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The effects of long and heavy trucks on the transport system

Report on a government assignment

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FINDING A BETTER WAY

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The effects of long and heavy trucks on the transport system. Report on a government assignment

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Trucks up to 25.25 metres in length and weighing up to 60 tonnes are permitted in domestic traffic in Sweden. This deviates from the EU standard, according to which trucks are not to be longer than 18.75 metres or weigh more than 40 tonnes.

The Ministry of Enterprise, Energy and Communications has commissioned VTI to study what economic consequences this deviation has had for Sweden and to describe the competition interface between road and rail transport. The effects on transport costs for business, exhaust and noise emissions, road wear, time delay for motorists and road safety have been estimated.

A very large proportion of freight transport by road takes place by vehicles that exceed the EU standard. Reducing vehicle size would lead to large economic losses. Transport costs would increase in particular, but significant cost increases would also occur in the areas of road safety, exhaust emissions and noise emissions.

It is noted in the study that it is difficult, at least in the short term, to bring about transfers between road and rail. This is due, in part, to high rate of utilisation of the railway capacity.

Keywords:
Heavy long trucks, competition, railways, transport costs, CBA, SAMGODS, road safety, noise emissions, exhaust emissions

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I Sverige tillåts lastbilar i inrikestrafik som är upp till 25,25 meter långa och 60 ton tunga. Detta skiljer sig från EU-normen, där lastbilar som regel inte är längre än 18,75 meter och väger maximalt 40 ton.

Näringsdepartementet har gett VTI i uppdrag att studera vilka samhällsekonomiska konsekvenser avvikelsen har medfört för Sverige samt beskriva konkurrensytan mellan väg- och järnvägstransporter. Effekterna på transportkostnader för näringslivet, avgas- och bulleremissioner, vägslitage, tidsfördröjning för bilister samt trafiksäkerheten har beräknats.

En mycket stor andel av godstransporterna på väg utförs med fordon som överskrider EU-normen. Att krympa fordonsstorleken skulle leda till stora samhällsekonomiska förluster. Framför allt är det transportkostnaderna som ökar, men det skulle även uppkomma betydande kostnadsökningar inom områdena trafiksäkerhet, avgasemissioner och bulleremissioner.

I utredningen konstateras att det är svårt, åtminstone på kort sikt, att åstadkomma överflyttningar mellan väg och järnväg. Detta beror delvis på att järnvägens kapacitet är högt utnyttjad.

Nyckelord:
Tunga lastbilar, långa lastbilar, konkurrens, järnväg, samhällsekonomisk analys, lastbilsdimensioner, transportkostnad, bulleremissoner, avgasemissioner, SAMGODS, tidsfördröjning

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Foreword

In March 2007 the Government commissioned the Swedish National Road and Transport Research Institute (VTI) to study the effects of long trucks on the transport system. The assignment consists in reporting on the competition between road and rail transportation and the consequences of only permitting vehicle combinations with a weight of 40 tonnes and a length of 18.75 metres in Sweden. The consequences for transport costs, wear, emissions, road safety and congestion are to be analysed and an economic assessment is to be made.

The assignment was carried out over the period from April 2007 to 1 December 2007. The initial work relating to *competition between road and rail transportation* was presented in a sub-report on 15 June 2007.[1]

The project manager has been Inge Vierth who, together with Håkan Berell and John McDaniel, has been responsible for overall analysis and for the analyses of changed transport patterns. Experts at VTI have made contributions on the individual effects: wear effects have been considered by Mattias Haraldsson, emissions by Ulf Hammarström and Mohammad-Reza Yahya, road safety by Gunnar Lindberg, congestion by Arne Carlsson and noise by Mikael Ögren. Urban Björketun has assisted with programming.

Robert Williams has translated the report into English on behalf of the Ministry of Enterprise, Energy and Communications.

Linköping in January 2008

Gunnar Lindberg

Research Director, Transport Economics

[1] VTI, Långa lastbilars effekter på transportsystemet, Sub-report 15.06.2007

Cover: Stina Andersson och Moa Hermelin, Vägverket and VTI/Hejdlösa bilder

Quality review

Review seminar was carried out on 13 November 2007 where Henrik Swahn, HS AB, reviewed and commented on the report. Inge Vierth has made alterations to the final manuscript of the report 28 November 2007. The research director of the project manager Gunnar Lindberg examined and approved the report for publication on 1 December 2007.

Kvalitetsgranskning

Granskningsseminarium genomfört den 13 november 2007 där Henrik Swahn, HS AB, var lektör. Inge Vierth har genomfört justeringar av slutligt rapportmanus den 28 november 2007. Projektledarens närmaste chef Gunnar Lindberg har därefter granskat och godkänt publikationen för publicering den 1 december 2007.

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The effects of long and heavy trucks on the transport system. Report on a government assignment

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Summary

Truck transportation with vehicles up to 25.25 meters in length and with a maximum gross vehicle weight of 60 tonnes is permitted in Sweden and Finland. The standard in the rest of the EU is 18.75 metres and 40 tonnes.

The Government has commissioned the Swedish National Road and Transport Research Institute (VTI) to investigate what effects long trucks have for the transport system in Sweden. We have interpreted the assignment as meaning that the effects of heavy trucks are also to be described. The assignment includes analysing the competition between road and rail transportation and making an economic assessment of present-day vehicle regulation in Sweden. The study is largely based on an examination of official statistics. The national goods transport model SAMGODS has been used to simulate how the choice of mode of transport and the transport costs of business are affected by a change in the length and weight of trucks. The change in exhaust emissions has been calculated using the European mathematical model ARTEMIS and noise effects using the European HARMONOISE model. Time delays and road-safety effects have been calculated using methods developed at VTI. Effects relating to road wear are based on a thesis recently presented at VTI.

A large proportion of freight transportation in Sweden takes place by vehicles that exceed the EU standard. Statistics show that 64 per cent of the tonnage (in tonnes) and 74 per cent of freight tonne-kilometres by road are accounted for by vehicles that weigh more than 40 tonnes and/or have seven or more axles. The measure of seven axles is used in the absence of information on the length of trucks.

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 and the number of trucks to increase 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 cost of transportation by truck is estimated to increase by 24 per cent.

Scenarios

Various scenarios for 2005 have been defined to obtain a picture of how the increased costs affect freight vehicle-kilometres on the roads and how freight vehicle-kilometres are shared between road and rail.

- 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 of transport is not possible. The trucks are up to 18.75 metres in length and are allowed to weigh up to 40 tonnes.
- In Scenario C transfer between road, rail and sea is permitted. The trucks are up to 18.75 metres in length and are allowed to weigh up to 40 tonnes.
- In Scenario D freight volumes in 2005 were shared out in an infrastructure in which capacity for freight trains has been strengthened. The trucks are up to 25.25 metres in length and are allowed to weigh 60 tonnes. This is a "supporting scenario" which has been stimulated in order to separate the effects of the two changes that take place simultaneously in Scenario C.

Everything else is assumed to be equal. We have assumed that no changes take place in the locations of activities and that employment in the labour market is not affected. Furthermore we have not studied how the total volume of freight transported alters with changed transportation prices.

The capacity situation for freight transportation by rail today is difficult. It is not easy to find new freight train paths to and from Stockholm, Göteborg and Malmö. The situation at the large shunting yard in Hallsberg is also problematic. This means that a change in trucks, in the short term, can be expected to produce a result that is quite close to Scenario B.

Scenario B

Freight vehicle-kilometres for heavy truck traffic 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.

The total cost of transportation to business is estimated to increase by around SEK 7.5 billion per year (all benefits and costs expressed in 2001 prices). The change in transport cost is found to be by far the dominant negative 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 SEK 491 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 to a combined annual value of SEK 583 million. Carbon dioxide accounts for 62 per cent, equivalent to around 240 000 tonnes.

Noise emissions are estimated to increase to an extent equivalent in value to SEK 690 million annually.

More trucks on the roads are estimated to mean time losses for motorists equivalent in value to SEK 50 million annually.

The only anticipated improvement is a reduction in road wear and an increase in government tax revenue. However, this 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 is SEK 8.9 billion per year.

The competition between road and rail

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.

A review of time series for road and rail transportation in the last 30 years, both at aggregate level and at 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. This is interpreted as meaning that there is a great difference between road and rail transportation from the point of view of transport buyers.

The possibility of rail operators raising their prices if road transportation becomes more expensive is another factor that should be taken into account.

Scenario C

Significant transfer to rail is anticipated in Scenario C. Despite this, freight vehicle-kilometres by road are estimated to increase by 14 per cent, with the result that transport costs for business are estimated to increase by around SEK 3.1 billion annually.

The cost of road traffic accidents is also estimated to increase in this case, as well as the cost of noise nuisance and delays to motorists.

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 just under three per cent of heavy goods vehicle emissions and is estimated at SEK 159 million per year.

Conclusion

A change in rules in favour of shorter and lighter trucks in Sweden would result in an economic loss which would be principally borne by trade and industry.

The investments in load-bearing capacity which the Swedish Road Administration began in 1988 in order to adapt the standard of roads to the demands of heavy vehicles are expected to cost a total of SEK 46 billion (at 2001 prices). This economic cost is recouped after just over five years in Scenario B and after just under twelve years in Scenario C.

Långa och tunga lastbilars effekter på transportsystemet. Redovisning av regeringsuppdrag

av Inge Vierth, Håkan Berell, John McDaniel, Mattias Haraldsson, Ulf Hammarström, Mohammad-Reza Yahya, Gunnar Lindberg, Arne Carlsson, Mikael Ögren och Urban Björketun
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Sammanfattning

Inom Sverige och Finland tillåts lastbilstransporter med fordon som är upp till 25,25 meter långa och som har en totalvikt på max 60 ton. Inom övriga EU är normen 18,75 meter och 40 ton.

Regeringen har givit VTI (Statens väg- och transportforskningsinstitut) i uppdrag att utreda vilka effekter de långa lastbilarna har för transportsystemet i Sverige. Vi har tolkat in att även effekterna av tunga lastbilar skall beskrivas. I uppdraget ingår att analysera konkurrensytan mellan väg- och järnvägstransporterna och att göra en samhällsekonomisk bedömning av nuvarande fordonsreglering i Sverige.

Utredningen bygger till stor del på en genomgång av den officiella statistiken. Den nationella godstransportmodellen SAMGODS har använts för att simulera hur valet av transportmedel och näringslivets transportkostnader påverkas vid förändring av lastbilarnas längd- och viktdimensioner. Förändringen av avgasemissioner har beräknats med hjälp av den europeiska beräkningsmodellen ARTEMIS och bullereffekter med den europeiska modellen HARMONOISE. Tidsfördröjningar och trafiksäkerhetseffekter har beräknats med hjälp av metoder utvecklade inom VTI. Effekterna för vägslitaget bygger på en nyligen framlagd avhandling vid VTI.

En stor andel av godstransporterna i Sverige utförs med fordon som överskrider EU-normen. Statistiken visar att 64 procent av tonnaget (ton) och 74 procent av transportarbetet (tonkilometer) sker med fordon som väger mer än 40 ton och/eller har sju axlar eller fler. Måttet sju axlar eller fler används i avsaknad av information om lastbilarnas längd.

Förutsatt att samma godsmängd skall transporteras medför kortare och lättare lastbilar att transportkostnaden per fordon minskar men att antalet fordon som behövs ökar. Kostnaden per lastbil beräknas minska med 5 till 12 procent inom de olika varugrupperna och antalet lastbilar öka med 35–50 procent. I genomsnitt antas det krävas 1,37 lastbilar med maximal EU-storlek för att ersätta en lastbil med maximal svensk storlek. Kostnaden för lastbilstransporter beräknas öka med 24 procent.

Scenarier

För att få en bild av hur de ökade kostnaderna påverkar trafikarbetet på väg och hur transportarbetet fördelar sig mellan väg och järnväg har olika scenarier för år 2005 definierats.

- Scenario A är referensscenario, lastbilarna är upp till 25,25 meter och får väga max 60 ton.

- I scenario B antas att överflyttning till andra transportslag inte är möjligt. Lastbilarna är upp till 18,75 meter och får väga max 40 ton.
- I scenario C tillåts överflyttning mellan väg, järnväg och sjöfart. Lastbilarna är upp till 18,75 meter långa och får väga max 40 ton.
- I scenario D fördelades 2005 års godsvolymer på en infrastruktur där kapaciteten för godståg har förstärkts. Lastbilarna är upp till 25,25 meter och får väga 60 ton. Detta är ett ”stödscenario” som simulerats för att det skall vara möjligt att separera effekterna av de två förändringar som sker simultant i scenario C.

Allt annat antas vara lika. Vi har antagit att det inte sker någon förändring av verksamheters lokaliseringar och att sysselsättningen på arbetsmarknaden inte påverkas och vi har inte studerat hur den totala transporterade godsvolymen förändras vid förändrade transportpriser.

Idag är kapacitetssituationen för godstransporter på järnväg besvärlig. Det är svårt att finna nya godståglägen till/från Stockholm, Göteborg och Malmö. Även situationen vid den stora rangerbangården i Hallsberg är problematisk. Detta gör att en förändring av lastbilarna, på kort sikt, kan förväntas ge ett utfall som ligger rätt nära scenario B.

Scenario B

För den tunga lastbilstrafiken som helhet (lastbilar med totalvikten 3,5–60 ton) beräknas trafikarbetet (fordonskilometer) öka med 24 procent när svenska fordon ersätts med EU-fordon.

Den totala transportkostnaden för näringslivet beräknas öka med ca 7,5 miljarder kronor per år (alla nyttor och kostnader uttrycks i prisnivå 2001). Transportkostnadsförändringen visar sig vara den helt dominerande negativa effekten av förändrade fordonsnormer. Av de övriga effekterna går de flesta i samma riktning.

Med fler lastbilar på vägarna beräknas kostnaden för trafikolyckor öka med 491 miljoner kronor per år. Ingenting i den studerade olycksstatistiken tyder på att kortare och lättare fordon skulle ge färre eller mindre allvarliga olyckor.

Dieselförbrukningen beräknas öka med drygt 6 procent, vilket leder till ökade utsläpp av avgasemissioner till ett sammanlagt värde av 583 miljoner kronor per år. Koldioxiden står för 62 procent motsvarande ca 240 000 ton.

Bulleremissionerna beräknas öka motsvarande ett värde av 690 miljoner kronor per år.

Fler lastbilar på vägarna beräknas medföra tidsförluster för bilisterna motsvarande ett värde på 50 miljoner kronor per år.

Den enda förbättring som beräknas uppkomma är att vägslitaget minskar och att statens skatteintäkter ökar. En förutsättning är dock att godset fördelas på fler axlar än dagens EU-fordon.

Den totala samhällsekonomiska kostnaden för att införa kortare och lättare fordon uppgår till 8,9 miljarder kronor per år.

Konkurrensytan mellan väg och järnväg

Det negativa utfallet av förändrade lastbilsnormer kan lindras ifall det är möjligt och företagsekonomiskt rimligt att flytta över delar av godsvolymerna till järnväg. En större överflyttning till järnväg kräver dock såväl ökad spårkapacitet som en förbättring av erbjuden servicenivå och tillförlitlighet.

En genomgång av tidsserier för väg- och järnvägstransporter de senaste 30 åren, både på aggregerad nivå och varugruppsnivå, visar att det är svårt att se tecken på att väg och järnväg tar volymer av varandra – även vid de perioder där vi vet att stora kostnadspåverkande förändringar ägt rum.

En tydlig observation är att det för de flesta varugrupperna finns ett transportslag som är kraftigt dominerande. Detta tolkas som att det från transportköparnas synvinkel är stor skillnad mellan väg- och järnvägstransporter.

Något som även bör beaktas är möjligheten att järnvägsoperatörerna höjer sina priser ifall lastbilstransporterna blir dyrare.

Scenario C

I scenario C räknas med en betydande överflyttning till järnväg. Trots detta beräknas trafikarbetet på väg öka med 14 procent, vilket gör att näringslivets transportkostnad beräknas öka med ca 3,1 miljarder kronor per år.

Kostnaden för trafikolyckor beräknas öka även i detta fall, liksom kostnaden för bullerstörningar och bilisternas tidsfördröjningar.

Avgasemissionerna beräknas dock minska jämfört med scenario A. Utsläppen av koldioxid beräknas minska med ca 106 000 ton per år, vilket är knappt 3 procent av den tunga lastbilstrafikens utsläpp och värderas till 159 miljoner kronor per år.

Slutsats

En regelförändring mot kortare och lättare lastbilar i Sverige skulle ge en samhällsekonomisk förlust som framför allt bärs av näringslivet.

De bärighetsinvesteringar som Vägverket påbörjade 1988 för att anpassa vägarnas standard till de krav som tunga fordon ställer förväntas i sin helhet kosta 46 miljarder (prisnivå 2001). Denna kostnad tjänas in av samhället efter drygt 5 år i scenario B och efter knappt 12 år i scenario C.

1 Introduction

1.1 Background

Sweden has a tradition of long and heavy trucks and vehicle combinations. In 1968 the Swedish Government established 24 metres as the maximum length for a vehicle combination. Previously there had not been any restrictions on length. A length of 25.25 metres has been permitted for modular vehicles since 1996. Maximum gross vehicle weight[2] (GVW) was successively increased from 37 tonnes (1968) to 51.4 tonnes (1974), 56 tonnes (1990) and 60 tonnes (1993).

Table 1.1 Maximum vehicle lengths and weights in Sweden and "rest of EU".

	Sweden		"Rest of EU"	
	Max. length	Max. GVW	Max. length	Max. GVW
1968	24 m	37 tonnes		
1974		51.4 tonnes		
1985			18 m	28 tonnes
1990		56 tonnes		
1993		60 tonnes		
1996	25.25 m		18.75 m	40 tonnes

On accession to the EU in 1995 it was decided that vehicles larger than the maximum length (18.75 metres) and maximum gross vehicle weight (40 tonnes) could continue to be used in Sweden.[3,4] Larger vehicles, with a maximum length of 25,25 metres and weight of 60 tonnes, are used in national traffic. At the same time it is made possible for hauliers from other countries to use modular systems. Using the modular system it is possible to create vehicles of 18.75 metres and 25.25 metres. Equivalent exemptions apply to Finland.

When EU Directive 96/53 was adopted it was feared that competition-distorting effects would arise if certain hauliers were to be able to use larger vehicles. A statement was therefore included in the minutes of the Council of Ministers meeting to the effect that all the member states at that time except Sweden and Finland undertake not "generally" within their territory to introduce or expand modular systems until the Commission has presented a report concerning the significance of the exemption, with an assessment of whether there would be justification for introducing the system in member states other than Sweden and Finland. The Commission has not presented any such report. The system has, however, spread in the form of experimental activity for instance in the Netherlands, Germany, Denmark and Norway. In some countries 44 tonne vehicles are authorised in general or in connection with multimodal transport.

[2] Gross vehicle weight is defined as the kerb weight of the vehicle and the maximum quantity of freight for which the vehicle is arranged.
[3] EU Directive 96/53 supersedes EU Directive 85/3.
[4] The maximum vehicle width is 2.55 metres (2.60 with refrigerated and freezer trailers) and the maximum height is 4.50 metres.

Some companies in Sweden have shown interest in even longer and heavier vehicles. A furniture company is currently conducting tests with vehicles 27 metres in length and the forestry industry is looking into the possibility of using vehicles with a gross vehicle weight of 80 tonnes.

Investments to increase load-bearing capacity in the road network

In Europe the European Community member states had differing load-bearing capacity standards until 1985, when harmonisation was introduced. At that time Sweden took an extensive load-bearing capacity initiative which meant, for instance, that bridges built before 1945 were replaced. The load-bearing capacity initiative was launched in 1988 and meant that maximum gross vehicle weight could be increased from 51.4 tonnes to 56 tonnes in 1990 and to 60 tonnes in 1993. The package of measures was largely funded by business through an increase in vehicle taxes. Load-bearing capacity initiatives have since been included in the National Road Administration's long-term investment plans, and up to 2007 these initiatives have cost around SEK 16 billion (at 2001 prices).[5] During 2007 the National Road Administration judged that load-bearing capacity investments would cost around SEK 30 billion at 2001 price levels (SEK 38 billion at 2007 price levels). The remaining investments relate not to expansion of all roads in Sweden but just to those roads deemed to be most important.

No targeted initiatives relating to load-bearing capacity were taken during the period up to 1988, and it has not therefore been possible to establish the level of expenditure on increased load-bearing capacity prior to 1988. There has been a general endeavour to allow as heavy vehicles as possible, and as ever greater proportions of the road network have coped with higher axle weights and tonnages, authorised vehicle weights have increased. Bridges have often been the governing factor, and when the bridges have been prepared for higher loading the whole road has ended up in a higher load-bearing capacity class, despite the roads sometimes not having been strengthened. This has resulted in higher maintenance costs.

In 2007, around 90 per cent of public roads and around 94 per cent of state-owned roads are open to 60 tonne vehicles.[6] Vehicles up to 25.25 metres in length are allowed on almost all public roads, with the exception of the central parts of some towns and cities.

Investments to increase load-bearing capacity in the rail network

Measures to increase load-bearing capacity were also taken in the railway infrastructure. An initiative was taken with *Stomnätsplan 1998–2007 (Main Line Plan 1998–2007)* Construction began around the year 2000 and is still in progress. In 2007 around 25 per cent of the rail network permits axle loads of 25 tonnes or more.

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[5] Other benefits and costs in this report are expressed in 2001 prices.

