LONGER COMBINATION VEHICLES - SOLUTION TO SUSTAINABLE PRE AND POST HAULAGE IN SWEDEN?

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ABSTRACT

Reduced energy consumption, optimization of the usage of the main strength of different modes, reduction of congestion on road networks, and low environmental impacts are considered as the main advantages of intermodal (road-rail) transport. However, there are disadvantages such as unease of monitoring due to complexity of the transport chain or high cost for pre-and post haulage. Recently sustainability has received increasing attention and with it also the role that logistics concepts can play in making transport more sustainable. One of these concepts is a concept of Longer Combination Vehicles, i.e. vehicles of up to 35 m in length, which might be good solution for pre and post haulage. This concept has potential to improve performance of intermodal transport in Sweden; however the same is not allowed by the regulations. Purpose of this paper is to investigate how to improve intermodal freight transports with use of long vehicles; from environmental and economic perspective. This study should support the recent discussions on whether the traffic regulations regarding the length of the vehicles should be investigated. Data for the study are collected through interviews, field observations and internal documents.
The results indicate that the use of Longer Combination Vehicles would decrease the number of trips per route and therefore lower the environmental effect on the route. However, to achieve transport cost savings the utilization rate should be high.

Keywords: intermodal freight transport, longer combination vehicles, environment, fuel consumption, Sweden

INTRODUCTION

According to European Commission (2001) there is a continuously increasing demand for transports within Europe. Road freight currently accounts for approximately 45 % of total transports (tonnes-km) within EU and improvements like for example implementation of Longer Combination Vehicles (LCVs) would contribute to sustainability of road transport (Åkerman and Jonsson, 2007). Sweden follows the predicted development in EU and an increasing globalization together with a low population density further emphasizes the importance the sustainable transport system (Berger, 2009; Åkerman and Jonsson, 2007). LCV on suitable road routes might be suitable supplementary solution since it does not need major investments in new infrastructure and it has potential to reduce the environmental impact by increasing the transport efficiency. LCVs are truck vehicles that are longer and heavier than what the traffic regulation today permits.

Sweden has a tradition of long vehicles and extensive work has been done to strengthen roads and bridges to endure vehicles with a length of up to 25.25 m and a weight of 60 tonnes (Lundqvist, 2007). In central Europe today there is an intensive debate on whether or not to allow longer vehicles, the limit today for central European vehicles is 18.75 m. The discussion in Sweden is about extending the length limits even further than today's 25.25 m. One example is a case with a 32 m LCV which has been operating for several years in the Port of Gothenburg, transporting containers from one terminal to the port (Bertilsson, Olsson, 2009; Åkerman and Jonsson, 2007)

The objective of the study is to find an LCV prototype that shall be evaluated in terms of transport efficiency and environmental impact, on public roads in Sweden. The study analyses different actors' views regarding LCVs; evaluates possible routes and LCV concepts regarding the economy, fuel consumption, transport efficiency, transport volume, and terminal handling.

FRAME OF REFERENCE

Although LCV would generate certain economic and environmental benefits (Åkerman and Jonsson, 2007) wider use of the concept is in debate in Europe and in USA due to safety related issues. If wider use of the LCVs is allowed it would be necessary to drive not only on highways but also on two lane roads causing the risk for vehicles overtaking the LCVs (Hanley and Forkenbrock, 2004). Furthermore, routing problems for trailers have been studied by many, for example Gerdessen (1995), Villegas et al (2010) and Lin et al (2009); the same would only amplify with LCVs. Consequently many aspects have to be taken into consideration before allowing wide use of LCVs. The European Union has common legislation when it comes to size and weight limitations for vehicles operating between the member states. However, Sweden and Finland have an exception from these rules due to the long distances that have to be covered in these countries as well as due to the fact that prior to the entry into the EU, both countries allowed considerably longer vehicles than the rest of Europe, up to 24 m. The rest of the EU had, and most member states still have, a maximum length and weight of 18.75 m and 40 tonnes, but it is up to the individual member states to set the limits for domestic traffic (Åkerman and Jonsson, 2007). In 1997, an extension was made to allow vehicle combinations of 25.25 m and 60 tonnes if the vehicles were built from the European Modular System (EMS) (Åkerman and Jonsson, 2007). This extension was not available only for Sweden and Finland, but for all member states, however, only Sweden and Finland have chosen to approve the 25.25 m and 60 tonne limitations from the start. The EU does, however limit border crossing vehicles to 18.75 m and 40 tonnes (Åkerman and Jonsson, 2007).

The EMS is built up from modules that by themselves or in combinations can be transported economically in the rest of the EU but also can be combined into combinations of 25.25 m for the markets with longer vehicles (Åkerman and Jonsson, 2007). The idea is that three European vehicle combinations can be rearranged into two combinations for the Swedish and Finnish road systems, see Figure 1.

