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FOREWORD

This report is a subreport to the wide-range T&E study called **"Internalising Social Costs of Transport"**. It is the purpose of this report to indicate the infrastructural costs of the heavy vehicles and to construct a system for taxation of these vehicles. The report is a European study, concentrating especially on Scandinavian and British conditions. The reason for this is that these countries represents different taxation systems, and that there has been relevant inquiries on these matters in the countries mentioned.

Acknowledgements

This report has benefited from the generous comments of many friends and experts. I would especially like to thank Per Kågeson (Project Manager for the main project "Internalising social costs of transport" and President of T&E) for his comments and patience. I am grateful to the Norwegian Ministry of Transport for financing this project.

Oslo, Norway, April 1993

Sveinung Oftedal

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1. INTRODUCTION

This report comprises a part of broader scheme; the external costs of transport. Here we will deal with infrastructural costs and heavy vehicles. Our goal is to give a broad view of cost issues concerning costs and taxation of heavy goods vehicles.

Dealing with **infrastructural costs**, we will especially look at the variation of costs in relation to different vehicles and different climates. Methodology of cost allocation will be an important issue.

The results of the part of the study concerning costs will be of major importance when the **taxation** of heavy goods vehicles is discussed. Theory and effects of different tax systems will be discussed, and finally an EC-tax system will be recommended.

2. INFRASTRUCTURAL COSTS

2.1 Introduction

The problem of allocation of infrastructural costs to different vehicles, demonstrates the need to subdivide the concept of "infrastructural costs" and to define different types of costs.

National budgets differentiate between

- maintenance costs
- construction costs.

It is important to differentiate between these two terms, but for taxation purposes it is more useful to have **variable** and **fixed** costs as a basis.

The costs, both the maintenance and construction costs, are affected by many variables. This study will concentrate on

- the difference in cost between vehicle classes
- the difference in cost between climatic zones.

2.2 Different approaches

There are different approches to the problem. Mainly we can divide them into:

- The technical/empirical approach
- The economic approach.

The technical approach is based on experiments with different vehicles under different conditions. To detect the impact of the different variables, it's usual to vary one factor and keep the rest constant. On an empirical basis conclusions can be drawn. It's also usual to use a wide range of field tests. But the detection of exact relations in a constantly changing system has never been an easy task. The main purpose of these investigations normally is to use the information in "best design strategies". That includes construction techniques, and maintenance programmes. But also the question of cost liability can be, and is, discussed within these frames. This appproach to the problem is characterized by the engineers way of thinking.

The economic approach uses road budgets and accounts as its basis. With statistical data and to some extent technical data as a supplement, cost liability is calculated.

This study will use both approaches.

2.3 Technical approach

2.3.1 The AASHO road test

In 1946 the American Association of State Highway Officials (AASHO) initiated the most comprehensive road inquiry ever done. The main purpose was to:

1. give a basis to geometric dimensioning of roads (surface and body)
2. give a basis to the question of cost liability of different groups of heavy vehicles.

To do this they had a test period (field tests) of two years (1958-1960). An analysis of the test results, approximately 300 mill data, is presented in curves and formulas that show the relation between serviceability, number of axel passages, axle load and pavement design parameters. Dimensioning models, material coefficients and regional factors (climate) were established as result of the road test.

Quite naturally the results have been received with greatest interest, not only in the US but also in Europe. Thus the applicability of the results to other locations than the site of the experiment has been debated. Especial attention has been paid to differences in the compostion of the traffic and differences in climate and subgrade properties.

2.3.2 STINA, a Nordic cooperative project

The purpose of the project was to give an improved base for pavement design, especially with respect to influence of subgrade, traffic load and to illustrate the influence of traffic load on investment and operation costs.

The STINA project program was:

- An inventory abroad

  The purpose of this inventory was, by literature surveys and by visits to selected countries, to find how the application and development of the AASHO road test results had progressed. Visits were paid to the US, Canada and Europe.

- An inventory of Nordic conditions

  The purpose of this inventory was to compile data from the Nordic countries required for examination of the applicability of AASHO road test results and other results therefrom. The inventory comprised road structures, climate, traffic load, failure data and test road data.

- Field trials and sampling

  The purpose of the field test was to start making an inventory of road engineering properties, predominant bearing capacity, of Nordic subgrade and their seasonal variation.

- Laboratory investigations

  The laboratory investigations of subgrade materials aimed at deformation and fatigue properties.

- Analyses

  Improved basis for analytical pavement design was one of the main purposes of the STINA project

2.3.3 Results from the AASHO & STINA projects

The results of both the AASHO road test and the STINA project are mainly used as a basis for dimensioning roads and as a basis for the maintenance program. Thereby the results ideally lead to optimal investments for construction and maintenance.

The fourth power law

Perhaps one of the most basic results from the AASHO road test is the fourth power law. This is used to calculate the traffic load's influence on dimensioning and maintenance. An estimation for the total traffic load on a road uses a factor for equivalent axel load,- traffic equivalence factor. The impact of different axel loads is converted to standard axel load which usually is 10 tons in Europe. On an empirical basis the AASHO test established a formula to calculate the traffic equivalence factor.

$$\mathbf{f_p = (P/10)^n}$$

f_p = traffic equivalence factor
P = the actual axel load
10 = standard axel load
n = exponent which usually is approximately 4

The value of the exponent is mainly dependent on

- road class
- type of pavement failure (time & structure).

The STINA project concluded that the factor could vary in the span 2.5-5.5 but usually between 3 and 5. An extreme permanent deformation gives the exponent 2.5.

TABLE 2.1 Total number equivalent 10 ton axel loads calculated for different values of the exponent on a measured axle load spectra.

EXPONENT	THE NUMBER OF EQUI. 10 TON AXLES	_%
2,5	653,8	31,7
3,0	581,1	17,0
3,5	530,4	6,8
4,0	496,6	0,0
4,5	471,8	-5,0
5,0	456,2	-8,1
5,5	448,3	-9,7

Each vehicle's contribution to road wear is reflected in the fourth power law. The formula shows that the vehicle's axle configuration is decisive for the vehicle's wear on the road.

Cost allocation

The AASHO's fourth power law has historically been used to quantify the cost liability of the vehicles. It is though not designed for this purpose.

The heavy vehicles contribution to the construction costs is not paid much attention to in the STINA project. The total costs of building a road is a sum of many kinds of costs. Many of the costs can be allocated to axle load. The STINA-report estimates the construction costs directly dependent on the traffic load to be 15-20%.

The AASHO's serviceability function can be used to calculate the different vehicles cost liability. Different axel loads' impact on the annual maintenance costs is calculated by eliminating different axel loads in a spectrum of axel load and estimating the decrease in annual costs.

TABLE 2.2 Annual instalments and relative cost allocation to different axle weights.

ELIMINATED AXLE LOAD	ANNUITY	TOTAL COSTS	DECREASE IN ANNUAL COSTS (%)
-	0,4939	3,309	-
2	0,4937	3,308	0,03
4	0,4911	3,29	0,6
6	0,480	3,22	2,9
8	0,453	3,05	8,4
10	0,394	2,64	20,3
13	0,212	1,42	57,1

As expected the differences are small when light axel loads are removed and very high when heavy axel loads are removed. But we have to remember that this table 2.2 is just an example. To estimate the different vehicles' cost liability with a road technical procedure, the engineers way of thinking, is a rather complex question. There are many variables which affect the wearing of roads, and there is a question of cost liability connected to each of the variables.

Main conclusions

The AASHO road test and the STINA project are primarily useful as a basis for

- an optimal design strategy
- an optimal maintenance strategy

Secondly these tests clearly indicate that the maintenance costs increase rapidly with increasing axel load.