[6] Vägverket, Lundqvist, Anders, Background to and experiences from traffic with Swedish long road trains, Memo 12.01.2007.

1.2 Assignment

The Swedish Government has commissioned VTI to study the effects of long trucks on the transport system. We interpret this assignment as also covering the effects of heavy trucks. The assignment includes elucidating the competition between road and rail transportation and an assessment of current vehicle regulation from the point of view of the economy.[7]

1.3 Description of problem and methods

This report compares the situation in Sweden, where it is possible to use longer/heavier trucks than in the rest of the EU, with a hypothetical situation in which the regulations in the rest of the EU apply. The analysis is carried out in several stages.[8]

1.3.1 Identification of affected vehicles in Sweden

We indicate the proportion of the volume of freight in Sweden transported on vehicles larger than those permitted in the rest of the EU and the proportion of freight tonne-kilometres accounted for by the vehicles concerned. Trucks are divided into two groups with respect to size:

- vehicles and vehicle combinations that fulfil EU requirements for a maximum gross vehicle weight of 40 tonnes and a maximum length of 18.75 metres for a truck with trailer or a maximum length of 16.5 metres for a tractor with semitrailer.
- vehicles and vehicle combinations with a gross vehicle weight in excess of 40 tonnes, which are assumed to be more than 18.75 metres in length. Heavy freight is mostly transported in 24 metre long vehicles, as the unladen weight of these is two tonnes lower than that of 25.25 metre long vehicles.

1.3.2 Definition of type vehicle

In view of the dominance of vehicles in the highest gross vehicle weight class, a Swedish type vehicle is defined by a weight of 50–60 tonnes and a max. length of 25.25 metres.[9] For EU type vehicles it is assumed that the maximum gross vehicle weight class of 34–40 tonnes and a maximum length of 18.75 metres are used.

1.3.3 Calculation of cost increases for affected vehicles

On the assumption that the transported quantity of freight is constant, cost increases specific to commodity groups are calculated on the basis of the reduced load capacity for EU type vehicles compared with Swedish type vehicles. The calculation is done for

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[7] See Appendix 1: Government assignment to VTI to study the effects of long trucks on the transport system.
[8] Appendix 2 contains background material and tables used in the calculations.
[9] See Table 1 and Table 2 in Appendix 2.

twelve different groups of commodities.[10] The cost reduction per vehicle is calculated on the basis of a costing model. The need for further vehicles is calculated on the basis of the official truck statistics and our own assumptions. The increase in transport costs per tonne-kilometre is calculated.

1.3.4 Calculation of effects on freight-tonne kilometres and freight vehicle-kilometres

Effects on freight tonne- kilometres and freight vehicle-kilometres on road and rail are deduced on the basis of the SAMGODS model, statistics and knowledge of the preferences of transport buyers and transportation companies.

The impact of increases in transport costs for heavy truck traffic (per tonne-kilometre) on freight tonne-kilometres and freight tonne-kilometres on road and rail is calculated for the four different scenarios. The scenarios are hypothetical and do not take account of specific consignments, vehicle design and any conversion costs. Everything else is assumed to be equal, and this also applies to the price of rail transportation.

Scenarios

A. a reference scenario for 2005.

B. a scenario based on EU truck standards and no transfer to rail. This scenario is assumed to provide a reasonable assessment of the effects in the short term.

Large parts of the rail network today are so congested that it is difficult to find space for new trains. Operators say that it is not now possible to obtain new train paths to either Göteborg or Stockholm at any time of the day or night and that the situation in Skåne is almost as difficult.

C. a scenario that combines the introduction of EU truck standards in Sweden with investments in rail capacity that makes a transfer of freight to the railways possible.

In Scenario C it is significant which investments are assumed to be made. An investment package is used here which was utilised when SIKA in 2005, in cooperation with the transport agencies, compiled a freight transport forecast for 2020.[11] The investments in passenger and freight traffic up to 2020 were assumed to total around SEK 60 billion (at 2001 prices). If the number of passenger trains is increased and/or they become faster and are given higher priority, the capacity available for freight trains is reduced despite an investment in the railways having been made. In work on the forecast, the National Rail Administration has made an assessment of how the new capacity will be distributed. The uncertainty mentioned here means that what is studied should be viewed as an example of effects that can arise if rail investments of around SEK 60 billion are made.[12]

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[10] See Table 3 in Appendix 2.

[11] SIKA rapport 2005:9, Prognoser för godstransporter 2020.

[12] The package of measures includes capacity investments in northern Sweden (new Kalix–Haparanda line and part of the Norrbotniabanan line: Skellefteå–Piteå), the Botniabanan line (Nyland–Umeå) and the Ådalsbanan line (Sundsvall–Långsele). Dual-track investments are made along the Godsstråket section through Bergslagen south of Hallsberg, on the Ostkustbanan line (Uppsala–Gävle), the Västkustbanan line (Göteborg–Lund line, including completion of the Hallandsås Tunnel) and on the Norway/Vänern line (north of Göteborg). Some four-track investments are made on the southern main line (near Malmö), as well as smaller capacity-raising measures in various parts of the country.

D. a supporting scenario in which a study is made of what effects would result from investments in rail capacity if the truck standards are unchanged. The aim is to be able to differentiate the effects of the two changes made in Scenario C.

In all the scenarios it is 2005 freight tonne-kilometres and freight vehicle-kilometres that are studied. No volume forecasts are used.

SAMGODS model

The effect of introducing EU vehicle standards in Sweden is simulated using the national SAMGODS model, which is designed to describe the interaction between the demand for and supply of freight transportation.[13] The model describes the supply of long-haul transport by road[14], rail and sea. Demand for freight transportation (in tonnes) is described for twelve groups of commodities and 462 regions in and outside Sweden. Domestic and international freight transportation and transportation in transit are presented. Transport within a municipality, trips of less than 25 km and transportation on trucks with maximum load of less than 3.5 tonnes are not included.

The choice of mode of transport and route by freight transportation customers in the model is made so that the *generalised transport costs* are minimised for the whole transport system, that is to say for all groups of commodities and modes of transport at the same time. Account is taken of various costs for the commodity groups, but not of consignment sizes.[15] The term generalised costs means the sum of *1) operational transport costs* and *2) freight time costs.*

The operational transport costs include en-route costs dependent on distance (stated in SEK per tonne-kilometre) and en-route costs dependent on time (stated in SEK per tonne-kilometre). In addition to these there are costs that arise in the loading and unloading of the freight at the point of departure and destination, any reloading costs at multimodal transport terminals and ports and costs in shunting yards. It is assumed that full competition prevails and that the operators' operational transport costs are equivalent to the transportation buyers’ prices.

Transfers at truck terminals and collections along the route are not included for road transport. All truck transport is assumed to go direct from sender to recipient, multimodal transport terminal or port.[16] With regard to rail transport, account has been taken of the capacity stated by the National Rail Administration for around 200 sections of track in 2001 and 2020. The National Rail Administration bases itself on the principle of priority being given to passenger traffic. Transportation times (and therefore generalised costs) are assumed to increase with increased utilisation of capacity. Multimodal transport terminal capacity is assumed to be adequate.

Freight time costs are freight-related quality costs and the term is intended to express the assessment by transport customers of such measures as affect the time taken for

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[13] SAMPLAN rapport 2001:1. The Swedish Model System for Goods Transport – SAMGODS. A brief introductory overview.

[14] The state-owned main road network in Sweden and motorways outside Sweden are described, as well as connections to senders and recipients of freight.

[15] The SAMGODS model is undergoing development. Consignment sizes, consolidation of consignments and utilisation of economies of scale in various parts of the transport system are modelled in the new model system. See SAMPLAN report 2004:1 The Swedish national freight model. A critical review and an outline of the way ahead.

[16] The new SAMGODS model takes account of various types of direct and indirect road transportation.

transportation. The applied values specific to commodity groups are based on what is known as the capital value method and, to simplify, express the cost of the tying-up of capital in the freight during transportation.[17] No account is taken of the time of day when transportation takes place.

The commodity group-specific operating costs and time values for freight time recommended by the *Working Group for Cost-Benefit Analyses (ASEK)* are used.[18] For transportation by truck and trailer with Swedish type vehicles we base ourselves on average operating costs of SEK 0.14/tonne-kilometre and SEK 11/tonne-hour and freight time costs of around SEK 2/tonne-hour.[19]

We base ourselves on the version of the SAMGODS model that was used in preparing the national freight transport forecast for 2020.[20] Volumes in 2005 are projected on the basis of demand for the baseline year of 2005.[21] Unlike the model version used in the forecast, trucks are divided into the categories of EU type vehicles with a maximum of 40 tonnes and Swedish type vehicles with a gross vehicle weight of 40-60 tonnes.

National statistics

The SAMGODS model is a simplified representation of the reality used to test the outcome in a constructed hypothetical situation. The simulation is therefore supplemented by reasoning based on the official statistics for the last 30 years and the knowledge we have of the competition between road and rail. An attempt is made to describe how weight and length provisions for road transportation have affected competition.

Cost-benefit analysis

The economic effects of changes in vehicle dimensions in Sweden are analysed on the basis of the calculations of freight vehicle-kilometres made using the SAMGODS model. It is analysed how transport costs, wear, road safety, delays for other traffic, exhaust emissions, noise emissions and tax payments change in Scenario B and Scenario C in comparison with the reference Scenario A.

Calculation methods, input data and sensitivity analyses are presented in separate subsections. The benefits and costs to society are calculated using data from the National Road Administration and the economic calculation values recommended by the *ASEK Group.* All benefits and costs are expressed in 2001 prices unless otherwise stated. In valuing noise and all exhaust emissions except for carbon dioxide account is taken of the built environment, i.e. how many people are affected. A distinction is made

[17] SIKA rapport 2002:9. Tid och kvalitet i godstrafik, Delrapport ASEK.
[18] SIKA PM 2005:16, Kalkylvärden och kalkylmetoder (Arbetsgruppen för samhällsekonomiska kalkyler ASEK). En sammanfattning av Verksgruppens rekommendationer 2005. (The calculation values are given at 2001 prices.)
[19] For a specification of the operating costs for twelve commodity groups see Table 4 in Appendix 2.
[20] SIKA reprt 2005:9, Prognoser för godstransporter 2020.
[21] The number of freight vehicle-kilometres with heavy trucks estimated in the model (including foreign-registered trucks but excluding transport within a municipality and trips of less than 25 km) totals 2.858 billion in 2005. This volume is adjusted upwards to the level shown by the statistics on distance travelled (4.230 bn vehicle-kilometres). The adjustment factor is far lower for vehicles over 40 tonnes that are analysed in the study (1.165) than for trucks with a weight of up of 40 tonnes (2.737).

between rural and urban areas. Around 15 per cent of heavy truck traffic and around nine per cent of freight traffic by rail are estimated to pass through urban areas.[22]

International transportation

Equivalent effects of replacing EU vehicles with larger Swedish vehicles for international transportation are briefly discussed.

Conclusions

Conclusions are presented in Chapter 6.

[22] According to Statistics Sweden all collections of buildings with at least 200 inhabitants are counted as urban areas, provided the distance between the buildings does not exceed 200 metres. See Table 5 in Appendix 2.

2 Transport costs for trucks

2.1 Affected vehicles in Sweden

Most of the volume of freight transported by road of around 400 million tonnes is carried on vehicles larger than EU vehicles. The proportion for Swedish-registered trucks is 71 per cent on the basis of gross vehicle weight and 61 per cent on the basis of actual weight, i.e. the vehicle's kerb weight plus the volume of freight actually transported. The share is 64 per cent if all vehicles with seven or more axles are considered, regardless of weight. The difference between the last two columns is explained by more high-volume freight being included. The fact that the larger vehicles account for an even greater proportion measured in terms of tonne-kilometres (than in tonnes) is explained by high load factors and long transportation distances for these vehicles.

Table 2.1 Proportion of transported quantity of freight (tonnes) and freight tonne-kilometres and of vehicles that are larger than EU vehicles.

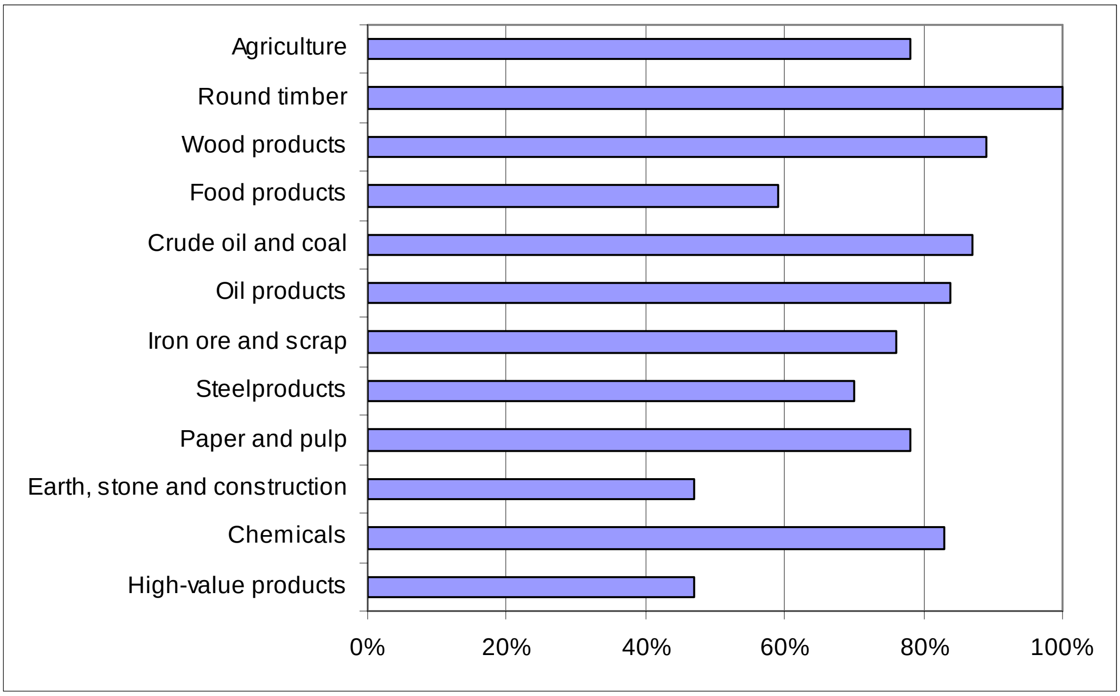
	Proportion of tonnes and tonne-km with vehicles of more than 40 tonnes gross vehicle weight[23]	Proportion of tonnes and tonne-km with vehicles of more than 40 tonnes actual weight[24]	Proportion of tonnes and tonne-km with vehicles of more than 40 tonnes and 7 or more axles
Tonnes	71 %	61 %	64 %
Tonne-km	89 %	71 %	74 %

Source: SIKA, *Inrikes och utrikes trafik med svenska lastbilar 2001*[25].

We describe the weight and number of axles of trucks by using the information from the distance-driven database (broken down by gross vehicle weight class) and truck statistics (broken down by gross vehicle class and number of axles).[26] This information is used to calculate the external effects of traffic in the form of noise and road safety. Actual weight is used in calculating wear costs. The statistics do not contain information on the length of trucks, which is to some extent relevant to calculation of the effect of vehicle dimensions on time delay and road safety.

All timber transportation takes place on vehicles with a weight of more than 40 tonnes and seven axles, while the proportion is less than 50 per cent for the commodity groups of high-value products and earth, stone and construction. High-value products include transportation equipment, machines, metal products, glass products, textiles etc.

[23] Gross vehicle weight is defined as the kerb weight of the vehicle and the maximum volume of freight for which the vehicle is arranged.
[24] Actual weight is defined as the vehicle's kerb weight plus the volume of freight actually transported.
[25] We do not have access to data from later years. We assume that the pattern is stable over time.
[26] See Table 1 and Table 2 in Appendix 2.



Source: SIKA, *Inrikes och utrikes trafik med svenska lastbilar 2001.*

Figure 2.1 Proportion of tonnes transported by truck which are transported by vehicles larger than EU vehicles per commodity group.

The proportion of freight vehicle kilometres with vehicles larger than the EU standard varies from region to region in Sweden. It is highest, at around 80 per cent, in Upper Northern Sweden, Central Northern Sweden and Småland (including Öland and Gotland). The high proportion in these areas is explained by the significance of the forestry industry. In Småland the storm known as *Gudrun* led to exceptional forestry transportation in 2005. The lowest proportions are in the most densely populated areas of Stockholm (44 per cent), Southern Sweden and Western Sweden (both 54 per cent).[27]

2.2 Transport costs per vehicle

The "types of transportation" used in the SÅKALK calculation model[28] of the Swedish Association of Road Haulage Companies are linked to the various commodity groups as shown in the following table. The SÅKALK cost estimate for each type of transport can consequently be used to estimate the cost per commodity group.

[27] See Table 6 in Appendix 2.
[28] Transport costs per vehicle were calculated by Lars Aspholmer Programmering AB.

Table 2.2 Assumed types of transport per commodity group.

Commodity group	Type of transport	Commodity group	Type of transport
Agricultural products	Part load	Iron ore and scrap	Part load
Round timber	Forestry product	Steel roducts	Part load
Wood products	Part load	Paper and pulp	Part load
Food products	Long-haul distribution	Earth, stone, construction	Construction transport
Crude oil and coal	Tanker and bulk transport	Chemicals	Tanker and bulk transport
Oil products	Tanker and bulk transport	High-value products	Long-haul distribution

Transport costs per 10 vehicle-kilometres are between SEK 130 for part loads and SEK 195 (at 2007 prices) for construction transport. The costs are dominated by personnel costs, comprising pay, benefits and employer's contributions. Fuels are the second-largest cost component for most types of vehicle. Fuel consumption is affected by the gross vehicle weight and how the vehicle is used. Transportation with a small number of stops and on good roads results in more even speed and lower fuel consumption than construction vehicles travelling on poor roads and making many stops, for example. The other vehicle costs (repairs, interest, depreciation, insurance etc.) vary from one vehicle type to another and account for 30 to 40 per cent of total costs.

The use profile differs with respect to annual hours of operation (2 400 hours to 4 000 hours) and annual distance driven (70 000 km to 180 000 km). In addition, the relationship between distance driven and time affects the proportions of costs for various types of vehicle. Construction vehicles travel 200 km in a working day of eight hours, for example, while most other types of vehicle travel twice that distance in the same time. The time factor contains not just travel time but also loading and unloading time.

Table 2.3 Use profiles.

	Part load	Forest raw material	Long-haul distribution	Tanker and bulk transport	Construction transport
Distance travelled relative to working time (km/h)	51.1 km/h	45.6 km/h	44.6 km/h	33.3 km/h	30.0 km/h
Distance km/year	138 000	180 000	180 000	120 000	70 560
Hours/year	2 700	3 950	4 032	3 600	2 352

We base our calculation of the notional costs for EU type vehicles on the same payroll costs as for Swedish type vehicles. The combined costs for the smaller EU vehicles are, however, lower due to lower fuel costs (nine to nearly 20 per cent) and vehicle costs (six to over 20 per cent).

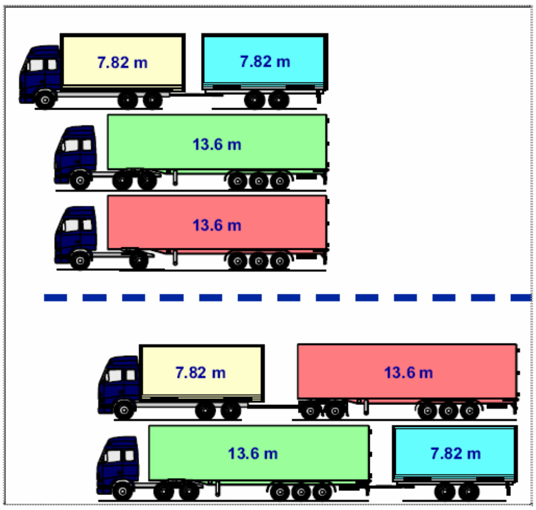
The table below shows the combined costs per 10 kilometres and the breakdown between personnel costs, fuel costs and other vehicle costs. The decrease in cost per vehicle is estimated to be five per cent for construction traffic, six per cent for tanker and bulk transport, ten per cent for part loads and twelve per cent for forest raw material and long-haul distribution.

Table 2.4 Costs for Swedish and EU vehicles.

	Part load	Forest raw material	Long-haul distribution	Tanker and bulk	Construction
Cost per 10 vehicle km for Swedish vehicles	SEK 130	SEK 149	SEK 144	SEK 178	SEK 195
Proportion of personnel costs	36%	33%	44%	42%	38%
Proportion of fuel costs	30%	30%	26%	22%	22%
Proportion of other vehicle costs	35%	37%	30%	37%	40%
Cost per 10 vehicle km for EU vehicles (compared with Swedish vehicles)	SEK 117 (-10%)	SEK 131 (-12%)	SEK 127 (-12%)	SEK 167 (-6%)	SEK 186 (-5%)
Proportion of personnel costs	42 %	37%	50%	45%	40%
Proportion of fuel costs	26 %	31%	24%	21%	20%
Proportion of other vehicle costs	31 %	32%	26 %	34%	40%

2.2.1 Need for more vehicles

More EU type vehicles are required in order to transport the same volume of freight as are carried by larger Swedish type vehicles. The figure below illustrates the fact that a Swedish 25.25 metre vehicle is usually made up of a truck with a 7.82 metre long swap body and dolly with a 13.6 metre long semitrailer. The vehicle is composed of the load carriers, known as modules, which are used in most other EU member states. Two Swedish modular vehicles can then be reconnected to three shorter vehicle combinations, consisting of a 7.82 m truck with a 7.82 metre long articulated trailer and two tractors each with a semitrailer of 13.6 metres.



