Finnra

Valuation of Impacts of Road Traffic Emissions

Summary

Finnra
Reports
10/1997

Helsinki 1997

Finnish National
Road Administration
Traffic and Road
Engineering

Finnra Reports
10/1997

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Helsinki 1997

ISSN 0788-3722
ISBN 951-726-323-6
TIEL 3200457E
Oy Edita Ab
Helsinki 1997

Julkaisun kustannus ja myynti:
Tielaitos, hallintopalvelut,
painotuotemyynti
Telefaksi 0204 44 2652

Joutsenmerkin arvoinen paperi

Tielaitos
Opastinsilta 12 A
PL 33
00521 HELSINKI
Puh. vaihde 0204 44 150

Valuation of Impacts of Road Traffic Emissions - Summary. Helsinki 1997, Finnish National Road Administration (Finnra). Traffic and Road Engineering. Finnra Reports 10/1997, 38 p. + appendices 10 p. ISSN 0788-3722, ISBN 951-726-323-6, TIEL 3200457E
Subject class: 05
Key words: road traffic, ecological effects, environmental costs, emissions, noise

Abstract

The publication "Valuation of impacts of road traffic emissions - Summary" reviews the bases and methods which enable determining the economic value of environmental effects caused by road traffic fuel emissions, resuspension and noise.

The working group has estimated the costs of road traffic emissions in 1990 based on Ekono Energy's studies. The new estimates are based on the fuel emissions throughout the whole fuel chain. A clear difference has been made between the effects on the urban area and on the rural area. The estimates are based on dose-response functions, as regards health effects (morbidity and mortality risk) on WTP estimates and as regards marketable commodities (roundwood and cultivated plants) on market prices. Greenhouse gas emissions have been estimated based on economic control instruments needed for halting the emission growth. Financial losses caused by noise were estimated through the Hedonic Price Method by reviewing the effects of noise on the market prices of houses.

The environmental effects caused by fuel emissions, particulates and noise of Finnish road traffic were valued at FIM 8.9 billion in 1990, of which FIM 2.1 billion are due to greenhouse gas emissions, FIM 3.4 billion due to other fuel emissions and resuspension and FIM 3.5 billion to noise.

The value of emission-caused effects was used as a basis for determining the unit damage values of different emission components. This information was further used to estimate the value of the environmental effects caused by different motor vehicles per kilometrage. Regarding the motor vehicles without a catalytic converter, the damage due to fuel emissions in highway driving is on average 5.1 p/km and in city driving 7.3 p/km (FIM 0.01 = 1 p). The emissions from a motor vehicle with a catalytic converter are lower and the damage caused by them by 20-30% smaller than the above figures. The damage caused by the present heavy vehicles is on average 27 p/km in highway driving and 83 p/km in city driving, whereas the corresponding figures of heavy vehicles of the latest model are 20-30% lower. In addition, damage caused by light and heavy traffic as particulates is valued at 4.9 p/km on average.

It has not been possible to estimate all effects. Ecological effects in population centres (parks, etc.) and health effects in the countryside have been omitted. The values of damage to buildings and constructions of considerable culture historical significance have not been assessed. No effects on biological diversity and no recreational use values are included in the estimates. No effects on waterways have been assessed, as they are probably rather minor. Further, the road traffic emissions damaging the ozone layer are also low.

The estimates obtained result largely from the calculation examples. Even though they include many uncertainty factors, they indicate the order of magnitude of damages and what effects and components are potentially the most significant. The most crucial factors regarding the estimates in this study are generalization of the results of the previous studies and their transferability from different settings, aggregation of damage values, uncertainty factors related to dose-response functions and viewpoints related to discounting.

Preface

The Finnish National Road Administration made the first study of the impacts of road traffic emissions and noise and their costs in 1992. On the basis of this study these costs were taken into account in the socio-economic calculations of road projects.

When the 1992 study was prepared, only a few or no appropriate research results were available about the effects of road traffic emissions and noise. Since then the number of researches and the amount of knowhow have increased markedly both in Finland and abroad. The Summary Report in hand includes the latest estimates of the impacts and related costs caused by road traffic emissions and noise in Finland.

The study now completed will be used to check the invoicing principles and unit prices of the damage caused by road traffic emissions and noise for the socio-economic calculations in road projects. Besides for the use of cost/benefit calculations, the study also provides additional information for discussion about the exterior costs of different forms of traffic. As these matters, especially in the EU, continue to be increasingly important, it is necessary that the study will be repeated after a few years.

The study was conducted by a working group, the members of which were Benny Hasenson from the Confederation of Finnish Industry and Employers, Antero Honkasalo from the Ministry of the Environment, Reino Lampinen from the Ministry of Transport and Communications, Juha Pyötsiä from the Ministry of Social Affairs and Health, and Pauli Velhonoja and Mervi Karhula from the Finnish National Road Administration. The secretary of the working group and the writer of the study was Ekono Energy Ltd represented by Tomas Otterström and Sari Sarin.

The Traffic and Road Engineering division of the Finnish National Road Administration expresses its thanks to all participants for their active and professional contibution to this work.

The Summary Report is also available in Finnish. The more extensive and detailed Main Report has been published in the series of the Finnra Reports, 8/1997.

Helsinki, February 1997

Finnish National Road Administration
Traffic and Road Engineering

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APPENDICES

1 INTRODUCTION

1.1 Background

This report is a summary of the report "Valuation of Emissions from Road Traffic" made by Ekono Energy Ltd to the Finnish National Road Administration. This report is based on Ekono Energy's earlier study " Valuation of the Impacts of Road Traffic Fuels Emissions" (Otterström et al. 1994) under the MOBILE research programme and on the specified and supplemented calculations made after the study. This report handles traffic noise, which was not dealt with in the earlier study under the MOBILE programme, the main focus of which was on traffic fuels emissions.

1.2 Valuation Methods Used

Several road traffic costs, such as road construction or arrangement of traffic control, are rather easy to express in money. However, road traffic also includes such costs which the market economy takes into account only partly or not at all; for example, traffic noise or environmental pollution. The purpose of the study made under the MOBILE research programme was to express the environmental impact of fuels-related emissions in money.

The valuation task is started from the relationships of road traffic and the environmental effects caused by it. There are several phases in which road traffic causes emissions, which in turn affect the environment depending on the way emissions disperse. The relationship between road traffic emissions and the changes in the environment can in some cases be expressed by means of a dose-response function. This can be either simple (for example, lost working days as a function of the sulphur dioxide concentration) or very complicated depending on many variables.

The following step is to value the impacts with the aim to find one of the following factors:

a) Society's Willingness to Pay, WTP, to reduce the damage
b) Society's WTP to ensure the benefit
c) Society's Willingness to Accept, WTA, compensation for the damage
d) Society's WTA compensation for the loss of the benefit

There are several methods to study society's willingness to pay (or willingness to accept compensation). The methods used in this study are described in the following:

The Conventional Market Approaches use market prices for commodities which are exposed to pollution. If market prices cannot be used as such, it is possible to use shadow prices based on them or calculated otherwise. When environmental damages or environmental benefits are shown as changes in the quantity or quality of marketable production factors or products, the value of the change can be measured by means of 'consumer and producer surpluses'. If the changes are small, the monetary value can be measured based on market values.

There are two different methods in the Conventional Market Approach:

(1) Dose-response method: A certain pollution level is related to a certain production, which can be valued in money using either market prices or shadow prices. For example, forest damages have been estimated using the price (market price) of roundwood. Market prices have also been used to estimate crop losses and partly health effects caused by emissions.

(2) The method based on replacement/repair cost studies the market price of the replacement or repair of damaged property. Materials damages have been estimated in this way.

The **Hedonic Price Method**, HPM, also uses real market prices as its starting point. It is here assumed that damage (eg noise) caused by emissions is included in the price (eg the value of estate) of a product in real markets. Studies made on this basis have been referred to in the section dealing with the environmental costs of noise. Another example would be risk compensation included in wages and salaries for mortality and morbidity changes caused by risks in the working environment.

The aim of **experimental methods** is to find out people's willingness to pay by asking them various types of structured questions. The following methods can be used:

(1) The Contingent Valuation Method, CVM, is based on the following question types: How much are you willing to pay for X to avoid Y?, which shows the willingness to pay, and "What would you like to have for compensation if you lose Z or tolerate A", in which case the willingness for compensation is found out.

(2) The Contingent Ranking Method, CRM, mainly strives to disclose the order of preferences, which can later be connected with some price or event to be followed on the market.

