CO-MODALITY– THE SOCIO-ECONOMIC EFFECTS OF LONGER AND/OR HEAVIER VEHICLES FOR LAND-BASED FREIGHT TRANSPORT

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ABSTRACT

The European Union legislation limits the size of road vehicles used for international freight transport to 18.75 m and 40 tonnes. Other dimensions are accepted for domestic services as long as vehicle combinations are based on the so-called European Modular System. Sweden allows combinations up to 25.25 m and 60 tonnes in domestic transport. This paper presents the results from a Cost Benefit Analysis of a case where Sweden limits the vehicle dimensions in domestic transport to the European size. The results show that using smaller vehicles leads to higher costs for society in terms increased transport costs, increased environmental and accident costs. even when transfers to rail are included. The investments in the road network (including bridges) are recouped after a short period.

The paper then goes further and discusses the future demand of even larger road and also includes rail vehicles. For road it is mainly a question of stretching the length and weight within the European Modular System. Experiences in countries outside of Europe and from the Swedish survey indicate that the main aspects of larger vehicles are traffic safety, infrastructure wear, environmental impacts and transport costs. The effects are dependent on where these vehicles are allowed and possibilities for modal shift. For trains no extreme changes are expected.

Keywords: vehicle dimensions, cost-benefit analysis, co-modality, longer and heavier vehicles.

1. INTRODUCTION

1.1 Background

The European Union legislation limits the size of road vehicles to 18.75 m and 40 tonnes when used in international freight transport services. However, the legislation accepts other dimensions for domestic services as long as these complies with the so-called European Modular System (EMS - see section 2). Sweden allows vehicle combinations up to 25.25 m and 60 tonnes in domestic transport based on EMS. The Swedish National Road and Transport Research Institute (VTI) conducted previously a study on behalf of the Swedish Government, concerning the socio-economic effects of using these longer and heavier road vehicles in Sweden compared to the majority of other European countries. The conclusion of the study was that the use of larger vehicles in Sweden, referred to as "Swedish vehicles", leads to benefits for society, even when transfers to rail are included.

If Swedish vehicles reduced the cost of society it cannot be ruled out that even longer and heavier vehicles than 25.25 m and 60 tonnes, referred to as LHV, will further reduce costs in Sweden. Therefore VTI has started the so called Co-modality project to find out if LHVs will generate additional benefits for society. Due to the importance of the competition and co-operation between road and rail the study covers dimensions for all land based transports. The term co-modality was defined by the European Commission during the review of the Transport White Paper as “the efficient use of different modes on their own and in combination, will result in an optimal and sustainable utilisation of resources” (COM(2006) 314, p.4). The project is funded by the Swedish Governmental Agency for Innovation Systems, the Swedish Energy Agency as well as the Swedish Road and Rail Administration (these administrations merged 1 April 2010). The aim of the project is to explore the potential of making the land based freight transport system more efficient by using larger dimensions for different combinations of road and rail vehicles.

1.2 Research questions and disposition

This is an intermediate paper which summarises our results so far from studies regarding demanded dimensions and effects altering the maximum dimension of road and railway vehicles in Sweden. However, the focus of this paper will mainly be on road vehicles.

In order to specify the purpose further the following for research questions have been formulated:

1. What are the socio-economic effects in Sweden of using longer and heavier road vehicle than in the rest of the EU?

2. What are the demanded future dimensions for road and railway vehicles in Sweden?

3. Which are the main (most crucial) aspects of longer and heavier road vehicles?

The Cost Benefit Analysis (CBA) that was is presented (section 2). The CBA compares vehicles used inside respectively outside Sweden. It is based on existing vehicles and decisions to improve the load-bearing capacity of the road network in 1985. The Swedish CBA-guidelines for infrastructure investments are applied.

The analysis of the potential future LHVs in Sweden need to be based on other methods. The design of this study and methods are discussed in section 3. We summarise the outcome of a literature review, survey and hearing to capture Swedish stakeholders and experts on freight transport on their views of future possible road and railway vehicle dimensions in Sweden (section 4). The dimensions identified will be the focus for our further research. Results from the Co-modality project so far and the possibilities to extend or transfer the results are discussed in section 5.

2. COSTS AND BENEFITS OF USING LARGER VEHICLES IN SWEDEN

2.1 The use of larger vehicles in Sweden

Sweden has a tradition of long and heavy trucks. A length of 25.25 metres has been permitted for modular vehicles since 1996. Maximum gross vehicle weight has successively been increased from 37 tonnes (1968) to 60 tonnes (1993). Around 1985 Sweden took an extensive load-bearing capacity initiative which meant e.g. that bridges built before 1945 were replaced. Today around 90 per cent of public roads and around 94 per cent of state-owned roads are open to 60 tonne vehicles. Vehicles up to 25.25 metres in length are allowed on almost all public roads, with the exception of the central parts of some cities.

The vehicle combinations and dimensions of single components used fulfilling the requirements of the European Directive 96/53/EC for domestic and international transports are illustrated in Figure 1 below.

