THE EXTERNAL COSTS OF TRANSPORT

Summary in English

SIKA Report 2001:7

The assignment

The government stated in its official appropriations document for SIKA for the year 2001 that the externalities of transport should be estimated on a regular basis. SIKA is to compile a report presenting estimations of the externalities of transport. This document is the report that has been compiled to meet the above-mentioned objectives and reporting requirements.

The report contains a survey of price-relevant marginal costs for the different modes of transport. There is also information on how marginal cost-related charges can be applied in practice. A corresponding account was compiled for the year 2000 in the SIKA reports 2000:6 and 2000:10 (in Swedish). The emphasis in the present report is on providing information on the new basic data compiled during the year 2001 and the considerations and conclusions arising from this data.

The report is based on material provided by the transport agencies and consultation has taken place in a reference group. The contact persons with principal responsibility were Stefan Pettersson for the National Rail Administration, Lennart Bergbom for the Civil Aviation Administration, Henrik Swahn and Lars Vieweg for the National Maritime Administration, Lars Bergman and Mulugeta Yilma for the National Road Administration and Gunnar Eriksson for the Swedish Ministry of Industry, Employment and Communications. Per-Ove Hesselborn from SIKA was the project leader and has compiled the report. The other SIKA members involved in the project are Anna Johansson, Roger Pyddoke and Anders Wärmark.

Infrastructural charges in Sweden and within the EU

The Riksdag's decision regarding the direction of infrastructural measures in autumn 2001 includes a confirmation of the view on cost responsibility laid down in the 1998 transport policy decision. The cost responsibility should therefore continue to be seen as an important means in the development towards an efficient and sustainable transport system.

The issue of transport infrastructure charges has also been highlighted in other contexts within the EU. In the white paper on the common transport policy which the Commission presented in September 2001 the Commission announces its ambition to present during 2002 a framework directive on infrastructural charges. According to the Commission, this directive should, among other things, establish principles and a structure for infrastructural charges and recommend a common method for establishing charge levels.

There is a large-scale operation in many parts of Europe to develop a kilometre tax system for heavy lorries. On 1 January 2001 Switzerland introduced such a system, designed to reflected externalities. Germany has announced its ambition to introduce an equivalent system during 2003. Austria and the Netherlands are also considering such action.

In February 2001 another EU directive was approved which, among other things, establishes charging within rail transport and states that the charges should correspond to "the cost arising as a direct result of the train traffic operated", i.e. marginal social cost. The directive is expected to be introduced in March 2003. At present implementation work is being carried out both at a European level and in Sweden.

Various investigative and developmental measures are also being carried out in Sweden and within the EU in connection with passenger transport on the roads and air and sea travel, and this can be seen as progress towards a more efficient charging policy.

Marginal costs within road transport

Road transport's *wear and tear costs* have previously been estimated on the basis of an acceptance of the size of the transport-dependent proportion of the National Road Administration's costs for operation and maintenance. These costs were then divided between heavy vehicles and cars based on the number of standard axles. A cost per vehicle-kilometre could thus be estimated per type of vehicle.

A research project carried out at the Swedish National Road and Transport Research Institute has now indicated a way of estimating marginal costs by linking engineering knowledge of deterioration correlations and economic theory. In principle the recommended approach allows detailed differentiation in terms of differences in road strength and the number of standard axles.

The marginal costs for wear and tear are between three and seven times as high for a light lorry as they are for a car. For heavy lorries they are about twice as high as for light lorries. No new estimates have been compiled for cars.

Marginal external *congestion costs* have been estimated on the basis of the National Road Administration's "volume-delay functions" at 10 points in rural locations in the national trunk road network. The estimates indicate that the marginal costs at four of the points are considerable. If the estimates prove to be accurate, we may conclude that congestion costs cannot be ignored in the rural road network.

The marginal *accident cost* consists of several components. There is a risk factor and there are also parameters which vary between different types of vehicle and their properties in relation to other vehicles that may be involved in an accident.

While it has previously been assumed that the risk increases with the number of lorries, a new estimate of risk elasticity indicates that the risk decreases the longer a lorry continues travelling. The result may be interpreted to mean that the risk increases on a certain road according to the lorries while the risk for a given lorry decreases with increased length of travel. Estimated risk elasticities vary according to weight category and average out at -0.8, which is far from the previously accepted 0.5. On average an accident cost obtained is only a tenth of what was previously estimated.