This study has used existing WTP studies (chiefly American) to value mainly health effects and to determine the value of a statistical human life. However, physical effects have first been assessed using dose-response functions.

The WTP studies include certain problems. For example, Pearce et al. (1992) are of the opinion that WTP and WTA should be very close to each other from the point of view of economic theory. In practice, however, it has been noticed that WTA is sometimes even several times as great as the corresponding WTP. According to one explanation, the errors made in studies based on questionnaires may distort the result. The form of questions affects the differences. It has been found out that when valuing unknown commodities which have not been on the market, the results may deviate a lot. On the other hand, it is possible that WTP and WTA do differ from each other. Individuals may avoid losses and give a higher value for the decrease in the quantity of a certain commodity than for its increase - a value function would be kinked at the point of the prevailing income level.

The WTP studies also include some methodological difficulties. For example, when a new road is built, local people have both benefits and losses. Several effects are experienced at the same time. Even if it would be possible in principle to identify personal WTPs to avoid this set of impacts, it must often be assumed in practice that WTP for avoiding a certain impact is independent of all other effects. According to some references in the literature, the combined value of WTPs for different effects overestimates the real total damage.

The valuation method used in Finland is described phase by phase in the following:

1. Finland is divided into the urban area and the rural area. The effects studied in the rural area are forest and cultivated plant damages, and the effects in the urban area are materials damages and health effects. Of global effects, the study has concentrated on climatic changes caused by greenhouse gases.

2. Emissions from road traffic and the concentrations and depositions of the critical emission components are examined. Thus, the goal is to clarify what quantity of the concentration road traffic causes per each emission component in population centres and correspondingly how big depositions traffic causes in the rural area.

3. Effects caused by emissions are surveyed. The aim is to find dose-response functions, which show the damage by means of concentrations (or depositions) (for example, how many statistical deaths are caused per 100,000 people when the particle concentration rises by one microgram in cubic metre)

4. The purpose is to express the value of damages in money. Valuation can be based either directly on market prices (for example, forest growth losses are valued on the basis of timber prices) or on the WTP people otherwise have expressed (for example, by means of a questionnaire survey asking "How much would you be ready to pay for to reduce respiratory infection risk by x%, which would mean an average of y colds less a year?) Climatic changes have been valued by applying two different approach methods; the extent of the damage and on the other hand, economic control instruments needed for halting the growth in emissions.

5. The combined damages are used to calculate damage values per a litre of petrol and a kilometre. Since in population centres the calculation concentrated on the damage to people and materials and in the countryside ecological effects were examined, the resulting unit damage values deviate from each other.

6. Noise damages have been assessed using the Hedonic Price Method, so that the fall in property values has been examined as a function of the noise level.

2 EMISSION LEVELS

The bases for the MOBILE study are the estimated air emissions in Finland in 1990. In addition, the study has used the forecasted emission levels for 2000. By assuming that a certain proportion of air pollutants originate from exhaust gases and road traffic fuels, it is possible to make an estimate of concentration levels caused by traffic. In this study it has not been taken necessary to modify these figures. But the study includes an estimate of the effect of particulates lifted up by road traffic (resuspension) on air quality.

The emission components taken into account include sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HC), lead (Pb) and particles (PM_{10} and resuspension). Hydrocarbons include several compounds, the most significant group of which being volatile organic compounds (VOC). PM_{10} particles are small respirable particles, less than ten micrometres in diameter.

Emission levels and emission level forecasts are presented in detail in the attached tables L1 and L2. Besides total emissions, the tables specify the emissions from passenger cars, vans, buses and trucks, and from petrol and diesel vehicles.

3 SPECIFIED RESULTS OF THE MOBILE STUDY

3.1 Total damage of road traffic emissions in Finland

After the results of the MOBILE study were specified, it was possible to calculate the values in Table 1 (in greater detail in Table L3) for the damage of Finnish road traffic fuel emissions and for the greenhouse effect abroad. For comparison, the damage estimates used by the Finnish National Road Administration (for the year 1989) are also given (Finnra 1992a)). The figures are largely the results of the calculation examples. Based on them it is possible to estimate the order of magnitude of damages and their rough order of importance.

Table 1. *Summary of damages caused by road traffic emissions and resuspension (FIM million/a, as regards the results of this study also proportion (%) of gross domestic product in 1990) in Finland and as for climate change globally (in greater detail in Table L3)*

Effects	Finnra 1992	This study	
	FIM million/a	FIM million/a	% of GDP
Health effects	560	2036	0.40
Materials damage	450	326	0.06
Forest damage	220	46	0.01
Crop losses	220	63	0.01
Effects abroad	Not estimated	872	0.17
Climate change	1500	2103	0.41
Total	**2950**	**5446**	**1.06**

It has not been possible to estimate all effects. Ecological effects in population centres (parks, etc.) and health effects in the countryside have been omitted. The values of damage to buildings and constructions of considerable culture historical significance have not been assessed. The effects on biological diversity and possible recreational uses are not included in the estimates. No effects on waterways have been assessed, as they are probably rather minor. Further, the road traffic emissions damaging the ozone layer are also low. Of the health effects, the most marked ones appeared to be morbidity risk caused by particles and cancer risk caused by hydrocarbon compounds. As regards materials damage, the wearing and fouling of construction materials were assessed. The forest damaging effects which were taken into account included acidifying sulphur and nitrogen dioxides and ozone. The ozone concentrations of cultivated plants were analyzed when assessing crop losses. Climatic changes are primarily caused by carbon dioxide, but also nitrous oxide and methane.

3.2 The effects caused by exported Finnish road traffic emissions

Most of Finnish sulphur dioxide and nitrogen dioxide emissions are carried abroad. This is also the case with road traffic fuel emissions. In addition, indirect emissions emerge when oil is produced and transported and when petrol is refined. To clarify these, the Finnish damage values were used to calculate unit damage values (FIM/kg) for the emission components, which were then applied to the emissions emerged abroad or travelled there.

The direct application of the unit damage values may overestimate the damage of "exported" emissions, since most of the emissions in Finland affect a large number of people and thus, health effects are emphasized. The emissions from the beginning of the fuel cycle most probably affect a small number of people, primarily those who work in oil fields and are involved in transport of oil. Some of the long-range transported emissions may also fall out into the sea. For this reason, the figure used to estimate the damage abroad caused by sulphur dioxide, nitrogen oxides, hydrocarbons and particles was half of the unit damage value calculated on the basis of the resulting damage in Finland.

The calculation of the damage abroad caused by Finnish road traffic fuel emissions resulted in about FIM 870 million/a. The most marked individual emission component is nitrogen oxides, the damage caused by which was valued at about FIM 714 million/a.

3.3 Unit damage values caused by motor vehicles

The MOBILE study first estimated the damage of all road traffic emissions in Finnish marks per year. Second, every known effect of every emission component was examined separately. Since in this way the total damage and total levels of emissions are now estimated, and the unit consumption and emissions of motor vehicles are easy to find out, it is possible to calculate the damage caused by motor vehicles in Finnish penni per kilometre and litre of petrol (1p = FIM 0.01).

The study has assumed that all emissions emerged in population centres stay there and cause health effects and materials damage and affect climate change. Correspondingly, emissions emerged in the countryside have been assumed to cause effects on climate change and in addition to that, only on forests and cultivated plants. As a result, we have different unit damage values for city and road driving.

Table 2. *Damages caused by different motor vehicles per kilometrage and amount of fuel consumed or km driven. More detailed results in the attached Table L4.*

	Light traffic, no cat.	Light traffic, w/cat.	Heavy traffic Model -90	Heavy traffic Model -95
City, p/km	6.47	3.74	80.63	47.70
Road, p/km	4.48	2.89	24.62	18.59
City, p/l	60.70	37.38	191.52	113.30
Road, p/l	56.01	36.14	58.48	44.16

The figures in the above table do not show the damage caused by dust lifted up by road traffic. By dividing this damage by the estimated 1990 kilometrage we arrive at an average damage of 4,9 p/km in population centres. A fairer division would not only be based on kilometres driven, but also on the weight and speed of motor vehicles.

3.4 Forecast for 2000

The presented calculations were based on the 1990 fleet of motor vehicles and the emission level. We also made an estimate for the forecasted emission level in 2000, in which case the order of magnitude of the total damage caused by Finnish road traffic fuel emissions and lifted-up dust was FIM 4.5 billion (FIM 5.5 billion in 1990).