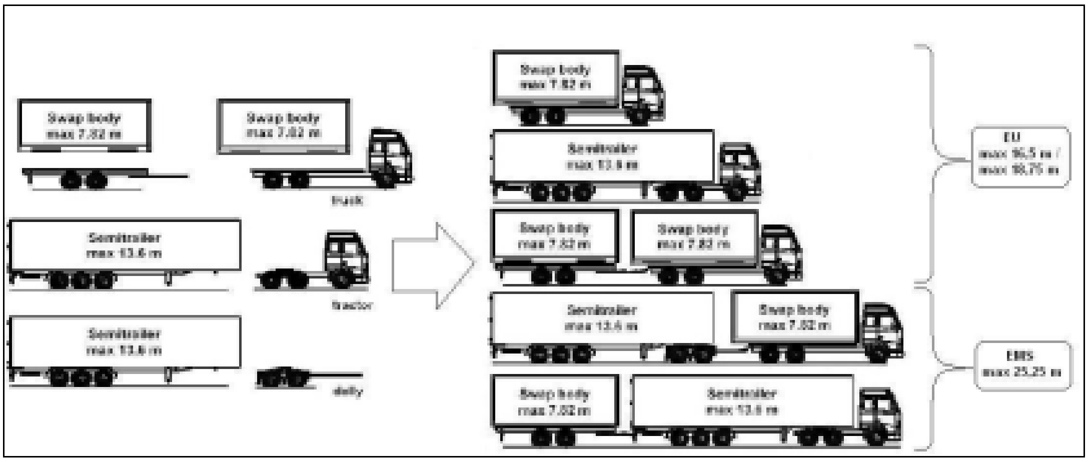

Figure 1 – European Modular System (EMS)

A large proportion of freight transportation in Sweden takes place on vehicles that exceed the EU standard. Statistics show that about 64 per cent of the tonnage and 74 per cent of freight tonne-kilometres are accounted for by vehicles that weigh more than 40 tonnes and/or have seven or more axles.[1] At the same time Sweden's share of rail freight is among the highest (35.3 per cent measured in tonne-kilometres in 2008) within the EU (Eurostat 2010[2]). Regarding the utilisation of weight and volume dimensions there are differences that can be explained by differences in transported commodity. All timber transportation takes places on vehicles with a weight of more than 40 tonnes and seven axles, while the proportion is less than 50 percent for the commodity groups of high-value products. (Vierth et al. 2008)

In Vierth et al. (2008) VTI compared the actual situation for domestic transports in Sweden with EMS dimensions of max 25.25 m and 60 tonnes to a hypothetic situation with EU-dimensions of max 18.75 m and 40 tonnes. Based on this, three different scenarios were defined:

- Scenario A is a reference scenario, in which trucks are up to 25.25 metres in length and are allowed to weigh up to 60 tonnes.
- In Scenario B it is assumed that transfer to other modes is not possible. The trucks are up to 18.75 metres in length and are allowed to weigh up to 40 tonnes. (This type of vehicle is used for international transports to/from Sweden)
- In Scenario C transfer between road, rail and sea[3] is permitted. The trucks are up to 18.75 metres in length and are allowed to weigh up to 40 tonnes.

The capacity situation on rail freight is quite difficult. Today it is not easy to find new freight train paths to and from the three largest cities in Sweden (i.e. Stockholm, Gothenburg and Malmö). The situation at the large marshalling yard in Hallsberg is also problematic. Consequently, a change in truck size, in the short term, can be expected to produce a result that is quite close to Scenario B. Everything else is assumed to be equal; it is e.g. assumed that no change takes place in the locations of activities and that employment in the labour market is not affected.

In the CBA it is analysed how transport costs (i.e. vehicle operating costs and transfer costs) road wear, road safety, delays for other traffic (congestion), exhaust emissions, noise emissions and tax payments change in Scenario B and Scenario C in comparison with the reference Scenario A. The study is largely based on official statistics and on the guidelines for CBA in the transport sector. The national freight transport model SAMGODS (based on the STAN-software for mode and route choice) has been used to simulate how mode choice and the transport costs are affected by a change in the maximum length and weight of trucks. The change in exhaust emissions has been calculated using the European model ARTEMIS and noise effects using the European HARMONOISE-model (see further section 3). Time delays and road-safety effects have been calculated using methods developed at VTI (Carlsson and Björketun 2004). Effects relating to road wear are based on a thesis presented at VTI (Haraldsson 2007).

[1] The study does not include trucks under 3.5 tonne.
[2] The rail share is lower in the Swedish statistics (app. 23 per cent) as these include maritime transports.
[3] There were hardly any transfers from road to sea in the model simulations.

2.1 Costs and benefits

Provided that the same quantity of freight is to be transported, shorter and lighter trucks mean that the transport cost per vehicle is reduced but that the number of vehicles needed increases. The cost per truck is estimated to decrease by five to twelve per cent in the various commodity groups but the number of trucks increases by 35-50 per cent. On average 1.37 trucks of maximum EU size are required to replace one truck of maximum Swedish size. The road transport costs are estimated to increase by 24 per cent. The increase in cost per tonne-kilometre is estimated to be smallest for the commodity group *High-value products* (19 per cent) and greatest for heavy bulk such as *Soil, stone and construction* (35 per cent), *Oil products, Crude oil and coal* (33 per cent) and *Round timber* (32 per cent).