Although considerable progress has been made in respect of the theory and empirical analysis of a vehicle type, there are still a number of problems to solve before we can provide reliable estimates of road traffic's external accident costs. SIKA's conclusion is that we should not now change the estimates of the accident costs previously presented by the National Road Administration.

Previous estimates of *exhaust emission costs* aimed to highlight the sizeable variation in respect of vehicle types, fuel consumption and where the traffic takes place. The emission cost levels presented were considered unreliable and merely indicative. The National Road Administration has now sought to take into account the fact that emission factors in built-up areas differ according to such parameters as population density, traffic intensity and road type. The aim has been to evaluate the variations in emission factors between different large built-up areas and to discuss how the emission factors can be assumed to vary for different road and street types.

In built-up areas the harmful effects are generally much higher. It is mainly the cost of discharged particles which makes the cost for diesel cars much higher in built-up areas than for petrol-driven cars. The marginal cost per vehicle-kilometre for emissions also increases in line with the size of the built-up area, mostly for diesel cars, with extremely high values in Stockholm's inner city.

There is also variation for heavy lorries in terms of the marginal emission costs for different types of vehicle, mostly due to weight but also to other properties. The cost for built-up areas is considerably higher than in rural areas. For lorries, this is also due to particle discharge. The cost is therefore especially high in Stockholm's inner city.

For cars in rural areas the cost of carbon dioxide is much higher than other emission costs, apart from petrol-driven cars without catalytic converters, which have the highest emissions of other substances. For lorries too, the carbon dioxide costs account for a higher proportion of the total emission costs in rural areas compared with built-up areas. The absolute carbon dioxide cost is, however, highest in built-up areas, especially for lorries with a high fuel consumption.

The amount of *noise* generated depends on a vehicle's noise properties and on traffic flow. The extent to which people are disturbed by road traffic noise depends in turn on how people live in relation to the road and how they are disturbed by the specific road traffic noise. Therefore, a factor which is of crucial importance is population density. This varies considerably between built-up areas and between sections of the built-up area in question.

The National Road Administration has tried to illustrate the variation in noise costs in different built-up areas. The analyses have been based on general assumptions in respect of the number of people disturbed and the traffic intensity. Although nothing definitive can be stated with regard to the marginal cost in the respective built-up area, we can, however, conclude that the estimates are dependent upon population density and traffic intensity. This means that a report

based on only two types of environment, built-up and rural, involves broad generalisations.

The noise costs have been estimated for cars, heavy lorries and other heavy vehicles. For heavy lorries an interval has also been specified based on the speed of the vehicle since the noise cost is considerably higher at low speeds. The estimated noise costs vary from SEK 0.008 per vehicle-kilometre for cars in rural areas to SEK 2.41 per vehicle-kilometre for heavy lorries driven at low speed in densely built-up areas.

The following tables show, in order:

- The size of the estimated total marginal costs for different types of road vehicle with different valuation of carbon dioxide emissions.
- How the energy tax on petrol and diesel oil equates to the estimated marginal costs for cars.
- How the energy tax on diesel oil equates to the estimated marginal costs for heavy lorries.

Table 1.1. Estimated marginal costs (mc) for different types of road vehicle with different valuation of carbon dioxide emissions.

	Total mc excl. CO_2	*Total mc CO_2 SEK 0.50/kg*	*Total mc CO_2 SEK 1.50 /kg*
Rural area			
Car, petrol with catalytic converter	1.98	3.18	5.59
Car, petrol without catalytic converter	4.69	5.87	8.23
Car, diesel with catalytic converter	2.55	3.84	6.42
Car, diesel without catalytic converter	2.48	3.74	6.25
Heavy lorry 3.5-16 tonne	3.15-3.34	4.42-4.61	6.97-7.15
Heavy lorry >16 tonne	2.61-3.20	3.88-4.46	6.41-7.00
Built-up area			
Car, petrol with catalytic converter	3.27	4.44	6.77
Car, petrol without catalytic converter	7.04	8.20	10.52
Car, diesel with catalytic converter	5.73	7.00	9.56
Car, diesel without catalytic converter	12.91	14.17	16.69
Heavy lorry 3.5-16 tonne	9.72-9.92	10.99-11.18	13.51-13.71
Heavy lorry >16 tonne	6.33-9.18	7.60-10.45	10.13-12.98

The estimates may differ considerably between different built-up areas. Landskrona is used as a typical built-up area. For noise, where estimates exist for different types of environment, the values for the environment with the densest population structure have been used. For wear and tear the interval's lowest section is for lorries without trailers, the highest section for lorries with trailers. For noise the interval's lowest section is for lorries at high speed, the highest section for lorries at low speed.