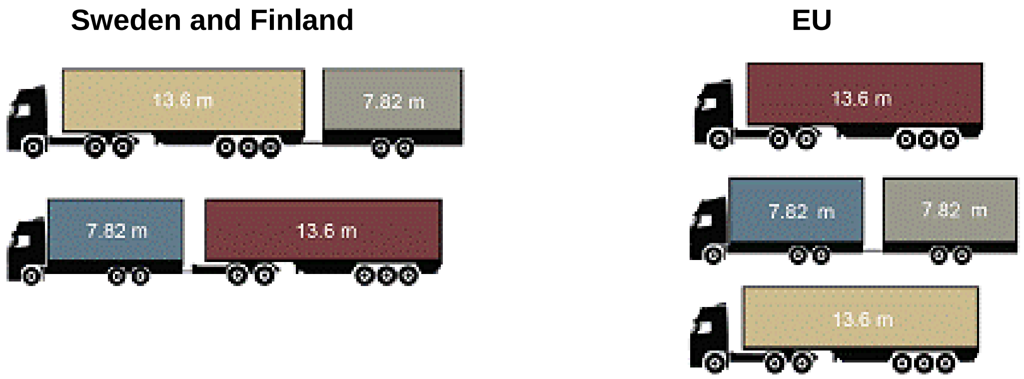


Figure 1: EMS modules and EMS vehicles allowed today in Sweden and Finland and in EU (Adapted from Berger, 2008)

The LCV concepts that were investigated in this study were all consisting of modules according to EMS and some examples are shown in Figure 2.

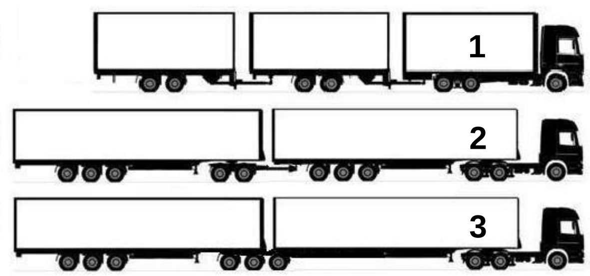


Figure 2: Examples of Longer Combination Vehicles (LCV). (Åkerman and Jonsson, 2007)

The Central European legislation, with a maximum length of 18.75 m for truck transports contributes to a 24% higher transport cost, per tonne kilometre, compared to the Swedish legislation of 25.25 m. The central European system does also require a 35-50% larger truck fleet compared to the Swedish system (VTI, 2008).

Reference projects

There are other research projects being planned and executed in Sweden involving LCVs, each investigating a unique vehicle concept used in separate logistical contexts. The main idea behind En-Trave-Till (ETT) project is that two LCV logging trucks can do the same work as three regular sized (24 m and 60 tones) trucks. The project is a jointly run between several actors such as: researchers at Skogforsk, the Swedish Road Administration, forestry industry, vehicle manufacturers like Volvo and hauling companies. The ETT-project is a test with a 30 m long LCV which has a weight of approximately 90 tones divided on eleven axels. The ETT vehicle consists of one rigid truck that pulls one dolly, one link and one semi-trailer, se Figure 2. This LCV performs daily transports on a distance of approximately 170 km between Piteå and Överkalix in the northern part of Sweden. The speed is 80 km/h which is higher than what is normally allowed for a vehicle with this many joints (Bertilsson and Olsson, 2009).

The Större-Travar (ST) project is a similar logging project as the ETT-project and both projects are managed by the same actors. Vehicles in the ST project consist of two 24 m trucks with approximately 74 tonnes weight which transport logs on a distance of approximately 150 km. This test does not include a longer vehicle than what is allowed in Sweden today, but the load exceeds the maximum weight limit.

Those projects are still going on but some conclusions can be made. The most common accident type involving trucks and cars today is a frontal collision and the relative velocity and the difference in weight between the two vehicles results in high risk of injuries for the occupants of the car. This means that the safety problem, regarding car crashes, should not increase with longer and heavier vehicles; but it should decrease due to fewer trucks on the roads. Regarding breaking distance, it is not affected by the heavier and longer vehicle, since every axel breaks its own weight, and axels are added in both test projects to support the extra weight. Regarding the longer distance needed for other vehicles to overtake an LCV, preliminary results from the field tests show no apparent difficulties. Regarding the road wear the ETT and ST vehicles will probably be slightly better than today existing logging vehicles since they have lower axel pressure. Regarding manoeuvrability the ETT-vehicle has shown good results. There is no major difference between the new ETT-vehicle and normal logging vehicles regarding manoeuvrability in curves and roundabouts. The ETT-vehicle also shows good results regarding reversing but it demand some skills and training from the driver. The main positive result so far from the ETT-project is the reduction in fuel consumption which is measured to approximately 20 %.

The first LCV related project in Sweden involved a vehicle for transport of containers on shorter routes in and around the Port of Gothenburg; the load capacity has been increased from one to two 45 feet containers. (Åkerman and Jonsson, 2007; Bertilsson and Olsson, 2009). The LCV consist of one tractor that pulls an extended link and the last part of the LCV is a standard semi-trailer which is hooked on to the extended link. This concept is performing transportations from one container terminal in Arendal to the port of Gothenburg and the transport distance for the truck is approximately 5 km (Bertilsson and Olsson, 2009). The project started in 2007 and after two years project the total number of vehicle used has been reduced consequently emissions reduced for 30-40% (Bertilsson and Olsson, 2009).

The “Maxi-cube” project is another LCV research project which is jointly driven by Volvo and Kinnarps. This project has not yet started to run on Swedish roads but the application work and the specification of vehicle concept has started. The vehicle is planed to be a rigid truck that pulls two centre axel trailers with a height of 4 m and a length of approximately 27 m. One of the goals with this project is to show positive vehicle splitting possibilities when a vehicle is travelling between Sweden and EU countries which allows shorter maximum vehicle lengths. The vehicle also needs to perform distribution transport on small roads in the nearby or within urban areas, which results in that flexibility is of great importance regarding this LCV.

RESEARCH APPROACH

This study has been conducted in two phases. The aim of the first phase is to choose the most suitable combination of the existing LCVs as well as the suitable routes for LCV. With the results from the first phase the second phase started to investigate applicability of the chosen concepts on the chosen terminals as well as to calculate fuel consumption.