In Scenario B freight vehicle-kilometres for trucks as a whole (trucks with a gross vehicle weight of 3.5-60 tonnes) are estimated to increase by 24 per cent when Swedish vehicles are replaced by EU vehicles. Transport costs are estimated to increase by around Euro 0.8 billion per year (all benefits and costs expressed in 2001 prices; it is assumed that 1 Euro corresponds to 10 SEK). The increase in transport cost is found to be by far the most dominant adverse effect of changes in vehicle standards. Most of the other effects point in the same direction. With more trucks on the roads the cost of road traffic accidents is estimated to increase by Euro 49 million per year. There is nothing in the accident statistics studied to suggest that shorter and lighter trucks would result in fewer or less serious accidents. Diesel consumption is estimated to increase by just over six per cent, leading to increased exhaust emissions of Euro 58 million. Carbon dioxide accounts for 62 per cent. Noise emissions are estimated to increase to an extent equivalent in value to Euro 69 million annually. More trucks on the roads are estimated to generate time losses for passenger car traffic equivalent in value to Euro 5 million annually. The calculated reduction of road wear costs is conditional on the freight being distributed between more axles than present-day EU vehicles. The total economic cost of introducing shorter and lighter vehicles in Sweden is Euro 0.9 billion per year, see Table 1.

Table 1 - Economic costs and benefits to society (in 2001 prices). A minus sign indicates a deterioration and a plus sign an improvement for society.

Cost function	**Scenario B Euro million /year**	**Scenario C Euro million /year**
Transport cost	-752	-315
Road wear	+14	+20
Railway wear	0	-8
Road safety	-49	-29
Time delay	-5	-3
Exhaust emissions[4]:		
Carbon dioxide	-36	16
Nitrogen oxides, VOC, PM	-22	7
Noise emissions road	-69	-39
Noise emissions rail	0	-3
Tax effects	+6	-9
Total	**-893**	**- 394**

The overall results are robust and most of the effects point in the same direction.

- In Scenario B exhaust emissions are judged to be the third largest effect. Carbon dioxide emissions account for the greater part of these. Carbon dioxide emissions from heavy truck traffic are estimated to increase by 240 000 tonnes, which is equivalent to around six per cent. In Scenario C the carbon dioxide emissions are estimated to decrease by around 100 000 tonnes.
- The number of people killed in accidents with trucks is estimated to increase in both Scenarios B and C, from 67 per year in Scenario A to 79 in Scenario B and 74 in Scenario C.
- The cost of road wear is estimated to decrease slightly if the freight is shared between EU vehicles with five, six or seven axles. On the other hand, the costs of wear are estimated to increase slightly if only vehicles with five axles are used. The converse situation applies to noise emissions, which increase with the number of axles.
- Noise nuisance increases in both Scenario B and Scenario C. The same applies to the time delays that have been calculated for passenger traffic.

An outcome close to Scenario B is to be expected in the short term. It is more difficult to assess the possibility of reaching the outcome in Scenario C as a number of conditions are attached to this. There is, however, potential for transfer to rail. It should also be borne in mind when choosing optimum truck length and weight that transport costs in the longer term influence total demand for transport. The location of activities may also be affected.

The negative outcome of changes in truck dimensions can be mitigated if it is possible and commercially feasible to transfer some freight volumes to rail. Increased rail track capacity and (an in some cases improvement in level of service) are, however, required for a major

[4] VOC = Volatile Organic Compounds, PM = Particulate Matter.

transfer to rail. A review of time series for road and rail transportation in the last 30 years, both at aggregate and commodity group level, shows that it is difficult to find evidence of road and rail taking volumes from each other – including in those periods where we know that large changes with cost implications have taken place. It is clearly apparent that there is one mode of transport that is heavily dominant for most commodity groups.

Significant transfer to rail is anticipated in Scenario C, i.e. ten per cent of road vehicle-kilometres. Despite this, vehicle-kilometres by road are estimated to increase by 14 per cent, with the result that transport costs are estimated to increase by around Euro 0.3 billion annually. The cost of road traffic accidents is also estimated to increase in this case, as well as the cost of noise disturbance and delays to other road users. However, exhaust emissions are estimated to decrease in comparison with Scenario A. Carbon dioxide emissions are estimated to decrease by around 106 000 tonnes per year, which is approximately three per cent of heavy goods vehicles' (in Sweden) emissions and is estimated at Euro 16 million per year.

A change in rules towards shorter and lighter trucks in Sweden would result in an economic loss which would be principally borne by transport industry and shippers, and in the end private consumers. The investments in load-bearing capacity in order to adapt the standard of roads to the demands of heavy vehicles which the National Road Administration began in 1988, in order to adapt the standard of roads to the demands of heavy vehicles, are expected to have cost a total of Euro 4.6 billion (at 2001 prices). These investments are recouped by society after about five years when no modal shift is assumed and after about twelve years when transfers to rail (which require rail investments) are included.

3. DESIGN OF THE STUDIES IN THE CO-MODALITY PROJECT

To be able to evaluate the socio-economic effects of new vehicle dimensions – longer than 25.25 m and heavier than 60 tonnes - it is necessary to move ahead of the standard effect functions describing the relationship between vehicle size and socio-economic cost. The basic method is illustrated in Figure 2. The starting point is current cost functions for road wear (infrastructure cost), traffic safety, travel time, noise cost, air pollution and greenhouse effects as well as transport costs. Transport cost includes the traditional vehicle operating cost (VOC) but also logistic costs due to new transport concepts. Separately, we will estimate the infrastructure investment or reinvestment cost (e.g. bridges) necessary to accommodate other dimensions.