4. ASSESSING THE RELIABILITY OF THE RESULTS

4.1 General uncertainty factors

Valuation includes several uncertainty factors, some of which are dealt with below:

Transferability of dose-response functions. The WTP estimates (related mainly to health effects) obtained earlier in other countries than Finland have been converted to Finnish marks (the 1990 value) by calculating the WTP estimate in the currency of the country in question by means of the 1990 consumer price index, after which the value has been changed to Finnish marks based on the purchasing power parity.

Aggregation of the results. In some cases care must be taken not to take into account the same damage twice, which would lead to a considerable overvaluation of the total damage. For example, damage to construction materials has been considered as a function of the sulphur dioxide concentration. Other emission components may also have caused some of the damage. However, reviewing the damages as a function of the particle concentrations as well and adding this to the above damage value would result in overvaluation, since the sulphur dioxide and particle concentrations would probably correlate.

Uncertainty factors related to input data. Uncertainty is associated with several phases of the valuation procedure. The estimated emission levels may contain uncertainty. Relationships between emissions, concentrations and depositions are not known with certainty. In addition, it may be difficult to estimate the proportion of a certain emission sector or source in the total concentrations. It is also difficult to estimate the average dose people are exposed to. Furthermore, dose-response functions often include a great amount of uncertainty. In this connection it should be emphasized that in Finland little research on health effects has been made so far, which would be of importance to this study, ie relationhips between the air quality of population centres and mortality/cancer morbidity, or the effects of respirable particles in general.

Discounting. "Discounting" is used to make future benefits and damages comparable to present benefits and damages. Here it is not question of fluctuations in the value of money, but more emphasis is placed on the benefits and damages of today than on events in the future. In the case of environmental pollution discounting is an important part of the valuation, since many environmental effects caused by today's operations will arise after several years. The higher the interest, the lower the value which is given to these damages. This study uses a discount rate of 3%, which can be regarded as some kind of compromise choice. The discount rate has been used to value forest decline and damages caused by climate change.

4.2 Assessing the reliability of the results by effects, and a sensitivity analysis

In general it can be said that on the scale of "very uncertain", "uncertain", "moderate", "good", none of the valuations is better than "moderate" in reliability. The most significant sources of error per effect are shown in the following, after which the fluctuation range for the value of different effects has been identified using the sensitivity analysis. "The best estimate" between the minimum and maximum limits is the value which was used for preparing Tables 1 and 2.

4.2.1 Health effects

Value of a statistical life

Estimating the value of a statistical life is possible using wage risk, WTP studies or different market prices. A total of 53 studies based on different valuation techniques were examined and the range of the best estimates of these studies is about GBP 1.4-3.1 million (Pearce et al. 1992). By omitting some results which were higher than others, the European average is about FIM 17.8 million (ECU 2.6 million).

Assuming that this value is valid for 30-year-old people and that the value will fall in direct proportion to the expected remaining lifetime, the results are as follows:

Table 3. *Value of a statistical life according to age (the author's own calculation), FIM million*

Age	< 30	40	50	60	> 60
Value of a statistical life	17.8	14.9	10.4	6.7	4.5

Nitrogen oxides

The EU project which studies the externalities of fuel cycles, ExternE, (European Commission 1994) assumed that the health effects detected are probably not caused by nitrogen oxides as such, but that the NO_x concentration acts as an indicator for the presence of other impurities which are not measured separately. As a conclusion, it can be stated that the direct health effects by nitrogen oxides cannot be omitted, but that their significance is probably small and they cannot be indicated reliably through the research results available.

The report by Leksell and Löfgren (1994) has studied such research reports which have assessed the relation between the NO_x concentrations and the proportion of those who experience air impurities as disturbing. They estimated that the proportions are 25% in the population of Stockholm, 20% in Gothenburg and about 18% in Malmö. On the other hand, they assessed that the risk to have some irritation symptoms is a lot smaller - in Gothenburg about 0.8% of the population would suffer from respiratory problems. So, the results indicate that "soft" health effects might represent more than 90% of all health effects. The results are not associated with nitrogen oxides only, because, the NO_x concentration probably correlates with the concentrations of other air impurity components.

Ostro (1994) points out in his report to the World Bank that the epidemiologic evidence of the impact of nitrogen dioxide on respiratory problems are on a more uncertain basis than in respect of other compounds. He also states that there exists at least one recent epidemiologic study which has found a relationship between the ambient concentration of NO_2 and health effects (Schwartz & Zeger 1990). The application of this would result in 258,100 respiratory passage symptom days/a caused by traffic fuel emissions in Finnish population centres. If it is assumed that the symptom days can be valued in the same way as the particle-induced symptom days (FIM 42/day), the damage is estimated to be about FIM 11 million/a.

In addition to this, nitrogen oxides affect formation of ozone and nitrates, the health effects of which are partly quantified. Nitrate has been dealt in connection with respirable particles. The nitrate-induced damage was estimated to be about FIM 133 million/a.

It is not yet possible to give any reliable estimate of the impact of nitrogen oxides. The estimated FIM 144 million/a has been used in the calculations. The dose-response functions presented by Ostro, Leksell and Löfgren are shown in the attached Table L5.

Ozone

The European ExternE project (European Commission 1994) has dealt with dose-response functions presented in the literature which describe health effects. Research has mainly focused on regions with high ozone concentrations. The summer has mostly been selected as a study period. So, it is unclear to which extent the results are valid in other target regions and in other seasons. The ExternE project concluded to deal with the selected dose-response functions as general, but, however, applied a threshold value of 120 $\mu g/m^3$ because of uncertainty factors. In other words, concentrations of less than 120 $\mu g/m^3$ are not assumed to cause any health effects.

The annual averages of ozone concentrations in Finnish population centres have varied between 20 and 60 $\mu g/m^3$. The background stations of the Finnish Meteorological Institute have recorded annual ozone averages between 50 and 80 $\mu g/m^3$ in the 1990s. When applying a threshold value of 120 $\mu g/m^3$ for possible health effects, it cannot be assumed that the ozone concentrations in Finland would cause any such impact.

Carbon monoxide

No dose-response function applicable to carbon monoxide-caused health effects has been found for concentrations generally existing in population centres. Specialists seem to share the same opinion that CO-induced health effects are probably rather small. However, in traffic congestion the CO concentrations may rise to a harmful level.

Sulphur dioxide

Dose-response functions for children's cough and adults' chest-discomfort were used as a basis for determining health effects due to sulphur dioxide (a total of FIM 2 million. It was also pointed out that SO_2 may be implicated in the frequency of asthma attacks and respiratory infections.

In addition to this, some components of sulphur dioxide form sulphate, which is shown in the concentration of respirable particles. Sulphate was discussed together with respirable particles. The sulphate-induced damage value was estimated to be about FIM 33 million/a.

Lead

The figure calculated for lead-related health risks (FIM 46 million/a) was considered as surprisingly high. Some amount of uncertainty is associated with dose-response functions and the unit damage values used. Since 1990, the lead emissions levels and concentrations have lowered along with the increasing use of unleaded petrol, and this is why lead-induced health effects are considered to be a nearly solved problem. The reliability of the result has to be classified as "very uncertain" and so, the fluctuation range is ± 50%, or FIM 23-69 million/a.

Respirable particles, mortality risk

The damage caused by respirable particles was studied on the basis of the PM_{10} concentrations, ie particles of <10 micrometre in diameter. Mortality risk caused by these particles proved to be in monetary value one of the most significant health effects assessed. A starting point for the used dose-response function was an average from several studies. By assuming that mortality increases by 0.5% as the PM_{10} concentration rises by 10 $\mu g/m^3$, the mortality risk due to respirable particles was estimated at 54 cases a year and the total damage was valued at FIM 362 million (direct emissions 36 cases and resuspension 18 cases). The partially overlapping impact of respirable particles and hydrocarbons was taken into account so that 18 of the 36 cases caused by VOC compounds were deducted from the number of the cases caused by the PM_{10} concentration. The total result is classified as "uncertain". The final result depends essentially on what unit damage value (FIM/case) is used.

The following consideration handles six (A-F) assumptions used when assessing direct particle emissions and particle-forming emissions (nitrogen oxides and sulphur dioxide, which form nitrate and sulphate).