2.4 Climatic variation

It is an aim for this projet to detect the different vehicles contribution to road wearing in different climate zones.

2.4.1 Different climatic variation

The climate varies with time:

- variation between night and day
- seasonal variation
- yearly variation

The climate varies with location:

- within countries
- between countries

These two variables, time and location, interact and of course always appear in a combination.

The climate doesn't know any borders, so nearly every country has different climatic zones within its borders. The most important climatic factors are temperature and precipitation. The climates of western european countries are classified according to these two factors (table 2.3 and 2.4). This table shows that many countries have a wide range of climatic conditions. Norway for example has ten different climatic zones according to this classification. One may ask; are there roads in every climatic zone? Are there any roads in the very wet polar zone in the Alps? These questions are of minor importance. The main conclusions are that:

- Most countries have several climatic zones within their borders.
- Only Denmark, Netherland, Luxemburg and Iceland are situated totally within one climate zone.

The relative climatic impact on road wear is dependent on the traffic load. If the average traffic load per day is > 5.000 vehicles, then the traffic load is the dominant road wear factor. With a lower traffic load, other factors such as climate are in percentage a more important factor.

2.4.2 Seasonal variation

The AASHO road test developed a seasonal weighting factor, q_t. To calculate the traffic load when regarding the climate factor the AASHO test used this formula:

$$w_t = n_t \bullet q_t$$

n_t= the actual number of vehicles passed

q_t= the seasonal weighting factor
w_t= the traffic load corrected for the climate (seasonal variation)

FIGURE 2.1 Variation with seasonal weighting factor with time. Some examples.

↑
1. AASHO results

↑
2. Nordic results

3. Nordic results →

TABLE 2.3 Climatic variation in some Western European countries

++++ = 100% --- = < 2% of the area		TEMPERATURE			
		POLAR	**BOREAL**	**COOL**	**WARM**
PERCIPITATION	**VERY WET**	Norway ++ Swed ++ Switz +/- Austr -- Italy - Iceland ++++	Norway ++ UK --- Switz -- Austr +/- France ---	Norway -- UK --- Switz ---	
	WET	Norway ++ Swed ++ Finl ++	Norway ++ Swed ++ Finl ++ UK --- Germ --- Switz -- Austr - France --- Spain ---	Norway -- UK - Germ -- Belguim --- France -- Austr -- Switz -- Italy - Portug --	
	MOIST	Norway --- Swed ---	Norway -- Swed ++ Finl ++	Norway -- Swed +/- Finl -- Denm ++++ Nederl ++++ Belgium +++ Luxem ++++ Germ +++ France +++ UK ++ Italy + Spain +/- Portug --- Greece -	Portug - Spain --- Italy - France --
	DRY			Swed --- UK --- Germ -- France -- Spain ++	UK --- France -- Italy + Spain ++ Portug ++ Greece +++

	DESERT	Norway -- Swed -- Italy --- Austr ---		Spain --	Spain ---

TABLE 2.4 Climatic variation in Western Europe, a regional division.

		TEMPERATURE			
		POLAR	BOREAL	COOL	WARM
PERCIPITATION	**VERY WET**	NORDIC COUNTRIES DENMARK EXCLUDED & THE ALPS	NORTHERN EUROPE DENMARK INCLUDED	SOUTHERN EUROPE	
	WET				
	MOIST				
	DRY				
	DESERT				

The variation shown in figure 2.1 is dependent on

- High water content in the pavement during spring thaw.
- High temperature, e.g. low rigidity in the asphalt, during road surfacing.
- Low temperature, e.g. high rigidity in the pavement during the winter.

This kind of information is of course useful to road constructors, but also it also indicates which periods that have the highest potential for road wear. In many regions the spring thaw period is the most vulnerable. But high temperature in the summertime can in other regions be just as damaging.

The seasonal variation illustrates that climate is an important variable regarding road wearing. We assume that the different vehicles' impact on road wear is not constant through different climatic zones. Is there any consistent data?

2.4.3 Precautions, vehicles and costs

To prevent damage due to climatic impact three main things can be and are done:

- improved construction techniques
- improved maintenance programme
- suitable restrictions.

The cost issue connected to climatic impact is rather complex. Two ways of approach can be:

- The cost of doing something. Does the need to improve the construction, maintenance and axle load restrictions on roads due to climatic impact increase the costs?
- What is the cost of the climatic impact if the needed improvements and precautions are not taken?

You will always find a combination of these questions in every region in each country in every climate. The different vehicles contribution to road wear in different climatic zones are of course dependent on these two questions.

In some areas, especially in wide regions in the Nordic countries and the Alps, winter maintenance is an obvious climatic impact. All other other forms of significant climatic impacts in other regions may not be that visible or obvious, but in some cases not of less importance.

In the accounts of the Norwegian Road Administration winter maintenance are specified (clearing the road of snow, gritting and salting the road, opening snow blocked roads, etc.). In 1989 special winter maintenance is estimated to 16.6% of the maintenance expenditures. In addition road wear due to studded tyres is estimated at 380 mill.Nkr the same year. A part of the resurfacing costs are allocated to climatic impact in general (weather and wind). Table 2.5 summarize the climatic impact on maintenance costs in Norway.

TABLE 2.5 Maintenance expenditures related to climatic impact. Norwegian numbers, avarage 1985-1989, 1989 price level.

COST SPECIFICATION	SUM (mill.kr)	%	FIXED/VAR	CAUSE
Winter maintenance	408.7	16.6	fixed	snow & ice
Resurfacing	255.7	10.4	fixed	general weather
Resurfacing	380.0	15.4	variable	studded tyre

SUM, "climatic costs"	1 044.4	42.4	fixed & var.	climate
TOT. mainten. exp.	2 464.7	100	fixed & var.	All

Is it reasonable to allocate 42.4 per cent of the total maintenance expenditure to climatic impact? The answer is that table 2.5 indicate that climate is an important factor which affects the maintenance costs, but discussion is needed. Is it reasonable to allocate the expenditures used on resurfacing of roads due to studded tyre to the climatic impact, or to the vehicles causing these damages? This study allocate it to the vehicle, because it is the vehicles' use of the road which causes the cost. It is possible to drive less, and its is surely possible to change tyres from studded to ordinary winter tyres. You can't tax the climate.

An optimal method to estimate and compare the effect of climate on maintenance and construction costs, is to choose a reference climate which by definition have no impact on the expenditures on roads (in practical terms this is wrong because climate is a very natural frame which always has an impact). Then you have to assume an optimal use, and a similar standard on the roads. The divergence from the reference climate, all other variables being constant, will illustrate the climatic impact on the the road expenditures.

In addition there are socio-economic question like:
What are the costs to society of:

- having the roads closed during wintertime?
- allowing climatic conditions to decrease speed?
- having spring thaw restrictions?

This study will not deal with these questions.

A conclusive remark is:

The higher the climatic impact, the more road wear can be allocated to heavy vehicles. The spring thaw restrictions are an evidence of this statement.

Further evaluation of this subject can be find in chapter 3.

2.5 Other variables

There are other variables that have a considerable impact on the wearing of roads. Among these are

- geological conditions (subgrade).
- tyre pressure

- axle configuration
- axle suspension

These factors show that both technical details on the vehicle and external factors are important for the road wear caused by different vehicles.