These cost functions are, with a link to the basic road database of Swedish Road Administration (this has not been used in the study described in section 2) coded on a detailed level in a network model which is a part of the new Swedish Freight model (SAMGODS[5] - Vierth et al. 2009). The model is based on a fixed production – consumption matrix of different commodity categories but will from there on, based on transport and logistic behaviour, predict the origin – destination (OD) matrix by different modes and finally

[5] The model was not available when the study described in section 2 was carried out

the number of new vehicles on the network. The coded cost functions will be used to evaluate the changes in socio-economic costs which will be compared to the necessary investment cost in network strengthening and other improvements. The freight model will be used to evaluate different scenarios of development of vehicle dimensions in the road and rail transport sector. As a base for the scenarios an extensive review of the literature as well as a survey and a hearing with the industry has been carried out (Mellin and Ståhle 2010).

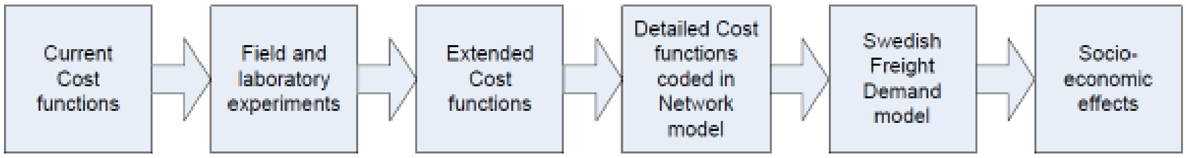

Figure 2 Basic method

Based on a limited number of field and laboratory experiments together with review of other research we will develop extended cost functions for these categories. The current cost functions used for this project are a development of the basic Swedish cost functions adapted for long and heavy vehicles, i.e. not exceeding 25.25 m and 60 tonnes (see Mellin et al. 2008).

- The road wear function is based on lifetime functions for rutting and fatigue cracking including initiation and propagation. A road wear elasticity is calculated based on number of passing standard axles, road strength measured as surfaces curvature index (SCI), a terminal value on cracking and rut depth and an assumption that the road will be repaved whenever one of these terminal values are reached. The changed present value of this new pavement behaviour is the resulting cost function.
- Cost of air pollution and greenhouse gas effects are in principle based on the impact pathway approach (IPA) (Bickel and Friedrich 2005). The approach includes a sequence of events that links the emissions to the impact and subsequent valuation, starting from the polluting emissions through transport and chemical conversion in the atmosphere to the impacts on various receptors, such as human beings, crops, building materials or ecosystems which are transferred into monetary values. However, the full IPA is only used to derive a set of unit values per emitted kilogram (see Maibach et al. 2007) and the emissions are based on the ARTEMIS model (Sjödin et al. 2009). The emission functions are dependent on vehicle type, emission class (e.g. EURO class), load factor, speed, traffic condition, road environment and gradient etc.
- The cost function for noise is based on the European noise calculation method for road traffic noise (HARMONOISE-model, de Vos et al. 2005). The sound source strength relative to one single passage per 24 h of a reference vehicle is calculated for different vehicle types dependent on speed and number of axles (used as an indicator of the vehicle length in the absence of information on the length). The exposure to the changed noise strength depends on population density and an evaluation of the exposure in monetary units is made[6].

[6] A complicating feature, however, is that the contributing effect on people of a single vehicle depends on the surrounding traffic and we can not simply isolate one particular vehicle and compute the "noise effect" without considering the traffic intensity.

- Traffic safety cost functions for LHV is not available. Currently, an average accident cost per kilometre for LHVs is used which are adjusted for the accident severity dependent on speed and road type based on the general model used by Swedish transport administration.
- Transport cost, which consists of a time and a distance based component, are based on the calculation model of the Swedish Haulier association (with fuel consumption information from the ARTEMIS model).

The above described current cost functions are our framework for designing the forthcoming field and laboratory tests and necessary alternative approaches. Field tests, with LHVs, are ongoing and planned as separate projects run by other organisations. However, these experiments are seldom planned as full scale experiments with randomized design. More often only a limited number of vehicles are re-designed, fitted with additional equipment and run on a specific corridor by a specific driver for a certain amount of time. A proper control group is seldom followed. The possibility to estimate extended cost functions based on these tests are therefore limited. The field tests will, however, guide the development of the transport cost, including changed logistic cost, due to new logistic behaviour for these vehicles. An additional use of the field test is to verify some of the extended cost functions developed by alternative methods. Two conclusions can been drawn from the usefulness of the field tests; first we have noted that, in opposite to for example medicine[7], a *guideline for good practice in allowing dispenses and accepting research trials on roads* that will guide the research benefit of the test is lacking and, secondly, we need to develop laboratory experiments. Possible laboratory experiments are of two types in this context, vehicle simulation study where driver behaviour is studied and road damage experiments with heavy vehicle simulator (HVS). We will use the VTI vehicle simulator to assess the accident risk of longer and heavier road vehicles. We will also perform field observations using cameras and radar mounted on the LHV. For road damage we will utilize result from previous HVS experiments and in other projects we have proposed an European large scale cooperation on HVS testing to evaluate road damage experiments (EURODEX – Hofko et al. 2008).