Table 1.2. Comparison between energy tax on fuel and marginal cost (mc) for cars.

		Energy tax (SEK/litre)	*Total mc (SEK/litre)*	*Tax/mc*
Rural area	Car, petrol with catalytic converter	3.16	1.98	1.60
	Car, petrol without catalytic converter	3.16	4.69	0.67
	Car, diesel with catalytic converter	1.323	2.55	0.52
	Car, diesel without catalytic converter	1.323	2.48	0.53
Built-up area	Car, petrol with catalytic converter	3.16	3.27	0.97
	Car, petrol without catalytic converter	3.16	7.04	0.45
	Car, diesel with catalytic converter	1.323	5.73	0.23
	Car, diesel without catalytic converter	1.323	12.91	0.10

Table 1.3. Comparison between energy tax on fuel and marginal cost (mc) for heavy goods vehicles.

		Energy tax (SEK/litre)	*Total mc (SEK/litre)*	*Tax/mc*
Rural area	Heavy lorry 3.5-16 tonne	1.323	3.15-3.34	0.42-0.40
	Heavy lorry >16 tonne	1.323	2.61-3.20	0.51-0.41
Built-up area	Heavy lorry 3.5-16 tonne	1.323	9.72-9.92	0.14-0.13
	Heavy lorry >16 tonne	1.323	6.33-9.18	0.21-0.14

Carbon dioxide is excluded, as is congestion. Built-up area refers to Landskrona, a medium-sized built-up area in terms of population size. Otherwise the same assumptions have been made as for the marginal costs in the tables above.

Marginal costs within rail transport

There is still a lack of detailed knowledge of how different parts of rail transport contribute to track deterioration. The National Rail Administration has therefore decided to base its estimate of rail transport's *wear and tear costs* on a cross-section analysis of the costs of track maintenance. The costs of track wear and tear have been estimated at SEK 0.012 per gross tonne kilometre as an average for all transport. The corresponding cost for the trunk network has been specified at SEK 0.084 per gross tonne kilometre. These estimates can be compared with today's wear and tear charge, which is SEK 0.028/gross tonne kilometre for goods transport and SEK 0.086/gross tonne kilometre for passenger transport.

The portion of the reinvestment cost that can be attributed to repair work is also relevant to the charge. The problem is that we do not currently know how great a proportion of the reinvestment relates to repair work in accordance with a given standard. Data problems have so far made it impossible to estimate the portion of the reinvestment cost that is relevant to the charge.

A project involving economic instruments for train path distribution was introduced within the framework of SIKA's and the National Rail Administration's joint commission concerning proposals for new track charges. The purpose of the project was to test models with actual operators within a

limited network. The results should be able to show whether there are any congestion costs in the defined network. The experiment was carried out during spring 2002.[1]

The theory for marginal external *accident costs* has been developed. The latest contributions make it possible to apply the theory to rail transport. In 2001 a special study was made of *level crossing accidents*. The results show that the average cost varies considerably between different types of crossing. Crossings with whole gates appear to incur half the costs compared with crossings with half-gates, which in turn incur half the costs of crossings controlled by light and sound signals. Level crossings with cross markings incur even higher costs. The marginal cost for level crossing accidents should therefore be estimated per crossing and not per average stretch. Moreover, the charges should vary according to such things as type of crossing and per crossing passage.

The National Rail Administration has recorded estimates of *emission costs* for diesel-driven rail vehicles. Emphasis is placed on the importance of identifying the environments in which the diesel-driven train transport is actually run and the aim is to produce new estimates that describe the emission costs for different types of environment.[2]

Emission costs expressed as Swedish kronor per litre of fuel for diesel-driven goods transport, shunting and marshalling work and for motor coaches can be seen below. The estimates are based on emission data from measurements that have been carried out and data received from engine manufacturers. The estimates give typical values for the different vehicle types and categories and should be seen as examples for the purpose of calculation.