Source: Volvo Trucks.

Figure 2.2 Modular system with 7.82 m and 13.6 m load carriers where three short EU vehicles are re-connected to two longer Swedish vehicles.

Our calculations are based on the assumptions for the twelve commodity groups presented in Figure 2.1. The truck statistics describe how much freight is loaded in terms of weight. As volume is often the limiting factor for a large proportion of truck transport, it is not possible to calculate using the statistics how many more trucks are required if dimensions become smaller. A three-step approach is applied to solve this problem.

1. We assume that Swedish type vehicles have a maximum load weight of 40 tonnes and a maximum load volume of 135 m^3, while EU vehicles are assumed to have a maximum load weight of 24 tonnes and a maximum load volume of 90 m^3.

Table 2.5 Differences in capacity between largest Swedish vehicles and largest EU vehicles.

	Swedish vehicles	EU vehicles	Difference
Max. length	25.25 m	18.75 m	6.5 m
Max. GVW	60 tonnes	40 tonnes	20 tonnes
Max. load	36–42 tonnes	22–26 tonnes	14–6 tonnes
Max. volume	130–140 m^3	85–96 m^3	45–44 m^3
EURO pallets	51-54	33-36	16-20

2. We calculate how many more vehicles are required with maximum vehicle utilisation. When a truck is fully laden it is either weight or volume that is the limiting factor. With maximum utilisation of weight, 67 per cent more trucks are required when the vehicle dimension decreases [(40–24 tonnes)/24 tonnes = 0.67]. With maximum utilisation of volume, 50 per cent more trucks are required when the vehicle dimension decreases [(135–90 tonnes m^3)/90 m^3 = 0.5]. In the case of commodity groups for which weight and volume cargo are common, an average of 58.5% is used [(0.67 + 0.50)/2 = 0.585]. Broad assumptions have been made for the aggregated groups.
3. The degree of "capacity utilisation" is assumed. It is not always possible to completely fill trucks. It is therefore necessary to ensure that the degree of load capacity utilisation in some cases is higher for the smaller trucks than for those that permit 60 tonnes/25.25 metres. Unfortunately the statistics do not provide much support at this stage. It is assumed here that capacity utilisation is 100 per cent for EU type vehicles and that it varies between 85 and 90 per cent for vehicles with maximum Swedish dimensions. The table below shows in the last column how many vehicles are assumed to be required per commodity group.

Table 2.6 Calculation of need for further vehicles per commodity group.

Commodity group	Need for vehicles with full capacity utilisation "Weight cargo"	"Volume cargo"	"Mixture"	Adjustment factor	Need for more vehicles
Agriculture			59 %	0.85	35 %
Round timber	67 %			0.90	50 %
Wood products			59 %	0.85	35 %
Food products			59 %	0.85	35 %
Crude oil and coal	67 %			0.85	42 %
Oil products	67 %			0.85	42 %
Iron ore and scrap			59 %	0.85	35 %
Steel products			59 %	0.85	35 %
Paper and pulp			59 %	0.85	35 %
Earth, stone, construction	67 %			0.85	42 %
Chemicals			59 %	0.85	35 %
High-value products		50 %		0.90	35 %
Average					37 %

With our assumptions for the various commodity groups between 35 and 50 per cent more vehicles are required. The weighted average with the transported quantity of freight is 37 per cent.

2.2.2 Changed transport costs

The average transport cost increases are estimated at 24 per cent. Both the distance-dependent en-route costs and the time-dependent en-route costs are affected.[29]

If we base ourselves on the extreme case that 50 per cent more trucks are required in all the commodity groups, the costs per tonne-kilometre would increase by 35 per cent. If we assume 33 per cent more trucks, a cost increase of around 20 per cent is estimated.

The increase in cost per tonne-kilometre is estimated to be smallest for the commodity groups *High-value products* (19 per cent) and greatest for transportation of heavy cargo such as *Earth, stone and construction* (35 per cent), *Oil products, Crude oil and coal* (33 per cent) and *Round timber* (32 per cent).

[29] See Table 7 in Appendix 2.

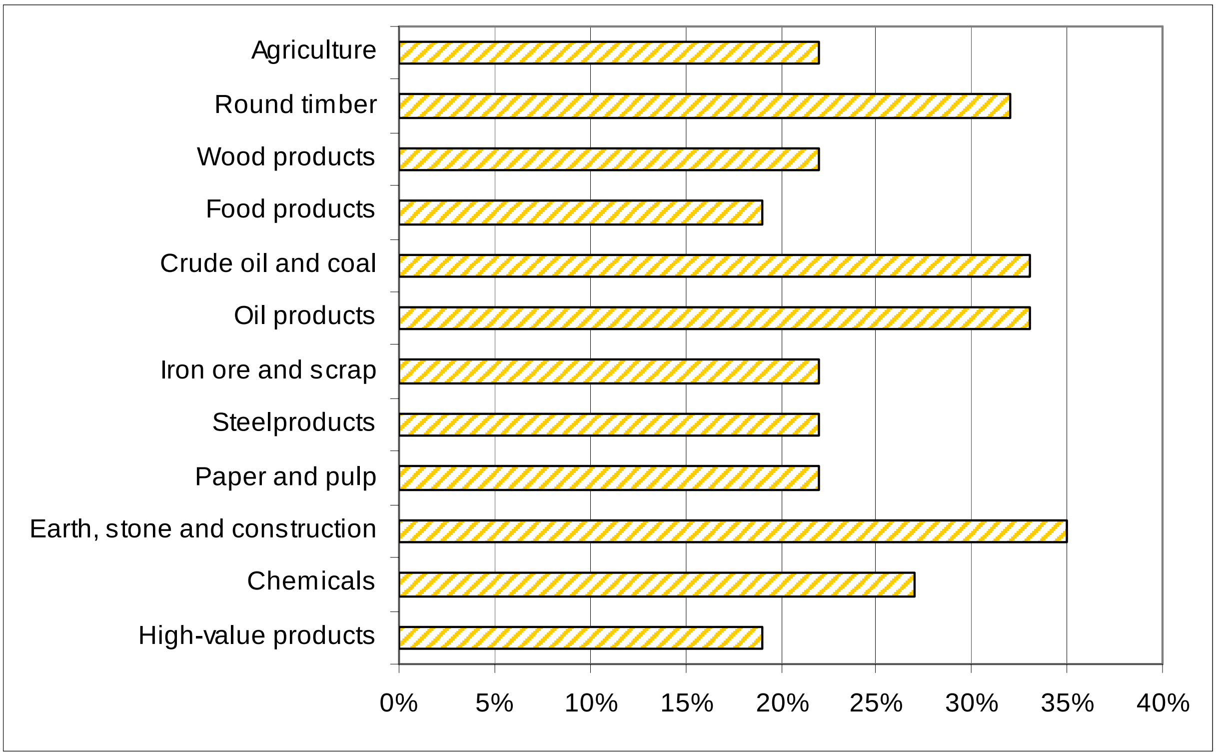


Figure 2.3 Estimated increase in cost to transport same quantity of freight, per commodity group.

3 Effects on tonne-kilometres and vehicle-kilometres on road and rail

The aim in this chapter is to show how changes in costs for heavy truck traffic affect freight vehicle-kilometres and freight tonne-kilometres and how freight vehicle-kilometres and freight tonne-kilometres are shared between road and rail. Figures are also broken down into different road types and urban and rural areas. The SAMGODS model, which stimulates the way in which the share of modes of transport is affected by changes in road transport costs, is used for this purpose. The model analysis is supplemented by a description of the competition between road and rail overall and for different commodity groups on the basis of national statistics.

3.1 Simulation using the SAMGODS model

The effect of transport costs by road increasing in accordance with what is indicated in Figure 2.3 is simulated using the SAMGODS model. The effects on the transport system are studied on the assumption that the quantity of freight transported is unchanged. The reactions and results assumed in the model should be interpreted with caution. The results should be seen as a broad indication of orders of magnitude rather than as an exact quantification of the effects.

In Scenario B (with EU standards for trucks and the assumption that no transfer takes place to rail) it is estimated that total freight vehicle-kilometres by truck increase by around 24 per cent despite freight tonne-kilometres being unchanged. In Scenario C, in which the EU standards for trucks are combined with investments in rail capacity and transfer to rail is permitted, a 14 per cent increase in freight vehicle-kilometres on the roads is estimated.

Two changes take place in Scenario C. Firstly truck transport becomes more expensive, and secondly rail capacity is strengthened. A supporting scenario D in which the truck cost is kept constant has been stimulated to differentiate these effects. It is found that the growth in rail (measured in tonne-kilometres) is explained in roughly equal parts by railway investments and the increase in cost for truck traffic.

The expanded rail capacity results in an increase in freight tonne-kilometres by rail of around 11 per cent (2.4 billion tonne-kilometres) and means that freight tonne-kilometres by road decrease by around two per cent (around 1 billion tonne-kilometres). The growth in the railways due to the investments estimated to take place largely at the expense of sea transport.

Table 3.1 Estimated freight tonne-kilometres (tonne-km) and freight vehicle-kilometres (vkm) on road and rail in reference alternative A and change in Scenario B, C and D.

	Road		Rail	
Scenario A. Reference alternative 2005	47.5 billion tonne-km	4.2 billion vkm	21.9 billion tonne-km	36.7 million train km
Scenario B. EU standards for trucks, no transfer to rail	constant	24%	constant	constant
Scenario C. EU standards for trucks, investments in rail capacity, transfer possible	-12%	14%	25%	30%
Scenario D. Swedish standards for trucks, investments in rail capacity, transfer possible	-2%	-1%	11%	13%

In a sensitivity analysis with a 35 per cent cost increase instead of a 24 per cent increase, freight vehicle-kilometres by road are estimated to increase by 35 per cent in Scenario B and 18 per cent in Scenario C. Elasticity in both cases is around 0.6.

3.2 Competition between road and rail in the last 30 years

The result of a model-based approach was presented in the previous section. The strength of the model is in comparisons of transport cost and time taken. The comparative advantages and drawbacks of the different modes of transport for different commodity groups and transport distances are described via the implemented cost functions. It is noted, for example, that the relative competitiveness of rail increases with increasing transportation distance. In addition, the model contains a description of access to infrastructure and its quality (for example maximum permitted speed on different road or track sections).

The model does not, however, consider factors such as reliability, flexibility and level of service. On the basis that reliability etc. are greater for road transportation than rail, this means that the SAMGODS model may exaggerate the potential for transfer between modes of transport in Scenario C. The model does not take account of long-term contracts, the investment needs of companies etc., but assumes that transportation is transferred directly between the modes of transport.

It is additionally assumed in the model that full competition exists, that is to say that the operators' costs are equivalent to the transportation buyers' prices. If this is not the case, the operators may, depending on the competitive situation, charge higher prices. For analytical reasons we assume that only road transport costs change and that everything else is kept equal. In reality, however, other factors change, such as rail transportation prices or transport policy instruments.

To elucidate the significance of the assumptions in the model, we study what choices the market players have made over the last 30 years and attempt, on the basis of this, to draw conclusions on how large the competition between road and rail actually is.

3.2.1 The market's choice – aggregated level

It is shown below how freight tonne-kilometres by road and rail in Sweden have developed since 1967.[30] Real gross domestic product (GDP) is presented an indicator of the state of the economy. It should be remembered that the analyses with the SAMGODS model above are based on a given quantity of freight which is to be transported, while the figure below shows the trend over the last three decades with increasing quantities of freight.

It can be seen in the figure that freight tonne-kilometres by road followed the rate of growth in the economy (GDP), while freight tonne-kilometres by rail did not change greatly. It should also be pointed out that only freight tonne-kilometres are shown. If measured in terms of value, the increase would be even greater for road transport.

After maximum truck weight increased from 37 to 51.4 tonnes in 1974, freight tonne-kilometres by rail decreased by nine per cent up to 1978. Over the same period freight tonne-kilometres by road increased by one per cent and GDP at fixed prices increased by four per cent.

The low increase in truck transportation makes it difficult to demonstrate that truck transportation increases at the expense of rail. Nor do the changes that took place in 1990 and 1993 to 56 and 60 tonnes gross vehicle weight appear to lead to transfers between road and rail.

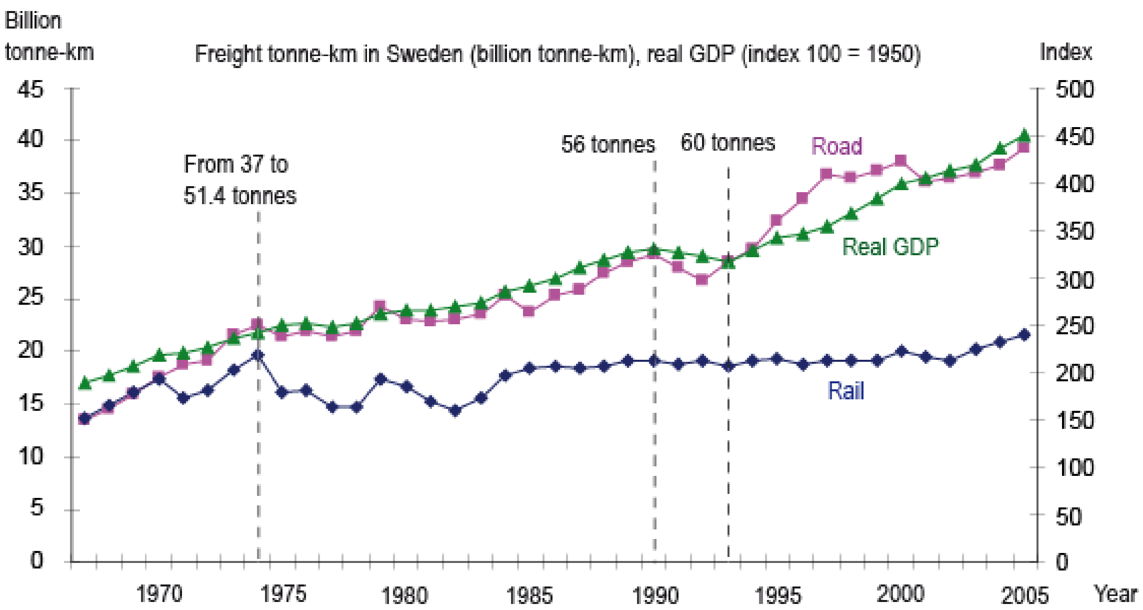


Figure 3.1 Freight tonne-kilometres in Sweden on road and rail (bn tonne-km) and GDP at fixed prices. Source: SIKA website, GDP from Statistics Sweden.

Improvements have also taken place in relation to rail. An initiative was launched in 2000 in which the axle load was successively raised from 22.5 tonnes and 25 tonnes on those parts of the rail network that are served by a large proportion of block trains. Upgrading is still under way, and as ever larger parts of the rail network become

[30] For a complete picture, including shipping, see our sub-report dated 15 June 2007.

available for 25 tonnes axle load more and more freight transportation will benefit from what is possible.

The market for freight transport by rail was deregulated in Sweden in 1996. Rationalisation has taken place, with freight train operators focusing on those areas where the railways have comparative advantages. Green Cargo reports that in 2004 it transported more freight than in 1989, despite the number of employees and the number of locomotives and wagons having declined by around 60 per cent over the same period.

It is unclear, however, to what extent deregulation, better utilisation of locomotives and wagons and better rail infrastructure explain the increase in the transport performance of the railways which can be seen to have started in 2003 and has continue to the present day. The upturn for the railways following the turn of the millennium has coincided with a strong economy and high international demand for example for metal and paper. The storm known as Gudrun also contributed to the upturn to some extent in 2005.

Rail transport is also increasing more rapidly than road transport in other countries. In Germany the market share of the railways in transport performance has increased for five consecutive years, from 15.7 per cent in 2001 to 17.1 per cent in 2006, which means an increase in freight tonne-kilometres by rail of 40 per cent over this period to 107 billion tonne-kilometres in 2006.[31] In the United Kingdom the market share of rail in freight tonne-kilometres has increased by 50 per cent since 1994, from eight per cent in 1994/1995 to twelve per cent in 2005/2006, representing an increase in freight tonne-kilometres of 70 per cent.[32]

3.2.2 Market choice – at commodity group level

The distribution of freight transportation between road and rail has also been studied at commodity group level. The breakdown for 1985 and 2005 is presented in the table below. One of the two modes of transport is heavily dominant in most of the commodity groups. In some cases road transportation is heavily dominant, in others rail. This suggests that trucks and freight trains are good at different things and that there is a great difference between them in terms of competitiveness. This also suggests that measures that result in modest changes in competitiveness are not expected to outweigh the existing comparative differences.

Unfortunately it has not been possible to draw up completely comparable statistics for road and rail transportation, but it has nevertheless been possible to draw conclusions. Transportation with Swedish-registered land-based modes of transport within the borders of Sweden is shown for 1985 (both transportation within the borders of the country and the domestic portion of international transportation). Rail transportation is shown in the same way for 2005 as for 1985, but road transportation relates to consignments carried by Swedish-registered vehicles with both the point of departure and destination within the borders of Sweden. The new international statistics present the entire transportation and do not allow for a breakdown into domestic and international portions. It is unfortunate that we only have data relating to Swedish-registered trucks as the share of foreign-registered trucks in freight-tonne kilometres increases over time.

[31] Source: Verkehr in Zahlen 2006/07 and Destatis 16/1 2007 and 15/2 2007.
[32] Source: Freight on Rail, 2007.

Table 3.2 Freight-tonne-kilometres by road with Swedish-registered trucks and rail (billions of tonne-kilometres), share of road traffic in ground transportation and change between 1985 and 2005.

Freight tonne-kilometres	1985				2005			
Commodity groups	Road	Rail	Total	Proportion by road	Road	Rail	Total	Proportion by road
Agriculture	0,7	0,2	0,8	79%	0,9	0,1	1,0	92%
Round timber	2,7	2,1	4,8	57%	4,7	2,3	7,0	67%
Wood products	1,2	1,2	2,3	50%	3,0	0,4	3,4	89%
Food products	3,3	0,5	3,8	87%	4,8	0,3	5,0	95%
Crude oil and coal	0,1	0,0	0,2	77%	0,2	0,3	0,5	47%
Oil products	1,2	0,3	1,5	82%	1,7	0,3	2,0	84%
Iron ore and scrap	0,3	4,0	4,4	8%	0,6	4,9	5,5	11%
Steelproducts	0,7	2,6	3,3	22%	0,8	4,7	5,5	15%
Paper and pulp	1,0	2,9	3,8	25%	1,2	3,7	5,0	25%
Earth, stone and construction	2,6	0,6	3,2	80%	3,5	0,5	4,0	88%
Chemicals	1,0	0,7	1,7	58%	1,3	0,5	1,9	70%
High-value products	6,1	2,2	8,3	73%	11,3	3,7	15,0	75%
Total	**20,9**	**17,3**	**38,2**	**55%**	**34,0**	**21,7**	**55,7**	**61%**

Source: SIKA, T30 SM 8702, Domestic and international traffic with Swedish trucks, and passenger and freight transportation by rail, in 2005

In the three commodity groups in which the share between road and rail was most even in 1985 (*Wood products, Round timber* and *Chemicals*) road transportation has reinforced its position and even become dominant in two of the groups. If transportation with foreign-registered trucks was included in the statistics, the change would probably have been even greater. Where rail was dominant in 1985 *(Iron ore and scrap* and *Steel products*) the dominance has persisted and it is unlikely that the addition of foreign-registered trucks would alter this. The dominance of one mode of transport has only been broken in one case, the commodity group of *Crude oil*. This may, however, be misleading as the quantity of freight moved on both road and rail was initially small.

The quantity of freight (in tonnes) increased by eight per cent and freight tonne-kilometres by 46 per cent from 1985 to 2005. In those commodity groups in which trucks have taken market shares this is to some extent due to them having taken a larger share of the quantity of freight, but more to the fact that truck transports have become longer. Trucks have become more competitive for long-haul transport.

Time series have been constructed for those commodity groups that appear to be of greatest interest from the point of view of transfer and for which it has been possible to produce unbroken and comparable time series. The only time series where it is possible to see signs of road and rail taking volumes from each other is that for *Paper pulp and waste paper*. It was not possible to create comparable time series for the commodity groups of *Crude oil*, *Chemicals* and *High-value products*.