A. Mortality increases by 0.5% as the annual average PM_{10} concentration changes by 10 $\mu g/m^3$. The Oak Ridge National Laboratory and Resources for the Future (1994) studied about ten reports on the relationship between respirable particles and mortality. On the basis of this investigation, their report presents that mortality increases by 0.64-1.49% as the PM_{10} concentration rises by 10 $\mu g/m^3$. The report also points out that the relationship appears to be valid with lower concentrations as well. However, it may be possible that a threshold value exists that would be close to 30 $\mu g/m^3$. In case no threshold value has been estimated for mortality increase, 0.5% can be regarded as a careful estimate. In case there is a threshold value, this estimation may overestimate the increase in mortality. Monthly average PM_{10} concentrations at the measurement stations in Helsinki varied between 20 and 50 $\mu g/m^3$ in 1990.

B. Population-weighted annual average PM_{10} concentration is 15 $\mu g/m^3$. Total dispersion is measured at several measurement stations in many towns. Some stations also measure PM_{10} concentrations. On the basis of the measurements, it can be estimated that roughly half of the mass of total dispersion consists of respirable particles. So, the population-weighted concentration will in any case be somewhat uncertain. In case the calculations concerning deaths due to respirable particles would use an annual average PM_{10} concentration of 12 or 18 µg/m^3, instead of 15 µg/m^3 , the damage would change in the same proportion to FIM 308 or 522 million/a.

C. As much as 20%, or 3 µg/m^3, of total PM_{10} concentration originates from road traffic fuel emissions. Fuel emission particles and other emission-caused particles are smaller and their chemical composition is more harmful than road particulates or other substances loosened from the road. So, the proportion of direct road traffic emissions in the PM_{10} concentration is higher than the proportion of road traffic in the concentration of total suspended particulates. If this proportion is assumed to be 15 or 25 per cent, the damage would change in the same proportion becoming 25% bigger or smaller.

D. Some 3.983 million people become exposed to the PM_{10} concentration under review. The variation of this variable becomes actual in particular if a threshold value is set for the emerging of the damage. In that case people in the population centres should be divided into two groups; those who do not, on average, become exposed to the threshold or higher concentrations and those who, on average, become exposed at least to the threshold concentration. If, for example, it is assumed that the number of those who become exposed to unhealthy particle concentrations is only half of the population, or 1.922 million people, the number of the cases is then nine and the damage is valued at FIM 60 million/a.

E. According to statistics, average mortality in Finland is 0.9% a year. The variation of this is probably not necessary.

F. The value of a statistical life is about 2.6 million ECU, or FIM 17.8 million (1990). It was assumed that the value depends on the expected value of the remaining life and that becoming ill (and dying) would occur on average at the age of 60, in which case the unit value would be FIM 6.7 million. When a value of FIM 8.6 million is applied, which corresponds to dying at the age of 55 on average, the total damage would be FIM 310 million. With a value of FIM 4.5 million (deaths on average at the age of 65) the damage would correspondingly be FIM 162 million.

Resuspension

A significant part of the concentration of total suspended particles consists of road particulates caused by traffic and wind (resuspension). Particles originating from sand, road surface, textiles, etc. form, together with the background concentration, about at least 80% of the concentration of total suspended particles, ie of all particles in the air.

The particle size in motor vehicle exhaust gases is of the order of 1 µm, whereas road particulates mainly comprise particles of >10 µm . Although the greater part of the concentration of total suspended particles originates from resuspension, the minority of the PM_{10} concentrations originate from particles lifted up from the ground. Some assessments have been made stating that components from combustion processes would be the most harmful ones. This study estimates that the effect of resuspension seen in the PM_{10} concentration is half of the effect of direct emissions per µg/m^3.

It is assumed that road traffic causes 40% of resuspension and that resuspension causes half of the harmfulness of direct emissions per µg/m^3. So, mortality risk caused by resuspension is valued at about FIM 121 million.

A summary of mortality increase cases due to particles is in the attached Table L6. There the effect of mortality due to particles has been valued at FIM 95-687 million, and using the best available data, the estimate is FIM 362 million/a.

Respirable particles, other health effects

The health impact of respirable particles was valued at FIM 1137 million/a (including resuspension) The result was based on the dose-response functions of American studies and the ExternE project and medical health care cost studies and WTP studies. Some amount of uncertainty is associated with both, so that the result is classified as" very uncertain". The figures will partly reflect the combined effect of respirable particles and other components, even though respirable particles are considered to be the most important cause to health risk. Mainly the same uncertainty factors apply to the valuation process as in the case of mortality caused by respirable particles; the annual PM_{10} concentration, teh exposed population and the proportion of road traffic in the PM_{10} concentration.

A possible source of error may also be the unit values used for diseases. They are based on American studies and they possibly over- or underestimate the unit prices in Finnish conditions.

A similar estimate may be used for resuspension from traffic and wind as in the above paragraph dealing with mortality due to particles. Assuming that road traffic causes 40% of resuspension and that resuspension is 50% less harmful than direct emissions per µg/m^3, the health damage caused by resuspension can be valued at about FIM 379 million.

The attached Table L7 shows a summary of particle-caused health risks. The range is FIM 338-1422 million and the best estimate FIM 1137 million.

Hydrocarbons

Hydrocarbons-induced cancer risk measured in money was the second most important health effect. The damage was valued at FIM 478 million/a. Uncertainty factors include population-weighted concentrations and the proportion of road traffic in emissions of different compounds. The combined effect of hydrocarbon compounds and particles was taken into account. The result is classified as "very uncertain".

Hydrocarbons-induced cancer risk was assessed mainly on the basis of the estimates made by Swedish Törnqvist & Ehrenberg (1993). Some uncertainty factors are discussed in the following:

A. Cancer risk through the food chain from Finnish road traffic emissions is 108 cases/a. According to Törnqvist's estimates, PAH compounds coming through food chains cause 300 cancer cases a year. When this is proportioned to the Finnish population and assuming that 60% of the emissions originate from road traffic, the result is 108 cancer cases. In that case emissions from abroad have not been taken into account. According to the researchers of the Finnish Institute of Occupational Health and the Public Health Institute, the bulk of the PAH dose people are exposed to originates from PAHs formed in cooking and smoking. The proportion of air pollutants in PAHs coming through the food chain would thus be marginal. Assuming that the risk of PAH emissions from Finnish traffic coming through the food chain would be 0, 11 or 32 cases, traffic-caused VOC emissions would cause a total of 62, 73 or 94 cases and the corresponding damage would be valued at FIM 415.4 million, 489,1 million or 629.8 million.

B. The value of a statistical life is 2.6 million ECU (FIM 17.8 million). Cancer cases were assumed to lead to death at the age of 60, in which case the damage of one cancer case is valued at FIM 6.7 million.

C. The Study cited. A recent Swiss study (BUWAL 1994) has estimated a risk of having lung tumour. Using the values of this study the number of deaths in Finland due to traffic fuel emissions would be 220/a, which would be equivalent to the damage value of FIM 1470 million.

A summary of cancer risk caused by hydrocarbons has been presented in the attached Table L8. The range of the damage is calculated to be FIM 279-630 million/a and the best estimate FIM 478 million/a.

4.2.2 Materials damage

Sulphur dioxide and nitrogen oxides, corrosion

Construction materials damage as a function of the sulphur dioxide concentration was estimated on the basis of the studies carried out in the Stockholm area (Kucera et al. 1993). The relation of the material frequency to the population figure was assumed to be the same in Finnish towns and Stockholm. Also, the material maintenance intervals and repair costs were assumed to be same. So, possible errors may exist, but to a lesser degree than in many other damage values. As a result, the damage was valued at FIM 18 million/a, the range being FIM 13-22 million/a.

Particles, fouling

The concentration of total suspended particles of 30 $\mu g/m^3$ was assumed to cause cleaning measures to a value of FIM 200 per capita a year. Traffic was estimated to account for 10%, which resulted in the damage value of FIM 62 million/a.

Fouling caused by resuspension is many-fold more significant than the damage caused by direct fuel emissions. By taking into account particulates caused by motor vehicle traffic and the uncertainty included in cleaning costs, the range is FIM 206-370 million/a, the best estimate being FIM 308 million/a.

4.2.3 Forest damages

Acid deposition

The author's own estimate was used in the calculations about forest growth decline when the critical loads of sulphur and nitrogen were exceeded. Forest growth was assumed to slow by 0.1% from the previous year during 1990-2090, while emissions were expected to remain on the 1990 level. A 3% discount rate was used. The effect was valued based on stumpage prices. Biological diversity and recreational activity were not valued. All in all, this estimate must be considered as very uncertain.

The total damage was valued at FIM 255 million/a, of which traffic fuel emissions represent 14 million/a. Unless future effects are valued with smaller weight than present effects, but 0 is used as a discount rate, the damage is valued at FIM 442 million/a, of which the traffic-caused damage is FIM 24 million/a.