[7] For example ICH guidelines for good clinical practice (ICH, 1996).

Table 2 – Cost function and corresponding method

Cost function		*Method*
Transport cost		Field tests and Haulier industry cost calculation program
Road wear		Previous HVS experiments
Exhaust emissions	Air pollution	ARTEMIS model
	Greenhouse gases and fuel consumption	ARTEMIS (field tests)
Noise emissions		HARMONOISE model
Traffic safety		Laboratory experiment and field observations
Driver's education etc		Literature review
Investment cost		Investment cost calculation (e.g. bridges)

In the design of the project a risk analysis suggests that the most important risks are failure in estimating cost function for transport cost, road wear cost and traffic safety cost. The vehicle operating and logistic cost has a vast impact on the result but the logistic concepts that will be developed in large scale introduction are not available for the moment. This means that we will have problems to evaluate the long term consequences for the haulier industry. In addition, the sample of the field test is very limited and the result can thus be questioned on its reliability. Road wear has relatively small impact in the evaluation of reduced vehicle size in Sweden. However, when moving to higher weights it is possible that we may have totally different cost functions. The form of these new cost functions may be difficult to verify. Finally, traffic safety is an important cost component and the risk is that our laboratory experiment will not give a comprehensive accident risk for these vehicles. The risk analysis suggests that less risk is in general related to the freight demand model, including modal split, but uncertainty around the logistic behaviour prevail here as in the first cost function above. The analysis of investment cost is based on the necessary upgrading of the network in a life cycle cost (LCC) approach where the current reinvestment trend is taken into account.

4. IDENTIFICATION OF VEHICLE COMBINATIONS IN THE CO-MODALITY PROJECT

4.1 Future demanded dimensions in Sweden

This section concerns the issue of which road and rail vehicles there are a demand for in Sweden and thus relevant for investigating the socio economic effects of. The Co-modality project includes road and rail vehicles to capture the improved efficiency of both modes as well as the co-operation and competition between the modes.

A literature review has been conducted to investigate the use of longer and heavier road and railway vehicles in other countries and if there have been any assessments of them. The result shows that there are considerably larger road vehicles than currently permitted in Sweden in regular use in Canada, USA, Mexico, Brazil and Australia (OECD 2010; Mellin and Ståhle 2010). The longest and heaviest vehicle found is 53.5 metres and weights 125 tonnes and operates on restricted roads in Australia (NTC 2009; Mellin and Ståhle 2010). For trains the permitted dimensions and weight are dependent on the specific track. In Sweden the maximum length and weight, which only are allowed on a few specific tracks, are (National Rail Adminstration 2009):

- Length 700 metre (more general 650 m)
- Axel load (i.e. a train's weight per pair of wheels) of 30 tonnes (more general 22.5 tonnes)
- Distributed load of 12.2 tonnes/metre (more general 6.4 tonnes/metre)

Train sets with greater dimensions and weights are used in the USA, Australia and South Africa, among other countries. There are examples of ore trains with lengths of several kilometres (Mellin and Ståhle 2010). Even our neighbouring countries as well as other EU countries allows longer trains. As can be seen several countries (e.g. USA and Australia) use both larger trucks and trains compared to Sweden.

To complement the literature review and capture the views of Swedish stakeholders and experts on freight transports, a questionnaire survey was conducted and a hearing were organised. The survey was undertaken to establish which road and railway vehicles would be in demand year 2030 in Sweden. The responses show that no extreme changes are expected for neither road or railway vehicle dimensions. With regards to road transports, it is mainly a strategy to continue to build on the concept of EMS.

Table 3 below summarises the vehicles that are considered relevant for further analysis. For road vehicles there are three different types of vehicles which are derived from the survey and hearing. The first two are different, mainly longer, combinations of EMS vehicles. (The literature survey, hearing and survey are all pointing at the larger demand for volume capacity rather than weight). *EMS-double semitrailer* can transport e.g. two 40 ft containers or two 45 ft containers, within approximately 32 metres depending on the exact configuration. This type of vehicle has earlier been given exemptions on specific routes and a new field test with double semitrailers is just about to start. The *EMS–triple swap-bodies* are a combination of approximately 27 metres and is not demanded for increased weight. The final one is the *ETT-vehicle* (= En Trave Till, lit. *one more stack)* vehicle which is currently in use in a field test carried out by the forest industry. It is not a configuration of the standard modules within the EMS, it is suited for transport of heavy goods such as timber which explains the rather large increase in demanded weight.

Table 3 – Future demanded vehicles in Sweden

Traffic mode	Vehicle	Length (m)	Weight
Road	EMS – Double semitrailers	Approx. 32	60/80 tonnes
	EMS – Triple swap-bodies	Approx. 27	60 tonnes
	The ETT vehicle	30	90 tonnes
Railway	Longer trains	750	–
	Heavier trains	–	Axle load 25/30 tonnes Distributed load 8 tonnes/m

Concerning the trains the possibility to use longer, heavier and larger (enlarged gauge) train sets have been put forward in the reviewed literature and at our hearing. However most feasible, especially for international transports, longer trains seem to be. The increases is as seen in Table 3 rather limited, which partly can be explained by the relatively large investments needed to be able to permit these longer and especially heavier trains on a larger share of the rail network.

