SOCIO-ECONOMIC EFFECTS OF LONGER AND/OR HEAVIER ROAD TRANSPORT VEHICLES – THE SWEDISH CASE

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Abstract

Sweden has a long experience of using longer and heavier road transport vehicles than in the rest of the European Union. The interest in efficient transport has also been expressed by field tests using vehicles with a length of 30 meters and 90 tonnes gross total weight. In this paper the socio-economic effects of using larger vehicles are evaluated. One case concerns Sweden's exception from the EU standard and includes effects from all types of cargo while another case analyses timber transports with larger vehicles than the ones used in Sweden today. The general finding is that larger vehicles can be cost effective even when external costs like road deterioration, traffic safety effects and air pollution is accounted for as long as no investments to improve the bearing capacity of bridges are required. It is recommended though that larger vehicles are used mainly on larger roads, use Electronic brake system (EBS) and that the condition of brakes are guaranteed. Traffic safety can also be improved by better facilities for drivers to rest and more distinct signs indicating the larger dimensions of the vehicle.

Keywords: Heavy Vehicles, Long Vehicles, Cost Benefit Analysis, Freight Transport

1. Introduction

Sweden and Finland have a long experience of using longer and heavier road transport vehicles than in the rest of the European Union (EU). About 65 per cent of the tonnage and about 75 per cent of the tonkm in Sweden is carried out by vehicles that exceed the EU standard. In Sweden and Finland, road transport vehicles up to 25.25 metres and a total gross weight of max 60 tonnes are allowed. In most of the other EU-countries the standard is 18.75 metres and 40 tonnes. (The European Modular System (EMS) is used in national and international transports.)

In recent years the Swedish interest in efficient transports has also been expressed by field tests using vehicles than are longer and heavier than the ones used in Sweden today. A 30 meters long vehicle with a total gross weight of 90 tonnes are used for timber transports in the ETT[1]-project (Löfroth & Svensson, 2010) and a 32.5 meter long vehicle is used for general cargo transports in the DUO2-project.[2] Longer and heavier trains for products from the forest industry are tested in the ELVIS-project.[3]

In Sweden, the Road and Transport Research Institute (VTI) has investigated, by commission of the Government, what effects the use of longer and heavier road transport vehicles than in other EU-countries has on the transport system (Vierth, o.a., 2008). The commission comprises both a socio-economic assessment of existing vehicle regulations in Sweden and an examination of competition between road and rail. Results from this study will be presented in this paper.

VTI has also conducted the research project "Co-modality" (funded by VINNOVA, the Energy Agency and the Transport Administration) in order to study if even larger road vehicles (larger than 25.25 metres and 60 tonnes) lead to larger socio-economic benefits. On part of this project is a cost benefit analysis of timber transports using 30 meter long vehicles with a total weight of 90 tonnes. The cost benefit analysis is also presented in this paper. A

[1] En Trave Till (One more pile)
[2] www.duo2.nu
[3] For more information about this project please contact Inge Vierth (inge.vierth@vti.se)

full length description of the analysis can be found in Haraldsson, Jonsson, Karlsson, Vierth, Yahya, & Ögren (2012). Another interesting question is to what extent the results are specific for Sweden or can be transferred to other countries or from national to international transports. Therefore, international transports to/from Sweden are studied in the sub project "corridor analysis" of the Co-modality project. VTI analyse the effects of using Swedish road vehicle dimensions in a corridor between Sweden (around Norrköping) and Germany (Ruhr area, around Herne). We also analyse the use of longer trains in the same corridor and it is studied 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. In this project the competition interface between road and rail, which is larger for cross-border transport than for domestic transport, is also analysed (Vierth & Karlsson, 2012).

2. Purpose

The purpose of this paper is to evaluate the usage of longer and heavier road transport vehicles in a cost benefit analysis that comprises all relevant effects of using these vehicles. Two cases are analysed: the first case is a general study in which all types of commodities are involved and where transports using trucks with the Swedish standards are compared to transport using European standard dimensions. The second case is more specific and compares timber transports using trucks with the current Swedish maximum dimensions with the same type of transport using larger vehicles of 30 meters length and a total weight of 90 tonnes.