The IIASA (International Institute for Applied Systems Analysis) has also assessed forest damages caused by acidification and arrived at values which are considerably higher than the above values. In the original study (Nilsson 1991) using a 0% discount rate forest damages due to acid deposition were valued at more than FIM 2.5 billion/a. If the estimate of forest growth decline used by the IIASA were combined to the 3% discount rate used in the MOBILE study, the share of traffic of forest damages would be about FIM 140 million/a.

The best estimate was FIM 14 million/a, the range being FIM 7-47 million/a.

Ozone

The effect of ozone on forest growth decline is considered as very probable, even though studies of this subject are still in progress.

There is a study going on under the UN ECE to identify the critical levels of ozone and other air pollutants for assessing damages to cultivated plants (UN ECE 1993). It has been agreed that ozone concentrations are presented by means of exposure index AOT40. This has been defined as an integral in relation to time (unit ppbh) of the difference between the concentrations exceeding the threshold concentration 40 ppb and this threshold , ie AOT40 always increases as the concentration exceeds a limit of 40 ppb.

The Finnish Meteorological Institute is carrying out the project financed by the Ministry of the Environment, entitled "Ozone sinks in the forest ecosystem - relation to critical concentrations and doses". The annual project report (Finnish Meteorological Institute 1994) has calculated exposure levels for both coniferous and non-coniferous trees covering different time periods. The following exposure levels are used here:

- An average used for coniferous trees describes coniferous trees' exposure to ozone in the thermal growing season in daylight during the period of 1989-1993. The exposure index is calculated separately based on the measurements by the Utö, Virolahti, Ähtäri and Tvärminne stations in southern Finland and the

Oulanka, Pallas and Raja-Jooseppi stations in northern Finland. The exposure index in southern Finland is 5450 ppbh and in northern Finland 1815 ppbh.

- An average for non-coniferous trees covers the period of 1990-1993 and describes non-coniferous trees' exposure to ozone in the thermal growing season during periods when birch is in leaf. The values are based on the measurements made by the Oulanka station. The exposure index is thus 1900 ppbh.

The ECE study has made a preliminary estimate for growth losses:

10000 ppbh concentration causes 10% growth loss to sensitive tree species

The estimate is based on one-year tests and is very uncertain. So, we use a more careful assumption:

- dose function is linear
- 0 ppbh does not cause growth loss
- 10000 ppbh causes a 5 % growth loss.

Using these assumptions, the total loss is FIM 215 million/a, of which the emissions from traffic make FIM 32 million/a. The range was determined to be FIM 19-86 million/a.

A problem is that this function does not take into account effects from several years. The report of the Finnish Meteorological Institute describes this as a serious drawback, since in Finnish weather conditions and the ozone concentrations damages result from effects occurring during several years. However, it may not be justified to assume that ozone would cause as far-reaching damage as acid deposition.

4.2.4 Damage to cultivated plants

Crop losses as a function of the ozone concentration vary from species to species. The estimate (FIM 63 million/a) includes the most important cereals; winter wheat, spring wheat, rye, oats, dry hay, silage and potato. Those left out include sugar beet, oil plants, vegetables, fruit and berries. The dose-response functions used are mainly American and Swedish. These estimates contain less uncertainty than several other calculated values.

The annual damage range was estimated to be FIM 44-84 million.

4.2.5 Climatic changes caused by greenhouse gases

To value greenhouse gas emissions, it is possible to apply two different approaches. Pricing can be based on the estimated value of the damage (damage costs) or on economic control instruments to be used for achieving the targets set by society.

Damage costs

Damage costs can be calculated from two different starting points. (1) Marginal damage costs are calculated for known emissions. So, the aim is to calculate real damages which are caused by the increase or reduction in carbon dioxide emissions in the present situation. (2) In optimization models marginal costs are calculated at a point where the marginal damage and the marginal emission reduction cost are equally high. Optimization models are therefore used to find the best possible carbon tax by international standard. On the other hand, this optimal damage estimate is only valid if damages really develop according to assumptions.

The MOBILE study utilized the CO_2 emission cost estimate, USD 5.5/tonne of carbon (about FIM 7.7/tonne of CO_2) based on Fankhauser's (1994) marginal damage costs. This estimate is based on a model which takes into account damages to, for example, agriculture, forests, sea level rise, water management, biological diversity and health. These were mainly valued using the cost of damage prevention and repairs. The results of different studies when using a 3% discount rate vary between USD 5.3 and USD 11 per tonne of carbon. In the first decades of the 2000s the damage is expected to be somewhat higher, some USD 8.1-65.9 per tonne of carbon.

Damage estimates have been criticized by saying that they are relatively small compared with possible catastrophes described in the literature. One reason for this may be the fact that the most pessimistic scenarios do not take into consideration possible adaptation measures. Another reason may be associated with the level of uncertainty. The above figures are "the best guesses" ie they describe the most probable damage scenario in the light of present knowledge. Because of the complexity of this phenomen it is not justified to leave out such a possibility that consequences could be more serious.

Other greenhouse gases

Besides carbon dioxide, methane (CH_4) and nitrous oxide (N_2O) also have an impact on the greenhouse effect. According to the background data collected by the Carbon Dioxide Committee II (Committee Report 1994:2), road traffic emissions in 1990 were 7600 tonnes of methane and 4900 tonnes of nitrous oxide. If Fankhauser's calculations are also applied to these figures, the total damage is valued at FIM 7.5 million/a.

Economic control instruments

Another approach is to value carbon dioxide emissions using economic control instruments. For example, by studying what kind of carbon tax would lower carbon dioxide emissions to that level to which Finland has committed when signing international agreements. The starting point would, in that case, be halting the growth of emissions by the year 2000.

The Report completed in June 1991 by the Carbon Committee I (Committee Report 1991:21) says that a FIM 150 tax per tonne of carbon might be sufficient to halt the growth of carbon dioxide emissions. This would require that all industrialized countries would pursue a common policy. Using these values, the cost of CO_2 emissions from road traffic would be about FIM 1892 million/a.

If the above figure (FIM 150 per tonne of carbon) is applied to methane and nitrous oxide emissions from road traffic, these emissions must first be converted to be comparable to carbon dioxide emissions. Since CH_4 emissions are considered to be 11 times as dangerous as carbon dioxide emissions and N_2O emissions 270 times, the cost of these greenhouse gases are FIM 13 million (CH_4) and FIM 198 million/a (N_2O).

It is possible to estimate the costs by using price elasticity of demand. Malka (Malka 1991) has estimated that in the long run the price elasticity of demand for petrol is -0.7 and for diesel oil -0,074. In other words, an 10% increase in the price of petrol would in the long run reduce the consumption of petrol by 7%. If the target is to halt the growth at the 1990 level by 2000, the relative price of petrol should, on the basis of the figures of Malka's study, be raised by about 30% (about FIM 1.5/l) and the price of diesel oil by about 60% (about FIM 2.1/l) (price level 1995). The costs required by economic control instruments were several times higher than the values based on the marginal or optimal costs. In fact, it is not possible to give an unambiguous value for greenhouse gases. However, the range of the economic impact can be FIM 104 - 2103 million/a.

Here it is a question of a very complicated and diverse whole of effects, of which there is not yet enough information for making moderate assessments possible. For this reason, it is justified to use economic control instruments as a starting point to achieve the targets set by society, in which case some kind of estimate of society's WTP to avoid damages can be obtained. So, the calculations use an estimated FIM 2103 million/a.

4.2.6 "Exported" emission effects

The damage abroad caused by fuel chain emissions from Finnish road traffic was calculated using average unit damage estimates of emission components in Finland as a starting point.

It is obvious that the effects of "exported" emissions differ to some extent from the effects in Finland caused by the same amount of emissions. Some of the "exported" emissions land on the sea and others form new compounds. It can be assumed that rather few emissions would affect concentrations in population centres and that ecological effects become more important instead. Hence, halving the unit damage value calculated for emissions in Finland when assessing the value of "exported" emissions is probably justified. If this were not the case, the value of "exported" damages would be FIM 1713 million/a.