4.2 Important aspects of longer and heavier road and railway vehicles

Traffic safety, infrastructure, congestion, environment and transport cost are the aspects that we identified as relevant when discussing longer and/or heavier road and railway vehicles. However, the relevance of the different aspects differs between the modes.

For road transportation, it is primarily traffic safety, infrastructure wear and tear, and environmental impact that are discussed, both in the literature and in the survey. Congestion is mainly discussed in the literature, e.g. the effects of LHVs manoeuvrability and the number of vehicles on the network. However, the congestion in Sweden, especially on the interurban network where most LHVs can be expected to operate, is not a major issue. The literature also indicates that the existing LHVs are mainly operating on road networks in low density regions. The effects on the other areas are also largely dependent on where (on which types of roads) LHVs are allowed to operate. We have, based on the literature survey and the hearing, identified three different areas of application for LHVs that partly overlap. These are:

1) Specific corridors (e.g. EU:s “green corridors”).
2) Haulage to and from terminals for combined transports.
3) Infrastructure limitations in parts of the road network (similar to today’s 25.25 metre vehicles in Sweden which are not allowed in central parts of some cities).

Where these vehicles would be allowed to operate depends on political decisions. One issue of interest is therefore the current regulatory model and how it is formulated. An alternative to current regulations with maximum lengths and weights is Performance Based Standards (PBS). PBS sets standards for the vehicles performance, rather than prescriptive mass and dimension rules. This is in use for LHVs in Australia since 2007 (NTC 2009). The purpose of PBS is to enhance the road safety and increase the productivity (through innovative design) without increasing the infrastructure costs at a given amount of goods. Examples of standards (which the PBS road vehicles, named SMART, would need to satisfy) included in the Australian PBS scheme is static rollover threshold (vehicle stability), high-speed offtracking (trailer dynamic performance), low-speed swept path (vehicle manoeuvrability) and bridge loading (infrastructure wear and tear) (OECD 2010). Further, the road network is divided into four different levels depending on the condition of the roads. These levels are related to the SMART vehicles performance. The aim is to link the SMART vehicle attributes with the roads which they will be used in traffic on. A first evaluation of the PBS scheme indicates a rather low participation since there is uncertain and limited access to the road network, limited flexibility and complex system generating high cost for applying (NTC 2009). This scheme may, however, be a viable alternative and also a partial solution to the problem concerning where the vehicles would be permitted to operate.

With regards to rail there is a more distinct focus on dedicated routes where the infrastructure needs to be upgraded to accommodate longer and/or heavier trains. The railway is to a lesser extent associated with the traffic safety aspects and saftey is therefore not a limiting factor in the same way as with LHVs. The need for using existing network more efficient is however discussed, and larger trains is seen as one way of increasing the capacity without the need for more train paths. In the literature review it has, however, been far less results of scientific literature considering longer and heavier railway vehicles compared to road.

An important aspect is the environmental impact. Improving vehicles' energy efficiency is important, as is switching from fossil fuel dependency to sustainable, renewable fuels. Both the literature and the responses given in the survey indicate a great deal of uncertainty as regards to which vehicle fuels will be used in the future; current thinking is that diesel engines will be the standard in the future and that various fuels which can be used in a diesel engine will constitute the primary alternative fuels. There is widespread belief in both second generation biofuels and hybrid power as elements in making energy use more efficient. Greater lengths and weights of road vehicles are seen as a means to achieve better energy efficiency but both trains and ships are in many cases superior to road vehicles as regards energy efficiency.

5. TRAFFIC SAFETY EFFECTS

5.1 Experiences from North America

Traffic safety is a crucial policy aspect of increasing vehicles dimensions and mass. It is also one of the more important cost functions in the previous conducted CBA.

Traffic safety of LHVs of different sizes has been studied over the years, primarily in the USA. A recent review, including a meta analysis, by af Wåhlberg (2008) analyses the change in accident risk of introducing LHVs. This area of research suffers from several methodological problems, with the main problem being the lack of good exposure data. As larger trucks tend to drive on bigger and therefore safer roads, road exposure for the different truck types needs to be taken into account. As a consequence, only trucks that travel on the same type of roads can be compared, and the results can not be generalised to other types of roads. Besides the difference in safety between roads another problem is to determine how much the different types of trucks are driven, i.e. the vehicle mileage. According to af Wåhlberg (2008) few studies have been able to use true vehicle mileage data from specific vehicles. Instead, three different methods have been used; induced exposure, inquiries among hauliers, and measurement stations. In the first method the number of passing vehicles of different types is counted at accident spots for trucks. The characteristics of the group of vehicles that did not crash at the spot, is compared with the group of vehicles that did crash. Possible differences between the groups are assumed to be related to the cause of accident. The second method involves collecting data from some hauliers on how different vehicles are used and on which roads they travel, with the assumption that this material is representative for the total population. In the third method data from measurement stations (probably for collecting fares) on some American roads has been used.