3. Method

The socio-economic effects of using vehicles of various size are studied by, in the general case, comparing the use of the European vehicles (of maximum size) to the use of the Swedish vehicles (of maximum size). In the timber transport case the Swedish vehicle is compared to an even larger vehicle of 30 meters length and a total weight on 90 tonnes. A cost benefit analysis (CBA) based on Swedish guide lines and the national freight model SAMGODS (that includes all modes) is carried out. The effects with regard to transport costs, road wear and tear, air and noise emissions, road safety and congestion are analyzed, as far as possible based on official statistics. Different models are used to calculate the effects on transport volumes, transport costs and external effects (road wear, air and noise emissions, traffic safety and congestion). In general the approach is similar for both cases, but cost estimates etc. are not identical. This difference is due to the fact that the general study dates a few years back, while the timber transport case is analysed this year.

4. Transports with Swedish trucks compared to European standard trucks – a general case

As described above, the weight and length of trucks allowed in Sweden deviates from the general EU standard. A very large proportion of freight transport by road in Sweden takes place by vehicles that exceed the EU standard. In 2007 the Swedish government commissioned to VTI to analyse what economic consequences this deviation has had for Sweden. VTI concluded that a change in regulations in Sweden to 18.75 meters and 40 tonnes would lead to a socio-economic loss (up to Euro 0.9 billion per year); it is thus not cost-effective to use shorter and lighter trucks. It was assumed that the same freight volume is carried by shorter and lighter road vehicles. The negative outcome of changes in truck standards can be mitigated if it is possible and commercially feasible to transfer some freight volumes to rail. Both increased track capacity and an improvement in level of service and reliability are, however, required for a major transfer to rail. The loss that would primarily be borne by the business sector due to higher transport costs (about 80 per cent of the total loss) but a change to the EU-standard in Sweden would also lead to increased air and noise emissions, more killed and injured people in traffic and longer delays for passenger cars.

5. Timber transport using trucks with 90 tonnes total weight

In this chapter we will analyse the potential efficiency gains from using trucks that are 30 meters long, have 11 axels and a total weight of 90 tonnes. We study the use of such trucks for timber transport. In recent years, a vehicle with this specification has been tested in a field experiment known as the ETT-trial (Löfroth & Svensson, 2010). The experiences from this project seem to be positive, but no cost benefit analysis, covering all relevant costs, have been done so far. In the following sections we first present estimates of the various costs associated with truck transports. The methods used to estimate these costs are described briefly. Finally the cost estimates are used to compute the socio-economic costs associated with three simulated scenarios.

5.1 Transport costs

The transport costs are computed using information from the ETT-project (Löfroth & Svensson, 2010) and various methods and parameters recommended by Swedish transport authorities for usage in cost benefit analyses (SIKA, 2002) (Trafikverket, 2012). The transport costs are costs on the firm level and it turns out that the heavier vehicles are 4 percent more expensive to use per hour than the lighter vehicle. The costs measured by kilometer are 30 percent higher for the heavier vehicle.

Table 1 Transport costs (SEK)

	60 tonnes	90 tonnes	Ratio
Wage per hour	272	272	1,00
Capital cost per hour	38,4	50,9	1,33
Total cost per hour	310,4	322,9	1,04
Depreciation cost per km	2,6	3,5	1,28
Tyres per km	1,2	1,3	1,08
Diesel per km	2,3	3,1	1,37
Total per km	6,1	7,9	1,30

5.2 Infrastructure costs

According to Trafikverket (2012) an average truck on the Swedish road network costs 0.24 SEK per vehicle kilometre (incl tax factor). In this analysis this value is differentiated between different roads and different vehicles.

The road differentiation model is based on pavement lifetime functions based on failure critera for fatigue cracking as well as rutting. These functions are based on data from the Swedish Long Term Pavement Performance (LTPP) database. From the lifetime functions deterioration elasticities can be derived, which show by how many percents the pavement lifetime is shortened by a one percent traffic increase and also the relation between marginal and average deterioration cost. A deterioration elasticity of -0.5 means for instance that MC=0.5AC. The deterioration elasticity varies between -0.02 on high quality roads with low traffic, where pavement failure is caused by cracks, to -1 on low quality roads, where rutting is the main cause of pavement failure. For a full length description of these models please refer to Mellin, Lindberg, Karlsson, & Benz (2009).