2.6 Economic approach

2.6.1 Introduction

In the introduction of this chapter we address two essential questions:

1. What kind of costs are calculated?
2. How are the costs calculated?

The conclusions that are drawn depend to a great extent on the answers of these questions. The methods chosen are often influenced by different

- **Tradition** in countries, research institutes etc.
- **Opinions** among scientists
- **Interests** of Departments, organisations etc.

Different methods have of course advantages and disadvantages, and agreement about these themes is not likely to occur. Anyhow, the point is to make the assumptions and the method used clear. This is of greatest importance if a comparison of data should make sense.

2.6.2 What kind of costs?

One of the aims of cost allocation is to construct a tax system which correlates cost and tax. An OECD report has classified the cost into five different groups.

VARIOUS THEORETICAL TAXATION SYSTEMS

A. Economic toll

This is a tax which balances capacity supply and demand. It is equal to the marginal increase in cost to society, in case of traffic congestion, by a charge known as "penal toll".

B. Marginal cost to society

This corresponds to an optimum allocation of resources which takes into account external influences; this method of taxation, though it cannot of course ensure budgetary equilibrium, is the most widely used.

C. Long-run marginal cost

This is the ratio of the discounted total additional expenditure incurred by variations in traffic to the discounted amount of these variations. This method of taxation ensures stable charges but results in a deficit and cannot balance supply and demand in the short term.

D. The full economic cost

This is the sum of maintenance, operating expenditure and capital costs (updated according to the replacement of the expenditures); it is broken down according to the marginal expenditure share which may be imputed to the various user categories. The remaining expenditure is allocated on a somewhat arbitrary basis. This method does not provide optimum use of infrastructure and poses problems of cost evaluation.

E. The system of budgetary equilibrium

There are methods of sharing the investment falling within the current period:

- the marginal cost to society and total expenditure entailed are calculated for each category of user. The user is charged a **balancing tax** equal to the difference;
- a function of utility for the community is maximised under certain constraints by acting on taxes, transport demand and other factors

The OECD report claims that all these taxation methods pose major problems in their implementation.

However, a division between fixed and variable costs is fundamental. A step further is to correlate a specific cost to a specific tax.

Marginal cost.

Economic theory favours that the vehicles should be confronted with the excess costs to society caused by their use of the roads. Thus the traffic load can reach an "optimal" level. "Optimal" is a subjective criterium, which to a great extent is defined by the input to the calculation of the excess costs. Normally excess costs includes such costs as increased level of road construction, road maintenance, accidents and environmental costs. The excess cost the road user adds himself and the society by driving one extra kilometer is defined as **marginal cost**.

MARGINAL COST:

- Confronts the road user with the excess cost to society
- Are favourable in relation to taxation methods
- Are favourable in relation to infrastructural planning

The excess cost is influenced by the time span used. Thus we can differentiate between **long term marginal cost** and **short term marginal cost**. Short term marginal cost use for example congestion cost. Capacity cost is the corresponding long term marginal cost. Given that the road network is acceptable, taxes on the basis of short time marginal cost is appropriate as a traffic regulating mean. Whichever basis is adopted, an important point is that marginal (social) costs will vary enormously according to time and space. Therefore average marginal costs are used. A complex system where marginal costs are charged specificaly according to time and location, demands complex calculations and an advanced road pricing system. The principle of road pricing is a principle we will support strongly.

Total cost.

Total cost is useful to illustrate the total cost of transport compared to other sectors. Furthermore, in a system with fixed and variable costs it is useful to compare them in a system of total costs.

The total tax level ought to be approximately similar to the total cost. The total cost is not a suitable basis for constructing a tax system.

2.6.3 Cost allocation, different results

The following results, represents different methodology, different allocation sytems, different inputs and different outputs. To compare data from different countries is not a straight forward thing. Sometimes it can be difficult to detect differences in methodology and allocation definitions. Nevertheless, a presentation of data follows.

I. THE BRITISH SYSTEM.

The British system for cost allocation and taxation of vehicles follows the guidance provided in 1968 Road Track Costs Report, and by the Armitage Commitee in 1980. That is, lorries should cover their track costs through a combination of Vehicle Excise Duty (VED) and fuel duty, with a margin to provide for external costs. The Chancellor has tended to fix that margin at around 30%. The Department of Transport has made The Allocation of Road Track costs as an annual report.

The practice currently used by the Department of Transport (DTp) in dealing with track costs is a cost allocation exercise under which all costs they consider to be public costs are allocated to individual types of vehicle. The basic method is to identify any cost component which can be said to be incurred by a particular class of vehicle and to charge those costs items to the relevant classes of vehicle.

The responsibility is calculated using five parameters, which relate vehicle characteristics to roads expenditure:

1. **Vehicle kilometers**. This parameter is a measure of the kilometres travelled by the vehicles during the year. It is used to allocate costs which are not related to a vehicle's size or weight, such as traffic policing.

2. **Average gross vehicle weight kilometres**. This is the vehicle kilometres multiplied by the average vehicle weight. It is used to allocate costs which are dependent on the weight of vehicles, such as bridge maintenance.

3. **Standard axle kilometres**. A standard axle is a measure of the relative road-wear caused by different vehicles. This value is then multiplied by the number of kilometres run to give standard axle kilometres. This

parameter is used to allocate the costs of repairing the road surface.

A standard axle is a computational device for comparing the road wear of different vehicles, taking account of the "fourth power law" of road pavement damage. It produces an index showing how much road wear a vehicle causes, compared to a 10 ton axle.

The standard axle of a particular vehicle can be calculated by summing the fourth powers of the weights (in tons) on each axle and dividing by 10^4. Thus for a fully laden 16 ton, 2 axle rigid vehicle with axle weights of 6 tons and 10 tons, the standard axles should be:

Install Equation Editor and double-click here to view equation.

This means that this vehicle causes 1.296 times as much wear to the road pavement as a 10 ton axle.

4. **Maximum gross vehicle weight kilometres**. This is calculated as the maximum permitted weight for a vehicle multiplied by the annual kilometres run. It is used to allocate part of the capital expenditure, because the weight of the vehicles means that roads have to be built to a higher standard.

5. **Passenger car unit (PCU) kilometres**. This parameter is a measure of the relative amount of road space used by different vehicles, multiplied by the kilometres run and is used to allocate the remainder of the capital expenditure.

   The heaviest large goods vehicle has a PCU of 2.5
   Results are shown in table 2.6 and 2.7.

TABLE 2.6 Total Road costs (Capital, current,policing & traffic wardens) for 1992/93 classified by road class and parameter

TABLE 2.7 Allocation of maintenance costs for 1992/1993: classified by expenditure item.

Critisism has been brought up

A. The DTp-report allocates too much of the costs to vehicle kilometer rather than to passenger car unit (PCU). Examples are:

   1. Allocation of winter maintenance costs
   2. Allocation of capacity costs

B. Secondly, the treatment of capital costs gives rise to many arguments. At present, current capital expenditure is spread over the traffic level of the year in question. Capital costs should be spread over the life of the road but related only to the extra traffic carried.

C. Failing to allow adequately for the extra costs imposed by heavy vehicles in terms of pavement thickness, lane width, gradient curvature and bridge strength

   The USA adopts similar allocation procedures to those in the UK, "cost allocation on the basis of cost occasioning" (U.S. federal Highway Authoroty, 1982). The policy means those vehicle groups giving rise to capital expenditure should pay for that expenditure; thus thicker or wider pavement costs are allocated to lorries, more road capacity to traffic in general on an incremental basis. The authors have calculated that the cost coverage in the USA for the years 1975, 1980 and 1985 was 65.0%, 61.2% and 62.0% respectively inclusive of State and local taxes. They also claim that the relationship of pavement wear to axle weight rises at a rate closer to its third power, rather than its fourth based on re-analysis of the AASHO test data allowing for residual life of some sections of pavement when the tests were completed.