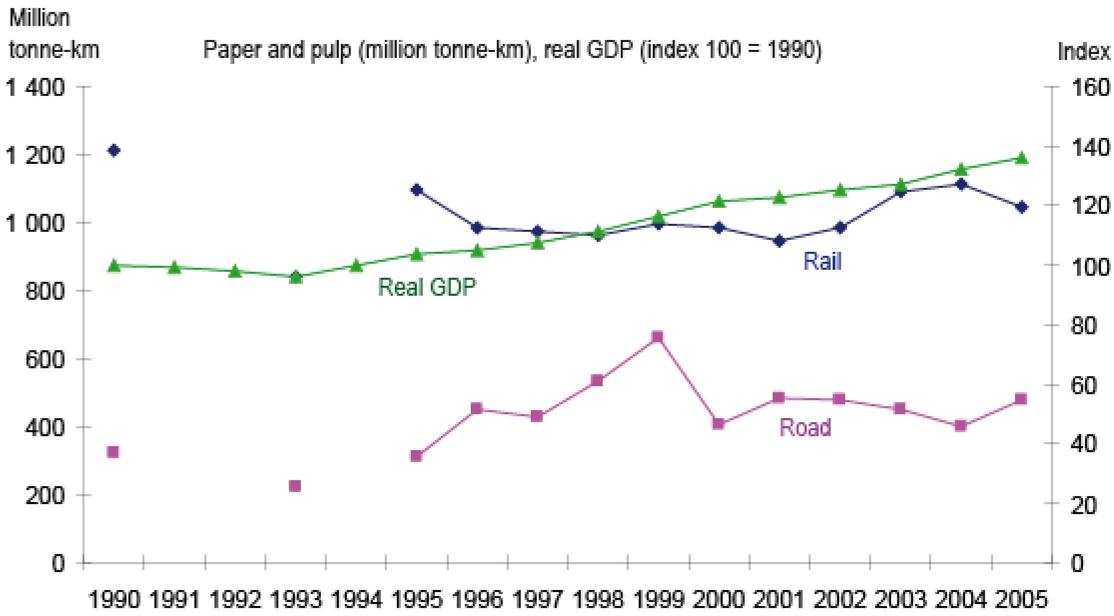


Figure 3.2 Freight tonne-kilometres by road and rail in the commodity group of paper and pulp and GDP in fixed prices. Source: SIKA and Statistics Sweden.

The commodity group of *Paper pulp and waste paper* shows signs of road and rail transport taking volumes from each other. An increase in road transportation coincides with a decrease in rail transportation between 1995 and 1999. The period from 2000 to 2005 also shows a pattern in which an upturn for one mode of transport coincides with a downturn for the other.

3.2.3 Comparative advantages and drawbacks of road and rail transportation

When transportation buyers were asked to rank factors that were of greatest importance to them in choosing mode of transport, cost and several other quality factors such as time and reliability came high on the list.[33] The railways are competitive when large volumes have to be transported over long distances. However, the quality of service offered is required to be sufficiently high for rail to be considered. The latter requirement has probably contributed to the choice of ground-based mode of transportation not having changed greatly over time. Partly in response to this the transportation industry, transportation buyers and infrastructure managers have gradually developed block and intermodal train concepts to boost competitiveness. As truck transportation is often faster, the railways tend principally to handle freight with lower commodity values. More expensive commodities may entail higher transport costs and transportation can therefore be allowed to cost more. Trucks are generally the only conceivable alternative for short trips and when consignment sizes are small.

Round timber and *Earth, stone and construction* are examples of bulky commodities of low value that are transported in large volumes - but where trucks are nevertheless heavily dominant. Here it is availability and short transportation distance that make it difficult for rail to compete.

[33] See also Chapter 4 of the sub-report.

Rail is particularly good in the areas of *Iron ore and metal waste, Metal products* and *Paper and pulp.* Iron ore and steel are transported in large volumes on a small number of routes, which is favourable to rail. In the area of paper and pulp there is a certain dominance for road transport if the number of transported tonnes is looked at, but rail dominates in terms of freight tonne-kilometres. It is thus transportation distance that favours rail.

3.2.4 Significance of transportation length

92 per cent of the quantity of freight and 60 per cent of freight tonne-kilometres are carried over distances of up to 300 km. If we hypothetically assume that rail becomes competitive at a distance of 300 km, the rail companies compete for eight per cent of the quantity of freight and 40 per cent of the freight tonne-kilometres performed by trucks in 2005. If we assume that a measure that alters relative price means that rail becomes competitive at 200 km, the rail companies compete for 14 per cent of quantities of freight and 55 per cent of the freight tonne-kilometres performed by the road haulage companies. However, for rail to gain transportation it is not sufficient to offer a price that is lower than the price charged by the road hauliers. Quality requirements must also be met.

The figure below shows the breakdown of domestic freight transportation by truck by differing transportation distance. The figure shows cumulative values.

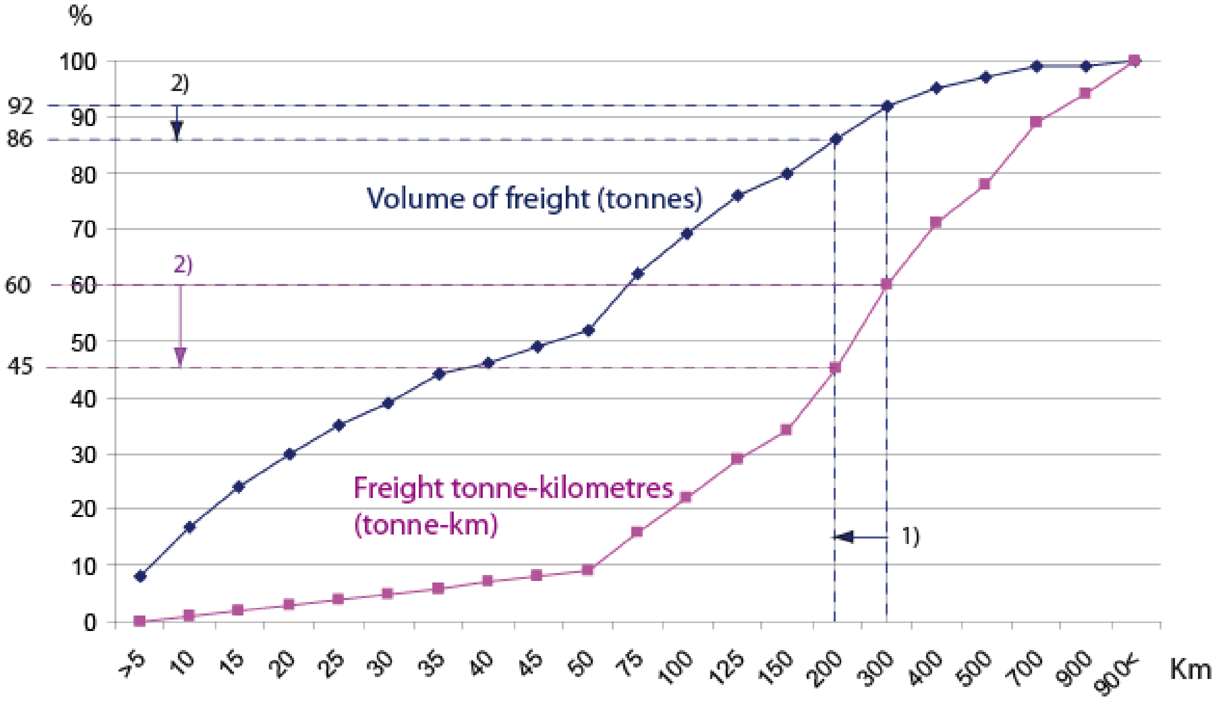


Figure 3.3 Domestic freight transportation by truck according to transportation distance (cumulative), 2005. SIKA.

3.3 Competition interface of road and rail traffic

A change-over from 60 tonnes/25.25 metres to 40 tonnes/18.75 metres would lead to a great change in transport costs[34], with 25 years of successive weight increases being eliminated.[35] The question then is whether it is possible and commercially reasonable to avoid parts of this increase in cost by transferring freight from road to rail.

It is difficult to indicate how large of proportion of present-day road and rail traffic competes. Some road transportation is inaccessible for the railways and some rail transportation is inaccessible for road haulage. In the short term there is probably a limited possibility of transfer between road and rail for capacity reasons.

The competition between road and rail is limited as road and rail transportation have different *competitive advantages.* The largest mode of transportation in different commodity groups is often heavily dominant, and in the review that has been made of statistics at commodity group level it has proved difficult to see signs of changes in transport costs leading to transfer between modes. Transfer of freight to rail is dependent on fundamental quality requirements being met with regard to reliability, time and flexibility. This has posed problems for the railways.

More expensive truck transportation only results in a change in relative price if the rail operators and the road haulage industry do not increase their prices by the same amount. This suggests that the rail companies can increase their revenue more by following the haulage companies in their pricing than by maintaining low prices and trying to compete by taking larger market shares. If the rail companies follow on price, no major changes will probably occur in mode of transport choices.

The results of the SAMGODS simulation in Scenario C suggest that around twelve per cent of road transportation could be transferred to rail in the event of a very large increase in road transport costs combined with extensive investments in rail capacity and/or reprioritisations that yield improvements for freight traffic at the expense of passenger traffic on the railways[36]. This scenario is, however, dependent on the railways fulfilling customers' quality requirements.

The competitiveness of the railways could also be improved by transport policy measures in the area of road transportation, for example a kilometre tax for heavy goods vehicles on the roads. The competitive situation for rail can be improved by better checks and compliance with existing rules on speed limits, overloading and contraventions of driving-time rules. The Swiss institute PROGNOS notes that haulage companies can reduce their costs by six euro cents per vehicle-kilometre by not complying with laws and regulations.[37]

If no other changes are implemented, we regard an outcome close to that predicted in Scenario B to be more realistic. Increased freight train capacity combined with changes in truck standards and other measures in the area of road transportation may make an outcome closer to Scenario C possible. Changes in quality and level of service are

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[34] See Chapter 2.

[35] The greatest increase in weight was from max. 37 tonnes to 51.4 tonnes in the early 1970s. However, on this occasion the vehicle length was not changed, which is the case in our analysis.

[36] See also SIKA report 2005:9, Prognoser för godstransporter år 2020, in which SIKA stimulated the effects of a large number of changes with an impact on demand (oil prices, investments in infrastructure, economic instruments, boom in Eastern Europe etc.) and found that prioritising freight trains has a great effect on demand for freight transportation which is focused on the railways.

[37] Prognos, Gesetzesverstösse auf deutschen Strassen lohnen sich, 2003.

nevertheless required for this to be achieved. This means, for instance, keeping terminals open and trains having to arrive at the right time.

Finally it should be remembered that we are working with scenarios that do not include all effects. Production volume, employment and geographical location of activities are assumed to be unchanged and only the load capacity of trucks and choice of mode of transport and route are changed. For example we do not make any attempt to analyse the effects that occur if increased transport costs lead to a change in the location of production facilities, warehouses and terminals.

4 Effects of changes in vehicle standards in Sweden

4.1 Transport costs for business

4.1.1 Results

The generalised costs to the owners of commodities of transportation by road, rail and sea[38] are estimated to total just over SEK 100 billion (at 2001 prices). These costs are estimated to increase by around SEK 7.5 billion per year in Scenario B, which assumes EU standards for trucks and no transfer to rail, and by around SEK 3.1 billion per year in Scenario C which is based on EU standards for trucks and investments in rail capacity.

A decrease in costs of around SEK 2.2 billion per year is estimated if only investments in rail capacity are assumed. The improved outcome from SEK -7.5 to -3.1 billion is thus explained half by the improved rail capacity and half by changed truck costs.

A minus sign in the table indicates a deterioration in cost-benefit analysis.

Table 4.1 Change in generalised costs per year (in SEK million at 2001 prices) compared with reference alternative A in different scenarios.

	SEK million
Scenario B. EU standards for trucks, no transfer to rail	-7 525
Scenario C. EU standards for trucks, investments in rail capacity	-3 147

In Scenario B the operational costs are equivalent to the generalised costs (apart from limited time delays due to congestion in towns and cities). The transfer of some transportation from road to rail in Scenario C meant that transportation time (including reloading) and therefore the capital tied up in freight increase slightly. As mentioned above, however, the impact of freight time costs on the generalised cost is marginal.

As expected, the cost increases are greatest for commodity groups where a large proportion of volumes are carried on trucks larger than EU vehicles. The cost increase for round timber is 22 per cent in Scenario B and twelve per cent in Scenario C. This is to be compared with a 32 per cent rise in costs for the portion of round timber transportation which in the initial situation went by road on trucks over 40 tonnes.[39] The equivalent cost increase for the commodity group of earth, stone and construction is 17 per cent in Scenario B and eight per cent in Scenario C, which is to be compared with a 35 per cent rise in costs for the portion of the volumes that went by road in the initial situation on trucks weighing more than 40 tonnes.

A relatively large absolute increase in cost is estimated for high-quality products. The relative increase is, however, far smaller when account is taken of the fact that a large proportion of products are already transported domestically and internationally with trucks that fulfil EU weight and dimension requirements today. The increase in cost is far smaller for freight which to a large extent is transported by rail and sea and/or outside Sweden. Examples of such commodity groups are iron ore and scrap and crude oil.

[38] Sum of operational transport costs and freight time costs.

[39] See Figure 2.3.

The generalised costs by road, rail and sea are estimated altogether to increase by seven per cent in Scenario B and three per cent in Scenario C.

The table below illustrates how the large increases in vehicle-kilometres by road for *Round timber, Earth, stone and construction* and *High-value products* result in large cost increases by road, rail and sea for these commodity groups. In Scenario B these groups account for more than 60 per cent of both the increase in vehicle-kilometres by road and the cost increase.

Table 4.2 Estimated change in vehicle-kilometres by road and total generalised costs by road, rail and sea per year (at 2001 prices) compared with reference alternative A per commodity group in different scenarios.

	Vehicle-km by road Scenario B		Vehicle-km by road Scenario C		Costs Scenario B		Costs Scenario C	
Agriculture	23	30%	11	15%	159	6%	55	2%
Round timber	222	44%	143	28%	2 063	22%	1151	12%
Wood products	73	29%	36	14%	587	7%	224	3%
Food products	61	14%	18	4%	348	8%	130	3%
Crude oil and coal	5	25%	4	23%	89	1%	30	0%
Oil products	40	34%	22	18%	522	8%	206	3%
Iron ore and scrap	16	30%	4	7%	139	2%	-98	-1%
Metal products	40	12%	8	2%	259	3%	74	1%
Papper and pulp	51	22%	-9	-4%	300	3%	122	1%
Earth, stone and construction	98	37%	33	13%	1 179	17%	528	8%
Chemicals	56	28%	14	7%	518	7%	132	2%
High-value products	336	19%	321	18%	1 363	6%	592	2%
Total	1 022	24%	605	14%	7 526	7%	3 146	3%

4.1.2 Comparison with other studies

The estimated increase in cost of SEK 7.5 billion (at 2001 prices) in Scenario B is slightly below the level in the TFK (Transport Research Institute) study from 1994.[40] TFK estimates that a change-over from Swedish vehicle dimensions to European ones in 2000 would mean an increase in costs of 15 to 20 per cent for all road transportation in Sweden, equivalent to SEK 6.5 billion (at 1990 prices) or SEK 8.4 billion (at 2001 prices).[41] The estimate is based on experience in the industry, data from Statistics

[40] TFK Minirapport MR85, Rolf Nordström, Anders Lindkvist, Konsekvenser av EU-anpassade fordonsvikter och -dimensioner, revidering i förhållande till EU-kommissionens förslag till direktiv i dokument COM (93) 679 final – SYN 486, Stockholm, 1994.

[41] Nelldal, Bo-Lennart, Järnvägssektorn efter järnvägsreformen 1988 – Förändringar i omvärlden, trafikpolitiken och järnvägsbranschen och I järnvägens marknad 1990-2000, Kungliga Tekniska Högskolan (Royal Institute of Technology), Arbetsrapport (working report) TRITA-IP AR 01-98, 2001.

Sweden and a transport costs program. The method is not described, and the result is therefore difficult to compare with our result. [42]

In the same year, 1994, a study published by the Finnish Ministry of Transport concluded that there would be an increase in costs of 23 per cent (equivalent to around €300 million) if Finland were to apply EU vehicle and weight dimensions.[43] The calculation was made through an expert panel consisting of representatives of the Ministry of Transport, haulage companies, manufacturers etc.

Nelldal notes that freight carriage prices in Sweden could be reduced by 22 per cent – in the case of full utilisation of capacity – as a result of the maximum load weight on trucks increasing from 51.4 tonnes to 60 tonnes.

A German study estimates 14 to 18 per cent lower costs if trucks with Swedish dimensions were permitted in Germany.[44]

4.2 Wear

4.2.1 Method

The calculation of the cost of wear for an vehicle of average weight is based on the National Road Administration's recorded costs for maintenance of the (surfaced) national road network over the period 1998–2002. To differentiate the cost of wear between different types of vehicles (differing weight and axle configuration), the fourth-power rule is used, which states that the axle load A causes degradation of the road equivalent to $(A/B)^4$ times the degradation caused by axle load B. This means for example that doubling the axle load increases degradation 16 times. The fourth-power rule is based on the AASHO trials carried out in the United States in the late 1950s. The axle load of ten tonnes is often used as reference (one standard axle). The load (in tonnes) on each axle is divided by ten and then raised to the power of four. The result of this calculation is then added together for all the axles. The sum represents the vehicle's standard number of axles and shows how many ten-tonne axles the vehicle is equivalent to in terms of wear.

The number of standard axles on a vehicle of average weight in Sweden has previously been estimated at 1.3.[45] This is equivalent to a 36 tonne vehicle with even weight distribution on five axles, a 41 tonne vehicle with 6 axles or a 46 tonne vehicle with 7 axles. The vehicle of average weight thus generates (assuming the fourth-power rule) road degradation and cost of wear equivalent to 1.3 ten-tonne axles.

A criticism that could be expressed is that the fourth-power rule does not take account of road standard, tyre pressure, climatic conditions etc. The only factor that affects the result is the axle load. This raises questions both on the possibility of transferring a calculation model from the United States in the 1950s to Sweden in the 2000s and on the appropriateness of applying the same rule to a road network that is geographically

[42] Rolf Nordström, TFK , e-mail dated 20 September 2007, "The intention was to present a more detailed account of future larger project sections which never came about."
[43] The Ministry of Transport and Communications of Finland, Harmonization of Vehicle Weights and Dimensions, Consequences in Finland, 7/3/1994.
[44] S. Keuchel, H. Ernst, C. Richter, M. Mühlhause, Fachhochschule Gelsenkirchen, Forschungsprogramm Strassenverkehrswesen FE 03.400/2005/ARB, Auswirkungen auf die Strasseninfrastruktur infolge einer Erhöhung der Abmessungen und zulässigen Gesamtgewichte von Lkw, Recklinghausen, November 2006
[45] Vägverket, Allmän teknisk beskrivning för vägkonstruktion ATB Väg 2003, Publication 111.

dispersed and heterogeneous in relation to standard and traffic. Despite acknowledged weaknesses, the fourth-power is widely used, and the method is accepted in the absence of alternatives that work in application contexts.

It is nevertheless important to estimate what the assumptions of the fourth-power rule mean for the results of the analysis, using various sensitivity analyses. In order to compensate to some extent for the deficiencies in the fourth-power approach, analyses are also carried out in which the power of three $(A/B)^3$ and five $(A/B)^5$ are used. Compared with the fourth power, the third power signifies a smaller increase in wear if the axle load increases, while the increase in wear becomes greater if the fifth power is used. This may correspond to roads which have better and worse ability to withstand heavy traffic in comparison with the fourth-power rule.

4.2.2 Input data and calculation values

An estimated ratio between the National Road Administration's costs of road maintenance and freight vehicle-kilometres shows that the marginal cost of wear is 15–17 öre per heavy vehicle-kilometre.[46] The mid-point of the range is used for the study, 16 öre per kilometre. The cost applies to the average price level over the period 1998–2002. The cost of wear is differentiated using the fourth-power rule. A value is calculated for each vehicle weight class (the middle of the weight range is used) and number of axles[47]. It is assumed in the calculations that the weight is evenly distributed over the vehicle's axles.

4.2.3 Calculation of changes

With a change-over from the Swedish exemption rules to the EU rules, all freight transportation now carried out with vehicles weighing more than 40 tonnes is redistributed to vehicles that weigh a maximum of 40 tonnes. It is therefore assumed in the analyses that the entire quantity of redistributed freight ends up on vehicles weighing 40 tonnes. The average load per vehicle in the gross weight class of 35–40 tonnes is estimated to increase from around 8 tonnes to around 13 tonnes. This is due to the fact that heavy commodities such as timber and paper will now be transported on 40 tonne trucks.

In view of the relationship between axle load and road degradation, the number of axles on the vehicles that transport the redistributed freight is of key significance to the costs of wear. The more axles, the lower the cost. As the axle distribution is not known for Scenarios B and C, calculations are made for three different cases. In the basic case in Scenario A, the load is distributed equally between vehicles with five, six and seven axles. Of those vehicles which today (Scenario A) have an actual weight of 34–40 tonnes, 43 per cent have five axles, 28 per cent six axles and 26 per cent seven axles.

A reasonable assumption is that adaptation to the EU rules in the slightly longer term would mean that the proportion of trucks with six or seven axles increases slightly so that these vehicle categories become as common as five-axle vehicle combinations.

Two more calculations with more extreme conditions are made to test what deviations from this assumption signify for the result. In the first of these, all freight is redistributed to vehicles with five axles, and in the second case the load is only redistributed to

[46] Haraldsson, M. Essays on Transport Economics, Uppsala: Economic studies 104 (PhD Thesis), 2007.
[47] See Table 2 in Appendix 2.

seven-axle vehicles. Redistribution to vehicles with only five or seven axles is presented in the section on sensitivity analyses.

4.2.4 Results

Based on the fourth-power rule and the distribution of vehicle-kilometres between different classes of actual vehicle weight/axle number, an average number of standard axles per heavy vehicle of 1.1 is obtained, slightly lower than previous figures. In the table below reduced maintenance costs are indicated as a positive benefit and increased maintenance costs as a negative benefit.

Table 4.1 Estimated effect on wear costs in different scenarios. Transferred freight evenly distributed between vehicles with 5, 6 and 7 axles. The fourth-power rule is used for differentiation.