In addition to the exposure problem, it has also been suspected that there are systematic differences between drivers of different trucks, but that is probably a weak effect according to af Wåhlberg (2008). From the meta study, af Wåhlberg (2008) concludes that the effects of accidents increase with increasing weight, at least up to a certain point, which makes the comparisons of accident risk sensitive to what type of accident has been investigated. However, by taking into account that larger trucks replace a higher number of smaller ones on the roads, he found that as a population, heavier trucks have fewer accidents, although the difference is small for the group of fatal accidents. af Wåhlberg (2008) also remarks that even though the total effects regarding truck size were positive, larger vehicles have specific problems. This could be e.g. time for overtaking and manoeuvrability. This indicates that in certain environments, like towns, they are put at higher risk. Since the underlying data in af Wåhlberg´s study comes mainly from the USA and Canada, his conclusions should be valid for those countries, but cannot directly be applied for Europe, or more specifically Sweden.

5.2 Analysis of accident risk

To assess the accident risks of new types of LHVs in Sweden, a new study needs to be undertaken, which would have to deal with the problems discussed above regarding exposure.

The conclusions in af Wåhlberg (2008) is consistent with the findings in the studies by VTI for vehicles up to 25.25 metre and 60 tonnes (Vierth et al. 2008). All accident where trucks above 3.5 tonne has been involved during the years 2003 to 2005 have been examined and assigned a cost based on official accident valuation for fatalities, severe and slight injury. The relevant accident cost per vehicle-kilometre depends on two elements; first the average accident cost per accident and the number of accidents per vehicle-kilometre.

Several studies have shown how the difference in weight between vehicles in a collision influence accident outcome, firstly so that the people in the lighter vehicle are injured more and secondly so that the total accident costs increase. The average accident cost per accident for trucks with trailers is around Euro 0.26 million, while it is around Euro 0.18 million for trucks alone. If we look at traffic environments we find that the average cost is Euro 0.15 and 0.12 million respectively in urban areas and Euro 0.3 and 0.27 million respectively in rural areas.

However, taking into account the number of accident per vehicle-kilometre the relationship is reversed with higher cost for trucks alone than for trucks with trailer. In Table 4 the accident cost per vehicle-kilometre is presented for the trucks operating on the roads of Sweden. The cost includes fatal accidents as well as severe and slight accidents. The higher accident cost per vehicle-kilometre for trucks can be explained by environmental factors where smaller trucks do not travel in the same places as the heavier vehicle combinations. In particular smaller trucks have more accidents in urban areas even tough they in general have milder consequences.

Table 4– Accidents cost per vehicle-kilometre (EUR/vkm)

Gross weight / Axles	2	3	4	5	6	7	8	9	Total
Truck 3.5 – 7.5 tonnes	-								-
Truck 7.5 – 12 tonnes	0.05								0.05
Truck 12 – 14 tonnes	0.15								0.15
Truck 14 – 20 tonnes	0.07	0.00							0.07
Truck 20 – 26 tonnes	0.05	0.21							0.13
Truck 26 – 28 tonnes		0.15							0.15
Truck 28 – 32 tonnes		0.31	0.51						0.34
Truck above 32 tonnes		3.91	0.21						0.30
Total Trucks	**0.07**	**0.19**	**0.32**						**0.12**
Truck below 28 tonnes		0.00	0.00						0.00
Truck with trailer 28-34		0.02	0.07						0.06
Truck with trailer 34-40		0.33	0.08	0.00	0.00				0.07
Truck with trailer 40-50		0.01	0.04	0.06	0.27				0.06
Truck with trailer 50-60 tonnes			0.03	0.02	0.06	0.05	0.10	0.20	0.05
Total Trucks with trailers		**0.04**	**0.05**	**0.03**	**0.06**	**0.05**	**0.10**	**0.20**	**0.05**

Reference: Vierth et al. (2008)

6. FIELD TESTS OCH SIMULATOR STUDIES

There are some preliminary results from one ongoing field test (the ETT-project) which allows a 30 metre long truck trailer combination with a gross weight of maximum 90 tonnes to rationalize the timber transports (i.e. the *ETT-vehicle*). The vehicle is able to carry four stacks of timber, instead of the usual three. The field test is limited to the national road E4 in Northern Sweden (on roads where the two directions of traffic is mainly separated), between the timber terminal in Överkalix and the sawmill in Munksund outside Piteå. After 15 months 60 000 m^3 timber have been transported. Preliminary results show that 40 tonnes diesel and 100 tonnes carbon dioxide have been saved - compared to transports using conventional

60 tonne truck combinations. Transport costs have been reduced by 20 per cent and the need for trucks has been reduced by 30 per cent. As the combinations spread its weight over more axles, road wear is believed to be either the same or improved (Löfroth 2010). Traffic safety will be specifically studied in the field test, from June to September 2010. This will be done by having cameras and radar mounted on the vehicle to monitor the overtaking time of the vehicle. The time of the test and also the location in the Northern part can affect the conclusions of the test, since the weather and road surface conditions during this time differs from winter time and this is also a area with very low traffic-density.

In the same program 74 tonnes combinations are evaluated for timber transports from forest to factory. These combinations are tested in the hilly region of Dalsland in West Sweden. In this case a ten per cent reduction of the transport costs is expected. One result so far is that the topography (hilly in Dalsland compared to flat region around Överkalix and Piteå), circumstances (location of forest in relation to road network, design of exemptions given by the authorities) and logistical solutions determine costs and benefits of the use of LHV combinations.