   The US system is not that different from that in use in the UK. However, a much greater share of the capital costs of new roads are allocated to new roads in the US. It could be noted that a study of car only roads could be built for some 75% of the cost of existing roads, rather than 85% as assumed by DTp (Echenique, 1987).

<u>II. SWEDISH RESEARCH.</u>

In the eighties (1985 and 1987) there were four Swedish research dealing with infrastructural costs. They used the principle of marginal costs, and differentiated the costs between light and heavy vehicles.

Capital costs are not included in those cost estimates that make use of short term marginal costs. Congestion costs are therefore used instead of capital costs. This provides a system with representative price on time and a good overview of the traffic picture.

Data are presented in table 2.8 and table 2.9

TABLE 2.8 Swedish estimates of marginal costs. SEK/vehiclekm. 1989 prices.

TYPE OF COSTS	VEHICLE GROUP				
	Passenger car	Light lorry	Heavy lorry	Heavy lorry w/ trailer	Bus
Maintenance	0.0093	0.0093	0.1824	0.3617	0.1824
Congestion	0.0232	0.0232	0.1855	0.2318	0.1855
SUM	0.0325	0.0325	0.3679	0.5935	0.3679

TABLE 2.9 Road wear costs (SEK/km). 1990 Prices. (After Ds 1992:44)

VEHICLE GROUP	TOTAL WEIGHT (ton)	ROAD WEAR COST (kr/km)
___G____...______)_) ❍❍ ❍❍ ❍❍ ❍ 7,5 + 11,5	60	0.86
____F___/-_______)_) ❍ ❍ ❍❍ ❍ 7,5 + 11,5 7	40	0.77
____E___..._______)_) ❍❍ ❍ ❍ ❍ 16 6 11,5 6,5	40	0.61
____D___/-_______)_) ❍❍❍ ❍ ❍ 22 11,5 6,5	40	0.59
____C___...________)_) ❍ ❍ ❍❍ ❍ 8 6 7,5+11,5 6,5	40	0.58
____B___)_) ❍❍ ❍ 7,5+11,5 7	26	0.49
____A___)_) ❍ ❍ 11,5 6,5	18	0.41

III. NORWEGIAN REASERCH

Three Norwegian research projects have the recently dealt with infrasructural costs. They have mainly similar methodology.

The research projects use long term marginal costs. This involves the calculation of road expenditures initiated by capacity problems. An optimal system where investments is implemented when increased financial costs are similar to or lower than reduced short term marginal costs (congestion). Roads built of other reasons, regional reasons or quality improvements, are not included in these calculations.

The numbers used in this research are from The Norwegian Public Road Administration (internal accounts) and other official statistics. And the roads included in the research are the roads under National governmental responsibility (construction and maintenance), hereafter called Trunk roads.

Construction costs:

For the calculation of capacity costs the PCU used for heavy vehicles is 2.5. Financial cost are not only related to new roads, but also to the excisting road network in such a way that interest burden and depreciation is included in the estimation of the total road capital. The total time of depreciation of a road is estimated to be 40 years.

Approximately 46% of the construction costs are related to improvement of capacity.

The marginal costs dependent on capacity:

Increased financial costs/increased traffic volume

Maintenance costs:

Maintenance costs are divided into three groups:

- Costs dependent on traffic volume
- Maintenance costs that are a condition for the roads to keep the traffic flowing
- Several fixed costs

The Norwegian research projects have used the principle of marginal costs approach, thus only costs dependent on traffic volume are included in the estimation of maintenance costs. The volume-dependent maintenance cost are subdivided into

- load-carrying capacity costs (support)
- studded tyre costs.

After estimation of maintenance costs dependent on traffic volume, the load-carrying capacity costs are then calculated of the basis on the estimation of total traffic volume costs. This calculation use the "fourth power law" from the AASHO Road Test and the STINA project. The Equivalencefactor is calculated using the formula:

Install Equation Editor and double-click here to view equation.

R is the carrying-load capacity equivalence factor measured compared to a passenger car p	is the measured axle load

a	is an exponent (normally between 2.5 and 5) which depends on the road characteristics

0.5	is the assumed axle load of a passanger car

Norwegian conditions result in an exponent between 2.5 and 3.0. There is room for a discussion about this. A better quality of roads (pavement, soil support etc.) will result in a higher exponent. That means that the roads are capable of carrying a larger number of heavy vehicles with less or similar maintenance costs allocated to the heavy vehicles.

TABLE 2.10 Vehicle group and typical payload

Payload Tonne	**Total weight Tonne**	**Typical axle load Front**	**Rear**
1-1.9	3-4	1	2
2-2.9	4-5	2	3
3-3.9	5-8	3	4
4-4.9	8-10	4	5
5-5.9	10-12	5	6
6-6.9	12-14	5	8
7-7.9	14-16	6	8
8-8.9	16-17	6	10
9-9.9	17-18	5	12 B
10-11.9	18-20	6	12 B
12-14.9	20-22	6	16 B
15-17.9	22-26	10	16 B
> 18	> 26	10	16 B

B=Boggie

TABLE 2.11 Marginal costs Nkr/vehiclekm. 1989 level of prices and production.

VEHICLE GROUP ttw = tonnes total weight B = Boggie	**MAINTENANCE COSTS** dependent on load exp. 2.5	exp.3.0	studded tyre	**CAPACITY COSTS**	**SUM MARG. COSTS**	**SUM MARG. COSTS**
	I	II	III	IV	I+III+IV	II+III+IV
Passenger Car	0.0017	0.0005	0.0154	0.1171	0.1342	0.1330
3-4 ttw	0.0420	0.0245	0.0770	0.2928	0.4118	0.3943
5-8 ttw	0.1646	0.1253	0.0770	0.2928	0.5344	0.4951
10-12 ttw	0.4049	0.3744	0.0770	0.2928	0.7747	0.7442
16-17 ttw	0.7678	0.8309	0.0770	0.2928	1.1376	1.2007
20-22 ttw (B)	0.7678	0.8309	0.0770	0.2928	1.1376	1.2007
26 → ttw (B)	1.0618	1.2062	0.0770	0.2928	1.4316	1.5760
Road train (45-50 ttw B)	2.1236	2.4124	0.1540	0.6000	2.8776	3.1664

IV. OTHER RESEARCH.

The European Community has proposed allocation guidelines for marginal expenditure according to vehicle category. Under this proposal all road expenditure (except for construction of new roads) would be split into four categories as defined below:

- Category D_0: This generally comprises: bridge maintenance, grass, hedge and tree cutting and other work on shoulders, road signs and signals, maintenance of footways and curbs, lighting, etc. By definition, this expenditure is not to be included in the marginal cost.

- Category D_1: This generally comprises: winter maintenance, road markings (all or part), crash barriers (all or part), etc. This expenditure, included in the marginal cost at a level of 50%, is distributed pro rata according to vehicle-km.

- Category D_2: This generally comprises: surface dressings, patching (all or part), bituminous surfacings (in part), road signs and signals (possibly in part - see D_0 above, etc.). This expenditure, included in the marginal cost at a level of 60%, is distributed pro rata according to vehicle-km weighted by Gross Vehicle Weight.

- Category D_3: This generally comprises: bituminous surfacings (in part), patching (in part), pavement strengthening and renewal, etc. This expenditure, taken into account in the marginal cost at a level of 75%, is distrubuted pro rata according to the number of equivalent axles.