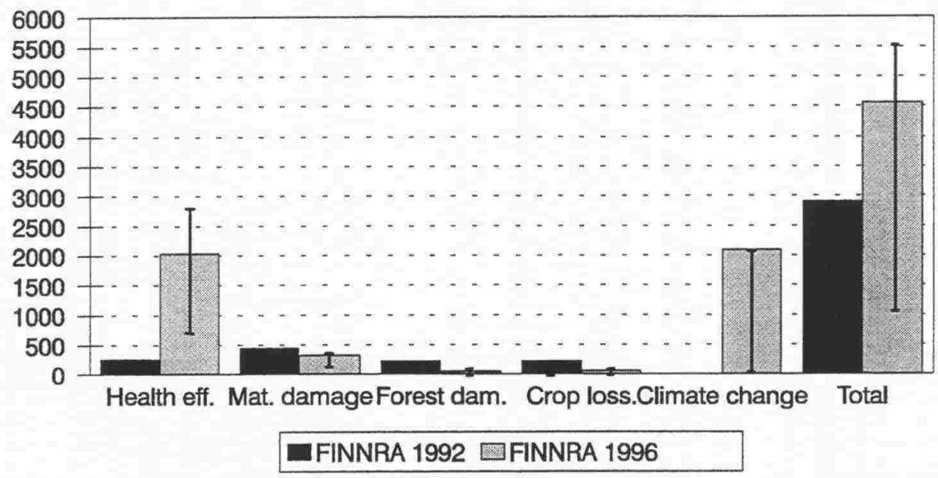
When the maximum and minimum limits of the damage range of different effects are applied (halving the unit damage of emissions affecting in Finland), the value of the damage caused by "exported" emissions from Finnish road traffic is FIM 241 - 912 million/a, the best estimate being about FIM 872 million/a.

4.3 Summary and comparison with the 1992 estimates

The following two diagrams summarize the environmental costs estimated in this study. Besides "the best estimates", the diagrams also show the estimated ranges. The results are shown in detail in the attached Table L9. It should be noted that some potentially significant values are not included in the estimates.

Such are effects on the aquatic environment, culture historical values of buildings and monuments and values of biological diversity associated with forests, and landscape and recreational values.

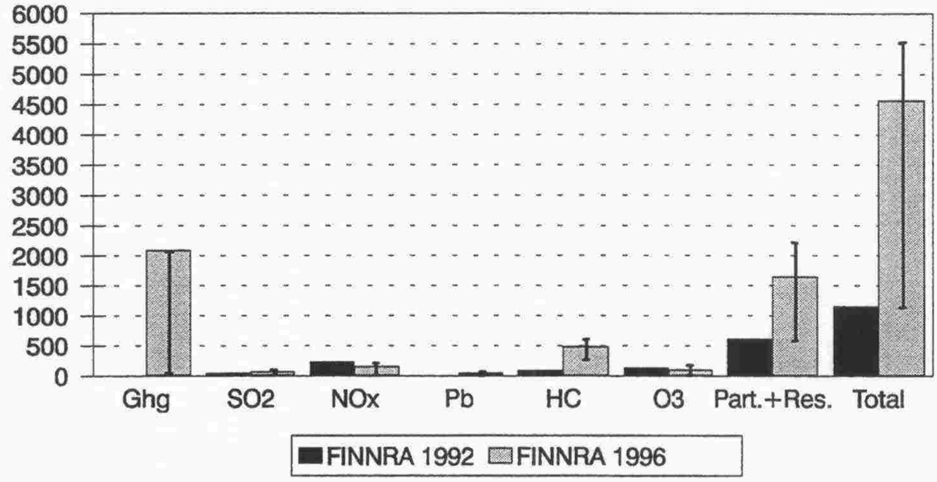
Figure 1. *Results of the previous study (Finnra 1992 b)) and this study by effects. Vertical segments show the estimated range.*



In addition to the above estimates made in 1992 (Finnra 1992 b)), the working group set by the Finnish National Road Administration estimated the discomfort value of exhaust gases to be about FIM 300 million/a, and using economic control instruments climate change was valued at FIM 1500 million/a (Finnra 1992 a)). Discomfort was divided equally among nitrogen oxides, hydrocarbons and particles (in addition to the values shown in Figure 2).

New estimates differ from the previous ones in particular with regard to health effects, for which the new estimates were notably higher, and with regard to ecological effects, for which the new estimates were lower. The estimates of climate change are based on the application of economic control instruments, but the new estimate also includes methane and nitrous oxide emissions (in addition to carbon dioxide emissions). Further, the emission estimates cover the whole fuel chain and not only exhaust gases as the previous estimate of the working group.

Figure 2. *Results of the previous study (Finnra 1992 b)) and this study by emission components (greenhouse gases, sulphur dioxide, nitrogen oxides, lead, hydrocarbons, ozone and particles incl. resuspension).*



Among emission components, particles and emission-based particles dominate and the new estimated figures are considerably higher than the previous ones. Hydrocarbons are also estimated to be higher. As regards other components, the differences are smaller.

The most significant methodological changes between the previous and new values are:

- New estimates are based on the emissions of the whole fuel chain, and not only on exhaust gases and resuspension
- A clear difference has been made between the damages to urban and rural areas, and the results for these areas (FIM/km) differ markedly from each other
- More recent data on health effects due to air pollution has been available, since health issues are the subject of intensive research. As a result, new estimates of health effects are higher than the previous ones.
- New estimates are based on dose-response functions. As regards health effects (morbidity and mortality risk), they are based on WTP estimates and as regards marketable commodities (roundwood and cultivated plants) on market prices. Greenhouse gas emissions have been valued by means of economic control instruments needed for halting the emission growth.

Despite rapid advances in valuation of environmental effects, valuation techniques and their areas of application continue to undergo development. Uncertainty is especially associated with some health effects, forest damages and economic consequences resulted from climatic changes. For that reason, results and valuation techniques have to be further revised under new research data.

5 NOISE

5.1 Hedonic pricing of noise

In some cases damages can be valued based on market prices - for example forest growth losses can be valued based on the price of wood. The hedonic price method values environmental commodities assuming that environmental factors are reflected in market prices. For example, by studying the prices and locations of properties it is possible to estimate how much the change in the noise level alters the price of property.

Many noise valuation studies based on the value of properties have been made in several countries. The results have been very converging, which gives reason to conclude that the results could also be used in other regions than in the area studied. According to the studies, a change of one decibel in traffic noise causes a fall of 0.5-1% in the value of properties.

5.2 Recent noise valuation studies

5.2.1 German noise study

The research programme of the German Ministry of the Environment "Cost of Environmental Emissions/Benefits of Environmental Protection" published a study in 1990 entitled "Noise Costs in Germany" (Weinberger et al. 1991).

Occupational hearing defect

In Germany 3-4 million employees are exposed to a noise level of 85 dB(A) during eight-hour work days. They have a risk of hearing impairment.

According to statistics, 1023 new more serious occupation-related hearing defect cases occurred in 1987, ie cases in which the hearing impaired by 40%. This kind of hearing defect is estimated to lower ability to work at least by 20%. Studies have shown that taking into account lower ability to work, annual wages and the remaining lifetime, the cost of a serious hearing defect amounts to DEM 123000 and the total cost of all cases DEM 126 million/a.

In addition, 2042 less serious hearing defect cases occurred in Germany in 1987 (hearing impaired less than 40%). In these cases, ability of work has been considered to lower by 16% on average. Total costs in this case as in the above amount to DEM 136 million/a.

Thus, the combined costs would amount to DEM 262 million/a, which the authors of the study regard as the minimum limit for damage costs.

Lower work performance

The results of several studies indicate that work performance falls by 0.5-1.5% per decibel. According to careful estimates, social costs are of the order of billion German marks. In case the noise is due to working places' own noise level, lower work performance is not an external cost, but a business economics problem. Viz. in this case an employing company both causes noise and suffers from it.

Cardiovascular diseases

Researchers estimate the number of people suffering from high blood pressure due to traffic noise by taking all those exposed to a noise level of over 50 dB(A) as a starting point. When we know that 15% of them are treated because of high blood pressure and that the corresponding figure with a noise level of 70 dB(A) is 23%, it is possible to estimate the number of noise-caused cases.

The authors estimate the cost caused by cardiovascular diseases by calculating both medical care costs and resource losses. In this way total costs regarding traffic noise are DEM 0.9-3.6 billion/a, which is considered to be the minimum limit.

Effect of noise level on property values

The effect of noise on the value of properties was estimated to be 0.5-1.26% per decibel. In addition, the study reviewed the variation of rent of dwellings according to a noise level. As regards road traffic noise, the result was DEM 0.98-2.4/month/person, which is equivalent to DEM 557-1404 million/month.