The first phase of the study, being qualitative, consisted of a literature review in order to get a deeper understanding on the subject as well as to find out about other similar projects going on. This literature study included scientific journals, academic literature used in education and research, EU projects, governmental research projects, business oriented publications and internal documentation from the actors involved. The literature review and problem definition was followed by the study that included several interviews with different actors and visits to important locations such as the chosen terminals. This study also included mapping of the current state of the relevant goods flows. The analysis is conducted as a cross comparison between literature and information collected from the interviewed actors. Eight different actors have been selected for the study and 12 semi-structured interviews were performed allowing the interviewees to introduce new issues. The selection of interviewees was done based on relevance to the study. Planned project members and representatives from government agencies with influence on the project were given the main focus. In addition, representatives from research groups and other stakeholders were included.

The second phase is grounded on the results from the first phase and is both qualitative and quantitative. The data was collected from interviews, field studies and from internal documentation. Calculations regarding goods volumes and costs have been based on information collected through interviews. This included both estimations done by i.e. haulier and third part logistics supplier, and data from their internal systems. Calculations regarding fuel consumption have been built on simulations in the simulation software PERF and then validated through interviews and literature. PERF is a basic simulation tool which has a straight forward fuel consumption estimation function. The fuel consumption used in this analysis is an average between several simulations with different LCVs at different road routes. Different LCVs with different engines, gearboxes, axels, number of tiers and tier types were simulated, and the simulations gave fairly similar results regarding fuel consumption. The simulated fuel consumption is to be seen as an indication, not a forecast.

FINDINGS FROM THE PRELIMINARY INTERVIEWS

This section covers findings from the preliminary interviews with different actors of the system; from those being very theoretical such as researchers to those being very practical such as the drivers. Here are their views regarding possible future LCV combinations based on the EMS, and with the simplification of treating all short trailers as similar, regardless of axle positions, eight different vehicle concepts are possible to form taking the EMS to the next length level. Furthermore, these eight concepts can be divided into four groups; three short pallet carriers, two long pallet carriers, one short and one long pallet carrier pulled by a rigid truck and finally two short and one long pallet carrier pulled by a tractor.

Researcher - transport and environment related

Generally, the academia-interviewee approves initiatives that make transportation more efficient. Efficient transports mean a more efficient use of our resources and thereby a decreased impact on the environment, at least in a short term perspective. Not only will longer vehicles address the need for less environmental impact, they also help reducing problems with overcrowded infrastructure. If longer vehicle combinations are allowed, the first effect will probably be a decrease in the number of transports performed, and a decrease of the cost for transportation. In a slightly longer perspective the cost reduction will probably lead to a price reduction for the customers. This may result in a slight increase in transported volumes, but not one that would be significant compared to the reduction in emissions that can be expected from the larger batch size in transports. On a long term perspective, however, there is a potential increase in long distance sourcing due to lower transportation prices, which may lead to significantly larger goods volumes. This means that improvements in efficiency may well lock us further into an unsustainable system. To prevent an efficiency increase from stimulating a volume increase according to the reasoning above, economic policy instruments should be designed to keep demand on a reasonable level. Furthermore, the academia-interviewee emphasized the need for such policy instrument to be correctly designed so that the resources are invested in reaching the intended purpose.

Regarding the slight possibility that longer road vehicle combinations would steal goods volumes from rail transports; instead of hindering improvements in other transport modes the rail transportation industry should focus on improving its own efficiency. In a longer perspective the goods volumes will increase anyway, creating a capacity shortage on the Swedish railway network.

Technologies for improving aerodynamics, such as different kinds of spoilers are already available, but in many cases legislative restrictions regarding outer dimensions of vehicle combinations create a trade-off situation between loading capacity and fuel consumption for hauling companies, a situation where loading capacity almost always ends up being prioritized. Package design for load ability is yet another area where improvements can be made to improve transport efficiency and reduce environmental impact.

Transport union

The union’s attitude towards longer transportation vehicles is in general positive. Implementations of LCVs would lead to higher productivity and lower environmental impact, altogether would stimulate the business environment within the field of road transportation. The union’s opinions are based on the historical improvements of truck load weights and maximum lengths, which all have had positive impacts on the transportation situation in Sweden, apart from satisfactory increase of the truck driver’s salaries.

According to the union there is no need for any new form of drivers' license for the truck drivers, but there is a need for complementary education and training. Furthermore, to speed up the process the complimentary education should be handled and offered to the drivers by the hauling companies and not as a driving skill test managed by the government.

Reference project

One of the main objections that the reference project ETT faced in the early phase was that a heavier vehicle had problems with breaking. This is, however solved with technology allowing each wheel pair to break its own axels load. The investigation from the ETT project did not show any problems with the vehicle folding during breaking. A design problem was that a longer vehicle generally takes up more space while turning, due to the fact that the rear of the vehicles has more trouble following the wheel path. This was solved with the design of the vehicle configuration chosen in the ETT project.

The main issue regarding the weight, beside those mentioned above, was the durability of bridges. Bridges shorter than the distance between the first and the last axle do not really pose a problem, since the entire vehicle never is on the bridge at the same time. Longer bridges however may be questionable.

Regarding the stability of the vehicles, those used in the project showed no problems. The length of the vehicle does affect the stability, but the design of LCV is of more importance; i.e. centre axle trailers reduce stability noticeably, especially if placed last in a combination.

In general, the safety on roads could improve with LCVs since it would lead to fewer vehicles on the roads, which would have a large impact on the number of accidents since approximately 50 % of all lethal car-truck accidents are front to front collisions.