Table 1.4. Emission costs for diesel locomotives for goods transport and motor coaches for passenger transport (SEK/l fuel).

	Rural area			*Built-up area, incl built-up area supplement*		
	NOx	*HC*	*Total rural area*	*Lands-krona*	*Malmö*	*Stockholm inner city*
Diesel locomotive						
T44-engine	3.6	0.06	3.7	7.6	12	21
Modern locomotive	3.0	0.05	3.1	6.0	11	16
Motor coaches						
Y1	4,2	0.12	4.3	12	25	37
Y2 and converted Y1	2,4	0.05	2.5	5.4	10	15

To date, when estimating transport's charge-relevant emission costs, attention has only been given to the cost of emissions originating from the vehicles. This therefore disregards emissions indirectly caused by the transport and those which occur at an earlier stage of production. The question of whether there are grounds for internalising the marginal cost involved in electric train traffic's consumption

[1] For a full report of the results, see *Nya banavgifter – Analys och förslag (new track charges – analysis and proposals)*, SIKA Report 2002:2.
[2] See also SIKA Report 2002:2.

of electricity and how in such a case this is to be managed has been addressed in the National Rail Administration's and SIKA's commission to investigate track charges.[3]

The social cost of *rail noise* has been estimated and specified in relation to vehicle kilometres and the distribution of train types. Goods trains, which comprise 20 per cent of the number of trains, account for around 35 per cent of the number of train kilometres. On the basis of this plus information on the numbers disturbed and the average annual traffic on different rail segments together with the estimated disturbance from different train types, it is estimated that goods traffic accounts for just under half, SEK 185 million, of the total noise cost. The corresponding cost for passenger traffic is SEK 202 million. The social noise cost per train kilometre varies considerably, depending on which rail segment is being used. The highest is the Southern main line: approximately SEK 16 per goods train kilometre and approximately SEK 5 per passenger train kilometre. On the Southern main line, the noise cost of a inter-regional train (passenger train with RC-class locomotive) is estimated to average SEK 3 300 per Stockholm-Malmö trip, whereas the corresponding estimated cost for a goods train comes to SEK 10 000. The equivalent cost for a Stockholm-Gothenburg trip on the Western trunk line is around SEK 800 for an inter-regional train and SEK 2 200 for a goods train.

The noise cost has also been estimated in relation to transport performance. For passenger trains with RC engines the noise cost per passenger-kilometre on the Southern main line is estimated at SEK 0.026 öre. For fast trains, assuming a cabin factor of 0.5, the corresponding value is 1.2. On the Western main line these values have been estimated at SEK 0.08 for RC engines and SEK 0.04 per passenger-kilometre for fast trains.

The National Rail Administration used the estimates for the average noise cost for different train types in different rail segments as a basis from which to estimate the marginal noise cost. These estimates indicate that the marginal costs may be considerably lower than the average. The question of train traffic's marginal noise costs needs, however, to be studied further.[4]

Marginal costs within air transport

In the field of air transport there is still a lack of basic data on which to make estimates of the externalities and the marginal costs related to them. The report therefore focuses primarily on identifying relevant cost components. Some specimen calculations intended to illustrate the size of the marginal costs are presented.

Wear and tear in the sense of the tyres wearing down the runway surface, and for example causing tracks to form is negligible. Transport-related wear and tear consists instead of the impact of carrying capacity. In fact, it is only at Arlanda and Landvetter and possibly Sturup that there is any noteworthy transport-related

[3] See also SIKA Report 2002:2.
[4] See also SIKA Report 2002:2.

wear and tear on the runways. At other airports the wear and tear is essentially caused by climatic impact and snow clearing.

The empirical study of traffic volume-related wear and tear carried out by the Civil Aviation Administration for the purpose of comparing traffic volume at a cross-section of airports with the time the surface layer stays in place at the respective airport indicates that there are no substantial differences in cost for a runway at a smaller airport compared with Arlanda. The conclusion is that transport volume-related wear and tear on runways is negligible.