WTP study based on questionnaires

The WTP study used questionnaires which were sent to close to 7000 households asking them their willingness to pay for a dwelling in a quieter environment. On the basis of the answers, an individual's WTP for a 1 dB lower noise level was given a value of DEM 1.67/month.

Conclusions

The order of magnitude of social costs caused by noise from all sources was estimated to be over DEM 30 billion/a. Traffic noise costs amount to at least DEM 10.7-12.8 billion/a, which is equivalent to DEM 360-490/a per motor vehicle.

The authors of the report also made an estimate of noise abatement costs. It was concluded that the benefits of noise abatement are higher than the costs.

5.2.2 Swedish noise study

In summer 1993 a survey ordered by the Ministry of the Environment of Sweden was completed including a proposal for a comprehensive plan for noise abatement measures. Among other things, it deals with social costs caused by traffic noise and ways of noise abatement (Kihlman et al. 1993).

The study also investigated people's WTP by mailing questionnaires to inhabitants living in areas with three different noise levels. Area 1 was relatively peaceful, the traffic noise level being 55 dB(A). Area II was noisy (> 70 dB), but the windows were insulated (indoor noise level < 40 dB). Area III was equally noisy as Area II, but the windows were not insulated. On the basis of the answers, a demand curve was made for a low noise area and a peaceful area. The results of the studies are shown in Table 4. The Swedish study was carried out by small resources: questionnaires were sent to 1250 people, of whom only 314 answered.

Table 4. WTP for noiseless residential areas in three population centres in Stockholm and Gothenburg

Measure	Area I	Area II	Area III
Fully insulated windows, SEK/window	5700	13000	13000
Fully noiseless traffic environment, SEK/dwelling	45000	100000	72000

5.2.3 The Green Paper

The Green Paper of the European Union deals with the external costs of noise (Euroopan Yhteisöjen Komissio 1996). The studies cited in the Green Paper have mainly focused on the noise of road traffic. The cost of noise has been estimated to about 0.2-2% of GNB. The studies indicate that the price of dwellings drops on the average by 1% as the noise level increases by 1 dB(A) from the 55 dB(A) level in the 1980's.

5.2.4 Finnish noise study

A doctoral dissertation (Vainio 1995) recently published in Finland deals with environmental costs of traffic. The paper applies the Hedonic Price Method (HPM) and the Contingent Valuation Method (CVM) to estimating noise and exhaust gas emissions in Helsinki.

According to the Hedonic Price Method, the price of a dwelling drops by FIM 18420 (0.36% of the value of a dwelling) as the noise level rises by 1 dB(A). According to the WTP survey, people's WTP for a fall of one decibel would be FIM 5160/a, which, according to the author is equivalent to FIM 51600 as a lump sum.

The results of the CVM survey are 2-3 times as high as those of the Hedonic Price Method. Possible reasons are many. The differences may be due to the shortcomings in the survey or to the fact that the results produced by the different methods really deviate from each other.

5.3 Estimate of road traffic noise costs in Finland and comparison with the 1992 estimates

The number of those exposed to traffic noise has been estimated in the study of Finnra completed in 1992. This study divides people into three groups: those exposed to a noise level of (1) 55-65 dB(A), (2) 65-70 dB(A) and (3) over 70 dB(A). A noise level of lower than 55 dB(A) was not assumed to cause any harm.

Noise has been valued using the results of Matti Vainio's doctoral dissertation (1995) and on the basis of the study made in Germany (Weinberger et al. 1991). The results based on the Finnish survey are presented in Table 5.

Table 5. *Traffic noise-caused costs in Finland in FIM million/a using the Hedonic Price Method (HPM) and WTP studies (CVM).*

	55-65 dB	65-70 dB	> 70 dB	Total
HPM	2238	872	359	3469
CVM	3858	2189	1189	7236

Total costs are thus about FIM 3.4-7.2 billion a year. If the results of the German study were used, total costs would be about FIM 1.0 billion/a. Because of the uncertainty factors related to the CVM study, we use here the estimates received from the HPM. So, the value of noise damage will be about FIM 3470 million/a, which is about 0.67% of Finnish GDP in 1990. The estimate includes uncertainty factors described in the following:

Vainio's dissertation did not separate home buyers' WTP for less road traffic noise from their WTP for reduction in noise from other sources (except air traffic noise), for example, for reducing possible industrial noise, noise from yards or neighbouring flats. For this reason, the results obtained by Vainio might describe the WTP regarding the reduction not only in road traffic noise but also in other noise sources.

Taking into account other noise sources might markedly increase the number of the dwellings which are located in the area of a noise level of >55 dB (areas defined on the basis of road traffic noise only), which was considered to be a threshold for detectable WTP. In this sense the resulted WTP may be underestimated.

On the other hand, it is possible that the results of Vainio's dissertation reflect WTP regarding the other characteristics of dwellings, in spite of his intentions to separate noise preferences. This may lead to either overestimation or underestimation.

Showing flats usually takes place on Sundays, when traffic is lower than usual. The HPM may thus give a measure for WTP for a lower traffic noise level, the starting point being the noise level on Sundays rather than an average noise level.

The area Vainio studied was Helsinki. Generalization of the results to cover the whole country can lead to miscalculation, for example, if the preferences of people living in Helsinki differ from those of the whole population on average. Using the average size and price of dwellings also includes possibility of error.

The working committee set by the Finnish National Road Administration (Finnra 1992 a)) estimated the value of discomfort caused by noise to be about FIM 1600 million a year. This was based on the assumption that at a noise level of 55-65 dB the proportion of those experiencing disturbing noise was 33%; at a noise level of 65-70 dB 50% and from a level of over 70 dB 100%. The unit damage price used was FIM 5000/person exposed.

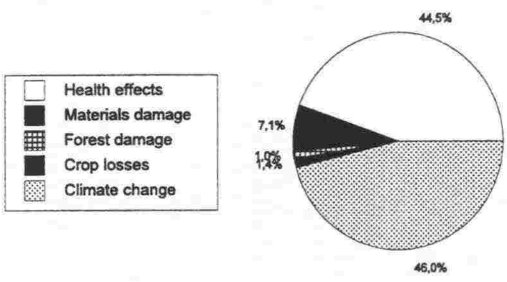
Table 6. *Traffic noise caused costs in Finland (FIM / inhabitant) according to this study.*

Noise level (dB(A))	Costs (FIM / inhabitant)
55 - 65	3365
65 - 70	8412
70 -	13459

6 CONCLUSIONS

The estimates made of external costs are largely results of calculation examples. Even though they include many uncertainty factors, they indicate the order of magnitude of damages and what effects and components are potentially the most significant. On the basis of the calculations made, health effects dominate the damages caused by road traffic fuel emissions. Health effects would be in the range of billion Finnish marks (FIM billion/a), whereas forest damages and crop losses would both be lower by a factor of ten (FIM 0.1 billion/a). Global impacts are as great as health effects if the basis for valuation is considered to be economic control instruments needed for halting the growth in emissions. The value of noise damages was estimated to be over FIM 3 billion/a.

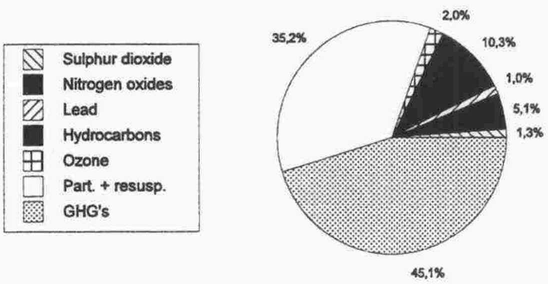
Figure 3. *Distribution of damages by effects*



It is somewhat surprising that health effects so clearly dominate, while ecological effects and global effects are astonishingly small. On the other hand, the effects of "exported" sulphur dioxide and nitrogen oxides are mainly ecological effects. So, the total ecological effects are also of the order of billion Finnish marks annually (FIM billion/a). One possible reason for the dominance of health effects is that the values are partially based on WTP assessments, while others are mainly based on market prices. On the other hand, the values of buildings and monuments of considerable culture historical significance and the values related to forests, such as biological diversity, landscape or recreational values, have not been assessed. The assessment of global impacts contains a particular amount of uncertainty.

When examining different emission components (effects in Finland and abroad in 1990), it can be noted that the damage of nitrogen oxides and particle emissions from road traffic dominates being of the order of billion Finnish marks (FIM billion/a), whereas the damage due to hydrocarbon emissions is only half of it (approx. half a billion/a) and the damage of sulphur dioxide emissions some hundred million (approx. 0.1 billion/a). The damages of lead emissions is clearly smaller (approx. FIM 50 million/a). If greenhouse gas emissions are valued based on the economic control instruments required for halting the growth in emissions the result would be some billion marks. When using the existing damage estimates, the result is considerably smaller (about 0.1 billion/a).