Secondly, the simulator studies will use VTI's traffic safety simulator to identify the reactions from drivers of passenger cars. The simulator study is performed with a selection of drivers which will perform driving tests in VTI's simulator 3. This is a moving base driving simulator with interchangeable cabins (i.e. cabins of different car models) and a premium performing motion base system. The situations studied will be overtaking of vehicles, reactions in cross roads and the influence of warning signs applied on LHVs. The vehicles used in the simulator will be passenger cars and trucks with the dimensions 18.75, 25.25 and 30 m. The design of the traffic simulator test has been influenced of the results from a focus group interview, an accident analysis and the anticipated future dimensions (see section 4.1). They are also chosen to have a substantial data for the reference vehicles and that the drivers of the passenger car will have a good perception of the different vehicles compared to passenger cars. The more generalised tests made in the simulator will be compared with the ones from the field tests.

7. DISCUSSION

In the comparison of Swedish and EU-vehicles for domestic transports in Sweden it could be noted that the availability of rail capacity has a significant effect on the transport costs. However, even with increased rail capacity and a modal shift to rail the result shows that smaller road vehicles lead to reduced benefit for society. The increase in transport costs when using smaller vehicles is the largest negative component. All other effects in the CBA are much smaller. One interesting observation in the scenario that includes modal shift is that the negative impact on increased noise and traffic safety exceeds the positive effects on less road wear and exhaust emissions. The reason is that there still will be more road vehicle-kilometres than in the reference scenario.

Increased dimensions and weight of road vehicles are aiming at increasing energy efficiency and decreasing transport cost. Hence, under certain circumstances they can improve the sustainability of the transport system. Preliminary results from the field tests within the ETT-project indicates that the tested vehicles lead to additional benefits in terms of e.g. reduced transport and emission costs. The cost reductions are, however, influenced by factors like logistic solution and topography. It is a question of how to optimise the transport according to the influencing factors. As presented earlier the use of LHVs could be permitted under different restrictions. One example is to only allow them for haulage between terminals which could enhance the efficiency of combined transports. In Sweden there has been a rather substantial development of combined transport, with rail and road, without any direct government support for these. The other approach is to allow LHVs in more or less the whole network except for city centres or allow them in specific corridors. The perspective of the introduction of the increased dimensions was set to year 2030. With this in mind the use of alternative fuels and energy sources are important, which affects the levels of emitted air pollutants and greenhouse gases as well as noise.

Traffic safety has been found to be one of the most crucial aspects of LHVs. The finding from previous experiences and literature review is that less vehicles on the roads has a positive effect on traffic safety. This indicates that the number of long and heavy vehicles could be more important than the increased dimensions and weights of the vehicles. The studies however suffer from several methodological problems, such as e.g. exposure problem - larger vehicles tend to operate on safer roads. The Co-modality project will perform simulator studies on traffic safety and use the field tests to further study the effects of 30 metre long vehicles.

Finally, one interesting question is to what extent the results are specific for Sweden and/or can be transferred to other countries or from national to international transports. The field test carried out in Sweden seems to be specific for this environment, which e.g. can be seen with the great differences between the results of the vehicle in Dalsland compared to the one in the Northern part of Sweden. The problem of transferring the experiences of LHV is also supported by the literature. Therefore, we will further study international transports from Sweden. The competition interface between road and rail is larger for cross-border transport than for domestic transport. Longer and heavier trucks in Europe might affect international transport by rail more than shorter and lighter trucks in Sweden. Within the Co-modality project we analyse the effects of using Swedish road vehicle dimensions in a specific corridor between Germany and Sweden (Marco Polo corridor Norrköping – Herne). We plan to analyse the use of longer trains in the same corridor. The overall goal is to study how the use of road and rail vehicles of different size on their own and in combination with each other can lead to an efficient utilisation of resources and benefit for society.

8. CONCLUSIONS

The socio-economic effect of using longer and heavier road vehicles in Sweden than in the rest of the EU has been seen to be positive due to lower transport cost for the industry and in the end private consumers. The investments in load-bearing capacity which started in 1988 were recouped by society in relative short time. If capacity restraints are applied on railway and maritime transport, leading to a marginal effect on modal shift, there will be a positive effect on emissions using longer and heavier vehicles. Cost of road wear has increase but it accounts for three to six per cent of the cost savings from lower transport cost. Independent of modal shift traffic safety has increased due to fewer trucks in traffic. The same effect can be noted regarding noise emissions.

The survey show that no extreme changes are expected for neither road nor railway vehicle dimensions in the future. With regards to road transports, it is mainly a question of continuing to build on the concept of EMS, stretching the length and tonnage.

Traffic safety, infrastructure, environment and transport cost are the main aspects that we identified as relevant when discussing LHVs. The effects of these aspects are to a great extent dependent on where (on which types of roads) LHVs are allowed to operate, logistic solution and possibility for modal shift. It is from a socio-economic point of view difficult to give a general conclusion regarding preferable road vehicle dimensions. The ongoing field test with LHVs indicates lower transport costs. However, if this means a positive socio-economic effect is still a question.

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