The differentiation between different vehicles is based on the fourth power law, which implies that road deterioration is proportional to the number of standard axes on that particular vehicle. The average truck on Swedish roads has 1.3 standard axes. A vehicle with 60 tonnes total gross weight and 7 axes 3.78 standard axes (loaded) and 0.03 standard axes (without load). The 90 tonnes vehicle has 4.93 standard axles (loaded) and 0.03 without load. On an average Swedish road this means that the 60 tonnes vehicle costs 0.35 SEK/vkm and the 90 tonnes vehicle cost 0.4 SEK/vkm.

5.3 Traffic safety

Within the Co-modality project several comprehensive traffic safety studies have been undertaken; one simulator study in which accident risk in overtaking situations are analysed (Andersson, o.a., 2011); one field study where actual overtakings are video recorded (ibid.) and one review of all types of traffic safety issues (Hjort & Sandin, 2012). The main result from these three studies is that the usage of larger trucks might increase the risk for accidents, but we lack a quantitative and significant estimate of this effect. Therefore, in our cost benefit analysis we assume that the accident cost is equal for 60 tonnes and 90 tonnes trucks, but varies between roads as indicated by the table below. These road differentiated costs are derived from a set of databases captured by VTI and Trafikverket (Mellin, Lindberg, Karlsson, & Benz, 2009).

Table 2 Accident costs

	SEK per vehicle kilometre
Four lane road	0,26
Main arterial road	0,81
Main arterial road (2+1)	0,43
Motorway	0,35
Ordinary road	0,90
Ordinary road (1+1)	0,70
Ordinary road (2+1)	0,69
Average	0,64

Due to the possible increase in accident risks when using larger trucks Hjort & Sandin (2012) recommend that larger vehiles are used mainly on larger roads and that they are used as little as possible in urban areas. Another recommendation is that longer and heavier trucks are constructed for stability and equipped with Electronic brake system (EBS). They also concludes that brake service should be improved and brake control intensified if 90 tonnes vehicles are allowed. Traffic safety can also be improved by better facilities for drivers to rest and more distinct signs indicating the larger dimensions of the vehicle.

5.4 Time delay

With larger vehicles transporting the timber, the number of trucks will decrease on our roads. This means that passenger cars are delayed by fewer trucks, an effect that is present only where the overtaking possibilities are limited. This is mainly the case on ordinary roads with two fields, less than 11.5 meters width and speed limits between 90 and 100 km per hour. The time delays are computed using a model developed at VTI (for a full length description and references see Vierth, o.a., (2008)).

First the hourly number of vehicles per road link is established for the reference scenario. Then the additional journey time for passenger cars associated with a one percentage point increase in the truck proportion is computed according to the formula below. This value is then multiplied by the change in the proportion of trucks for each link and an average journey time supplement is obtained. The total delay over a year is obtained by multiplying by the annual vehicle-kilometers for cars on the link concerned. The delay cost is then computed by using a time cost of 150 SEK, which represents an average car journey.

$$\Delta \text{journeytime/truck\%} = k1*(1-e^{-k2*qtot}) \qquad (1)$$

Where Δjourneytime/truck% (s/km) is the addition to journey time for cars when the proportion of heavy vehicles increases by one percentage point. k1 and k2 are constants and qtot is the total flow in both directions and is expressed as vehicles per hour. k2 has the same value on all roads (0,0012), while k1 varies between 0,10 and 0,26, with the highest values (highest delay) on narrow roads with low traffic and vice versa.

5.5 Fuel consumption and emissions

Emission factors for the 60 tonnes vehicle are obtained directly from ARTEMIS/HBEFA (Sjödin, o.a., 2009). For the larger vehicles emission factors are estimated by extrapolation from smaller vehicles. A 60 tonnes vehicle is estimated to use 4.1 litres of diesel per 10 km, while the larger 90 tonnes vehicles have a fuel consumption of 5.64 litres per 10 km.