How road expenditures are allocated in practice in Denmark, France and the United Kingdom is illustrated in figure (numbers are taken from 1977-1979).

FIGURE 2.2 Allocation of road expenditure in Denmark, France, and UK.

Table 2.12 shows the share of expenditure attributable to heavy goods vehicles.

TABLE 2.12   Share of expenditure attributable to heavy vehicles

COUNTRY	% of TOTAL EXPENDITURE	% of MARGINAL EXPENDITURE
Denmark	18.5(1)	56.2(1)
France	36.0	70.0
United Kingdom	31.0(2)	60.0(2)

1) 26% and 80% respectively discounting construction expenditure
2) Estimate

The OECD research also claimed that for increasing traffic load of heavy vehicles, the elasticity of heavy vehicles' impact on maintenance and construction costs decreased. This is a reasonable statement, the importance of one extra heavy vehicle decreases with increasing traffic load.

Another Swedish study, Energieffektiviteten för person- och godstransporter i Sverige, 1979, has the following assertion:

- The traffic load occupies space on the road and contributes to road wear.
- The axle load have a destructive effect on the pavement structure.

This is illustrated in figure 2.3

FIGURE 2.3   Effects of traffic load on the road surface, and the axle load on the pavement structure.

2.7 Comparison of data

2.7.1 A coarse comparison

To compare data which is calculated by different methods is a rather tricky thing to do. The methods which are most similar, are the Swedish and the Norwegian methods. Further, if the Norwegian results are recalculated it is possible to compare them with the data from the OECD report. These results compare the heavy vehicles' share of the marginal expenditures, but there are no division into vehicle classes.

TABLE 2.13 Share of expenditure attributable to heavy vehicles

COUNTRY	% of MARGINAL EXPENDITURE
Denmark	56.2
France	70.0
United Kingdom	60.0(1)
Norway	56.3(2)

1) Estimate
2) Estimate done by this author

The data presented in section 2.3, Technical approach, doesn't directly allocate costs to vehicle classes, but by example shows the effect of eliminating different axle load in a certain axle load spectra. Furthermore the results from the "technical approaches" forms the basis for the cost allocation in the results presented under section 2.6, Economic approach.

All the research presented here, independent of method used, shows clearly that the heavy vehicles are a major contributor to road wear costs and road contribution costs. This contribution seems to increase rapidly with increasing axle load.

2.7.2 The problems of combining fixed and variable costs; the British, Swedish and Norwegian research.

This report is based on a fundamental division between fixed and variable costs. A comparison of data must be a comparison of the same type of costs.

The British allocation system as presented by The Department of Transport, does not have the same approach. The annual report, The Allocation of Road Track costs, is based of the calculation of total costs. The allocation parameters used for maintenance costs, vehicle kilometres, average gross vehicle weight kilometres, standard axle kilometres, do not, as this author read them, clearly divide between fixed and variable costs. Vehicle kilometer seems to be a variable cost, but do all the expenditures allocated to this parameter, such as policing costs, vary with the traffic load? Nor do the allocation parameters used for construction costs, maximum gross vehicle weight kilometres and passenger car units, clearly differentiate between fixed and variable costs. Passenger car unit is a fully variable cost. But the costs allocated to maximum gross vehicle weight, a primarily fixed parameter, are multiplied by annual kilometres run and are thereby dependent on the vehicles travelling distance which is variable. These considerations have consequences for the recommended tax systems (Chapt. 3). The British allocation systems fit badly with the tax system we will recommend.

Further remarks on the Brittish allocation system are given in chapter 2.6.3.

The Norwegian and Swedish research methods are more or less similar. The Swedish results presented in table 2.8 use congestion costs (short term marginal costs), while the Norwegian research uses capacity costs (long term marginal costs). The Norwegian research estimates marginal cost of heavy vehicles (table 2.11) which are much higher than the Swedish estimations. The reason for this is methodology, the difference in estimating capacity costs and congestion cost, rather than, for example, climatic differences. A calculation of congestion costs use more subjective criteriums than the calculation of capacity costs.

The latest Swedish estimation of marginal costs of heavy vehicles, are not the fully marginal costs of the heavy vehicles. Only the maintenance costs are calculated. Even these are much lower than the Norwegian results. As we know the Norwegian research results, there is no reason to claim that the Norwegian estimates are too high.

It is necessary to be aware of the content of the costs calculated when comparing. For example does the Department of Transport in Great Britain include traffic policing costs in the expenditures on maintenance, while the Norwegian research has not included policing costs in their cost estimates.

We have also some comments about the Norwegian estimation method:

- **Financial costs.**

The estimation of financial costs uses a total depreciation time of 40 years. Then the financial value of the road is zero. If this theoretical estimation has a practical inplementation, there should be no need to maintain such a road. If the maintenance expenditures on a totally depreciated road are significant, the estimation of the road networks financial value is wrong.

- **Construction costs.**

The estimation of construction costs is based on official accounts. An evaluation of these expenditures should be done. A reason for this is the costs of acquisition of land. Acquisition of land from an environmental point of view, isn't necessarily important from an economical point of view. What is the price of the eternal loss of an oak forest or agriculturally important areas? The results from the research presented here must be judged also by the awareness of these kinds of value assessments.

2.7.3 Different arguments in a comparison of data

Some important arguments in a comparison of data have to be discussed.

- **"Car only" costs.**

  In the question of cost allocation, there is a school of "car only" philosophy. The construction and maintenance costs allocated to heavy vehicles are estimated by a theoretical calculation of the cost of a car only road.

  It is impossible to construct the transport system which would exist if there were no heavy vehicles, and far less the costs of such a system. Such a calculation is based on freezing of many variable factors.

  In our point of view the relevant questions should be:

A.1 - What are the costs of increasing/decreasing the weight of the vehicles?
A.2 - What are the costs of increasing/decreasing the traffic volume of the heavy vehicles?

  We do not favour calculations based on the question:

B. - What if the heavy vehicles were non existing?

  Theoretically the limits of question A.1 and A.2 are 0 and ∞, so it can some times be difficult to divide between the two methods. We favour the method which has the existing traffic situation as a basis. This approach is also favourable in relation to infrastructural planning.

- **Comparison of costs and road standards in different countries.**

  Is it reasonable to compare costs of countries with completely different standard of roads as, for example, Germany and Portugal? Should we compare the maintenance costs actually used, or the costs which ought to be used? We propose that the actual expenditures on maintenance must be held together with qualitative research on how satisfied the differnt road users are of the standard of roads. If there is divergence between the road users' satisfaction with the road network, this has to be added when data is compared. Such inquiries are done in Norway. The road users in Norway are satisfied with the standard and serviceability of the roads questioned.

Criterias have to be evaluated: What should be a road users' optimal judgement of the roads? Further it should be the people of Portugal which should judge the roads of Portugal and not Germans. This point of view is not that obvious when it comes to international roads. Anyhow, this research don't intend to answer these questions, but it's important to raise them.

2.7.4 Allocation of costs, conclusive remarks

Within Europe each country uses different methods to recover expenditures on its road system. This makes a comparison of data difficult.

We favour the research which divide between fixed and variable costs.

The Norwegian method has fewer imperfections.

3. TAXATION

3.1 The purpose of a tax system

The purpose of a tax system ought to be the decisive factor in the design of the system and the level of the taxes. Some important assumptions in an optimal tax systems follows:

1. **The taxes transport should pay to society should be equal to costs to society due to transport.**

   If it isn't so, the government needs to make it clear whether transport is subsidized by society, or whether it is financed by other public expenditures.

2. **The tax system ought to include and visualize the different costs. The tax thereby ought to be fair between the different modes of transport incuding different vehicles.** This demands a dynamic tax system.