	Difference comp. with A (SEKm)	Total cost of wear (SEKm)	Cost of wear per vehicle km (SEK)
Scenario A. Reference alternative 2005		676	0.160
Scenario B. EU standards for trucks, no transfer to rail	+140	536	0.108
Scenario C. EU standards for trucks, investments in rail capacity	+201	475	0.104

It can be seen from the table above that in reference scenario A road wear from heavy traffic costs around SEK 676 million annually. With Scenario B the annual cost of wear decreases by around SEK 140 million. If transfer to rail is made possible by investments in the railway network (C), the cost of wear would decrease by around SEK 201 million. The cost of wear per vehicle-kilometre in the reference alternative (A) is 16 öre per vehicle-kilometre. In scenarios B and C the cost of wear per vehicle-kilometre decreases to 10.8 and 10.4 öre respectively.

4.2.5 Sensitivity analyses

In this section it is tested how sensitive the results are to the assumption on the fourth-power rule. What results are obtained if the third or fifth power is used instead? Provided the load is distributed evenly to vehicles with 5, 6 or 7 axles, lighter vehicles according to Scenarios B and C will reduce wear regardless of which of the three powers is used. The saving is even greater if all the freight is put on six-axle vehicles.

If the load is only put on five-axle 40-tonne trucks, the wear increases in Scenario B, regardless of power. The reason for this is that the decrease in wear is not sufficiently great to compensate for the increased freight vehicle-kilometres.[48] The outcome of scenario B thus hinges on the assumption of the number of axles on the forty-tonne vehicles.

[48] This is in line with the calculations made by the Swedish Association of Road Haulage Companies (Sveriges Åkeriföretag, 2007). Their calculations show that a sixty-tonne vehicle with 8 axles produces a lower wear cost per tonne than forty-tonne vehicles with only 5 or 6 axles.

In Scenario C the cost of wear also decreases if the freight is placed on five-axle trucks, which is due to road freight vehicle-kilometres not increasing as much, as freight can be transferred to rail. The differences in wear costs are shown in the two tables below.

The middle row in the table corresponds to the principal alternatives in this study (uniform transfer of freight to trucks with five, six or seven axles and cost differentiation using the fourth-power rule).

The outcome of Scenario B is thus not entirely clear. In comparison with Scenario A the wear costs can both increase and decrease. With Scenario C the signs are the same regardless of the combination of calculating rule and assumption on transfer. The cost of wear decreases in all cases in comparison with A. In the table below reduced maintenance costs are indicated as a "positive benefit" and increased maintenance costs as a "negative benefit".

Table 4.2 Scenario B, Estimated difference in cost of wear compared with Scenario A (SEKm).

		Third, fourth and fifth power rule		
		3	4	5
Transfer of freight to	5 axles	-72	-41	-3
	5, 6, 7 axles	64	140	206
	7 axles	181	287	366

Table 4.3 Scenario C, Estimated difference in cost of wear compared with Scenario A (SEKm).

		Third, fourth and fifth power rule		
		3	4	5
Transfer of freight to	5 axles	22	134	229
	5, 6, 7 axles	53	201	321
	7 axles	88	257	390

4.3 Road safety

4.3.1 Method

We can imagine three different methods of assessing the effects of different truck combinations on road safety: i) experimental studies, ii) theoretical studies and iii) statistical studies of actual accidents. We focus here entirely on the actual experience that exists of long and heavy truck combinations in Sweden and utilise Swedish accident data in the analysis, i.e. method iii).

In-depth analyses were made in Sweden during the 1970s to establish the effect of reducing vehicle length on road safety. The conclusions were that the risk could be assumed to increase with vehicle length, that the consequence of the accidents was independent of length but that the expected increase in freight vehicle-kilometres counteracts these effects, and that the reduction in length overall would therefore adversely affect road safety.[49] Our analyses point in the same direction.

Over the past ten years an average of 6.6 people have been killed sitting in heavy trucks in road traffic accidents. This represents 1.3 per cent of all deaths in accidents reported to the police. We know that vehicle weight protects the person sitting in a vehicle, while it increases the risk to other road users in an accident.[50] In addition to the 6.6 people killed in heavy trucks 88 more people a year on average are killed in collisions with trucks. This means that for each person killed in a heavy truck thirteen more die outside the truck. The equivalent figure for light trucks is two killed outside the truck for each death in the truck, and in the case of cars an average of 1.6 people are killed outside the vehicle for every death inside the car. The focus in this analysis is on studying the total effect on traffic safety, both inside and outside trucks, of large truck combinations, and we therefore include everyone killed or injured in accidents involving heavy trucks.

The characteristics of heavy trucks – the fact that they are heavier and larger than cars, have poorer acceleration than cars and worse braking ability – means that accidents involving trucks can be expected to be different and more serious than other vehicle collisions.[51]

The fact that a difference is found between accidents involving trucks and accidents involving cars means that a difference might be expected between different types of trucks. The Traffic Safety Commission (1977) points to the wide difference in risk between vehicles with semitrailers and those with trailers. Vehicles with more than one trailer may also be at greater risk under certain traffic conditions[52]. However, the literature does not report any clear conclusions on the size of trucks and accident risks. The *US National Highway Traffic Safety Administration* concludes in a study of accidents between 1979 and 1986 that trucks lead to more accidents involving injuries than trucks with trailers.[53] This highlights one of the problems with these studies: we can expect different categories of vehicles to have different types of accident exposure. Interest in this analysis is, however, focused solely on the very heaviest vehicle combinations which, in addition, will retain the same transportation pattern in the various scenarios.

The analysis below is based on three components: firstly accident data from STRADA (*Swedish Traffic Accident Data Acquisition*), secondly estimates of freight vehicle-kilometres as described in Table 8.1 in Appendix 2 and thirdly the economic valuations of accidents.

We perform the analysis is two stages: we first study the consequences and characteristics of the accidents that actually occur and then the risks by relating these accidents to the exposure measured in vehicle-kilometres.

[49] Ds K 1977:1 (1977) Långa fordon och fordonskombinationer – betänkande avgivet av trafiksäkerhetsutredningen. Kommunikationsdepartementet. Stockholm 1977.
Trafiksäkerhetsutredningen (1977) Studie av effekten på trafikolyckor av en minskning av högsta tillåtna fordonslängd från 24 till 18 meter. Liber 1977, Stockholm.
[50] See Lindberg, G. (2006) Valuation and Pricing of Traffic Safety. Örebro Studies in Economics 13.
[51] Chaumel, J-L., J-M. Grandbois, F.Ruest, L.Lafrance and D.Lebel (1986), Road accidents involving long-distance heavy trucks, CIRAST, Quebec.
[52] Forkenbrock, D.J.;Hanley, P.F. (2003) Fatal crash involvement by multiple-trailer trucks. Transportation Research Part A: Policy and Practice 37, 419–433.
[53] National Highway Traffic Safety Administration (1992) Heavy Duty Trucks in Crashes NASS 1979–1986. US Department of Transportation, Washington.

For accidents we made use of individual accident information for accidents reported to the police with injuries in which heavy trucks have been involved over the period from 2003 to 2005. We have observed 934 such accidents over the studied period. Data loss according to other studies[54] is significant in the reporting of accidents, and here we correct the number of severely slightly injured persons by applying general data loss factors. This means that we assume that there is correlation between data loss and the characteristics of the vehicle etc.

The exposure measured in vehicle-kilometres is rarely at vehicle level,[55] and we are forced to rely on broader categorisations of vehicle combinations. This means that we cannot make the same type of analyses for risks as for consequences.

4.3.2 Input data and calculation values

An average of 934 accidents causing injuries involving heavy trucks per year occurred over the period 2003 to 2005. Of these, 615 occurred with trucks alone and 345 with trucks and trailers. We have information on weight and number of axles for 715 of the accidents.

An average of 67 persons per year were killed in the accidents. The deaths are broken down between vehicle categories as shown in the table below. In cases in which heavy trucks are involved we present information on the heavier vehicle. We have also compiled a breakdown between severely and slightly injured casualties for the analysis.

[54] See Larsson Jörgen (2004). Bearbetning av patientstatistik för 1088-2001 avseende trafikskadade. VTI notat 8-2004. Linköping
[55] See Lindberg, G. (2006) Valuation and Pricing of Traffic Safety. Örebro Studies in Economics 13.

Table 4.4 Number of people killed per year in accidents involving heavy trucks (average 2003–2005).

Gross weight / Number of axles	2	3	4	5	6	7	8	9	Total
Truck 3.5–7.5 tonnes	0.0								0.0
Truck 7.5–12 tonnes	1.7								1.7
Truck 12–14 tonnes	0.3								0.3
Truck 14–20 tonnes	5.0								5.0
Truck 20–26 tonnes	1.0	6.0							7.0
Truck 26–28 tonnes		7.3							7.3
Truck 28–32 tonnes		3.7							3.7
Truck above 32 tonnes		0.7	0.3						1.0
Total Trucks	8.0	17.7	0.3	0.0	0.0	0.0	0.0	0.0	26.0
Truck with trailer below 28 tonnes									0.0
Truck with trailer 28–34									0.0
Truck with trailer 34–40			0.3						0.3
Truck with trailer 40–50				1.3	0.3				1.7
Truck with trailer 50–60 tonnes				1.0	4.3	11.7	0.3	0.3	17.7
Total Trucks with trailers	0.0	0.0	0.3	2.3	4.7	11.7	0.3	0.3	19.7
Total	8.0	17.7	0.7	2.3	4.7	11.7	0.3	0.3	45.7
Unknown Trucks									8.3
Unknown trucks with trailers									13.0
Combined total									67.0

The economic valuation of traffic accidents consists of material costs in the form of damage to vehicles, medical care and medication for injuries. Loss of production (net) is also included in these costs. However, the dominant component is the risk assessment, which expresses the individuals' preferences for lower risks of being killed or injured. Extensive recent research verifies a valuation of a statistical death at around SEK 20 million.[56] The values recommended by the ASEK group are used in the analysis.

Table 4.5 Economic costs per accident (SEK).

	Material costs	Risk assessment	Total cost	Data loss	Per case reported to police
Killed	1 242 000	16 269 000	17 511 000	1	17 511 000
Severely injured	621 000	2 503 000	3 124 000	2.4	7 497 600
Slightly injured	62 000	113 000	175 000	2.4	420 000

Source: SIKA 2005:16 and National Road Administration Effektkatalog

We correct data on the severely and slightly injured with the estimated data loss in reporting. This means that these injuries are multiplied by a factor of 2.4.[57]

We focus here on the injuries, which represent the dominant cost. The average economic cost over the period 2003 to 2005 for all accidents involving heavy trucks is SEK 3.1 billion per year. The loss of data is significant. We lack information on the

[56] Hultkrantz, Lindberg, Andersson (2006), The value of improved road safety. Journal of Risk and Uncertainty, 32:2, pp 151–170.

[57] National Road Administration catalogue of effects.

weight of the truck or vehicle combination for just under SEK 1 billion per year. The data loss is greater for trucks with trailers as we then need information on both the truck and the trailer.

In the table below we have calculated the costs of accidents per year broken down by weight of truck and the number of axles or weight of vehicle combination (truck with trailer) and the number of axles. In cases where more than one truck has been involved the cost has been allocated to the heavier vehicle. This is an arbitrary allocation which disfavours heavier vehicles.

Table 4.6 Average costs of accidents per years (SEK million per year).

Gross weight / Number of axles	2	3	4	5	6	7	8	9	Total
Truck 3.5–7.5 tonnes	37								37
Truck 7.5–12 tonnes	86								86
Truck 12–14 tonnes	26								26
Truck 14–20 tonnes	268								268
Truck 20–26 tonnes	51	271							322
Truck 26–28 tonnes		352							352
Truck 28–32 tonnes		132	32						164
Truck above 32 tonnes		12	25						37
Total Trucks	468	767	57	0	0	0	0	0	1 292
Truck with trailer below 28 tonnes									0
Truck with trailer 28–34		0	3	0					3
Truck with trailer 34–40		3	11	0					14
Truck with trailer 40–50		0	3	38	11				52
Truck with trailer 50–60 tonnes			3	45	168	428	23	6	672
Total Trucks with trailers	0	3	20	84	179	428	23	6	742
Total	468	770	78	84	179	428	23	6	2 034
Unknown Trucks									476
Unknown trucks with trailers									571
Combined total									3 081

Longer vehicles take longer to overtake and might therefore be more involved in overtaking-related accidents than shorter vehicles. Previous experimental Swedish studies show a slight trend for 24-metre vehicles to result in more risky overtaking manoeuvres than 18-metre vehicles.[58] The same result is obtained in more modern international studies.[59] The time gap in relation to oncoming vehicles in overtaking manoeuvres was estimated at 4.5 seconds for the shorter vehicle and 4.3 seconds for the longer one. A change-over to shorter vehicles might reduce the time gaps by six per cent on narrow roads, but this difference is not statistically significant.

There is nothing in this material to suggest that overtaking-related accidents are more common for longer vehicles. The proportion of overtaking-related accidents out of all accidents with trucks only is around 0.11, while it is 0.08 for trucks with trailers. A simple linear logit model that attempts to explain the proportion of overtaking-related accidents by the length, weight and number axles of the vehicle combination cannot

[58] Hammarström, U. (1976) Omkörningar av långa fordonskombinationer – studie av mötesmarginaler. VTI Rapport 103, Linköping 1976.
[59] Hanley, P.F., D.J. Forkenbrock. (2005) Safety of passing longer combination vehicles on two-lane highways. Transportation Research Part A: Policy and Practice 39, 1–15.

identify any clear correlation. With non-linear correlations we find that the probability of observing an overtaking-related accident falls with increased length (elasticity -2.8) but increases with the square of the length (elasticity 1.5). The probability of observing an overtaking-related accident among the accidents decreases with an 18-metre vehicle combination compared with a 24-metre vehicle combination. On the other hand, an average overtaking-related accident is less serious than other accidents (SEK 0.96 million compared with SEK 2.2 million). This means that, for the total number of accidents, an increased proportion of overtaking-related accidents in principle reduces the average accident cost (-2 per cent in this model on moving from 24-metre to 18-metre). There is no reason to believe, from our material, that changing over from long to shorter vehicles would reduce accident cost depending on the proportion of overtaking-related accidents.

On the other hand, the consequences of an accident may be affected by the weight of the vehicle. 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 SEK 2.6 million, while it is around SEK 1.8 million for trucks alone. If we look at traffic environments we find that the average cost is SEK 1.5 and 1.2 million respectively in urban areas and SEK 3.0 and 2.7 million respectively in rural areas. The wide difference in cost is due to a greater proportion of urban accidents for the lighter vehicle combinations. However, we cannot say for certain whether accident cost is influenced by weight or length among the various sizes of vehicle combinations.

Freight vehicle-kilometres for different categories of vehicle combinations have been discussed previously. Based on the accident information we find that the average accident cost per heavy truck kilometre is SEK 0.73 per vehicle-kilometre. If we focus on the heaviest vehicle combinations over 50 tonnes, the cost is SEK 0.47 per vehicle-kilometre, while the next heaviest (40–50 tonnes) has a cost of SEK 0.63 per vehicle-kilometre.[60] If we look at the group just below 40 tonnes, we obtain a kilometre cost of SEK 0.67 per vehicle-kilometre. Trucks with trailers on average have an accident cost of SEK 0.48 per vehicle-kilometre, while trucks without trailers on average have a cost of SEK 1.18 per vehicle-kilometre.

[60] Including an upward adjustment for the vehicles for which we do not have sufficient information.

Table 4.7 Accident cost per vehicle-kilometre (SEK/vkm).

Gross weight / Number axles	2	3	4	5	6	7	8	9	Total
Truck 3.5–7.5 tonnes	-								-
Truck 7.5–12 tonnes	0.53								0.53
Truck 12–14 tonnes	1.47								1.47
Truck 14–20 tonnes	0.71	0.00							0.71
Truck 20–26 tonnes	0.46	2.06							1.34
Truck 26–28 tonnes		1.52							1.52
Truck 28–32 tonnes		3.10	5.12						3.36
Truck above 32 tonnes		39.05	2.09						3.03
Total Trucks	0.70	1.89	3.15						1.18
Truck below 28 tonnes		0.00	0.00						0.00
Truck with trailer 28–34		0.21	0.66						0.58
Truck with trailer 34–40		3.28	0.83	0.02	0.00				0.67
Truck with trailer 40–50		0.11	0.40	0.55	2.65				0.63
Truck with trailer 50–60 tonnes			0.32	0.20	0.55	0.50	1.04	2.19	0.47
Total Trucks with trailers		0.36	0.54	0.27	0.58	0.50	1.04	2.19	0.48

Note: The proportion of unknown trucks is 0.37, by which all costs for trucks alone are adjusted upwards. The equivalent proportion for truck + trailer is 0.77, which has been used to adjust the cost for this category upwards.

The higher cost per kilometre for trucks alone that we see can probably be explained by environmental factors: smaller trucks do not travel in the same places as the heavier vehicle combinations. The proportion of accidents in urban areas is 59 per cent for trucks alone, compared with 31 per cent for trucks with trailers. Although the average consequence is milder per accident, significantly more accidents occur in this environment. However, it is more important to focus on the heaviest vehicle combinations for this analysis. The two heaviest categories (trucks + trailers over 40 tonnes) are replaced by the EU-authorised category of vehicle combinations of 34–40 tonnes. The freight vehicle-kilometres and axle configuration of these vehicles vary in different scenarios but the traffic environment can be expected to be constant.

4.3.3 Calculation of changes

Our basic assumption is that the accident cost per vehicle-kilometre is identical, that is to say SEK 0.48 per vehicle-kilometre, for the vehicle combination classes used in the analysis. There is nothing in our material to suggest that the accident cost per kilometre differs significantly between the various categories concerned.

In the analysis we have, however, a change in freight vehicle-kilometres of 24 per cent in Scenario B and 14 per cent in Scenario C. These changes in freight vehicle-kilometres will affect the number of accidents and total costs. The relationship between traffic flow and accidents is uncertain. It is usually assumed that the risk is constant per vehicle on links, while it increases with the number of vehicles at intersections. The consequence is a slightly increasing risk of accident with increasing traffic flow and number of intersections. However, it has been difficult to verify this correlation at an aggregated level. Many studies have instead found a declining risk with increasing traffic[61]. We choose here a conservative assumption that the risk is constant with a

[61] Winslott, L. (1998) The external costs of traffic accidents – an empirical analysis of the traffic flow. Lund University.

change in traffic flow. The accident cost per kilometre is consequently also constant with a change in traffic flow.

4.3.4 Results

Based on the material and the considerations above, we can calculate the anticipated effects of the various scenarios. Our principal analysis is presented in the table below. Negative numbers (in the right-hand column) signify an increase in the accident cost to society and positive numbers a decrease.

Table 4.8 Deaths (number) and economic consequences per year (SEK million).

	Deaths per year	SEKm per year
Scenario B. EU standards for trucks, no transfer to rail	+12	-491
Scenario C. EU standards for trucks, investments in rail capacity	+7	-291

The sharp increase in freight tonne-kilometres in Scenario B increases the cost of accidents by SEK 491 million per year. In Scenario B the cost increases by SEK 291 million per year. As we cannot find any statistically significant difference in accident risk depending on the number of axles, the same result will be obtained regardless of whether the smaller vehicles will be fitted with five, six or seven axles.

4.3.5 Sensitivity analyses

Let us, despite everything, assume as a sensitivity analysis that the change-over from vehicle combinations over 40 tonnes and more than 18.75 metres in length to vehicle combinations between 34–40 tonnes with maximum length of 18.75 metres, with constant freight vehicle-kilometres, would lead to a decrease in risk. Let the accident cost per kilometre fall by 10 per cent. This means that the accident cost falls from SEK 0.48 to 0.43 per kilometre when the dimensions decrease. The number of vehicle-kilometres increases at the same time, which means that the aggregate accident cost increases by SEK 228 million in Scenario A, SEK 49 million in Scenario B and decreases by SEK 236 million in Scenario C.

Table 4.9 Deaths (number) and economic consequences per year (SEK million).

	Deaths per year	SEKm per year
Scenario B. EU standards for trucks, no transfer to rail	+6	-228
Scenario C. EU standards for trucks, investments in rail capacity	+1	-49

An assumption of negative risk elasticity, i.e. that the accident risk declines with increasing traffic volume, points in the same direction as the sensitivity analysis above, and we have therefore not explicitly included this.

4.4 Time delay

4.4.1 Effects on road category

The table below shows how the freight vehicle-kilometres in the National Road Database (VDB) are broken down between the various road types. Around 40 per cent of the freight vehicle-kilometres with heavy trucks are estimated to be driven on motorways, dual carriageways and 2+1 roads. Around 25 per cent travel at 90 km/h and 110 km/h respectively on two-lane roads that are up to 11.5 metres wide.

Passenger traffic to a large extent travels on roads with 70 km/h and 50 km/h speed limits (34.2 per cent of traffic performance with passenger cars) and on motorways, dual carriageways, four-lane roads and 2+1 roads (31.3 per cent of vehicle-kilometres with passenger cars).

Table 4.12 Vehicle-kilometres and road length for different road types.