Table 3 Emission factors and emission costs (Euro IV)

		Emission factors g/vkm		SEK/vkm		
	Emission cost SEK/kg	60 tonnes	90 tonnes	60 tonnes	90 tonnes	Cost ratio
CO2	1,75	1064,21	1458,91	1,86	2,55	1,37
NOx	109,10	5,85	7,73	0,64	0,84	1,32
PM	614,88	0,05	0,06	0,031	0,037	1,20
SO2	53,64	0,0014	0,0019	0,000075	0,00010	1,36
CH4+NMHC (VOC)	57,61	0,023	0,031	0,0013	0,0018	1,35
Total				2,53	3,44	1,36

5.6 Noise

The noise emissions are computed by using the NORD 2000 model. The noise emissions are mainly generated by tyres, so the larger vehicle with 11 axles has higher costs for noise than the smaller 7 axle vehicles. The noise cost also varies with the size of the population in the surroundings of the road and with average annual daily traffic (AADT). A detailed description of the model can be found in Haraldsson, Jonsson, Karlsson, Vierth, Yahya, & Ögren (2012).

Table 4 Noice cost (SEK/vkm)

Population density	0	1 – 100	100 – 500	500 – 1500	1500–4000	> 4000
AADT 0 – 500						
Share of network	22.7 %	28.9 %	2.9 %	2.4 %	0.7 %	0.1 %
60 tonnes 7 ax.	0	0,000091	0,000110	0,000013	0,000012	0,000000
90 tonnes 11 ax.	0	0,000145	0,000174	0,000021	0,000019	0,000000
AADT 500 – 2000						
Share of network	22.7 %	14.7 %	1.5 %	0.1 %	0.0 %	0.0 %
60 tonnes 7 ax.	0	0,002936	0,011992	0,059097	0,126909	0,000000
90 tonnes 11 ax.	0	0,004648	0,018986	0,093563	0,200999	0,000000
AADT 2000 – 10000						
Share of network	4.4 %	10.5 %	1.9 %	0.5 %	0.1 %	0.0 %
60 tonnes 7 ax.	0	0,003554	0,028675	0,082230	0,198296	0,219004
90 tonnes 11 ax.	0	0,005631	0,045431	0,130292	0,314203	0,346953
AADT > 10000						
Share of network	0.4 %	0.9 %	0.4 %	0.3 %	0.1 %	0.0 %
60 tonnes 7 ax.	0	0,004150	0,045899	0,131776	0,279949	0,458872
90 tonnes 11 ax.	0	0,006575	0,072739	0,208835	0,443661	0,727233

Mean values weighted by network share show that in average the smaller trucks generates noise costs of 0,0031 SEK per vehicle kilometre while the noise cost for larger trucks are 0,0049 SEK per vehicle kilometre.

5.7 Tax effects

Taxes are in most instances not relevant for a cost benefit analysis since they are merely transactions. Sometimes and to some extent though revenues from one tax means that other and potentially more harmful taxes can be avoided. The guidelines provided by Swedish

Transport Administration recommend that 30 percent of the net change in tax revenues should be included in the cost benefit analysis. Tax incomes from transports for instance means that Based on the vehicle taxes, fuel taxes and estimations of annual distance, we have estimated this effect to -0,62 and -0,83 SEK per vehicle kilometre for 60 tonnes and 90 tonnes vehicles respectively. It is important to notice that this is a benefit, not a cost.

5.8 Compilation of costs per vehicle kilometre

The costs per vehicle kilometre are 30 percent higher for a 90 tonnes vehicle compared to a vehicle with 60 tonnes total gross weight. The time related costs differ by 5 percent.