3. **The system ought to function as an incitement towards a planned goal.**

4. **The tax system ought to be surveyable and simple to administer.**

These assumptions have many implications. They imply that you can't have a fixed tax on a variable cost. A differentiation of costs result in a wide range of taxes. Table 3.1 is an overview, not complete and not necessarily correct, but nevertheless an overview showing which costs ought to have a corresponding tax.

Assumption 1 is essential in order to achieve an optimal tax system. However, we have to bare in mind two important points about the concept of "optimal".

1. The external effects included in the account are highly decisive for the meaning of the concept "optimal".
2. There are many external effects which are not priceable. These external effects, which can be of great importance for society, will not be regarded in the construction of an optimal cost/tax-system.

The question of an optimal cost/tax system on transport is a question of how much of societies' resources, private and public time and money, nature resources, etc, should be allocated to transport. The optimal tax system will minimize resources used on transport.

TABLE 3.1 Taxes and purpose of them.

TAX SPECIFICATION	FIXED/VAR	PURPOSE
tax on the vehicle stock	fixed	To achieve the optimal stock of vehicles.
tax on different vehicle groups	fixed	To achieve the optimal vehicle configuration.
tax differentiated between vehicle models	fixed	An incentive to favour the "best" models of a certain vehicle group.
tax on road use	variable	To achieve an optimal use of roads.
tax on fuel	variable	To achieve an optimal use of fuel and an optimal dispersion between different types of fuel.
deposit on wrecking	fixed	To achieve an optimal age dispersion on vehicles, and to avoid waste problems.
administrative tax	fixed	To finance an administrative unit.
fiscal tax	fixed	To contribute to the national state income.
etc.		Etc.

The classification fixed and variable is set after the definition: The tax and/or cost is variable when it's dependent on the use of the vehicle.

To achieve the defined cost optimal transport system, a combination of economic and adminstrative means are normally used. This study will not consider this question.

The tax system we will support, is divided between

1. Marginal cost liability
2. Total cost liability.

The marginal cost liability assumes variable taxes on societal excess (marginal) costs to society.
The total cost liability assume, in addition to the marginal cost liability, fixed taxes which equal the fixed costs of infrastructure. To equate total costs to total tax, the fixed might have a function as a balancing tax.

3.2 Principles of taxation of heavy goods vehicles

The heavy vehicles are subjected to the same principles of taxation as any other vehicles. This study is limited to infrastructural costs, maintenance and construction, and no other external effects.

Among these, are both fixed and variable costs. A simple division is set in table 3.2. The British allocation system is different, and doesn't clearly divide between fixed and variable costs (table 2.7).

The allocation of costs independent of method are more or less underlaid subjective judgements. The construction costs that may be considered marginal are the costs of roads built because of capacity problems. But which are these? In historical terms few, at the present situation. It ought to be the majority of the roads built. The reason is that historically roads were built to regions that were difficult to acces. This period is mainly over in our part of the world, and in an optimal system roads ought to be built when short term marginal costs exceeds long term marginal costs. If this is the policy, we have to assume that as a principle, all the roads constructed today as a rule are buildt because of capacity problems. There are, however, exceptions (reducing the number of accidents, reducing travelling time, etc.).

All the marginal costs should be taxed by a system that reflects the vehicles' use of roads. For this purpose a mileage tax differentiating between each vehicle group would be an ultimate tax system. In this system would easily take into account the cost of each vehicle.

TABLE 3.2 Division of fixed and variable taxes and costs

	MARGINAL COSTS VARIABLE TAXES	TOTAL COSTS FIXED TAXES	
M A I N T E N A N CE	**Costs:** All costs resulting from the use of vehicles. **Examples:** Resurfacing Subgrade damages **Taxes:** All taxes regarding the use of vehicles **Examples:** Mileage tax Fuel tax Road pricing	**Costs: 1.** Expenditures necessary to keep traffic flowing **Examples:** Traffic signs, road markings, winter maintemance. **2.** Other fixed costs **Examples:** Traffic signs, road markings, winter maintenance, avalanches. **Taxes:** Weighting taxes, annual taxes, registration taxes, investment taxes	**M A I N T E N A N C E**
C O N S T R U C T I O N	**Costs:** Total construction costs when the road is built due to capacity problems. **Taxes:** Mileage taxes Fuel taxes Road pricing	**Costs:** Total construction costs when the road is built due to other reason than capacity. **Taxes:** Weighting taxes, annual taxes, registration taxes, investment taxes.	**C O N S T R U C T I O N**
	MARGINAL COSTS VARIABLE TAXES	**TOTAL COSTS FIXED TAXES**	

Taxation of fuel should have other purposes than to cover up infrastructural costs. Among these are

- energy optimalization
- reducing pollution.

With high fuel taxes, I would primarily try to increase my energy efficiency by improving driving habits, technical improvements, etc., and not my driving distance. On the contrary I could choose things which would increase the infrastructural marginal costs for instance by choosing another axle configuration, another vehicle. Furthermore, a fuel tax can't differentiate between vehicle classes. It has to be combined with regular (annual) weighting tax. The weighting tax is not an incentive to reduce my driving distance. On the contrary, the vehicles which will gain by a combined weighting tax and fuel tax, are the heaviest vehicles with the longest annual driving distance.

Transportation is an international business, therefore the terriotorial principle is preferable to the national principle regarding infrastructural costs and justice.

Territorial principle:	Identical vehicles pay the same tax for use of roads within a country.
National principle:	Taxation in the country the vehicle is registered.

3.3 Tax harmonization

There are many harmonization models. Three examples follows:

1. Full harmonization. This means full harmonization of tax system and tax level.

2. System harmonization. Harmonization of the system, not necessarily harmonized tax level. Allthough a bottom line of the level is possible.

3. Level harmonization. This means harmonization of the level of certain taxes.

The advantages of harmonization lays within the nature of international trade and transport. Harmonization has advantages such as:

- Gives fair competition
- Gives administrative advantage
- Is favourable to a common transport policy.

Research show that infrastructural costs have many variables, and vary all over Europe. This because of differences in traffic load, vehicle configuration, climatic and geological differences, road technical differences. Based on a common system, a common bottom line tax level is preferable. In addition every country has to have a national tax level. The result ought to be that every nation has a system where marginal costs equal marginal taxes. The territorial principle will make this possible.

International road haulage of Europe has been governed by bilateral agreements based on reciprocity. These agreements concern both freight haul quotas and vehicle taxes. A harmonized tax system and the territorial principle, would make these agreements superfluous. In addition a non-restrictive cabotage system will be less complicated, but not without complications. This because fixed taxes follow the national principle.

3.4 Exceptions

Exceptions like compensation for extraordinarily difficult climatic conditions, for example, are debated. Firstly, if exeptions are accepted, the exeption criterias are not obvious, and the size of and form of compensation are less obvious. Secondly, why should exeptions be accepted at all? If the road user is not confronted with the excess costs to society, his behavior will not be affected by the cost issue, including infrastructural costs. The goal of resource optimalization will then be abandoned. If there are climatic conditions which increase the external costs of transport, and this is not reflected in the tax system, the costs to society will increase because of a non optimal behavior of the road-user. This is not acceptable. This study will not discuss regional consequences, but will remind the reader that there are many means available to fullfill a policy whatever it might involve.

3.5 Taxes on heavy vehicles in Europe

3.5.1 Introduction

The tax systems and the tax level on heavy vehicles in Europe varies. Scandinavian countries and Switzerland are known to have the highest tax on heavy vehicles, and Greece and Luxemburg the lowest (Table 3.3)

This table should be supplemented by comments on nearly every country, but the most important drawback is that its not correctly divided in fixed and variable charges. Still it gives a broad indication on the tax level in European countries.