Road type	Road length (Km)	Vehicle-kilometres Car (%)	Vehicle-kilometres Truck (%)
Motorways, dual carriageways, four-lane roads, 2+1 roads	3 155	31.3	37.7
2-lane roads: > 11.5 metres, 90–110 km/h	2 405	9.7	11.3
2-lane roads: 10–11.5 metres, 90–110 km/h	310	1.1	1.1
2-lane roads: 5.5–10 metres, 90–110 km/h	23 165	23.5	24.0
Roads and streets with 50–70 km/h limit	63 465	34.2	25.8
Total	92 500	100	100

It is studied below whether/how an increased proportion of heavy goods vehicles in the traffic flow leads to a delay in journey time for other traffic.

Motorways, four-lane roads, 2+1 roads

An increased proportion of heavy vehicles on motorways and four-lane roads may lead to further congestion and time delay on sections with very high hourly flows in peak traffic. There is a shortage of capacity on roads into the metropolitan areas principally during the morning hours. The proportion of heavy vehicles is, however, only six to seven per cent, of which 40 to 50 per cent are trucks with trailers. Capacity decreases with increase in proportion of heavy vehicles at unchanged total flow, as a heavy vehicle is equivalent to 1.5–2 cars from the point of view of capacity.

No or marginal extra delay for cars is assumed on 2+1 roads or narrow four-lane roads as tailbacks are assumed to be eliminated in the two-lane sections.

Two-lane roads with 90–110 km/h speed limit, more than 11.5 metres wide

On wide two-lane roads with a width of more than around 11.5 m trucks are largely passed using the hard shoulder (or by the truck keeping to the right in wide lanes of 5.5 m). It is therefore assumed that increased proportion of heavy vehicles does not add any or only adds margin time delay for cars.

Two-lane roads with 90–110 km/h speed limit, less than 11.5 metres wide

On two-lane roads with 90 or 110 km/h and a width of around 5–11.5 m increased truck traffic leads to time delays for passenger traffic which are calculated and assessed below. Narrower roads result in greater delay.

All roads and streets with 70 km/h and 50 km/h speed limit

The proportion of heavy vehicles plays very little role on all roads with a speed limit of 70 km/h (or 50 km/h) as the same speed limit applies to heavy and light vehicles. This applies to both four-lane and two-lane designs.

4.4.2 Method for calculation of time delay

Delays principally occur on roads where cars are allowed to travel faster than trucks and where the road only has two lanes which together are narrower than 11.5 metres. Calculations are therefore only made for the category of *two-lane roads with 90–110 km/h speed limit, less than 11.5 m wide.* The delays are calculated using a model developed at VTI.[62] The road network contained in the SAMGODS model is used in the calculations. The method briefly means that:

1) The number of vehicles per road link is established for reference scenario A. The number of vehicle-kilometres per link featured in SAMGODS is used in the calculations. As we make use of calibration constants that depend on how much traffic runs on the various links, a division is made into three different categories that describe the load on the basis of annual daily traffic (ADT). The categories are: ADT < 5 000 vehicles/day, 5 000 ≤ ADT ≤ 10 000 vehicles/day and ADT > 10 000 vehicles/day.
2) The number of vehicles per hour and road link is calculated. The average hourly flow on national roads in rural areas is 6.2 per cent of ADT (average daily flow). At a load of 5 000 vehicles per day the number of vehicles per hour is 5 000 * 0.062 = 310
3) An addition to journey time per car and link for the average hourly flow is calculated. The formula used is:

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

where Δjourneytime/truck% (s/km) is the addition to journey time for cars when the proportion of heavy vehicles increases by one percentage point

k_1 and k_2 are calibration constants

q_{tot} is the total flow in both directions and is expressed as vehicles per hour

The constant k_1 depends on visibility and route and varies from 0.17 for a straight flat road to 0.32 for a curved and hilly road. The following values for the constant k_1 are used for two-lane roads with 90 or 110 km/h speed limit and a width of around 5-10 metres:

[62] Carlsson, A. Björketun, U. Hastighetsflödesmodeller för väglänkar landsbygd, VTI PM 2004-09-20.

A. For road link with low annual daily flow (ADT), below 5 000, k_1=0.26

B. For road link with medium ADT, 5 000-10 000, k_1=0,20

C. For road link with high ADT, over 10 000, k_1=0.17

For roads with a width of 10–11.5 metres (around 1.3 per cent of the road length) the delay can be expected to be lower, and for these roads k_1=0.155, k_1=0.12 and k_1=0.10 have been chosen with the same ADT division as above.

The constant k_2 is assumed to be constant for all road types and alignment and has the value k_2=0.0012.

4) An annual delay for the whole country is obtained by adding up for all affected links.

The journey time supplement in accordance with (1) is multiplied by the change in proportion of trucks for each link and an average journey time supplement is obtained for the link concerned. The total delay over a year is obtained by multiplying by the annual vehicle-kilometres for cars on the link concerned. We obtain:

$$\text{Annual delay} = 365 * \text{ÅDT}_{Pb} * L * \Delta Lb\% * \Delta \text{journeytime}/lb\% \qquad (2)$$

Where ADT_{Pb} is the ADT of the link for a car

L is the link length

ΔLb% is the change in proportion of trucks in percentage points

Δjourneytime/lb% is the average journey time supplement as above and

with

q_{tot} = 0.062*ADT

The mean value of the number of trucks before and after is used in calculating q_{tot}.

4.4.3 Input data and calculation values

We make use of the weighted time value for cars applied by the National Road Administration of 150 per vehicle hour.[63] The value is based on there being 2.18 persons in the car on an average private journey and there being 1.54 persons in the car on an average business journey.

4.4.4 Calculation of changes

On roads with assumed time delays (two-lane roads with 90 km/h and 110 km/h speed limit and width less than 11.5 m) freight vehicle-kilometres with heavy trucks are estimated to increase by 28 per cent in Scenario B and 18 per cent in Scenario C. The proportion of trucks on these roads is estimated to increase from 10.9 per cent in Scenario A to 13.5 per cent in Scenario B. The increase is 2.6 percentage points on these roads and 2.3 percentage points on the whole road network.

The time delay for cars due to an increased proportion of trucks is obtained by adding together the delay on each road link. Table 4.13 shows the annual delay for cars on two-lane roads which are around 5.5–11.5 metres wide and have a speed limit of 90 and

[63] Vägverket, Publication 2006:127, Vägverkets samhällsekonomiska kalkylvärden, pages 40–41.

100 km/h, divided into Scenario B and Scenario C. The annual extra cost for cars is obtained with the valuation of SEK 150 per car hour. In the table negative signs mean an economically negative change.

Table 4.13 Time delay (hours) and annual cost (SEK million) for cars on two-lane roads with a width of 5.5–11.5 metres.

	Delay hours per year	SEKm per year
Scenario B. EU standards for trucks, no transfer to rail	-331 360 h	-49,7
Scenario C. EU standards for trucks, investments in rail capacity	-225 232 h	-33,8

Extra delays are thus obtained for Scenario B due to increased proportions of trucks of around 330 000 hours per year, which is valued at around SEK 50 million per year. The time delays for Scenario C total around 225 000 hours per year, valued at SEK 34 million per year.

The calculation means an underestimate of the total cost of time delays for passenger traffic, as some delay also occurs on roads other than narrow two-lane roads with speed limits of 90 km/h and 110 km/h. It has not been possible to quantify these. This applies principally to busy motorways when capacity is overloaded.

4.4.5 Sensitivity analyses

The greatest uncertainty is the estimated change in freight vehicle-kilometres for trucks in the different scenarios. A deviation in the estimate of freight vehicle-kilometres for trucks of +/- 10 per cent is equivalent to a deviation of +/-1.35 percentage points in change in proportion of trucks in Scenario B. This in turn results in a deviation of +/-51 per cent in annual delay for cars. As can be seen from Formula (2) above, the annual delay is directly proportional to the changed proportion of trucks, ΔLb%.

It is emphasised above that no extra delays on motorways or four-lane roads are assumed. This is not entirely correct. On road sections with very large hourly flows in peak traffic where there is a shortage of capacity an increased proportion of heavy vehicles can result in further congestion and delays. Assume that the freight tonne-kilometres for trucks with trailers increase by 50 per cent. The proportion of heavy vehicles then increases by 1.5 percentage points, from 6–7 per cent to 7.5–8.5 per cent. This means that capacity decreases by one per cent. In the case of large and long upward slopes, for example in tunnels, the effect is even greater. On a 5–6 per cent slope a truck is equivalent to around four cars. This means that if the proportion increases by 1.5 percentage points capacity decreases by around 3.5 per cent or around 140 vehicles per hour.

4.5 Exhaust emissions

4.5.1 Method

ARTEMIS

ARTEMIS (*Assessment and Reliability of Transport Emission Models and Inventory Systems*) is a European programme for the calculation of the exhaust emissions of road traffic at regional or national level. Work has been under way for several years to implement ARTEMIS for the description of exhaust emissions from road traffic in Sweden.[64] The implementation is directed by an expert reference group with representatives from both authorities and the automotive industry.[65] An important motive for choosing ARTEMIS is to use a model for which there is a consensus. Monitoring of exhaust gas emissions from road traffic in Sweden has been based on ARTEMIS since 2004.[66] The representative nature of the model with respect to carbon dioxide (CO_2), carbon monoxide (CO), volatile hydrocarbons (HC)[67] and nitrogen oxides (NO_X) has been evaluated with good results.

The exhaust gas calculations in ARTEMIS in principle are simple: emission factors per traffic situation multiplied by freight vehicle-kilometres. The ARTEMIS model contains emission factors which are to be capable of providing representative emission calculations throughout the EU area because the same requirement levels (Euro classes) of emissions apply. The emission factors are coded in the program and cannot be changed by the user. What complicates the simple principle of calculation in use is the fine division of the vehicle fleet and the division into traffic situations.

Input data into ARTEMIS can be broadly classified into: vehicle fleet, freight vehicle-kilometres and other. The vehicle fleet in turn is divided into vehicle categories: passenger car, light truck, heavy truck, urban bus, long-distance bus, moped/motorcycle. The total number of vehicles per category is given as input data for each year of calculation.

In a first program stage ARTEMIS works only with a gross vehicle weight classification of the actual truck, and then in a subsequent stage describes a vehicle combination as a function of the proportion of driving with a trailer per weight class. Input data relating to weight class distribution is given as a percentage number distribution per vehicle category and year of calculation. Further subdivisions are made into age classes and requirement level classes, both of which are given at weight class level.

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[64] The programme principally has a traditional structure for exhaust gas calculation. What distinguishes ARTEMIS from other emission models is the fine division into traffic situations. Of the total of more than 200 possible traffic situations, 69 are used to describe Swedish traffic. The division into traffic environments is made at two levels: a) higher level: urban not motorway; urban motorway; rural not motorway and rural motorway; b) lower level: for each in the previous item a division according to road width; speed limit; alignment and traffic load.

[65] The work has been funded by a research programme known as EMFO.

[66] Another application has been environmental evaluation of the Stockholm trial, see Evaluation of the effects of the Stockholm trial on the exhaust gas emissions of road traffic. VTI publication 2006-06-19. Swedish National Road and Transport Research Institute Work is also in progress to implement selected parts of ARTEMIS in the National Road Administration’s object analysis model EVA.

[67] The term VOC is used instead of HC in this report. This is because the calculation values established by SIKA/ASEK are defined in relation to VOC. HC is divided in ARTEMIS into the groups CH4 (methane) and NMHC (non-methane hydrocarbons).

Traffic activity comprises annual average distance driven per vehicle category and per weight class, annual distance driven as a function of vehicle age per weight class, the distribution of freight vehicle-kilometres between traffic situations per vehicle category and load factors for heavy trucks, as a function of vehicle age per class. Other input data include the following: properties of fuels used during the year, temperature conditions during the year, distribution of journey length, distribution of parking times for different times of the day.

Economic valuation

A calculation procedure which needs to be described in greater detail is used in the economic evaluation of emissions in urban areas. A simple multiplication of calculation of calculation values, expressed in SEK/kilogram and quantity, takes place for regional and global effects, but both many people are affected and where in the country the emissions take place are taken into account in assessing the local effects. In order to be able to take account of how many are affected by the emissions, the method specifies that exposure units must be calculated. The value sought is the calculation value expressed in SEK per kilogram, which is obtained using the following formula:

SEK per kilogram = 0.029 * F_v * populationsize^{0,5} * SEK/exposure unit

F_v is a ventilation factor which is 1.0 in the coastal areas of southern Sweden and becomes higher the further north we go in Sweden and amounts to 1.6 in the inland areas of the counties of Norrbotten and Västerbotten. The ventilation factor 1.0 is used in the calculations as we do not have detailed information on where the emissions take place. The population size in our case is equal to the average size of an urban area in Sweden, which is 27 000 inhabitants.

4.5.2 Input data and calculation values

The reference alternative in Scenario A is assumed to correspond to the calculation conditions for the National Road Administration’s 2006 annual report. A key item of input data for the calculations of exhaust gases with ARTEMIS is freight vehicle-kilometres per vehicle category, where heavy truck is one such category.

*Table 4.10 Exhaust emissions for heavy truck traffic (tonnes) in 2005.**

Tonnes	CO2	CH4	NMHC	NOx	PM
	3 799 439	36	1 749	39 584	943

* Marginal differences compared with the emission statistics may occur as a result of minor adjustments, improvements, of input data.

The exhaust gas effects of a reduction in maximum gross vehicle weight to 40 tonnes in ARTEMIS calculations are expected to be manifested through the redistribution of freight vehicle-kilometres between weight classes and change in load factors.

A change in maximum permitted gross vehicle weight to 40 tonnes has been assumed to signify a redistribution of freight vehicle-kilometres over 40 tonnes to trucks with trailers in the 34–40 tonnes gross vehicle weight class according to the table below.

Table 4.15 Freight vehicle-kilometres (millions of vkm) in 2005.

Gross vehicle weight class (tonnes)	Scenario A	Scenario B	Scenario C
3.5–34	1 397	1 397	1 397
34–40	155	3 855	3 439
40–50	641		
50–60	2 037		
Total	4 230	5 252	4 836

Emission factors differ in urban and rural areas. In the present study the proportion of urban driving for heavy trucks with trailers has been estimated at around 15 per cent in all scenarios.

The breakdown of freight vehicle-kilometres into requirement levels for exhaust emissions in each weight class is of great significance for the regulated emissions. The heavier the vehicle combination, the greater the shift towards the older requirement levels, i.e. towards higher emissions expressed as grams/kWh. A new breakdown for 34–40 tonnes has been formed for the alternative with maximum limit 40 tonne gross vehicle weight so that the breakdown of freight vehicle-kilometres into requirement levels (Euro classes) is identical to the average distribution for all vehicle combinations with a gross vehicle weight of more than 34 tonnes in the present situation.

Table 4.16 Breakdown of freight vehicle-kilometres, proportion, by requirement level classes for different gross vehicle weight classes of vehicle combination in different scenarios.

	Scenario A			Scenarios C and D
Requirement level	30–40 tonnes	40–50 tonnes	50– tonnes	max. 40 tonnes
50s	0.0%	0.0%	0.0%	0.0%
60s	0.1%	0.0%	0.0%	0.0%
70s	0.1%	0.1%	0.2%	0.2%
80s	1.8%	3.4%	4.7%	4.2%
Euro-1	4.1%	5.6%	7.2%	6.7%
Euro-2	35.0%	39.7%	42.0%	41.1%
Euro-3	58.2%	50.5%	45.5%	47.3%
Euro-4	0.5%	0.5%	0.4%	0.4%
Euro-5	0.1%	0.1%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%

The breakdowns shown in the table relate to Swedish traffic, which has been used in the calculations as representative of all traffic per weight class on Swedish roads.

A change in maximum permitted vehicle combination weight is expected to affect the load factors. The average load factors in the table below have been used in ARTEMIS calculations of emission quantities for different scenarios. It is taken into account in the table that the volume of freight per truck transported on average in the weight class 34–40 tonnes increases from around eight tonnes to 13 tonnes.

Table 4.17 Load factors (%) per scenario and weight classes for description of relative effects.

Gross vehicle weight class (tonnes)	Scenario A	Scenario B	Scenario C
34–40	34.6%	55.8%	55.8%
40–50	46.9%		
50–	46.9%		

The following method has been chosen to describe emissions according to the alternative scenarios:

- Calculate total emissions for the weight class 34–60 tonnes with load factors according to Table 4.17
- Calculate the following ratios for each substance and area type: B/A and C/A
- Multiply the values according to the emissions statistics for 34–60 tonnes by the calculated ratios, which gives the total emissions for 34–40 tonnes with the alternative weight limit.

Emissions of CO_2 have been calculated as a function of fuel consumption according to ARTEMIS, expressed in tonnes, by multiplication[68] by 3.07 for diesel. These factors take account of the present of renewable fuels in diesel in 2005.

The cost-benefit calculation values used are taken from ASEK[69].

Global effects

Carbon dioxide SEK 1.5/kg

The sum of emissions in urban and rural areas is used to calculate the global effect.

Regional effects

NOx SEK 62/kg
VOC (CH4 + NMHC) SEK 31/kg

The sum of emissions in urban and rural areas is used to calculate the regional effect.

Local effects

NOx SEK 1.5/exposure unit
VOC (CH4 + NMHC) SEK 2.5/exposure unit
Particulates SEK 426/exposure unit

68 Information from Håkan Johansson, National Road Administration.
69 SIKA PM 2005:16, Kalkylvärden och kalkylmetoder (Arbetsgruppen för samhällsekonomiska kalkyler ASEK). En sammanfattning av Verksgruppens rekommendationer 2005.

Figures on emissions in urban areas are used to calculate the local effect. This means that emissions in urban areas are used twice. However, the calculation values are adapted so that no duplicate counting takes place.

Figures on how many are affected by the emissions are required in order to calculate the local effects. The average size of urban area in Sweden, which is 27 000 inhabitants, is used here. 15 per cent of the volume of traffic in terms of freight vehicle-kilometres is assumed to be in urban areas.

4.5.3 Results

Emission quantities

Total emissions and emissions broken down by rural and urban area according to the various scenarios are shown in the tables below.[70]

Table 4.18 Total effects (tonnes) in 2005 according to different scenarios.

	Diesel	CO2	CH4	NMHC	NOx	PM
Scenario A	1 235 866	3 799 439	35.7	1 749	39 584	943
Scenario B	1 314 775	4 041 688	40.5	1 987	42 201	1 014
Scenario C	1 201 422	3 693 696	37.3	1 828	38 612	930

Table 4.19 Effects on rural areas (tonnes) in 2005 according to different scenarios.

	Diesel	CO2	CH4	NMHC	NOx	PM
Scenario A	858 884	2 640 688	23.2	1 135	27 510	651
Scenario B	911 940	2 803 571	26.4	1 291	29 231	701
Scenario C	833 835	2 563 787	24.2	1 188	26 767	643

Table 4.20 Effects in urban areas (tonnes) in 2005 according to different scenarios.

	Diesel	CO2	CH4	NMHC	NOx	PM
Scenario A	376 982	1 158 751	12.5	614	12 074	292
Scenario B	402 834	1 238 117	14.2	695	12 970	313
Scenario C	367 587	1 129 909	13.1	640	11 845	287

Economic valuations of exhaust emissions

Emissions of carbon dioxide, which leads to global warming, represent the dominant effect. Regional emissions principally have harmful effects on nature but also have some health effects (VOCs). The local emissions principally have health effects but to some extent lead to soiling and corrosion. The local health effects are given a low valuation in comparison with global warming and damage to nature.

[70] Note that the emission levels shown also include emissions from trucks with petrol engines. Fuel consumption is constant between the scenarios and is therefore not shown.

The cost of all exhaust emissions increases in Scenario B. The converse applies to all emissions in Scenario C except VOCs.

Table 4.21 Economic valuations of exhaust emissions in Scenarios B and C (SEK million per year).

	Scenario B (SEKm/year)	Scenario C (SEKm/year)
Global effect		
Carbon dioxide	-363	+159
Regional effect		
NOx	-162	+60
VOC	-7	-2
Local effect		
NOx	-6	+2
VOC	-1	0
Particulates	-43	+10
Total	-582	+229

4.6 Noise emissions

4.6.1 Method

Data from the A, B, C and scenarios has been used to study the noise emission of heavy traffic and the economic effects together with data on noise emissions from the EU-wide mathematical model HARMONOISE.[71] The European model is intended to gradually replace the national calculation methods used today. Noise emission can be calculated on the basis of a vehicle's class, number of axles, speed, acceleration and the road surface concerned.

The advantage of HARMONOISE over the Nordic model[72] for road traffic noise is that it is possible to calculate noise emissions on the basis of a heavy vehicle's speed and number of axles. The Nordic model only differs between heavy and light vehicles so that all vehicles with a gross vehicle weight of more than 3.5 tonnes are treated as equally noisy.

The noise emission from heavy traffic consists of both a contribution to the equivalent 24-hour level (a kind of mean level over a period of 24 hours) and a maximum level at the actual time of passing. The maximum level over a 24-hour period is determined in principle by the noisiest pass, while the equivalent level is affected by the sum of all passes. The following analysis only considers what happens to the equivalent level, but in principle a redistribution of vehicles so that they become shorter and lighter will

[71] de Vos, P. M. Beuving and E. Verheijen (2005). Harmonised Accurate and Reliable Methods for the EU Directive on the Assessment and Management of Environmental Noise – Final technical report.
[72] Jonasson, H. and Nielsen, H. Road traffic noise – Nordic prediction method. TemaNord 1996:525, Nordic Council of Ministers, Copenhagen, Denmark, 1996. ISBN 92-9120-836-1, Naturvårdsverket, Vägtrafikbuller. Nordisk beräkningsmodell, revised 1996. Report 4653.

mean that there are more high peaks during the same period of time, but the peaks are typically slightly lower.

