods these modes attract, thus limiting the scope of the rebound effect.

Although the rebound effect makes the topic of HCT controversial, from a business perspective it can be said that operating costs and the environment speak in favor of HCT. However, it is agreed upon that monetary profit should not come at the expense of safety. While this study has not investigated impacts of HCT on traffic safety in great depth, HCT vehicles could not be connected to an increased rate of accidental incidents, neither in theory nor through the interviews. Nevertheless, it recognizes that this aspect will have to be dealt with more thoroughly by both business actors and policy makers should there be a nationwide implementation of HCT in the future.

Furthermore, it was acknowledged in both literature and by the interview respondents that HCT vehicles would not be suited for all types of roads and locations. Therefore, HCT transport would be constrained to some extent by network restrictions. Although this will present some challenges to road transport operators through limiting their flexibility, the effect was found to be negligible, as these vehicles would primarily be used on longer distances with high volume flows. In this respect, time restrictions were found to be a greater barrier on the use of HCT, as these necessitate more specific delivery windows.

In a final step business actors must evaluate their ability to accommodate HCT vehicles in their terminals. This aspect is slightly more difficult to assess, as it differs from company to company. Whereas larger companies with bigger terminals will have an easier time in this respect, small companies could encounter difficulties. This is because the productivity of the terminals needs to be increased, as the amount of goods throughput is expected to rise (OECD 2011). This is due to the fact that incoming and outgoing HCT vehicles carry more load

than regular sized trucks. Nevertheless, the overriding impression gained from the interviews was that this would only present a minor challenge and that HCTs could, in most cases, be received at the terminals with only a few adjustments.

The impacts from HCTs on the infrastructure, mainly roads and bridges, have to be assessed by including a number of different factors. For roads previous research shows that the axle load is the most important factor to consider when calculating the wear and tear of them (Dodoo and Thorpe 2005). This view was also shared by the respondents of the interviews. To introduce HCTs in Sweden the problems related to the potential increase in the wear and tear of roads must be solved, and they must be solved in such a way so that HCTs are not too limited. If too many limits are imposed upon them then the benefits will face the risk of decreasing to a critical level. The proposed ways of counteracting an increase in the wear and tear of the roads include limiting the access of HCTs, specific technical regulations for HCTs, design roads with durability in mind as well as an increase in maintenance of roads (OECD 2011). Out of these the simplest solution would be to limit the access for HCTs, although this could limit the usage of them depending on where the limits are imposed. If the limiting were to be combined with some specific technical regulations, so that the number of available routes could be as high as possible, then this would probably be the easiest solution as well as the simplest. Designing the roads with durability in mind as well as increasing the maintenance would be too costly in comparison. For bridges the problems were recognized to be mainly focused on the maximum weight that they could withstand. This means that it is important to properly distribute the weight over the whole length of the bridge to avoid damage due to overstress. There are also the problems related to the long-term damage of the bridges, namely fatigue. To avoid and counteract these problems all the roads along routes prospected for usage by HCT must be examined and then strengthened if necessary. Due to this a cost aspect comes into the equation although these costs should be relatively cheap in the long run compared to increasing capacity for other modes of transportation such as rail. If bridges are not deemed strong enough along a certain route then there will be restrictions imposed upon the usage of heavily laden HCTs and they must then take detours when their load exceeds certain limits for specific routes. This will remove some of the recognized potential for using HCTs.

6.3 Target Group

The mode of choice for a certain haul is mainly based on the distance it has to be transported as well as the type of goods that is included. This is thus the basis upon how one can decide which the potential target group of HCT is. It has also been mentioned that volume is an important factor for low density goods and that weight is an important factor for high density goods (McKinnon and Edwards 2010); these things must also be considered when contemplating where one can possibly use HCTs with good results. HCTs are mainly being considered for long distance transports, as that is where the large-scale benefits can be put to the best of use (De Ceuster 2008). This is something that would work well with the current transport flows in Sweden as goods are being transported along a few main routes, providing significant flows of goods and thus providing the basic flows needed for the usage of HCTs (Vierth et al. 2012). Large capacity is good when it can be put to full use so that the fill rates are high enough. The goods that would benefit from being transported in Sweden are mainly long distance high value goods such as foods and grouped goods. High value goods tend to be transported by road, as they are relatively sensitive in terms of delivery times and flexibility. These goods would also rely mainly upon the additional volume that is provided by HCTs as that could lower the transport cost per unit. An interesting thing that has come up in the results of this paper is that there are also possibilities of using HCTs for certain shorter hauls. The forest industry in Sweden has to use road-based options to transport the timber from the forests to the terminals and/or mills for further refinement or continued transport. As this type of good is considered to be low value and high density the transport cost stands for a relatively high portion of the total value, traditionally making road based transport unsuitable for this type of good. However, as there are no available alternatives in the forests, road has to be used for the initial leg of the transport. HCTs would thus improve the efficiency and lessen the costs for this stretch of the total haul for this industry.