Trailer manufacturer

The trailer manufacturer is positive to the implementation of LCVs, on suitable road routes in Sweden. One of the main benefits would be less road wear since LCVs usually have more axels than normal trucks and thereby creates less axel pressure, which means less road wear.

The chosen routes have good road characteristics and possibilities for rearrangement, as well as the chosen LVV. Other vehicle modules, such as centre axel trailers, are far more difficult to rearrange than an LCV concept with links which would also provide high flexibility and a well working module system which could be of great use in terminal traffic. However, the weight of a link is two times the weight of a centre axel trailer. A link plus cargo carrying unit weighs approximately 7 tonnes and a centre axel trailer with cargo carrying unit weighs about 3.5 tonnes. A dolly weighs approximately 2.5 tonnes. If a short trailer, such as a centre axle trailer is positioned last in a combination, it is not allowed be higher than 4 m for stability reasons, which means that quite a lot of volume capacity is lost. This is not the case for links.

Links can be used either in an extended mode or in a compressed and shorter mode. The benefits with the compressed alternative are that it can be backed up against the loading dock at a terminal and the fact that they can be used in urban distribution, since the entire vehicle then is shorter than 12 m. The benefits with the extended alternative are a higher maximum loading weight, but mainly the possibility of connecting a second link or a semi trailer to it. The shifting between the two modes is easily preformed using the trailers breaks and the tractors engine power or with help of hydraulics. The driver does not have to do as much work outside the cab when rearranging links, as when rearranging centre axel trailer or dollies.

The Swedish Road Administration

The LCV exemptions, given by The Swedish Road Administration (SRA), are only one time exemptions and most of the information in this part is regarding such one time exemptions. The factors affecting exemptions are not necessarily the same as those affecting the directions given by the Swedish Transport Agency, but since SRA is in charge of administering and maintaining the Swedish road network, their input is still valuable to understand the conditions placed on the vehicle and the flow. Exemptions are also in general only given to transports for cargo that cannot be split and not to general cargo of mixed goods as in the case of this research project. However, it gives an indication to what factors are important for an LCV to be accepted on the Swedish road network.

The length of the LCV in general is not a problem and the exemptions from the 24 m and 25.25 m regulation have been given for LCVs. However, a vehicle with two or more trailers only is allowed to drive at the speed of 40 km/h. There is however an exemption from this 40 km/h rule and that is the EMS vehicle of 25.25 m consisting of one tractor pulling a semi-trailer and a centre axel trailer or a link and a semi trailer, both of which are allowed in Sweden today. For temporary exemptions, LCVs longer than 30 m need to have a warning vehicle driving after the LCV and that an LCV longer than 35 m also needs to have a traffic director accompanying the LCV.

The LCVs that are granted an exemption are always directed to highways or bigger roads with road median barriers if possible. LCVs with exemptions are also often directed to night traffic, to minimize traffic disturbances and to improve road safety.

The axel pressure for the new LCV concept, should be kept at the same or lower level than today, since axle pressure has large impact on road wear. The odd is higher to get an exemption if the axel pressure is decreased. Furthermore, a max weight of the vehicle of 90 tonnes should be a major problem and that 70 tonnes sounded more reasonable, but still could be a problem for some roads. The LCV to be tested should have equipment for continuous measurement of the axel pressure.

When calculating durability of for example bridges, an extra 10 % weight is added to the calculations to make sure that loading mistakes do not cause durability problems. That extra calculated weight is not added if the vehicle has axle pressure measurement equipment, which means that an extra 10 % can be added to the allowed weight. The weight is most critical regarding transportations over bridges but he also mentioned turning and curves as potential problem situations.

The Swedish Transport Agency

There are around ten research projects, in different stages, concerning implementations of LCVs on Swedish roads. Some of them are applications, but none has resulted in any direction yet, that is no application has yet been approved nor disapproved. While the Swedish Road Administration cannot allow permissions for longer vehicles if the cargo is dividable, such restrictions do not apply to the STA's mandate for directions

Today an LCV longer than 30 meters with cargo that cannot be separated can apply for a one time permission at the Swedish Road Administration. If the dispensation is approved the LCV must be followed by a warning vehicle and if it is longer than 35 m it must be accompanied by both a warning vehicle and a traffic director. As with dividable cargo, such restrictions do not necessarily apply to STA's directions.

Haulier

The most commonly used vehicle by the haulier is the regular 24 m long vehicle, which has a rigid truck pulling a 12 m long trailer with a fuel consumption of 4.5 litres of diesel per 10 kilometres. One requirement that needs to be fulfilled to handle direct cargo is that the whole vehicle or parts of the vehicle need to be able to visit customers, along smaller roads. Since a full LCV probably would not be able to operate smaller roads, it is important that the ingoing modules in the vehicle can be rearranged into a shorter combination that can operate the smaller roads out to the customer. Regarding terminal handling, even at smaller terminals, rearranging the vehicle would be possible, at least in a test project, where only a limited number of LCVs are handled. If LCVs would be generally implemented, the size of the terminals could be questionable. No major safety problems with LCV are recognized by the haulier.

The haulier disapproves centre axel trailers and prefers LCV-concept of the tractor pulling two semi-trailers with a height of 4.5 m. The main argument for this choice is that it consists of already well working and known modules. The possibility to rearrange the vehicle into two currently legal vehicles was also a benefit since full LCVs are unlikely to be able to visit any direct cargo customers.