Table 3.3 Taxes and dues applying to domestic road haulage by a road train of 38 tons gross weight and annual haul stretch of 90 000 kilometers.

NOK 1990.

In nearly all the European countries the most important taxes are

- annual taxes
- tax on fuel consumption.

Until 1992 the main tax on heavy vehicle in Norway and Sweden has been a mileage tax. Norway and Sweden will change this system the first of october 1993.

3.5.2 EC recommendation

One aim of the EC transport policy is liberalisation of the transport market. Free cabotage is the best example of this. A proposal of free cabotage within the EC from 1996, is delayed until the question of tax harmonization is solved..

The next key word is harmonization. Not only on taxation, but also on technical standards, emission limits etc.

The EC Commissions proposal has full infrastructural cost liability as a basis.

All the vehicles should pay for their use of roads, and in addition fixed charges should be paid so that the total infrastructural costs is covered. We fully support these intentions.

The system (Answer) by which these objectives are to be met gives rise to a few comments- these are summarized at the end of this sub-chapter.

The original proposal from the commission did contained:

- **A two-step fuel tax.**

  1. A minimum rate established 01.01.93.
  2. A goal of a fuel tax level x for every country to reach.

TABLE 3.4 Minimum EC fuel rates and goals of fuel tax level (ECU/l).

FUEL	DECIDED MINIMUM RATES	PROPOSED GOAL OF TAX LEVEL
Leaded petrol	0.337	0.450
Unleaded petrol	0.287	0.400
Diesel oil	0.245	0.245-0.270

The fuel tax on diesel is flexible to allow for a possible CO_2 tax.

- **A proposal on CO_2-tax**

- **A proposal within the commission on tax on vehicles**

  The tax rate is not yet decided, but the principles are discussed. Because both the territorial principle and the national principle are practiced, the road network is divided into
  - toll roads
  - other roads.

  Vehicles registered in countries with no taxation by toll roads, should be eligible for a toll refund.

  For all other roads a common EC vehicle tax will be introduced. This vehicle tax is meant to cover the infrastructural costs which are not covered by the variable taxes. The tax system is based on:

  1. Calculation of fixed and variable infrastructural costs for each group of vehicles.

  2. The Vehicle tax for each group of vehicle is based on:

- infrastructural costs for each vehicle
- annual diesel consumption for each vehicle
- the coverage of the marginal costs

3. To prevent a "double tax" for some vehicles, toll will be refunded for these.

The proposed taxes will only cover approximately 15% of the real costs. Every second year the taxes will be raised so that the goal of full cover of the costs can be reached by the year 2000. The proposed taxes are minimum rates. Each country is free to excede these minimum rates in their taxation.

The allocation of infrastructural costs and calculation of vehicle taxes will probably follow the British allocation system set by the DpT.

However, the milage tax system is a long-term goal for the EC.

3.5.3 The mileage tax

Sweden and Norway[1] has/had a mileage tax as the most important tax on heavy vehicles. In Norway it was introduced in 1959 and abandoned in october 1993. It was applicable on all diesel-powered cars and also trailers heavier than 2 tons total weight. As a principle the mileage tax follows territorial principle, but at least Norway has bilateral agreements which excempt some countries from the tax. The tax is claimed by the weight of the vehicles and the distance travelled. The tax is claimed each quarter of a year by reading a plombed distance meter on Norwegian vehicles. Foreign vehicles get their distance registered when the border is passed (both directions) and thereby a tax can be claimed. Norwegian vehicles are given excemptions for the distances travelled in other countries (goods vehicles only).

The tax is differentiated between the various groups of vehicles by weight. In Sweden there are 25 different weight-differentiated vehicle groups.

The purpose of the mileage tax is to confront the road user with the cost of the use of the road. The mileage tax is very well suited to fullfill this purpose because the tax is calculated taking **distance, vehicle weight** and **the number of axles** into account.

[1]) 01.10.93 will Norway and Sweden leave the mileage tax system.

3.5.4 Effects of changing a tax system

Calculations done by The Institute of Transport Economics (Norway) shows that the last years the mileage tax equals the marginal road costs of the light diesel-powered vehicles. For the other vehicle classes it does not (Figure 3.1 & table 3.5)

FIGURE 3.1 Marginal road costs (accidents included) and taxation (toll roads included) in 1989 prices. Nkr per vehicle km.

If the vehicle exceeds an annual driving distance of 30 000 km, it is eligible for discount (illustrated in fig. 3.1 and shown in tab. 3.5). The majority of the heaviest vehicles exceed this distance. 100.000 - 150.000 km per year is quite normal for the heaviest road trains.

TABLE 3.5 Marginal costs and taxes in 1989 prices. Nkr per vehicle km.

VEHICLE GROUP ttw = tonnes total weight B = Boggie	**TAX** annual distance < 30 000 km	> 30 000 km	**MARG. ROAD COSTS** (exp. 2.5)	**DIFFERENCE** < 30 000 km	> 30 000 km
	I	II	III	I - III	II - III
Passenger Car (diesel)	0.1540	0.1540	0.1342	0.0198	0.0198
3-4 ttw	0.1670	0.0700	0.4118	-0.2448	-0.3418
5-8 ttw	0.2420	0.1370	0.5344	-0.2924	-0.3974
10-12 ttw	0.4410	0.2440	0.7747	-0.3337	-0.5307
16-17 ttw	0.8890	0.6410	1.1376	-0.2486	-0.4966
20-22 ttw (B)	1.3210	1.0490	1.1376	0.1834	-0.0886
26 → ttw (B)	1.4760	1.2020	1.4316	0.0444	-0.2296
Road train (45-50 ttw B)	2.3670	1.9010	2.8776	-0.5106	-0.9766

The accounts (1989) of marginal costs and taxation shows a deficit.

INCOME:		
Taxation	6 131	Mill kr
COSTS:		
Total capital costs	6 388	Mill kr
Total maintenance costs	2 464	Mill kr
DEFICIT	2 721	Mill kr

This deficit has to be covered by other taxes.

In spring 1992 the Norwegian parliament decided to change the tax system for heavy vehicles. The mileage tax was abandoned, and replaced by a fuel tax combined with an annual vehicle tax based on weight. The reason for this was EC harmonization, particularly with regard to the competitive ability of Norwegian freight transport by road. This was done even though the stock of Norwegian vehicles in direct competition with EC vehicles are small compared to the total stock of heavy vehicles. And further, even with the mileage tax system, from 1985 to 1989 inclusive, Norwegian truckers raised their share of freight transport to and from Norway from 46 to 52 per cent.

The calculated consequences are illustrated in figure 3.2.

FIGURE 3.2 Calculated marginal road costs, present mileage tax, new fuel tax on heavy vehicles.

The change in tax system will be neutral regarding proveny, but major changes between vehicle classes will occur (fig. 3.2 & tab 3.6). The figure shows a tax decrease for the heaviest vehicles, and a tax increase for the lighter vehicles. This picture will be amplified with increasing annual driving distance. But none of the vehicles will be taxed so that they cover their actual marginal road cost.

TABLE 3.6 Old and new tax system in Norway. Consequences for some vehicles with varying annual travelling distance.