6.4 Alternatives

In the interviews some alternatives to the usage of HCTs were mentioned. Among them were electrified roads, although this would come with a couple of complications in terms of implementation. Nevertheless, it also comes with benefits in the areas of being less dependent on fossil fuels and being generally a less emitting choice than conventional transports. The investments needed for creating a network with electrified roads would be monumental though, as the type of large scale infrastructural development needed for this requires huge investments to be realized. These things mean that it would not be possible to introduce electrified roads in the short run, as it takes time to develop the infrastructure. There is also the investment problem, the funding needs to be taken from somewhere and that is currently not possible, as other things having a higher priority need the available funding.

An alternative to the use of electrified roads would be the use of platooning. Compared to the electrified roads concept platooning would be able to utilize current infrastructure, as no modifications would be needed to the current road network. This lessens the need for investments significantly, which to a great extent lowers the hurdle of implementation. The platooning concept would mean that the highways could almost be used as railways, something that might result in the railway feeling threatened and thus being against this type of development.

Using new types of fuels have also been brought up, but finding alternatives are not easy. Electricity, hydrogen and biofuels are possible replacements of the current fuels, although they all suffer from various drawbacks making an implementation more or less unfeasible. Electricity suffers from range issues (Cullinane and Edwards 2010), which currently limit its use too much to be a feasible alternative for long distance transports, an area where HCT is proposed to excel. The environmental benefits from electricity are also highly dependent on the source of energy, something that can make or break the whole point of using it. Hydrogen has the main advantage of only producing water as a tailpipe emission, but it also suffers from the problem related to the production of the fuel (Cullinane and Edwards 2010). Furthermore, there is a high dependability on distribution infrastructure for a possible implementation. This leads to a high need for investments and as the benefits from using

hydrogen are still being debated there is next to no possibility of introducing this on a large scale in the foreseeable future. Biofuels come with the benefit of being usable together with the current distribution infrastructure and they can also be used in the current fleet of vehicles with only minor modifications (IEA 2011). As good as that sounds biofuels also suffer from problems, one of the main ones being the “land-take” issue which covers how changes in land usage can change agricultural production and other land-using types of productions etc. In the interviews it was also stated that there is no possibility for Europe to shift from current fuels to biofuels at the moment. Together all of these things effectively work against the topic, creating a situation where more research has to be made before the winds can change and a possible shift in fuels can come to be discussed.

7 Conclusions

What are the practical experiences of HCT in Sweden?

Previous usage of HCT in Sweden has revealed a number of opportunities; the main findings of the ETT and Duo2 trials have been that HCT can provide benefits in terms of transport efficiency, fuel consumption and environmental impact on routes with high volume flows.

What are the enablers and barriers of implementing HCTs in the market for transport in Sweden?