Driver

The driver's response to the idea of LCVs was very positive, without concerns for making the driving more difficult or inconvenient. Regarding safety aspects, the LCVs would carry more goods, the total number of trucks would decrease which should result in improved traffic safety. However, the overtaking, even with today's length, preferably should be forbidden on motorways for trucks since it increases risks for accidents and increases fuel consumption. Furthermore, additional drivers training should be mandatory in a form similar to the one for transportation of dangerous goods; which means a special training that is to be renewed at certain intervals to get updates on regulatory changes. However there is a higher potential for flat tires simply because there are more tires with more axels; although flat tires are very rare today due to good quality of tires.

Handling the LCV is not considered to be a problem but the same should be allowed only on the major roads. LCVs take more space on the roads and they are probably rather difficult to reverse, if there is limited manoeuvring space. These factors are no issues on major roads, but may be problematic on smaller roads with less accessibility. Another handling problem may be that the heavier vehicle may have problems taking off on icy road conditions. This may make the planning of the loading more important so that enough weight rests on the drive axels.
There is a positive attitued towards technologies for improving aerodynamics however air resistance reducing components are very exposed and can easily be damaged. The same could be avoided if vehicles with those components are only on major roads.

ANALYSIS OF PRELIMINARY INTERVIEWS

This chapter will narrow down the number of routes and vehicle concepts so that the remaining alternatives will be investigated.

Choice of suitable routes

Today the chosen haulier operates and manages fourteen project related transportation routes. Since the haulier is one of the partners in this project, all routes were seen as potential future routes for LCV traffic. So far in this study all routes have been investigated, but this part will reduce the number of suitable routes according to restrictions found in the preliminary interviews. Three main criteria have been identified for reducing the number of routes for further study, see Table 1. The first one concerns road conditions and the criterion is named “highway”. This means that a route that passes this criterion has only highway between the terminals, except from some kilometres of road in the proximity of the terminals, connecting the terminals to the highway. Highways are according to the interviewed actors best suited for LCV transportation in Sweden. The second criterion concerns road conditions focusing on how large part of the road route consists of conventional roads without median separation barrier; i.e. only conventional road routes shorter then 50 km were considered as suitable. This is done since meetings and overtaking could be problematic and are experienced as risky on conventional roads when LCVs are involved. The third criterion treats if some of the routes are recommended, mentioned as possible or interesting routes by any actor and for that reason should be further investigated.

Table 1: Choice of transportation flows for further research based on three criteria. Flows that fulfil the criteria are marked with an X.

Terminals		Criteria		
Terminal 1	Terminal 2	Highway	Conventional road<50km	Suggested by actors
Vänersborg	Karlstad			
Vänersborg	Linköping			
Vänersborg	Jönköping			

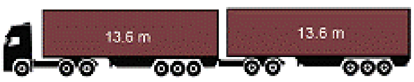
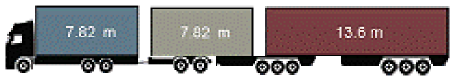
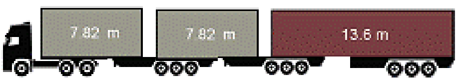
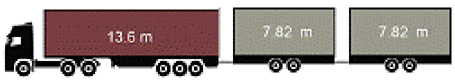
Vänersborg	Borås			
Vänersborg	Hultsfred			
Vänersborg	Värnamo			
Vänersborg	Halmstad	X	X	X
Vänersborg	Helsingborg	X	X	X
Vänersborg	Karlshamn			
Vänersborg	Kristianstad			
Gothenburg	Karlstad			
Gothenburg	Linköping		X	X
Gothenburg	Karlshamn			
Gothenburg	Kristianstad			

Consequently three routes will be further studied. The flows between Vänersborg and Halmstad and between Vänersborg and Helsingborg share the same road route between Vänersborg and Halmstad and can be regarded as one combined route. This combined route has better road conditions than the route between Gothenburg and Linköping. However, the part of road between Gothenburg and Linköping that does not have median separation is planed to be improved and that improvement is scheduled to start during 2010, according to the Swedish Road Administration. The road work will not pose a problem for the field test, since the current road will remain in its current form. The improvement will be a completely new road route that is planned to be completed in 2013. Worth mentioning is that all three routes have good enough road conditions for LCVs according to the Swedish Road Administration, with possible exception for weak bridges.

Choice of the vehicle concept

To be able to reduce the number of possible LCV concepts, two main criteria have been identified, see Table 2. The first criterion is the Swedish Transport Agency’s requirement that the LCV studied here must be unique; i.e. different form other ongoing LCV research projects in Sweden. Therefore two concepts can be eliminated since they are similar to the vehicles that are used in the ETT and the Maxi-Cube project.
The second criterion is based on the result form the interviews which clearly indicates that many actors do not recommend using centre axel trailers. No actor has anything positive to say about the centre axel trailer, but criticism like stability issues and problems during rearrangement has been brought forward. One positive thing with the centre axel trailer is its low weight compared to its loading capacity, but that seems to be the only positive argument for that type of trailer. This criterion of not containing centre axle trailers eliminates all remaining concepts but two. If short trailers are used instead of centre axle trailers the rearrangement would be easier, but the problems with stability and manoeuvrability would remain or even increase.

Table 2: Choice of LCV concept for further research based on four, for this study important, criteria. (Pictures adapted from Berger, 2008)

	Uniqueness	No centre axel trailers
	No (Maxi-Cube, Kinnarps)	No
	Yes	Yes
	Yes	No
	No (ETT, Skogforsk)	Yes
	Yes	No
	Yes	No
	Yes	Yes
	Yes	No

The two LCV concepts which will be further investigated in this study as scenarios are the tractor pulling two semi-trailers and a dolly, further on called the DuoTrailer, and the tractor that pulls two links and one semi-trailer, further on called the DuoLinkTrailer.