Table 5 Costs per vehicle km och hour

	SEK per vehicle km		
	60 tonnes	90 tonnes	Ratio
Depreciation tires, diesel*	6,4	8,4	1,31
Road deterioration*	0,35	0,46	1,31
Accident costs	0,64	0,64	1,00
Delay costs			
CO2	1,87	2,56	1,37
NOx	0,64	0,84	1,32
PM	0,028	0,038	1,36
SO2	0,000072	0,000099	1,37
CH4+NMHC	0,0013	0,0018	1,36
Noice	0,0031	0,0049	1,58
Tax effect	-0,62	-0,83	1,34
Sum	9,31	12,11	1,30
	SEK per hour		
	60 tonnes	90 tonnes	Ratio
Capital cost+drivers wage*	324,1	341,1	1,05

*Inkl tax factor 1,21

5.9 Scenario analysis

We have used the national goods model SAMGODS (Vierth, Lord, & Mc Daniel, 2009) to simulate the truck transports of timber. Three scenarios are analysed. In the first, which is the reference scenario, only 60 tonnes vehicles are used. In the second and third scenarios 90 tonnes vehicles are used. In the second scenario the vehicles are allowed to use all roads, while in the third scenario only roads without restricted bridges are used. After the simulations all types of costs are computed using link flows from the model and road network information from NVDB (national road data base).

The results from these analyses are presented in the table below. According to the reference scenario timber transports using same type of trucks that are used today generate costs of about 4 billion SEK annually. This corresponds to a cost per vehicle kilometre of 13,7 SEK. Should vehicles with 90 tonnes total weight be allowed to use all bridges, that is drive on exactly the same set of roads that the 60 tonnes vehicles use, the total cost would decrease by 163 million SEK (4 percent). In reality though, this requires quite extensive efforts to reinforce bridges. The cost of such work has not been estimated here, but it is clear that the efficiency gains from timber transport to some extent motivate such efforts. It is important to notice though, that the cost estimates might be subject to errors and that a share of the net in the cost benefit analysis should be reserved to account for such uncertainty.