Businesses are faced with a number of enablers and barriers that they must take into consideration when deliberating the possibility of implementing HCT. The expected growth of freight transport in Europe speaks in favor of HCT, due to its ability to carry an increased amount of goods with the advantage of utilizing on existing infrastructure, which will limit the amount of public investments needed. Instead, investments into new equipment will have to be made on side of the transport providers in order to be able to accommodate HCT vehicles, which will be necessary to uphold their competitive position. However, in light of the operational advantages that can be gained from using HCT it is possible to justify these investments, as companies can save money on fewer drivers and vehicles, as well as less fuel consumption, resulting from gains in efficiency. This is because the number of vehicle movements to transport a given amount of goods is reduced, which results in both environmental and cost advantages. However, this only holds true on the micro level; when economy-wide effects are taken into account it can be argued that the decreased costs of road transportation stemming from HCT might lead to overall longer transport distances, as well as a modal shift away from railway and inland waterways to road, which would be in contrast to the goals of the EU. Fear of the public regarding the safety of HCT is another major barrier to implementation that has been identified and is a topic that will need to be addressed in more depth, particularly in a sense of how both policy makers and businesses plan to work with this issue. Network restrictions, on the other hand, were not recognized as a major challenge, as HCT would primarily be used on main routes. Furthermore, by building on the modules of the EMS, HCT would not experience difficulties crossing borders to neighboring countries. Similarly, terminal infrastructure was generally not considered a barrier to implementation for businesses. On a national level the effects on infrastructure, mainly roads and bridges, from HCT are considered important as these represent a cost to

society. The impact of HCT on the wear and tear of roads is primarily decided by the design of the vehicles and as such this will be one of the main issues to cover before an implementation. Bridges on the other hand would have to be examined and reinforced if needed along certain routes to be able to accommodate HCT.

What would be the target group of HCTs in Sweden?

The target group for HCT can be divided into two main subdivisions: volume constrained high value products and weight constrained raw materials. For high value products the transport costs represent a small percentage of the total value, but due to them requiring a high degree of flexibility and reliability makes HCT a viable option for long-haul distances. For raw materials where the transport costs represent a relatively larger fraction of the total value, HCT offers advantages only on short distances, from the forests/mines to the rail/inland waterway terminal, as other modes of transportation are better suited for these types of goods. Although there are also some alternative methods that have been presented in this paper, which can provide some of the benefits as HCTs; the issue with these alternatives is that they can only cover a few of them and thus lack the full impact, which HCT has. Therefore, it can be concluded that the advantages of HCT outweigh the drawbacks, which generates a market for them in Sweden.

7.1 Further Research

Prior to a nationwide implementation further research will need to be conducted, particularly in the areas of safety, infrastructure and competitive effects on other modes of transportation. More research also has to be done regarding the aspect of making the railway more efficient as a way to compliment HCT, as the railway was out of scope for this study. In addition, the demand for HCT should be investigated in more depth regarding the market share that these vehicles could capture in real numbers.

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Appendix

Appendix 1: Interview Guide

General:

1. Do you see any potential benefits from using HCTs in Sweden?
2. Do you recognize any potential problems from using HCTs in Sweden?
3. Do you think the benefits outweigh the drawbacks?
4. What type of freight flows would primarily come into question for HCTs?

Institutional:

5. Would there be restrictions on the use of HCTs with regard to type of roads or times?

Projects:

6. What is the aim of the project in more detail?
7. What are the main findings/results from the project regarding the use HCT to date?

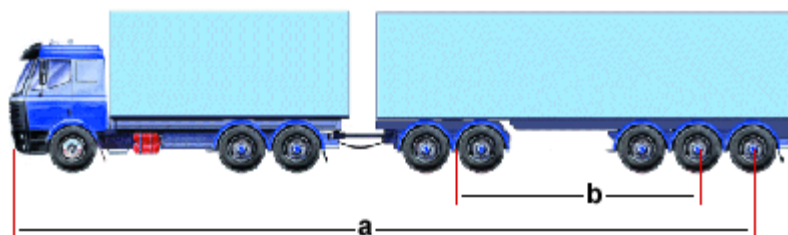
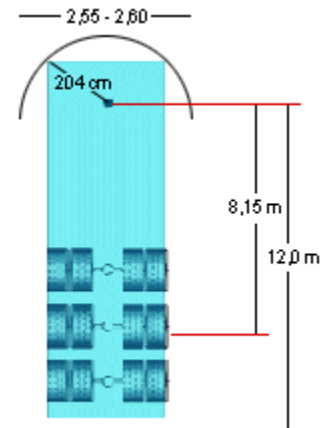
Business:

8. How would restrictions on road types/routes affect your choice to use HCTs?
9. How would HCTs affect your operations / logistics structure?
10. How would HCTs affect your costs?
11. What would be the biggest burden for implementation from your point of view?
E.g. infrastructure / investments
12. Are you looking into alternatives to making your transport operations more efficient? E.g. platooning

Appendix 2: Additional Regulations

These are the additional rules that 25,25 meter vehicles must adhere to in order to traffic the Swedish road network.