FINDINGS FROM THE SCENARIOS

In this chapter the findings from the research related to the scenarios are presented, i.e. concepts and routes chosen in the preliminary study are further studied.

The chosen terminals' perspective

Terminal in Vänersborg.

The most common vehicle frequenting this terminal now is regular 24 m vehicle. EMS vehicles also visit the terminal, but one of the reasons to why the regular 24 m vehicle is used more often than the EMS vehicle of similar capacity is the fact that the EMS vehicle weighs approximately three tonnes more than the regular 24 m vehicle. The weight capacity is most often not used in mixed goods transportation, but it is important for hauliers to be able to take the extra weight in the cases when it is necessary.

The size of the terminal could be a limitation if several LCVs have to be handled, however the size of the terminal area outside the terminal building will be enough for all LCV combinations to turn and reverse (no the full length) and parking lots will not be a problem if only one truck will be implemented. However, rearranging the vehicle combinations could be time consuming. Furthermore, the DuoTrailer is preferred since it only requires two loading docks and it has good reverse and turning ability and is easy to rearrange. The possibility to split up the vehicle in two EMS vehicles is considered to be a huge benefit.

Terminal in Gothenburg

The flow at the terminal is unpredictable regarding volumes from day to day, and there is no system in place to give information to the planners in advance on how much goods that will arrive. Most types of today allowed vehicle combinations are handled at the terminal. The concept with four small trailers is considered to have a huge long term potential from a flexibility point of view. Such a modular vehicle, providing it is safe to operate, would make consolidation between different routes a lot easier. The driver could transport modules bound for different destinations and simply decouple and attach new ones at terminals en route to the final destination. This way, a high fill rate can be maintained for the longer transports at the same time as the batch size can be kept down at the terminals. The idea of small modules can be found in the DuoLinkTrailer. Even though there might be a huge potential in that kind of flexible and combined system, a large structural change in the organization of the terminals would be needed to make such transports possible. The system today where the hauling companies own their route makes consolidation between the routes difficult, if not impossible. For a short term solution benefits for the hauliers are in using the DuoTrailer, but again, that concept is the least flexible and thus furthest from the scenario described above. Therefore, vehicle combinations that easily can be rearranged into vehicles that are allowed on smaller roads or for international transports would be the best outcome, so that at least some flexibility can be achieved.

Terminal in Linköping

The area around the terminal building is quite narrow rail tracks are located just a couple of meters outside the terminal area. Furthemore railway route is planned to be expanded between one and two meters further into the terminal area, reducing the already narrow gap. When no trucks are parked along the fence separating the rails from the terminal area, there are usually no problems for the drivers to back up against the loading docks. However, when vehicles are parked along the fence, even regular 24 m combinations have some difficulties. Such difficulties will increase further when the railway expands.

The trucks do park along the fence due to shortage of parking space at the terminal area. Apart from parking lots, the terminal area also includes space for voluminous goods that cannot be handled inside the terminal building. This lack of space may show challenging since there may be problems finding room for LCVs to rearrange their trailers before backing them up to the loading docks.

DuoTrailer concept is favoured for this terminal, the main benefit is that the concept has only two carriers which means that the driver only needs to back up twice to unload or load the goods, instead of three times as with the DuoLinkTrailer.

Terminal in Halmstad

A significant portion of the goods intended for the Halmstad terminal are pipes in different lengths and sizes, some up to 12 m in length. This puts special requirements on the length of the trailers carrying the cargo. A system where only shorter pallet carriers are used would not allow transportation of all the goods, and is therefore not suitable for this flow. Both the DuoTrailer and the DuoLinkTrailer would have the necessary length capacity to handle the transportation of pipes.
It is considered that the Swedish rail network does not have the capacity to take the day to day deliveries requested by their customers, so rail transport is not a real option. Therefore, longer road vehicles can decrease both cost and environmental impact for road transports. However, the implementation of LCV is not without obstacles; the biggest one is roads with median separation and alternating overtaking lanes. Furthermore, regarding the situation at the terminal there are two potential problem areas; the entrance to the terminal area, and a rather narrow curve with weak road verge. When approaching the entrance to the terminal from northwest, a rather sharp right-turn at the entrance causes some problems even for the vehicles in use today. However, trucks can drive around one block and approach the entrance through a wider left-turn. Apart from the entrance to the terminal area there should be no problems manoeuvring a larger vehicle outside the terminal area, for example between the motorway and the terminal.
The main potential for LCVs is for consolidating mixed goods and part loads. This is due to the fact that most of their mixed goods flows in Sweden do not fill up a standard 24 m vehicle today. The favoured concept is DuoTrailer since it only requires two gates, or one change of pallet carrier at the same gate. The DuoLinkTrailer requires three gates or two changes of pallet carrier at the same gate. However, the DuoLinkTrailer concept can also be interesting, since two shorter pallet carriers can give flexibility for consolidation of different flows.