VEHICLE GROUP	Mileage TAX (kr/km)		NEW TAX SYSTEM		Annual change (in kr) in taxes for different vehicles regarding annual driving distance					
	<30 000 km	>30 000 km	Fuel tax (diesel) kr/km	vehicle weight Kr/year	5000 km	15000 km	30000 km	50000 km	100000 km	avarage
Passenger car (diesel)	0.160	0.160	0.175	0	80	240	480	800	1600	300
Vans:										
2-3 ttw	0.160	0.059	0.265	0	520	1560	3120	7220	17470	1880
Lorries:										
7-8 ttw	0.277	0.152	0.530	0	1260	3770	7530	15050	33850	4270
16-17 ttw	0.925	0.667	0.705	4000	2900	690	**-2630**	**-1890**	**-40**	**-1070**
22-25 ttw (B)	1.356	1.071	0.835	11000	8400	3200	**-4600**	**-9300**	**-21050**	**-4690**
Road trains:										
24 + 26 ttw	2.367	1.901	1.130	26000	19800	7420	**-11150**	**-26600**	**-65220**	**-15900**

The heaviest vehicles with the longest annual travelling distance will get a dramatic tax reduction with the new tax system. This reduction will increase with increasing vehicle weight and increasing annual travelling distance.

For example, a road train of 45-50 tons total weight and with an annual travelling distance of 80.000 km, has average marginal road costs of 2.90 kr/km. With a fuel consumption of 0.5 l/km the marginal charge of this vehicle will be:

Present fuel tax:		0.27	kr/km
New fuel tax;	1.10	kr/km	
Annual vehicle weight tax:	0.33	kr/km	
Sum marginal road tax:		1.70	kr/km

This road train will only cover 58.6% of its marginal road cost.

The change to a new tax system, a fuel tax combined with an annual vehicle tax based on weight, has the following major implications:

- None of the heavy vehicles will pay its actual marginal road costs. This difference is largest for the heaviest vehicles (road trains). The larger the marginal road cost for a vehicle, the lower is its degree of coverage from the vehicle's marginal taxes.

- The difference between marginal road costs and charges from the new tax system will increase with increasing annual travelling distance, especially for the heaviest vehicles. This shows clearly that this sytem is not suited as a system to tax the costs of using roads.

- The heaviest vehicles, especially road trains, will have a competitive advantage compared to other means of long distance freight transport as trains and ships.

- The mileage tax which follows the territorial principles completely, will be replaced by a system which follows both the nationality principle (annual vehicle weight tax) and the territorial principle (fuel tax).

- The new tax system will make it more expensive to have heavy vehicles with little annual travelling distance. The reason for this is the annual vehicle tax based on weight. This indicates a higher efficiency of the vehicle stock.

There are some practical problems with the new tax system:

- Foreign vehicles are excused the annual vehicle tax based on weight.

Marginal road costs are differentiated between vehicle weight (Chapt.2). This will not be reflected in the fuel tax system. The vehicle's fuel consumption which is dependent on a variety of vehicle charateristics, and to a lesser extent the vehicle's weight will decide the burden of taxation for each vehicle. Furthermore, a foreign vehicle might not tank fuel at all! The result of this might be that a foreign vehicle can avoid paying for the use of roads in another country.

- Fuel tax free diesel will be distributed for the use of tractors. To prevent illegal distribution of "tax free" fuel, the fuels has to be differentiated by colour. A control system and a means of inflicting penalties has to be established.

3.6 Recommended tax system

This research has stongly underlined the importance of differentiating between fixed and variable costs. This has to be reflected in the taxation of heavy vehicles. The variable costs will be taxed after the marginal principle. Then we strongly recommend a **mileage tax**.

The Norwegian example shown in the previous chapter (3.5.4) shows clearly the effects of a mileage tax system and the effects of a combined fuel tax and an annual tax based on vehicle weight.

This example shows clearly that the mileage tax is the most favourable regarding taxation of infrastructural costs. The mileage tax demands the territorial principle.

The fixed infrastructural costs will preferably be taxed by a fixed annual tax based on weight. The fixed infrastructural costs will be taxed after the nationality principle.

The tax level has to be discussed further, but **as a principle we will strongly recommend a mileage tax which equals the marginal costs of the vehicles.** Concerning the tax level, we have to remember that the Norwegian mileage tax is far to low in relation to the variable costs in Norway (table 2.13).

The tax system recommended here has to be supplemented by other taxes to to cover other costs to society. For example, environmental costs have to be taxed by a fuel tax. However, some environmental costs can be taxed by a mileage tax. NO_x and VOC emissions are dependent on the combustion, and therefore these emissions can be taxed by a mileage tax.

4. CONCLUSIONS

The allocation of infrastructural costs to different vehicles must differentiate between fixed and variable costs. This is advisable in relation to taxation.

We therefore recommend the Scandinavian allocation models. The Norwegian model which calculate the long term marginal costs, is favourable to the estimation of the variable infrastructural costs. All the research used in this report shows clearly that the infrastructural costs increase rapidly with increasing axle load.

The climate has an important impact on the infrastructural costs. We recommend no tax deductions due to climatic variations.

We recommend the EC to

- to introduce mileage tax to tax the use of roads, based on territorial principle.
- to introduce an annual vehicle tax based on weight, based on nationality principle.
- It is necessary to introduce a harmonized mimimum level of the mileage tax. We advise this level to be equal to the Norwegian kilometer tax of 1992.
- We advise EC to carry these points into effect at 01.01.1996.

A fuel tax is imperfect regarding taxation of the use of roads (fig. 4.1)

FIGURE 4.1 The relation between fuel tax and marginal costs

APPENDIX

SOURCES

Brendemoen, Anne og Glomsrød, Solveig og Aaserud, Morten. Miljøkostnader i makroperspektiv. Statistisk Sentralbyrå 1992

Eidhammer, Olav & Lyng, Bjarne J., Vegtransporter i Norge og EF, Transportøkonomisk Institutt, 1991

Finans- og Tolldepartementet. St.prp. nr.1 (1991-92) For budsjetterminen 1992, (Norwegian National budget 1992)

Fowkes, AS., Nash, CA. and Tweddle, G. The Track and External Costs of Road Transport. Institute for Transport Studies, The University of Leeds, 1990.

Hansson, Lars & Lindberg Gunnar, Trafikavgifter på samhällsekonomiska villkor, Kommunikationsdepartementet 1992

Hjelle, Harald M. Biltrafikkens vegholdskostnader. Transportøkonomisk Institutt 1990

Killi, Marit. Avgiftssytemer i godstransport, Transportøkonomisk Institutt 1991

Lea, Rolv og Skarstad, Odd og Thune-Larsen, Harald. NSB's kjørevegsavgift. Transportøkonomisk institutt 1992

OECD, Road Research, Impact of heavy freight vehicles A report prepared by an OECD road research group, dec 82

Skarstad, Odd og Thune-Larsen, Harald og Østmoe, Knut. Jernbanens kjørevegskostnader, kjørevegsavgiftene sammenholdt med vegholdskostnader, Transportøkonomisk Institutt 1990

Statens Vegvesen, Årsberetning 1991

Statens Vegvesen, Driftsregnskap og Driftsstatistikk 1991

STINA, Samarbetsprosjekt för tillämpning i Norden av AASHO-undersökningen Slutrapport, teknisk del A 1977:3, Nordiska Ministerådets sekretariat

STINA, Arbetsrapport 1975:12

STINA, Slutrapport Allmän del, A 1977:2

Stina, Slutrapport teknisk del, bilagor, A 1977:4

STINA, Arbetsrapport, 1975:11

The Department of Transport, The Allocation of Road Track Costs 1991/1992, Statistics Bulletin 1991

The Department of Transport, The Allocation of Road Track Costs 1992/1993, Statistics Bulletin 1992