4.6.2 Input data and calculation values

The input to HARMONOISE used here is the number of axles and vehicle-kilometres, which gives the acoustic source strength provided the speed distribution, driving style and road surface are assumed to be identical in the four cases. Note that the changes in noise emission only apply to heavy traffic, and cannot be directly translated to increased sound levels at speeds close to the road network. The economic valuations are taken from SIKA (Swedish Institute for Transport and Communications Analysis) report 2003:2.[73]

4.6.3 Calculation of changes

The calculation of the change in economic external cost is based on the proportion of vehicle-km in urban and rural areas, which using the marginal cost as stated in SIKA report 2003:2 can be directly translated to change in economic cost. The total cost of noise from heavy road traffic is SEK 3 billion per year.[74]

4.6.4 Results

The results of calculation are summarised in Table 4.22, where the change in total noise emission and the change in external noise cost are presented for the different calculation cases A-C. Only the number of axles and vehicle-kilometres play a role in the result for the choice in total noise emission, but the proportion of traffic in urban areas is also important for the external cost as noise from heavy vehicles is valued around nine times higher in urban than in rural areas.

On the assumption that light traffic is identical in the three cases, the increase in external cost for heavy traffic can be converted to apply to total road traffic. Heavy traffic accounts for around six per cent of total freight vehicle-kilometres, but converted to noise this becomes 38 per cent of total noise emission as heavy vehicles are noisier than light ones.

It is worth noting that the calculations of the external cost are expressed in the form of vehicle km and assume an unchanged vehicle fleet, but in this type of analysis the average vehicle on the roads changes with the different assumptions that apply. In the case of the introduction of EU rules for length and weight it is likely that the average vehicle has fewer axles and consequently becomes somewhat quieter. In the basic case transferred freight is assumed to be distributed equally between vehicles with five, six and seven axles.

[73] SIKA Report 2003:2, Trafikens externa effekter - Uppföljning och utveckling 2003.
[74] The total noise from road traffic is valued at SEK 5–10 billion per year according to SIKA report 2003:2. 40 per cent of the noise costs of road traffic come from heavy truck traffic according to Kjell Strömmer of the National Road Administration.

Table 4.22 Effect on noise cost of introducing EU rules for length and weight. Transferred freight evenly distributed between vehicles with 5, 6 and 7 axles.

	Axle km (vehicle km multiplied by number of axles)	Change in total noise emission	Number of vehicle km in urban areas	Change in external noise cost for heavy traffic	Total change in external noise cost
Scenario A	20.9	0	15 %	0	0
Scenario B	27.0	+1.1 dB	14.8 %	+23 %	+9 %
Scenario C	24.5	+0.7 dB	14.8 %	+13 %	+5 %

An increase in the noise from heavy goods traffic on roads of 23 per cent according to Scenario B is estimated to lead to an additional economic cost of SEK 690 million per year. An increase of 13 per cent results in an additional cost of SEK 390 million per year.

As SIKA does not indicate any marginal costs for noise emission of rail traffic, it is difficult to evaluate how transfer to rail affects the figures. It is likely, however, that the extra cost of noise emission by rail traffic is lower than if the equivalent volume of freight had been transported by road as fewer people are exposed to high noise levels from rail traffic than from road traffic in Sweden. A rough valuation is made in 4.8.

4.6.5 Sensitivity analyses

In order to study sensitivity to the assumptions, two cases were examined in which freight was entirely redistributed to vehicles with only five or seven axles. An idea can be obtained in this way of how sensitive the analysis is to the assumption of how the freight is distributed between different numbers of axles.

Table 4.23 Sensitivity analysis of the cost of noise. Transferred freight is distributed to vehicles with 5 or 7 axles instead of being evenly distributed between 5, 6 and 7 axles.

	Change in total noise emission	Change in external noise cost of heavy traffic
Scenario B	0.9–1.3 dB	18–28%
Scenario C	0.6–0.8 dB	9–17%

As the number of axles does not have any impact on SIKA’s change in the external cost of noise (which is based on the number of vehicle km), it is assumed in the analysis that the sound level of the average vehicle is affected in the same way as is described in HARMONOISE, and therefore also the economic cost.

An attempt has been made to estimate what it means to include the number of axle km through a knowledge of how the SIKA values depend on the sound level, which is calculated with HARMONOISE. This is a relatively rough simplification, but at least gives a probable interval in which the cost can vary.

4.7 Tax effects

4.7.1 Method

If more lighter/shorter trucks are used, government revenue from vehicle taxes and Eurovignette charges change and a change in fuel consumption affects receipts of energy taxes and carbon dioxide charges.

Tax receipts are to be regarded as transfers, where one party gains what the other party loses and in themselves are not of economic relevance. However, a relevant real effect occurs which consists in the alternative way of paying in tax, for example through payroll taxes, being associated with distorting effects which may, for example, consist in some people choosing to work less when taxes increase or in increased tax planning. The alternative to vehicle and fuel taxes is thus associated with a cost that society avoids if tax revenue comes from vehicle and fuel tax. The distorting effect has been estimated at 30 per cent[75], which means that 30 per cent of the change in tax has to be included in the calculation.

4.7.2 Input data and calculation values

Vehicle taxes and Eurovignette charges

Statistics show that the freight vehicle-kilometres performed by vehicles longer/heavier than specified by EU standards totals around 2 770 million vkm. If an average distance travelled per year for a heavy truck with trailer of 120 000 kilometres is assumed, around 23 100 vehicle combinations with a gross vehicle weight in excess of 40 tonnes would be affected and replaced. According to our calculations in section 2.2 the vehicle need increases by 37 per cent when the lengths/weights of vehicles are reduced. Around 8 500 more EU vehicles and a total of around 31 600 EU vehicles (23 100 + (23 100 * 0,37) = approx. 31 600) are therefore required to perform the same number of freight tonne-kilometres.

In Scenario A central government receives vehicle taxes and Eurovignette charges from 23 100 Swedish type vehicles. In Scenario B central government would instead receive payments from 31 600 EU type vehicles and in Scenario C from 27 900 EU type vehicles.[76]

Vehicle taxes (for truck and trailer for the Swedish type vehicle and tractor for the EU type vehicle), Eurovignette charges at 2001 prices and the calculated tax revenue are shown in the table below.

[75] Source: ASEK.

[76] In Scenario A the number of vehicle-kilometres totalled 4.23 billion per year. In Scenario B this increases by 24 per cent (=1.015 billion vehicle-kilometres) and in Scenario C this increases by 14 per cent (=0.592 billion vehicle-kilometres). In Scenario C the number of vehicles needs to increase by 0.592/1.015 = 56 per cent of the increase that was required in Scenario B. In Scenario C 23 100 Swedish vehicles are thus replaced by (23 100 + (8500 * (0.592/1.05)) = 27 900 EU vehicles.

Table 4.24 Tax cost of vehicles of differing size (SEK per vehicle and year, at 2001 prices).

Scenario	Type vehicle	Vehicle tax per vehicle (SEK)	Eurovignette charge (SEK)	Tax per vehicle (SEK)	Tax revenue per year (SEK)
A	23 100 Swedish type vehicle	27 039	10 658	37 697	870 800 700
B	31 600 EU type vehicle	14 238	10 658	24 896	786 713 600
C.	27 900 EU type vehicle	14 238	10 658	24 896	694 598 000

Source: SÅKALK (cost calculation model developed by the Swedish Association of Road Haulage Companies

Fuel taxes

Fuel taxes amounted to SEK 3.04 per litre, of which carbon dioxide tax accounted for SEK 1.53 per litre and diesel tax SEK 1.51 per litre. Fuel consumption for trucks with trailers is assumed to be 0.441 litres per vehicle-kilometre.[77] The results obtained with the ARTEMIS model (see 4.5) are assumed in estimating how diesel consumption changes. Diesel (environmental classes 1 and 2) weighs 800–820 kg per cubic metre.[78] It is therefore assumed here that 1 kg is equivalent to 1/0.81 = 1.23 litres.

4.7.3 Calculation of changes

In Scenario B, payments of vehicle taxes and Eurovignette charges for vehicles with a maximum gross vehicle weight of 60 tonnes are estimated to decrease by 23 100 * 37 697 = SEK 871 million. Payments of vehicle taxes and Eurovignette charges for vehicles with a maximum gross vehicle weight of 40 tonnes are estimated to increase by 31 600 * 24 896 = SEK 787 million. Consumption of diesel increases by 78 900 tonnes in Scenario B. 78 900 tonnes is equivalent to 97 million litres, which produces an increase in tax revenue of 97 million * SEK 3.04 = SEK +295 million per year. The economic value of the resultant tax effect is estimated at SEK +63 million per year.

In Scenario C, payments of vehicle taxes and Eurovignette charges for vehicles with a maximum gross vehicle weight of 60 tonnes are estimated to decrease by 23 100 * 37 697 = SEK 871 million. Payments of vehicle taxes and Eurovignette charges for vehicles with a maximum gross vehicle weight of 40 tonnes are estimated to increase by 27,900 * 24 896 = SEK 695 million. Consumption of diesel increases by 34,400 tonnes in Scenario C. 34 400 tonnes is equivalent to 42 million litres, which produces a decrease in tax revenue of 42 million * SEK 3.04 = SEK -128 million per year. The economic value of the resultant tax effect in Scenario C is estimated at SEK -91 million per year.

[77] Banverket (National Rail Administration) BVH 706. Beräkningshandledning, hjälpmedel för samhällsekonomiska bedömningar inom järnvägssektorn.
[78] Source: www.shell.com

Table 4.25 Estimated tax effects in comparison with Scenario A.

	Vehicle taxes, Eurovignette charges SEKm/year	Fuel taxes SEKm/year	Total tax revenue SEKm/year	Economically relevant tax effect SEKm/year
Scenario B. EU standards for trucks, no transfer to rail	-84	+295	+211	+63
Scenario C. EU standards for trucks, investments in rail capacity	-176	-128	-304	-91

4.8 Economic analysis

The extreme case of no volumes being transferable to rail is studied in Scenario B. This provides the worse outcome from the economic point of view. Our judgement is, however, is that this scenario is not so far removed from what can be expected in the short term.

In Scenario C three is an expansion of the railways of around SEK 60 billion (at 2001 prices). The package accommodated the passenger and freight traffic-related measures used when SIKA drew up a freight forecast for 2020 in cooperation with the traffic agencies. Most of the measures are justified by benefits for both freight and passenger traffic, and several of the projects signify deteriorations for freight traffic as the number of passenger trains and/or the speed of passenger trains has increased. Other effects are obtained if freight traffic is prioritised ahead of passenger traffic, so there is no reason to adhere to the figure of SEK 60 billion.

Effects are calculated for the following areas:

Transport cost

If more trucks are required to accomplish a particular level of freight tonne-kilometres, transport cost is estimated to increase by around SEK 7.5 billion per year. If large investments in rail capacity are made, a transfer to rail may take place which reduces the increase in transport cost to SEK 3.1 billion per year. A sharp increase in cost for business is also estimated in this scenario.

Wear

Road wear: The economic cost depends on how axle weights change. The number of trucks is rising, but in our baseline case it is assumed that the new 40 tonne trucks have more axles (evenly divided between five, six and seven axles) than trucks which today are included in the 40 tonne category in Sweden (principally five axles). Road wear costs are thus estimated to increase when the number of trucks increases and they become lighter: by SEK 140 million per year in Scenario B and SEK 201 million in Scenario C.

If the number of axles in the 40 tonne category is not changed a net increase in cost of road wear occurs instead. More axles mean higher vehicle costs. We have not, however, studied the cost distribution between the infrastructure maintainer and the transport industry.

Railway wear: In Scenario C around 5.5 billion tonne-kilometres are transferred from road to rail. On the basis of a cost of war for freight trains of 1.5 öre per tonne-kilometre, wear costs on the railways are estimated at around SEK 83 million.[79] The tax effect of increased payment of track charges is not taken into account.

Road safety

The number of trucks increases, but they also become lighter. However, there is nothing in available accident statistics to suggest that the reduction in truck lengths and weights means that the cost of accidents decreases. A change-over to shorter and lighter vehicles is estimated to lead to an increased number of deaths and injuries and increased costs to society: SEK 491 million per year in Scenario B and SEK 291 million in Scenario C.

Time delay

When the number of trucks on the roads increases, cars will be caught behind trucks increasingly often. This delay is assumed only to arise on narrow roads with two lanes where the speed limit is either 90 or 110 km/h. According to our calculations this entails time delay costs of SEK 50 million in Scenario B and SEK 34 million in Scenario C.

Exhaust emissions

Carbon dioxide: The number of trucks increases, but they become lighter. The economic effect is linked to fuel consumption, which increases in Scenario B and decreases in Scenario C. The economic cost of increased emissions in Scenario B totals SEK 363 million per year. The decrease in emissions in Scenario is valued at SEK 159 million per year.

Other substances: Emissions of NO_X, VOC and particulates increase in Scenario B and decrease in Scenario C. The cost of increased emissions in Scenario B is valued at SEK 220 million per year and the decrease in Scenario C is valued at SEK 69 million per year.

We do not take account of exhaust emissions from rail traffic in Scenario C. Diesel traffic only accounts for a small proportion of freight vehicle-kilometres on the railways and it is assumed that no exhaust gas emissions occur in electricity generation.

Noise emissions

Road noise: The costs to society of noise emissions on the roads are estimated to increase by SEK 690 million in Scenario B and SEK 390 million in Scenario C. The number of trucks on the roads rises, but account also has to be taken of the change in the number of axles. The economic cost depends on how axle weights change. The reverse situation applies compared with the cost of wear. More axles result in more noise but less wear.

Railway noise: The relationship between the economic valuation of road and railway noise is used to obtain a rough estimate of the order of magnitude of the increase in noise on the railways in Scenario C. We assume that the cost of noise nuisance from heavy truck traffic amounts to SEK 3 billion pear year. SIKA Report 2003:2 states that

[79] Andersson, Mats. Empirical Essays on Railway Infrastructure Costs in Sweden, 2007.

nuisance from rail traffic can be valued at SEK 0.46 billion per year.[80] Approximately half of this nuisance comes from freight traffic on rail, which results in a cost of SEK 0.23 billion per year. Noise nuisance from freight traffic on rail represents 0.23/3 = 7.7 per cent of the noise nuisance from heavy road traffic. In Scenario C the noise nuisance of road traffic is estimated to increase by 13 per cent, compared with 23 per cent in Scenario B. In Scenario C the noise nuisance from road traffic is estimated to decrease by three billion * 0.13 = 0.39 billion SEK and the noise from the railways is estimated to increase by around 390 million * 0.077 = 30 million SEK per year.

Tax effects

Payments of vehicle taxes and Eurovignette charges change when trucks increase in number but become smaller. Increased fuel consumption leads to increased payment of fuel taxes to central government. However, it is not the whole amount that is economically relevant here but 30 per cent, which is considered to be equal to the economic cost of tax take. The justification for this calculation is that vehicle and fuel taxes signify less distorting effects (for example people working less due to higher payroll tax) than if the same amount was collected via distorting tax on work.

In Scenario B tax payments increase by SEK 211 million per year, which leads to an economic benefit of SEK 63 million per year. In Scenario C tax payments increase by SEK 304 million per year, which leads to an economic cost of SEK 91 million per year.

[80] Source: SIKA Rapport 2003:2, Etappmål för en god miljö, pages 23–24.

Table 4.26 Economic benefits in the case of a reduction in permitted truck lengths and weights (minus sign indicates a deterioration, plus sign an improvement).

	Scenario B SEKm/year	Scenario C SEKm/year
Transport cost	-7 525	-3 147
Of which change in tax[81]	*+211*	*-304*
Road wear	+140	+201
Railway wear	0	-83
Road safety	-491	-291
Time delay	-50	-34
Exhaust emissions		
Carbon dioxide	-363	+159
Other substances[82]	-220	+69
Noise emissions road	-690	-390
Noise emissions rail	0	-30
Tax effects	+63	-91
Total	-8 925	-3 941

The total of benefits and costs estimated to arise when the trucks in Scenario B become shorter and lighter is around SEK 8.9 billion per year if it is not possible to transfer freight to rail.

Note that the lower cost in Scenario C is a consequence of two changes. Firstly large investments have been made in the railways, which in itself leads to freight being transferred to rail. The total cost to society decreases by around SEK 2.2 billion per year as a consequence of this. In addition to this there is the decrease in load capacity of trucks, which leads to a further transfer to rail, signifying a decrease in the cost to society of lower load capacity on the road of SEK 3.9 billion per year.

The cost of transport dominates the CBA. According to our rough calculations business recoups the volume of investment in increased load-bearing capacity of SEK 46 billion in just over six years (in Scenario B) and fifteen years (in Scenario C). The remaining cost of measures to increase load-bearing capacity is recouped after four years (in Scenario B) and just under ten years (in Scenario C).

[81] The projected change in vehicle cost relates to all changes in costs for business. This also includes changes in tax payments. The change in tax payments is, however, a transfer in which one party gains at the expense of the other and there is thus no net effect for society. The costs to business increase in Scenario B because they have to pay more tax than in Scenario A. However, the extra tax benefits society in another way, and this amount is therefore added as a positive item. In Scenario C tax payments by business decrease in comparison with Scenario A. The gain for business (which has been calculated) is offset here by the loss (to central government) being added as a costing item.

[82] NOx, VOC, particulates.

Sensitivity analysis

The dominant effect is the cost of transport. The principal source of error in Scenario B is probably how many further vehicles are required when load capacity per truck decreases. This uncertainty is, however, not so great as to prevent the result being regarded as very robust. Shorter and lighter vehicles entail large additional costs for transportation buyers. The uncertainty in Scenario C is far greater as we attempt here to estimate how much freight can be transferred to rail. Despite there being great uncertainty regarding the size of the transfer, it is also clear here that shorter and lighter vehicles result in large increases in transport costs.

After transport cost it is noise and exhaust emissions that weigh most heavily. It may be interesting to note that the transfer to rail that takes place in Scenario C is sufficient for exhaust emissions to change between positive and negative.

The calculation of road wear was found to be sensitive to the assumption on how many axles a future 40-tonne fleet of trucks will have. If these future vehicles do not have more axles than the present-day trucks in the 40-tonne class, an increase in wear will instead arise for the projected decrease in wear. However, this uncertainty does not weigh heavily when set against the change in transport costs.

5 Effects of changed vehicle provisions outside Sweden

There is great international interest in Swedish experience with larger vehicles. To shed light on what effects can be expected if longer and heavier trucks are authorised in the EU as a whole, the European Commission has ordered a study which is due for completion in the summer of 2008.[83] OECD/ECMT[84] have launched a three-year period entitled *Heavy vehicles: regulatory, operational and productivity improvements*.

The experience and conclusions presented above concerning the use of longer and heavier trucks in Sweden cannot be automatically transposed to other countries or the whole of Europe. The composition of commodities transported by road and the proportion of road and rail transport differ. The characteristics of the infrastructure and its utilisation for passenger and freight transport as well as patterns of building development and the external effects of traffic differ between different countries.

Infrastructure

In contrast to most countries Sweden has made investments in the road network that allow for heavier and longer trucks. Measures to increase load-bearing capacity have also been implement on the railways, which strengthens the ability of the railways to compete with long and heavy trucks. Both longer trucks and longer trains are used in Sweden than in other countries.

From the international point of view, the degree of utilisation of the Swedish road network is relatively low. Congestion occurs in the metropolitan areas at certain times of the day. The capacity in the rail network is utilised to a great extent and the same tracks are used for passenger and freight traffic.

Composition of commodities

Sweden has a high proportion of raw material-related industry based on timber, paper and minerals. It has a high proportion of exports. This, combined with the fact that Sweden is an elongated country, has meant that the railways are better placed to compete with heavy trucks than in the rest of the EU. Large volumes of relatively low-value freight are moved over long distances, often from a small number of large production facilities, which makes concentrated freight flows possible. These circumstances do not just strengthen the competitiveness of the railways but also mean that businesses have good opportunities to make full use of the capacity of heavy and long trucks.

International transport

Some differences become apparent if Sweden’s domestic and cross-border transport are compared. Around four-fifths of all freight tonne-kilometres carried between Sweden and its neighbours in northern Europe (Denmark, Norway, Finland, Germany and the

[83] http://ec.europa.eu/dgs/energy_transport/tenders/index_en.htm Study on the effect of adapting the rules on the weights and dimensions of heavy commercial vehicles as established within Directive 96/53/EC regarding their ability to match the needs of advanced logistics and sustainable mobility.
[84] Organisation for Economic Co-operation and Development/European Conference of Ministers of Transport

Netherlands) in 2005 was accounted for by trucks registered abroad and one fifth by Swedish-registered trucks.[85]

Swedish-registered and foreign-registered trucks together carried at least 20.4 million tonnes to/from Sweden. However, there are some unreported figures as we do not have statistics for trucks registered in countries other than those mentioned above. Around 25 million tonnes are transported by to/from Sweden by rail. (No comparisons of freight tonne-kilometres are presented because foreign statistics are not comparable for road and rail.)

Proportion of international transport for road and rail

Significantly larger volumes of freight are transported by road than rail in Sweden. With regard to transport to and from Sweden, however, volumes are greater by rail. This is largely due to the extensive transporting of iron ore from Kiruna via Narvik in Norway to destinations in Europe and other parts of the world. If iron ore is excluded the international proportion for the railways falls from 39 per cent to 24 per cent. It may be added that shipping is by far the dominant mode of transport for international transport.