The haulier's perspective

The haulier doesn't consider the route between Vänersborg and Halmstad/Helsingborg to be suitable for the chosen LCVs. This is mainly due to the fact that the terminal cargo volumes are too small and the flow of direct cargo is too complex to consolidate together with terminal cargo. The complexity of the direct cargo flow comes partly from the layout of the Halmstad pick up area, which is quite long from north to south and the terminal is positioned in the south end of it. Since an LCV would not be allowed outside the set route and for time reasons, LCVs cannot be used for the part loads from the Halmstad area. Due to low volumes, the terminal cargo does not fill a 24 m vehicle today, even when both Halmstad and Helsingborg are consolidated, so direct cargo is today also transported in the same truck.
It would be considerably easier to find a way to utilize an LCV in the flow between Gothenburg and Linköping. The general cargo volumes are bigger and there are no apparent

distribution problems. For the long haul part of the flow there would be no big difference between the two chosen LCV concepts, but for direct cargo distribution DuoTrailer is preferred over the DuoLinkTrailer. The reason for this is that many customers do not have a fork lift which means that the pallet carriers must be accessed from the rear. The fact that the LCVs must be rearranged before direct cargo distribution gives that the DuoLinkTrailer will likely result in a shorter vehicle with a link pulling either another link or a semi-trailer, handling direct distribution. This in turn means that, in order to access the first link the second unit must be disconnected. This can be a fairly time consuming operation, which may be difficult if it is needed often, as on a direct cargo run. The DuoTrailer would likely not need to disconnect any pallet carriers at the direct cargo customers. On the other hand, the capacity for each direct cargo vehicle would be lower with the DuoTrailer. For the vehicles that both handle long haulage and direct cargo distribution, the long haulage stands for approximately 80 % of the total distance driven, while direct distribution stands for the remaining 20 %, in the flow between Gothenburg and Linköping. Although variation exists, it very seldom has any major effect on the fill rate or on the number of trucks needed.
Regarding fuel consumption the haulier has an average diesel consumption of 4.62 litres per 10 km and that the cost for diesel stands for approximately 25 % of the company's total cost. Fuel costs are the second highest cost after salary cost which stands for approximately 50 % of the total cost. The profit margin for 2009 is estimated to be between 3 to 4 % and for 2008, 2007 and 2006 the profit margin was around 7 %.

ANALYSIS OF THE SCENARIOS

Assumptions

Current fuel consumption for a 24 m long truck:
The hauliers' average fuel consumption is 4.61 litres per 10 km, for the entire fleet. The fuel consumption on large roads between terminals, like in this case, is probably somewhat lower. Because of this, the consumption that will be used in this analysis is 4.5 litres per 10 km. Reference simulations for vehicles similar to the ones in the hauliers fleet end up near the average fuel consumption given by the haulier.
Fuel consumption for an LCV:
The fuel consumption used in this analysis is an average between several simulations with different LCV vehicles at different road routes. Different LCV vehicles with different engines, gearboxes, axels, number of tiers and tier types were simulated, and the simulations gave fairly similar results regarding fuel consumption.
PERF Simulation for a new FH16 depending on weight and specification gives approximately 5.5 litres per 10 km. This number is in line with, even slightly more than, what different actors estimated. This fuel consumption will be used in both our remaining LCV concepts, since the maximum weight will be the same. The 35 m long LCV will probably consume slightly more fuel than the 32 m long LCV since it can transport three pallets more. Simulations also show that the one or two extra axles of the 35 m LCV would increase the fuel consumption slightly. However, the difference in fuel consumption is judged to be significantly smaller than the

uncertainty of the simulation, why using the same consumption for both LCVs is thought to be a fair approximation.

Weight-to-load metre conversion:

The number of trucks and transportation statistics from the haulier together with information collected during interviews give the following approximation:

- 1 tonne of terminal cargo is transported today on one load meter
- 1 tonne of white cargo is transported today on one load meter
- 2.5 tonnes of direct cargo is transported today on one load meter

Volumes

This section investigates whether the two chosen routes are suitable for LCV transportation regarding the volumes transported. The volumes need to be high enough to fill the LCVs, otherwise the routes will not be applicable.

The number of total load meters on a 32 m long LCV with two semi trailers is approximately 27 lm (2 x 13.6 lm) and the total number of load meters on a 35 m long LCV with two links and one semi-trailer is approximately 29 lm (2 x 7.82 lm + 13.6 lm). This can be compared to the regular 24 m vehicle that can carry approximately 20 load meters. The average daily volumes per flow can be seen inTable 3.

Table 3: Average daily volumes per flow, in round off numbers.

	Terminal Cargo (1 tonne / lm)	**Direct Cargo (2.5 tonnes / lm)**	**White Cargo (1 tonne / lm)**	**Total**
Gothenburg to Linköping	32 tonnes 32 lm	135 tonnes 54 lm	10 tonnes 10 lm	177 tonnes 96 lm
Linköping to Gothenburg	22 tonnes 22 lm	92 tonnes 37 lm	15 tonnes 15 lm	129 tonnes 74 lm
Uddevalla/Vänersborg to Halmstad/Helsingborg	10 tonnes 10 lm	65 tonnes 22 lm	0 tonne 0 lm	75 tonnes 32 lm
Helsingborg/Halmstad to Vänersborg/Uddevalla	10 tonnes 10 lm	55 tonnes 18 lm	0 tonne 0 lm	65 tonnes 28 lm

As seen Table 3 the flow between Gothenburg and Linköping has total average daily goods volumes large enough to easily fill up two vehicles of either of the remaining LCV concepts in each direction. The flow between Uddevalla/Vänersborg and Halmstad/Helsingborg barely has average goods volumes to fill-up one DuoTrailer in each direction. The DouLinkTrailer is only filled one way and has to run with reduced fill rate in the northbound part of the flow.

To summarize this part the most suitable goods flow considering goods volumes is the one between Gothenburg and Linköping. This flow can fill up both the remaining LCV concepts. The flow between Uddevalla/Vänersborg and Halmstad/Helsingborg can be used but volumes are so low that even slight daily variations may cause fill rate problems.