- The width of the vehicle are not allowed to exceed 2,55 meters, this includes containers, trailers and all other removable extensions.
- Every part of the vehicle must be equipped with ABS-brakes and fulfill the requirements of the 71/320/EEC directive.
- The coupling pin of the trailer must be placed so that the maximum distance to the front is 204 centimeters. The distance to the back of the trailer may not exceed 12 meters.
- The towing vehicle must be able to turn within a circle with an outer radius of 12,5 meter and an inner radius of 5,3 meters.
- The vehicle must be able to turn within a circle with an outer radius of 12,5 meters and an inner radius of 2 meters.
- The demands of turning are considered fulfilled if the distance a in the figure below is maximum 22,5 meters and that distance b is maximum 8,15 meters.



- To be allowed a maximum speed of 80 km/h:
 - The fifth wheel must use bearings.
 - The rearmost trailer are not higher than 4,0 meters
 - The distance from the coupling pin to the middle point of the rearmost trailers non-steering axles must be at least 7,5 meters and only the front axle/axles are used for steering in speeds exceeding 40km/h.
 - It must be possible to turn with full steering on the towing vehicle without any contact between the parts of the road train.
 - If any one of these requirements are not fulfilled the maximum allowed speed is 40km/h.

(Transportstyrelsen 2013a)

Appendix 3: National annual road transport 2002-2011

Data extracted from the Eurostat database (European Commission 2013a). National annual road freight transport by distance class and type of transport (Mio Tkm) [road_go_na_dctt].

Total transported goods in Sweden measured in millions of tkm for 2002-2011.

The percentages for tkm are calculated by the following formula:

$$\text{Share of total in percent} = \frac{\text{Distance specific tkm}}{\text{Total tkm}}$$

Total transported goods in Sweden (millions of tkm)

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Distance										
Total	31 836	31 467	32 691	34 701	35 474	36 395	37 952	32 123	32 732	33 402
< 150 km	10,534	10,246	10,721	11,925	11,601	12,054	12,044	10,301	10,327	9,557
150-499 km	14 928	14 266	14 949	15 276	16 507	16 922	18 207	14 694	14 298	16 122
500 km >	6 373	6 954	7 021	7 500	7 366	7 419	7 701	7 129	8 107	7 722
< 150 km	33%	33%	33%	34%	33%	33%	32%	32%	32%	29%
150-499 km	47%	45%	46%	44%	47%	46%	48%	46%	44%	48%
500 km >	20%	22%	21%	22%	21%	20%	20%	22%	25%	23%

Distance	Average percent (2002-2011)
< 150 km	32%
150-499 km	46%
500 km >	22%

Appendix 4: National annual road transport in thousands of tonnes 2011

Data extracted from the Eurostat database (European Commission 2013a). National annual road freight transport by distance class, type of transport and group of goods (1 000 t), from 2008 onwards [road_go_na_dctg].

Total transported goods in Sweden measured in thousands of tonnes for 2011.

The percentages are calculated by the following formula:

$$\text{Share of total in percent} = \frac{\text{Group of goods in tonnes}}{\text{Total transported goods in tonnes}}$$

Total transported goods = 325 411 thousand tonnes

Total transported goods in Sweden

Group of goods	Thousands of tonnes	Percentage of total
Total transported goods	325 411	100 %
Products of agriculture, hunting, and forestry; fish and other fishing products	51 300	15,8 %
Metal ores and other mining and quarrying products; peat; uranium and thorium	98 632	30,3 %
Food products, beverages and tobacco	24 292	7,5 %
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	27 052	8,3 %
Other non-metallic mineral products	15 491	4,8 %
Secondary raw materials; municipal wastes and other wastes	15 898	4,9 %
Equipment and material utilized in the transport of goods	18 901	5,8 %
Grouped goods: a mixture of types of goods which are transported together	32 018	9,8 %
Other	41 827	12,8 %