Figure 5.1 Volume of freight (tonnes) transported within Sweden and internationally by road and rail in 2005.

As well as *Iron ore and scrap*, which accounts for almost 60 per cent of the volume of freight transported by rail to/from Sweden, *Metal products* (2.5 million tonnes) and *High-value products* (3.7 million tonnes) are moved internationally.

[85] Eurostat, SIKA/SCB: Undersökning Inrikes och utrikes trafik med svenska lastbilar, 2005.

Table 5.1 Volume of freight (millions of tonnes) transported by rail, broken down into domestic and international, and the share of international rail transport in total rail transport (%) in 2004.

Commodity group	Domestic	International	Proportion international
	million tonnes	million tonnes	
Agriculture	0.13	0.04	24%
Round timber	4.61	0.48	9%
Wood products	0.67	0.21	24%
Food products	0.46	0.09	16%
Crude oil and coal	0.19	0.00	0%
Oil products	0.96	0.02	2%
Iron ore and scrap	13.09	15.28	54%
Steel products	5.99	2.52	30%
Paper and pulp	1.36	0.58	30%
Earth, stone, construction	0.56	0.21	27%
Chemicals	0.55	0.44	44%
High-value products	7.83	3.69	32%
Total	36.37	23.54	39%

Source: SIKA/National Rail Administration

The competitiveness of the railways in Sweden is probably affected more if longer/heavier trucks are permitted in the rest of the EU than if trucks longer than 18.75 m and heavier than 40 tonnes are not permitted in Sweden. This is principally due to changes abroad affecting long-haul transport and changes in Sweden affecting shorter-distance transport.

The railways hold a strong position in Sweden compared with other countries, however, partly due to efficiency improvements and block train initiatives.

No symmetry

Symmetrical conditions cannot be assumed. Where we can see long and heavy trucks being used we know that the haulier considers the volumes to be moved to be sufficiently large for the greater load capacity to be utilised.

In a situation in which longer and heavier vehicles are permitted, we do not know how high a proportion of consignments can benefit from the greater load capacity. It is estimated that 25 per cent of short-haul and long-haul freight in Germany could be carried by modular vehicles of the Swedish type.[86]

[86] Keuchel, S. Ernst, H. Richter, C. Mühlhause, M. Fachhochschule Gelsenkirchen, Forschungsprogramm Strassenverkehrswesen FE 03.400/2005/ARB, Auswirkungen auf die Strasseninfrastruktur infolge einer Erhöhung der Abmessungen und zulässigen Gesamtgewichte von Lkw, Recklinghausen , November 2006.

6 Conclusions

An analysis compares the situation in Sweden, where it is possible to use longer/heavier vehicles than in the rest of the EU, with a hypothetical situation in which EU rules are introduced in Sweden. The volume transported is assumed to be constant. Two scenarios have been studied, Scenario B, where no transfer to rail is possible, and Scenario C, where transfer is possible.

The result is that it is not cost-effective to use shorter and lighter trucks. The loss is estimated to be greater in Scenario B (around SEK -8.9 billion) than in Scenario C (around SEK -3.9 billion).

The dominant effect is increased transport costs.

The investments in load-bearing capacity which the National Road Administration began in 1988 to adapt the standard of the roads to the demands of heavy vehicles are expected altogether to cost SEK 46 billion. This cost is recouped by society after just over five years in Scenario B and after just under twelve years in Scenario C.

Table 6.1 Economic costs and benefits to society (at 2001 prices). A minus sign indicates a deterioration and a plus sign an improvement for society.

	Scenario B SEKm/year	Scenario C SEKm/year
Transport cost	-7 525	-3 147
Of which change in tax[87]	*+211*	*-304*
Road wear	+140	+201
Railway wear	0	-83
Road safety	-491	-291
Time delay	-50	-34
Exhaust emissions		
Carbon dioxide	-363	+159
Other substances[88]	-220	+69
Noise emissions road	-690	-390
Noise emissions rail	0	-30
Tax effects	+63	-91
Total	-8 925	-3 941

[87] The projected change in vehicle cost relates to all changes in costs for business. This also includes changes in tax payments. The change in tax payments is, however, a transfer in which one party gains at the expense of the other and there is thus no net effect for society. The costs to business increase in Scenario B because they have to pay more tax than in Scenario A. However, the extra tax benefits society in another way, and this amount is therefore added as a positive item. In Scenario C tax payments by business decrease in comparison with Scenario A. The gain for business (which has been calculated) is offset here by the loss (to central government) being added as a costing item.

[88] Nitrogen oxides (NOx), VOC, particulates.

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.

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.

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.

This work has been limited by deficiencies in the available statistics. Figures on transported volumes measured in cubic metres and complete figures for transportation on trucks registered abroad, for example, are lacking.

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Assignment

	Government decision	II 4
SWEDISH GOVERNMENT	03.04.2007	N2007/3271/TR

Ministry of Enterprise, Energy and Communications

Swedish National Road and Transport Research Institute

581 95 LINKÖPING

<u>Assignment to study the effects of long trucks on the transport system</u>

Background

The maximum vehicle length for truck transportation between countries in the EU and EEA is 18.75 metres (Directive 96/53/EC). If a member state wishes to permit longer vehicles for freight transportation this is only possible for national traffic and provided that the transportation is carried out with specialised vehicles or that the member state permits transportation based on modules that can be used by the hauliers of other countries, the 'modular concept'.

Only Sweden and Finland in the EU and EEA have made use of the possibility of allowing trucks up to 25.25 metres and 60 tonnes gross vehicle weight. Denmark and the Netherlands have carried out trials with the modular system and some federal states in Germany also allow longer vehicles. The purpose of these trials is to examine what effects introducing long vehicles would have for the transport system. There is concern in the EU and EEA that longer and heavier trucks would lead to a deterioration in the competitiveness of the railways, increased wear on the roads, increased emissions and a deterioration in road safety. Studies that have been done both support and contradict these claims. There is therefore a need to develop and collate knowledge in this area with the aim of making an economic and commercial assessment of what effects the long truck combination has on the transport system.

The assignment

Competition between road and rail transportation

The Swedish National Road and Transport Research Institute (VTI) is to investigate whether long truck combinations lead to a deterioration in the competitiveness of freight transportation by rail. In this investigation VTI is to describe what proportion of present-day road and rail traffic competes with each other and ways of influencing competition conditions for rail traffic by various measures in the area of road traffic. A report on this is to be presented by 15 June 2007.

Wear on the road network

VTI is to investigate what effect the current Swedish rules have for wear on the Swedish road network and the annual cost of this. In addition, VTI is to investigate what wear on the Swedish road network would be like if only 18.75 metre trucks and 40 tonne maximum weight were permitted.

Emissions

VTI is to compare the level of emissions from present-day freight transportation by road with a hypothetical situation in which only 18.75 metre trucks and 40 tonnes maximum weight are permitted. This analysis is to take account of any effects on rail traffic.

Road safety

VTI is to compare the number of accidents with present-day freight transportation by road with a hypothetical situation in which only 18.75 metre trucks and 40 tonnes maximum weight are permitted. This analysis is to take account of any effects on rail traffic.

Congestion

VTI is to present an assessment of how the number of trucks on the Swedish road network will change with an imagined situation in which only 18.75 metre trucks and 40 tonnes maximum weight are permitted. This analysis is to take account of any effects on rail traffic.

Economic assessment of present-day vehicle regulations

VTI is to report on what economic effects present-day regulations with 25.25 metre trucks and 60 tonnes maximum weight has in comparison with regulations under which only 18.75 trucks and 40 tonnes maximum weight are permitted.

Final report

VTI is to present a final report to the Swedish Government Offices (Ministry of Enterprise, Energy and Communications) on the results of the above investigations by 1 December 2007.

On behalf of the Government

[signed]

Åsa Torstensson

[signed]

Johan Ericson

Copies

Swedish Institute for Transport and Communications Analysis

National Road Administration

National Rail Administration

Tables

Weight of and number of axles on trucks

Table 1 Freight vehicle-kilometres with trucks based on gross vehicle weight classes[89] *(according to Körsträckestatistiken – statistics on distances driven) and number of axles (according to Lastbilsstatistiken – truck statistics) in 2005.*

	Number of axles								
Gross vehicle weight / Number of axles	2	3	4	5	6	7	8	9	Total
Truck 3.5–7.5 tonnes	0.0%								0.0%
Truck 7.5–12 tonnes	5.2%								5.2%
Truck 12–14 tonnes	0.6%								0.6%
Truck 14–20 tonnes	12.2%	0.0%							12.2%
Truck 20–26 tonnes	3.5%	4.3%							7.8%
Truck 26–28 tonnes		7.5%							7.5%
Truck 28–32 tonnes		1.4%	0.2%						1.6%
Truck over 32 tonnes		0.0%	0.4%						0.4%
Truck with trailer under 28 tonnes		0.2%	0.1%						0.3%
Truck with trailer 28–34		0.1%	0.2%						0.2%
Truck with trailer 34–40		0.0%	0.6%	0.3%	0.0%				0.9%
Truck with trailer 40–50		0.1%	0.3%	2.9%	0.2%				3.5%
Truck with trailer 50–60 tonnes			0.4%	9.6%	12.7%	36.1%	0.9%	0.1%	59.8%
Combined total	21.6%	13.5%	2.1%	12.8%	12.8%	36.1%	0.9%	0.1%	100.0%

[89] Gross vehicle weight is defined as the vehicle's kerb weight and the maximum quantity of freight for which the vehicle is arranged.

Table.2 Freight vehicle-kilometres with trucks based on actual weight classes[90] (according to Körsträckestatistiken – statistics on distances driven) and number of axles (according to Lastbilsstatistiken – truck statistics) in 2005.

	Number of axles								
Actual weight / Number of axles	2	3	4	5	6	7	8	9	Total
Truck 3.5–7.5 tonnes	1.8%								1.8%
Truck 7.5–12 tonnes	8.4%	2.2%	0.0%						10.6%
Truck 12–14 tonnes	2.9%	2.7%	0.2%						5.8%
Truck 14–20 tonnes	4.1%	4.9%	0.2%						9.2%
Truck 20–26 tonnes	0.1%	4.7%	0.2%						5.0%
Truck 26–28 tonnes		0.5%	0.1%						0.6%
Truck 28–32 tonnes	0.0%	0.1%	0.2%						0.3%
Truck over 32 tonnes	0.0%	0.1%	0.0%						0.1%
Truck with trailer under 28 tonnes		0.3%	1.0%	5.7%	5.0%	11.1%	0.3%	0.0%	23.5%
Truck with trailer 28–34		0.0%	0.2%	2.4%	1.7%	1.7%	0.1%	0.0%	6.2%
Truck with trailer 34–40		0.0%	0.1%	3.0%	2.0%	1.8%	0.1%	0.0%	7.0%
Truck with trailer 40–50			0.0%	1.8%	3.1%	4.9%	0.2%	0.0%	10.0%
Truck with trailer 50–60 tonnes				0.3%	1.6%	17.8%	0.3%	0.0%	20.0%
Combined total	17.3%	15.4%	2.3%	13.2%	13.3%	37.3%	0.9%	0.1%	100.0%

[90] Actual weight is defined as the vehicle's kerb eight plus the quantity of freight actually transported.

Commodity groups

Table 3 Contents of the commodity groups.

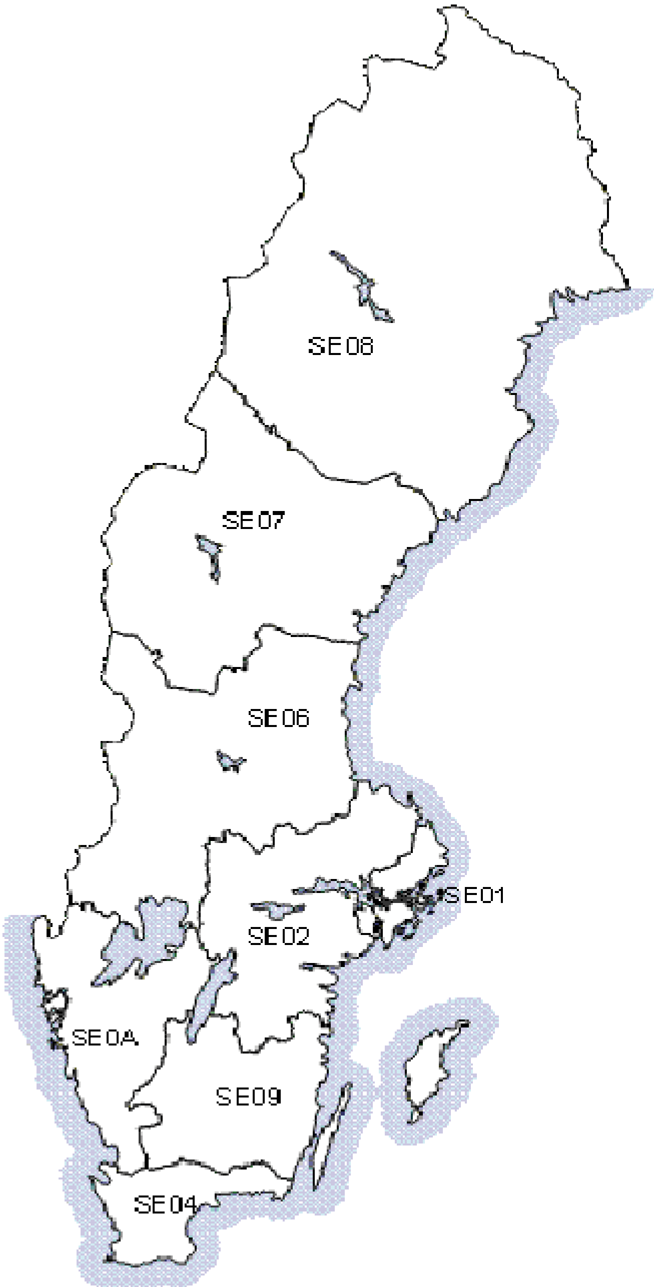
Commodity group	**Contents**				
Agriculture	Cereals	Potatoes, other fresh and frozen vegetables	Live animals, sugar beet	Oilseed and oil-containing fruits	
Round timber	Round timber				
Wood products	Sawn and planed wood products	Chips, wood and sawmill waste	Cork		
Food products	Food products				
Crude oil and coal	Solid mineral fuels	Crude oil			
Oil products	Oil products	Coal-based chemicals, tar			
Iron ore and scrap	Iron ore, iron and steel scrap	Non-ferrous metals or			
Steel products	Steel products				
Paper and pulp	Paper pulp and waste paper	Paper, board and products			
Earth, stone, construction	Cement, lime, building material	Unprocessed or processed mineral substances			
Chemicals	Chemicals other than coal-based and tar	Natural and commercial fertilisers			
High-value products	Transport equipment, machinery	Metal products	Glass, glassware and ceramic products	Leather, textiles, clothing	Other products incl. empty packaging Unknown cargo

Transport costs in the SAMGODS model

Table 4 Average en-route costs (at 2001 prices) for truck with trailer in the Samgods model for each commodity group.

Commodity group	SEK/tonne-km	SEK/tonne-hour
Agriculture	0.1426	9.1127
Round timber	0.1545	19.3858
Wood products	0.1268	14.2277
Food products	0.1326	8.4943
Crude oil and coal	0.1529	18.7951
Oil products	0.1651	14.2477
Iron ore and scrap	0.1105	10.9712
Steel products	0.1269	8.6235
Paper and pulp	0.1210	21.0542
Earth, stone, construction	0.1420	10.2587
Chemicals	0.1302	7.7878
High-value products	0.1381	7.7878
Weighted average	0.1381	11.08

Regional division



Regions

SE01 Stockholm
Stockholm County

SE02 Eastern Central Sweden
Uppsala County
Södermanland County
Östergötland County
Örebro County
Västmanland County

SE09 Småland with the Islands
Jönköping County
Kronoberg County
Kalmar County
Gotland County

SE04 Southern Sweden
Skåne County
Blekinge County

SE0A Western Sweden
Halland County
Västra Götaland County

SE06 Northern Central Sweden
Värmland County
Dalarna County
Gävleborg County

SE07 Central Northern Sweden
Västernorrland County
Jämtland County

SE08 Upper Northern Sweden
Västerbotten County
Norrbotten County

Urban and rural areas

Just over 15 per cent of total heavy truck traffic is estimated to run through urban areas. According to Statistics Sweden urban areas are “all collections of buildings with at least 200 inhabitants, provided that the distance between the buildings normally does not exceed 200 metres. The distance can be allowed to exceed 200 metres, however, in the case of collections of buildings within the area of influence of a larger locality. On the other hand, the maximum distance between buildings should be set lower than 200 metres where the character of the building development indicates that this is appropriate, namely when a clear urban centre is evident in small urban areas and in cases where the boundary between urban and rural area is diffuse, in other words where building development in the urban area does not appear to be substantially more dense than in other nearby built-up areas”. In 2005 there were a total of 1940 urban areas in Sweden. The table below shows that the majority of urban areas have less than 3000 inhabitants. The ten localities with a population of more than 80 000 are in southern or central Sweden.

Table 5 Number and size of urban areas in different parts of the country.

	< 300	< 500	< 1000	< 3000	< 5000	< 10000	< 15000	< 25000	< 40000	< 60000	< 80000	<100000	≥ 100000	Total
Stockholm	23	23	25	15	9	11	3	3	5	1	1	0	1	120
Eastern central Sweden	53	73	70	65	22	19	10	3	3	0	1	3	2	324
Småland with the islands	43	57	56	53	15	10	5	5	1	1	0	1	0	247
Southern Sweden	50	51	71	58	21	27	4	5	4	0	1	1	1	294
Western Sweden	68	85	107	79	26	16	7	9	3	2	1	0	1	404
Northern central Sweden	55	61	62	46	9	15	8	2	2	1	1	0	0	262
Central northern Sweden	26	34	35	24	4	2	1	1	1	2	0	0	0	130
Upper northern Sweden	32	42	28	36	9	6	0	3	1	1	1	0	0	159
Total	350	426	454	376	115	106	38	31	20	8	6	5	5	1 940

Source: Statistics Sweden.

The proportion of vehicle-kilometres of heavy traffic passing through urban areas is highest by far in Stockholm (50.2 per cent) and lowest in Upper Northern Sweden (6.9 per cent). The proportion of vehicle-kilometres in urban areas for other parts of the country is between 11.3 per cent (Eastern Central Sweden) and 18.6 per cent (Southern Sweden).

Regional breakdown of freight vehicle-kilometres

Table 6 Estimated freight vehicle-kilometres with heavy vehicles per region and proportion of vehicle-km with vehicles larger than the maximum EU dimension.

Region	Million vkm	Proportion of vkm with vehicles larger than maximum EU dimension
Stockholm	187	44 %
Eastern central Sweden	888	66 %
Småland (incl. the islands)	442	80 %
Southern Sweden	504	54 %
Western Sweden	1 138	54 %
Northern Central Sweden	590	65 %
Central Northern Sweden	242	79 %
Upper Northern Sweden	260	82 %
Total	4 250	63 %

Source: SIKA statistics on distances driven, own calculations.

Increases in transport costs

Table 7 Estimated increase in costs to transport same volume of freight.

Commodity group	Estimated increase in cost per tonne-km in Sweden	Increase in cost for personnel and other per tonne-hour	Increase in cost for fuel per tonne-km
Agriculture	22%	25%	12%
Round timber	32%	31%	34%
Wood products	22%	25%	12%
Food products	19%	22%	10%
Crude oil and coal	33%	33%	34%
Oil products	33%	33%	34%
Iron ore and scrap	22%	25%	12%
Steel products	22%	25%	12%
Paper and pulp	22%	25%	12%
Earth, stone, construction	35%	38%	27%
Chemicals	27%	26%	27%
High-value products	19%	22%	10%
Average	24%		

The table also shows how much fuel costs and personnel and other vehicle costs are affected. The breakdown is explained by assumptions on how the vehicles are used (annual hours of operation, annual distance driven, relation between distance driven and time).

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VTI är ett oberoende och internationellt framstående forskningsinstitut som arbetar med forskning och utveckling inom transportsektorn. Vi arbetar med samtliga trafikslag och kärnkompetensen finns inom områdena säkerhet, ekonomi, miljö, trafik- och transportanalys, beteende och samspel mellan människa-fordon-transportsystem samt inom vägkonstruktion, drift och underhåll. VTI är världsledande inom ett flertal områden, till exempel simulatorteknik. VTI har tjänster som sträcker sig från förstudier, oberoende kvalificerade utredningar och expertutlåtanden till projektledning samt forskning och utveckling. Vår tekniska utrustning består bland annat av körsimulatorer för väg- och järnvägstrafik, väglaboratorium, däckprovnings-anläggning, krockbanor och mycket mer. Vi kan även erbjuda ett brett utbud av kurser och seminarier inom transportområdet.

VTI is an independent, internationally outstanding research institute which is engaged on research and development in the transport sector. Our work covers all modes, and our core competence is in the fields of safety, economy, environment, traffic and transport analysis, behaviour and the man-vehicle-transport system interaction, and in road design, operation and maintenance. VTI is a world leader in several areas, for instance in simulator technology. VTI provides services ranging from preliminary studies, highlevel independent investigations and expert statements to project management, research and development. Our technical equipment includes driving simulators for road and rail traffic, a road laboratory, a tyre testing facility, crash tracks and a lot more. We can also offer a broad selection of courses and seminars in the field of transport.

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