Environmental and Economical effects

Environmental impact

This part focuses on the fuel consumption which directly influences the environment in terms of fuel emissions; assuming that the fuel used is fossil fuel like for example diesel. The reduction in fuel consumption corresponds to a similar reduction in exhaust gases, which affects the environment. The fuel consumption, recalculated in relevant terms, for the currently used vehicles and for the two LCV concepts, is listed below.

Regular 24 m long vehicle

Fuel consumption:	0.225 l / (lm * 10 km) (litres per 10 km per loading metre)	
	0.113 l / (ton * 10 km) (litres per 10 km per tonne of real weight)	
	0.094 l / (pallet * 10 km) (litres per 10 km per pallet)	

DuoTrailer: LCV, a tractor pulling two semi-trailers and one dolly, 32 m long.

Fuel consumption:	0.204 l / (lm * 10 km)	- 9 %
	0.108 l / (ton * 10 km)	- 4 %
	0.083 l / (pallet * 10 km)	- 12 %

DuoLinkTrailer: LCV, a tractor pulling two links and one semi-trailer, 35 m long

Fuel consumption:	0.19 l / (lm * 10 km)	- 16 %
	0.112 l / (ton * 10 km)	- 0 %
	0.08 l / (pallet * 10 km)	- 15 %

As seen above, the largest fuel consumption reduction will be in volume terms and it is noticeable that the fuel consumption reduction per tonne will be very small. As mentioned earlier mixed goods are more often volume dependent than weight dependent and therefore the fuel consumption reduction per pallet or loading meter is what is essential for a project like this.

Economical effects for the Haulier

Since 25 % of the total cost consists of costs for fuel, for a haulier, the fuel consumption reduction presented in previous paragraph will result in a total cost decrease of between 2 and 4 %, assuming high fill rate and volume dependent cargo. This is a huge change for a haulier with approximately 3 to 8 % in profit margin.

Since LCVs carry between 25 and 45 % more cargo per driver, introducing an LCV should reduce the driver cost by approximately 20 to 30 %, for the goods transported in that LCV. This gives a total cost decrease of between 10 and 15 % for this vehicle on this flow, since cost for drivers in general stands for 50 % of a hauliers total cost. From the interview with the transportation union, one outcome was that an increase in productivity, like the one described here, most probably would be followed by demands for a salary increase. To be moderate in the calculations, it is assumed and calculated that 10 % of the total driver cost reduction is consumed by a rise in driver salary per remaining LCV driver. Assuming that only the affected LCV drivers get the salary increase, this means an increase of 15 % in salary per LCV driver. That leaves a total cost decrease of 9 to 13.5 % for the hauling company from the decrease of driver cost.

DISCUSSION AND CONCLUSION

One argument that stood against LCVs was that such legislative changes would affect the competitive situation between road and rail transports, resulting in less goods being transported by rail. LCVs in this study would be used on shorter distances and would serve for delivery purposes as well which is not market niche for rail. This is a day to day delivery of mixed goods segment, with short transport distance; LCVs are therefore beneficial in that segment, assumed that the goods volume is high enough.
The DouLinkTrailer dominates concerning the volume flexibility, compared to both the DuoTrailer and a regular 24 m truck, and should be possible to use beneficially in cases were a flexible combination of terminal, with different types of cargo is needed. The DuoTrailer may be more suitable in for example rail to road intermodal flows or in container transportation flows, where the LCV does not need to be divided for any part of the flow. The DuoTrailer is a simple construction and consists of modules that are commonly used by hauliers in all of Sweden, while the links in the DuoLinkTrailer are new to most of the actors, and therefore seen as risky. Table 4 presents the pros and cons of the two LCV alternatives, the scale consists of "- -", "-", "0", "+", and "+ +" and the criteria are not weighted and therefore not possible to sum up. A "0" indicates that no major change is evident compared to the regular 24 m vehicle in use today, "-" and "- -" indicates that the performance of the LCV can be expected to be worse ore much worse than the regular 24 m vehicle whereas "+" and "+ +" indicates that better or much better performance is expected.

Table 4: Pros and cons of the two LCV concepts compared to the regular 24 m vehicle.

	DuoLinkTrailer	DuoTrailer
Volume Flexibility	+	0
Load Volume	+ +	+
Direct Cargo Distribution Planning	0	-
Actors opinions	-	0
Hub to Hub transportation	0	0
Terminal/direct customer handling	- -	-

Finding suitable flows for LCVs would be a lot easier if the company could consolidate cargo between different flows. One example of consolidation between flows would be if one LCV could transport goods from Gothenburg to Borås, from Borås to Jönköping and from Jönköping to Linköping. The current structure makes this impossible since different hauling companies own those three flows, and no one wants to give up a flow. For the long haul part of the flow, the difference between the two LCV concepts is minimal. For the direct cargo distribution in the nodes, however, the fact that one more tractor has to be used in the DuoTrailer case gives the DuoLinkTrailer an advantage. Due to the existing positive view among actors regarding the DuoTrailer, the DuoTrailer is recomended in this study.

LCVs are suitable for volume dependent mixed goods in long haulage transportation. The outcome of the analysis indicates that the DouLinkTrailer has a lot of benefits compared to regular 24 m long vehicles and the DuoTrailer. However, the most popular LCV concept among interviewees was the DuoTrailer and that concept is also possible to implement on the chosen route between Gothenburg and Linköping. The findings indicate that the DuoLinkTrailer would give better economical and environmental results, mainly due to its better volume flexibility and due to the fact that no vehicles need to be added in the direct cargo distribution. It does have a major drawback in not being favoured by the actors.

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