The discussion of *congestion costs* has largely focused on the availability of slots. However, congestion en route can also be considerable, at least for lines between Sweden and the parts of Europe where traffic is most intensive. There is also congestion at parking areas and in the terminals.

According to the Civil Aviation Administration good conditions already exist in 2002 for estimating congestion costs both for producers and consumers in the field of air transport. A methodology still needs to be devised, however, for estimating the external congestion effect, i.e. how the arrival of one more passenger or one more plane affects the total flying time for other passengers and aeroplanes.

The most important externalities with regard to *accidents* probably occur within the air transport service's areas of responsibility. The Civil Aviation Administration's survey indicates that the ongoing work should focus on the external accident cost of an additional aircraft. This can be considerable. An accident cost that is relevant to marginal cost price setting should be determinable from an estimated measures cost for maintaining the desired level of safety.

The emission costs per flight for different aircraft and for their typical flight routes have been estimated. The estimates indicate that the flight's total emission costs are considerable and that this is mainly due to the costs of carbon dioxide emission. Nitrogen oxides also contribute to the flight's emission costs, although to a much lesser extent than carbon dioxide, while the discharge of hydrocarbons is of minimal importance in this context. The costs during the flight are normally much higher than the costs incurred during take-off and landing.

SIKA considers it essential that efforts be made to improve the basic data on flight-related emission costs. This should be achieved by seeking to apply the "ExternE model" recommended by the EU Commission and it would provide a more complete and credible picture of the size of the emission costs.[5]

[5] A study of air transport emission costs during the take-off and landing phases jointly financed by the Civil Aviation Administration and SIKA was initiated in autumn 2002. The results of the study will be presented in spring 2003.

Marginal costs within sea transport

The studies that have been carried out indicate that the marginal costs for *fairway activity* are small and that it is mostly the costs of piloting and ice-breaker assistance that change with the volume of traffic.

The emission costs appear therefore to be the dominant component in the total charge-related marginal cost. There are, however, major individual differences between vessels that can cause considerable variation in the vessel-specific discharges. The best vessels, too, however – best from an emission point of view and with the best fuels – will probably also find that the emission cost represents a major proportion of the total marginal cost.

The differences in emission costs recorded for Swedish shipping, depending on the method of evaluation and varying definitions, are worthy of note, which is why it is important that the differences be analysed in the results. As part of this clarification process the National Maritime Administration and SIKA have jointly commissioned a study in which the ExternE methodology is used in conjunction with an advanced distribution model for vessel movements on certain Swedish routes as well as for manoeuvres/loading/unloading/ in port.[6]

The ongoing work

In order to be able to estimate different types of transport externalities there needs to be further method development in a number of important areas. One such is also planned within the framework of various existing European and Swedish research projects. The task for SIKA and the transport agencies in this context is to monitor and attempt to take on board the new research results relating to proposals for methods for estimating external marginal costs.

SIKA and the transport agencies have as an important ongoing assignment the task of acquiring marginal cost estimates from the methods developed by the researchers, from the transport agencies' own experts, from independent consultants or from the researchers themselves. An even more important task for SIKA and the transport agencies next year, however, will be – after dialogue with the researchers – to define the basic material, i.e. the data that is needed in order to be able to produce marginal estimates from the recommended methods and, not least, to find forms in which this data can be expressed.

In SIKA's view, the transport agencies need to take on the role of producer and supplier of the data necessary for cost estimates far more clearly than they have done in the past. SIKA believes that the objective should be to be able to report to the government a system for continuous monitoring and updating of different charge-related external costs covering all types of transport.

[6] The results of the study were recorded in May 2002 in the report *Estimation of marginal environmental emission costs of maritime transport – pilot study based on the ExternE methodology*. The study was carried out by Electrowatt-Ekono Oy.

SIKA concludes that the ongoing work should chiefly focus on the question of how the transport's still inadequately quantified externalities should be internalised within different types of transport. In particular the conditions for an increased differentiation of charges from existing charge/taxation systems should be investigated. SIKA also intends as part of the ongoing work to prioritise the discussion of how the transport policy cost responsibility might be developed in terms of the internalisation of external costs.

Phone: +46 8 506 206 00 Fax:+46 8 506 206 10

sika@sika-institute.se

www.sika-institute.se

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