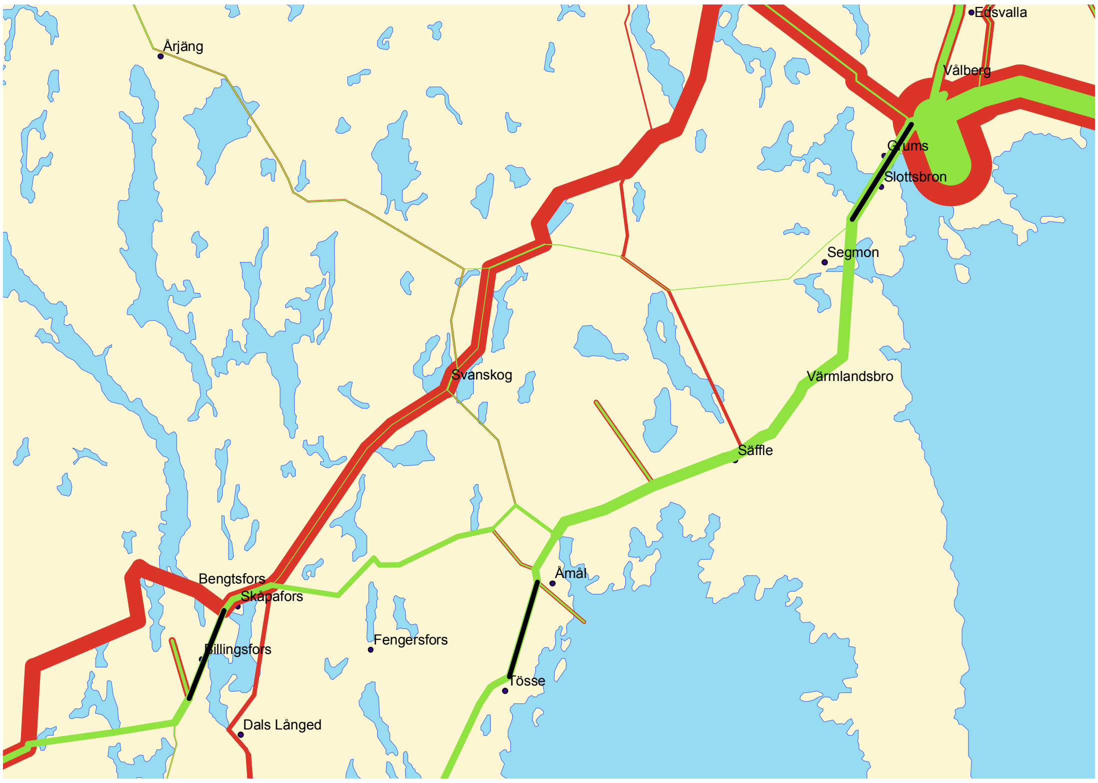

Figure 1 Timber transports with lorries in part of Sweden (Värmland/Dalsland). Black color indicate bridges with weight restrictions. Green color indicate flows with 60 tonnes trucks, while red is used for 90 tonnes flows.

On the Swedish road network there are 1417 bridges that 90 tonnes vehicles are not allowed to use without exemption. This means that it is necessary to use alternate routes, often on smaller roads. It also means that the shortest road is not a viable alternative. An example is shown in the figure 1. The most important road through this part of Sweden, E45, runs from north east to south west in the rightmost part of the map (Grums-Säffle-Åmål). When vehicles with 60 tonnes total gross weight are used (green color) E45 is the major route. However, along E45 there are bridges with limited bearing capacity at several places (black color). Using road E45 is therefore not possible for vehicles with 90 tonnes total weight (red color). Instead, they have to use smaller roads, adding an extra distance to their route.

If the larger vehicles are not allowed to use the bridges, then using those does no longer improve efficiency, at least not in general. Should all timber transports use 90 tonnes vehicles and be required to drive around all 1417 bridges with limited bearing capacity the total transport costs would increase by 16 percent compared to the reference scenario. This number is a little bit high, since in the simulations not even trucks without load are allowed to pass these bridges.

In some sense this scenario lacks realism, since in reality larger vehicles should not be utilized if it was less costly to use a 60 tonnes vehicle. But, there are routes without restraining bridges and it might also be cases where it is cost effective to use 90 tonnes vehicles even if detours then become necessary.

Table 6 Results scenario analysis

	Scenario 60-tonnes	90 tonnes (without bridge restrictions)	90 tonnes (with bridge restrictions)
Vehicle km per year	295544285	234796835 (-21%)	275329141 (-7%)
Hours per year	3947787	3139830 (-20%)	3761031 (-5%)
Emission costs (incl. CO2)	747727041	807701112 (+8%)	947132245 (+27)
Road deterioration costs	168080175	173790408 (+3%)	287329362 (+71%)
Accident costs	228294347	181433883 (-21%)	226406693 (-1%)
Noise costs	1258138	2007946 (+60%)	1647803 (+31%)
Time delay	51658334	40260942 (-22%)	37683333 (-27%)
Time cost vehicle	1225393231	1013882624 (-17%)	1214474648 (0%)
Distance based cost vehicle	1802820136	1854895000 (+4%)	2175100322 (+22%)
Tax effect	-184064980	-195538805 (-6%)	-229294108 (-25%)
Sum	4041166423	3878433109 (-4%)	4660480298 (+16%)
SEK/vkm	13,67	16,52	16,93

6. Conclusions

In general it seems like larger vehicles can be cost effective even when external costs like road deterioration, traffic safety effects and air pollution is accounted for. With the necessary infrastructure in place this is clearly the case as was shown by comparing transports using vehicles with Swedish dimensions with European standard vehicles. Increasing vehicle size to 30 metres/90 tonnes increase efficiency even more as long as no investments to improve the bearing capacity on bridges are required. There are routes without limiting bearing capacity that could be used for transports with 90 tonnes vehicles. However, many bridges need to be reinforced. The cost for such operations is crucial but has not been estimated here.

For traffic safety reasons it is recommended that larger vehicles are used on larger roads and that their use in cities are limited to a minimum. Another recommendation is that longer and heavier trucks are constructed for stability and equipped with Electronic brake system (EBS). Brake service should be improved and brake control intensified if 90 tonnes vehicles are allowed. Traffic safety when using larger trucks can also be improved by better facilities for drivers to rest and more distinct signs indicating the larger dimensions of the vehicle.

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