Total transported goods in Sweden for distances less than 50km

Group of goods	Thousands of tonnes	Percentage of total
Total transported goods, less than 50km	179 041	55,0 %
Products of agriculture, hunting, and forestry; fish and other fishing products	18 360	5,6 %
Metal ores and other mining and quarrying products; peat; uranium and thorium	87 357	26,8 %
Food products, beverages and tobacco	6 162	1,9 %
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	12 421	3,8 %
Other non-metallic mineral products	7 825	2,4 %
Secondary raw materials; municipal wastes and other wastes	9 066	2,8 %
Equipment and material utilized in the transport of goods	14 908	4,6 %
Grouped goods: a mixture of types of goods which are transported together	6 598	2,0 %
Other	16 344	5,0 %

Total transported goods in Sweden for distances between 50km and 149km

Group of goods	Thousands of tonnes	Percentage of total
Total transported goods between 50km and 149km	74 610	22,9 %
Products of agriculture, hunting, and forestry; fish and other fishing products	23 998	7,4 %
Metal ores and other mining and quarrying products; peat; uranium and thorium	9 920	3,0 %
Food products, beverages and tobacco	4 873	1,5 %
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	7 373	2,3 %
Other non-metallic mineral products	4 397	1,4 %
Secondary raw materials; municipal wastes and other wastes	4 079	1,3 %
Equipment and material utilized in the transport of goods	2 393	0,7 %
Grouped goods: a mixture of types of goods which are transported together	5 899	1,8 %
Other	11 678	3,6 %

Total transported goods in Sweden for distances between 150km and 499km

Group of goods	Thousands of tonnes	Percentage of total
Total transported goods between 150km and 499km	60 680	18,6 %
Products of agriculture, hunting, and forestry; fish and other fishing products	8 531	2,6 %
Metal ores and other mining and quarrying products; peat; uranium and thorium	1 251	0,4 %
Food products, beverages and tobacco	10 296	3,2 %
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	6 322	1,9 %
Other non-metallic mineral products	2 845	0,9 %
Secondary raw materials; municipal wastes and other wastes	2 465	0,8 %
Equipment and material utilized in the transport of goods	1 370	0,4 %
Grouped goods: a mixture of types of goods which are transported together	15 499	4,8 %
Other	12 101	3,7 %

Total transported goods in Sweden for distances above 500km

Group of goods	Thousands of tonnes	Percentage of total
Total transported goods above 500km	11 080	3,4 %
Products of agriculture, hunting, and forestry; fish and other fishing products	412	0,1 %
Metal ores and other mining and quarrying products; peat; uranium and thorium	104	0,0 %
Food products, beverages and tobacco	2 961	0,9 %
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	936	0,3 %
Other non-metallic mineral products	423	0,1 %
Secondary raw materials; municipal wastes and other wastes	287	0,1 %
Equipment and material utilized in the transport of goods	230	0,1 %
Grouped goods: a mixture of types of goods which are transported together	4 022	1,2 %
Other	1705	0,5 %

Appendix 5: National annual road transport in million tkm 2011

Data extracted from the Eurostat (European Commission 2013a) database. National annual road transport by group of goods and type of transport (1 000 t, Mio Tkm), from 2008 onwards [road_go_na_tgtt]

Total transported goods in Sweden measured in millions of tkm for 2011.

The percentages for tkm are calculated by the following formula:

$$\text{Share of total in percent} = \frac{\text{Group of goods in tkm}}{\text{Total transported goods in tkm}}$$

Total transported goods in tkm = 30 659 millions of tkm

Total transported goods in Sweden

Group of goods	Millions of tkm	Percentage of total
Total transported goods	30 659	100 %
Products of agriculture, hunting, and forestry; fish and other fishing products	4 508	14,7 %
Metal ores and other mining and quarrying products; peat; uranium and thorium	2 296	7,5 %
Food products, beverages and tobacco	4 851	15,8 %
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	3 152	10,3 %
Other non-metallic mineral products	1 551	5,1 %
Secondary raw materials; municipal wastes and other wastes	1 105	3,6 %
Equipment and material utilized in the transport of goods	886	2,9 %
Grouped goods: a mixture of types of goods which are transported together	6 995	22,8 %
Other	5 315	17,3 %