Figure 4. *Distribution of damages by emission components*



Since the above results are based on the motor vehicle fleet in operation in 1990 and on the emission situation of that year, the values calculated in the same principle but using more recent parameters could deviate from the results obtained in this study. This is due to the increasing proportion of cars equipped with catalytic converters, launching of new low-emission fuels on the market and exhaust gas tests to be performed during motor vehicle inspections.

When the same valuation methods are applied to the predicted emission level of the year 2000, the damages will be, as expected, smaller than in 1990. The cut in the total damages by a third (except for greenhouse gas emissions and resuspension) from the 1990 level roughly corresponds to the predicted fall in road traffic emissions. Only carbon dioxide emissions are expected to rise.

According to the results of the study, the damages of petrol traffic emissions reduce proportionally more than those of diesel traffic emissions, and the damages of light traffic emissions more than those of heavy traffic emissions.

The most significant health effects are caused by the PM_{10} concentrations. Additional deaths caused by air pollution form a marked proportion of all health effects. According to the more accurate calculations made in this study (Section 4), road traffic fuel emissions and resuspension would cause about 120 deaths annually due to respirable compounds (just over 50 cancer cases and about 60 cardiovascular cases) and about 10 cases through the food chain. According to calculations, air impurities from all emission sources and resuspension would cause about 240 deaths through respirable compounds (about 100 cancer cases and about 140 cardiovascular cases) and over 10 cases through the food chain. The above estimate (240) is slightly higher than the estimate previously given in Finland, according to which pollutants caused by both traffic and energy production would cause about 100 deaths each due to respirable compounds (Tuomisto 1992 - the calculations behind these figures are not known to the author of this study). Furthermore, deaths caused by emissions from industry, etc. would add to this figure. There are also estimates in the literature that the polluted air in population centres due to the use of fossil fuels would cause 5-10 cancer cases per 100,000 inhabitants partly as a result of the combined effect with smoking. In total, it has been estimated that pollutants of the polluted air in population centres cause 1-2% of all cancer cases (Doll & Peto 1981). At the maximum the increase in total mortality due to respirable particles has been estimated to be as high as 9% per every 10 $\mu g/m^3$ respirable particulate concentration (Dockery et al. 1993). In the light of these figures, the estimates given in this report do not appear to be too high. In general, the valuation of health effects is associated with a considerable amount of uncertainty, in particular with regard to additional mortality due to respirable particles and hydrocarbons and additional morbidity due to respirable particles.

The calculated corrosion damage is small with regard to total damage, which was expected. Sulphur dioxide concentrations in Finnish population centres were decreasing throughout the 1980s, which has also reduced air pollution-induced corrosion. Further, the proportion of road traffic in these concentrations is small. Construction materials damages as a function of the sulphur dioxide concentration were estimated on the basis of the thorough investigations carried out in the Stockholm area. The result obtained contains less uncertainty than the values of most other damages calculated in this study.

As regards particulate-caused fouling, the proportion of road traffic emissions in the concentration of total suspended particulates was estimated to be about 10% and including resuspension 50%, in which case the road traffic damages would amount to FIM 300 million/a. The fouling damage caused by the total concentration of total suspended particulates (all emission sources and secondary emissions included) is thus significant, about FIM 600 million/a. The fouling effect of particles can easily be estimated with higher figures and it is therefore a matter of agreement how to determine the value of this damage per capita at different concentrations.

The low level of forest damage due to road traffic emissions can widely be explained by the fact that the majority of acidifying sulphur (about 75%) and nitrogen (80%) comes from abroad, in which case the proportion of domestic emission sources remains small (proportion of road traffic in sulphur emissions is 5% and in nitrogen emissions 10%). On the basis of the calculations the total forest damage would be half a billion Finnish marks in 1990 (of which road traffic represent FIM 50 million). About 100-200 million of this would be caused by acid depositions, which is only 10% of the figure which IIASA has arrived at when assessing forest damage due to sulphur emissions in Finland. The estimated value of forest damage is based on the example calculation which assumes that annual forest growth decline due to acidification would be 0.1%/a during the next 100 years. An ozone exposure of 10,000 ppbh over a threshold concentration of 40 ppb was estimated to lead to 5% growth decline.

The estimated "exported" damage caused by sulphur and nitrogen emissions from road traffic fuels, about FIM 830 million in 1990, comprises mainly ecological effects.

Crop losses causing ozone originates mainly from other sources (85%) than from traffic fuel emissions (15%). Researchers begin to also have a view of the dose-response functions of cultivated plant damages caused by ozone. The values of ozone-caused plant damages contain a lower degree of uncertainty than the other estimated values in this study.

The economic impact of greenhouse gas emissions (CO_2, CH_4, N_2O) was estimated at just over FIM 2 billion/a based on economic control instruments needed for halting the growth in emissions, and just over FIM 0.1 billion/a based on damage estimates. Finland's proportion in the world's greenhouse gas emissions is 0.1-0.2 per cent, whereas Finnish road traffic emissions account for about 20% of Finnish carbon dioxide emissions. The given estimate includes many uncertainty factors, not only because the greenhouse effect is a very complicated process, but also because it is very difficult to assess the consequences of global warming.

The method for assessing new values differs from the method used in 1992 (Finnra 1992 a)), for example, so that new estimates are based on the emissions from the whole fuel chain and not only on exhaust gas emissions and resuspension. In addition, the study makes a clear division between the effects directed to population centres and the effects directed to the rural area. Research on health effects caused by air pollutants has produced a lot of new information, as a result of which the new estimates are higher than the previous estimates in this respect. Discomfort can be taken to be included in the new health effect estimates. The new values are based on dose-response functions and with regard to health effects (morbidity and mortality risk), on WTP estimates. The previous health effect assessments were based on mere medical care costs and production losses. As regards marketable commodities, such as roundwood and cultivated plants, the new values (as the previous ones) are based on market prices. Greenhouse gas emissions have been valued in the same way as in 1992, viz. on the basis of necessary economic control instruments needed for halting the growth in emissions, but, besides carbon dioxide emissions, methane and nitrous oxide emissions are also included in the newer estimate. The changes in the value of money should be taken into account e.g. by using the cost of living index when applying the unit damage costs presented in this report.

Noise-caused damages were valued based on the Hedonic Price Method by using the results of the study of Helsinki's traffic noise areas (noise min. 55 dB). The estimate used as a starting point was a decrease of 0.36% in the value of a dwelling per decibel.

Uncertainty factors related to the estimate are, for example, omitting other noise sources, except road and air traffic, and uncertainty about how well noise has been eliminated from the other factors affecting the price of dwellings. In addition, the WTP assessed using the Hedonic Price Method may be based on the noise level at the time of showing the flat rather than on an average noise level. Generalization of the results of the original study to cover the whole country and the application of an average size and price are also sources of error.

The calculation method of the new estimate differs from that of the 1992 estimate (Finnra 1992 a)), which was based on the assumption that at a noise level of 55-65 dB the proportion of those experiencing disturbing noise was 33%; at a noise level of 65-70 dB 50% and from a level of over 70 dB upward 100% and that the unit price is FIM 5000/person exposed.

The sum of the above damage estimates (about FIM 8.8 billion/a) accounts for about 1.7% of Finnish GDP (1990), being divided as follows: climatic changes caused by greenhouse gas emissions about 0.41% of GDP, damages caused by other emissions and resuspension about 0.63 % of GDP (of which the damage emerging abroad was valued at about FIM 900 million/a, equivalent to 0.18% of GDP) and noise-caused damages about 0.67% of GDP. Since damages caused by road traffic fuel emissions and noise are most obviously significant when valued in money, their further research and valuation is well justified. Results and valuation methods should also be checked when emission levels change or more accurate research results are available.

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Table L1. *Estimate of Finnish emissions into the air in 1990, 1000 tonnes*

Sector	SO_2	NO_2	Par-ticles	CO_2	CO	HC	Pb
Road traffic			3)				
Emissions from consumption	5,36	157,6	11,19	11209	405,4	61,4	0.19
Passenger cars, petrol	0,92	86,1	2,09	6020	349,4	46,9	0.18
Passenger cars, diesel	0,74	4,9	1,92	837	4,8	1,2	0
Vans, petrol	0,04	3,6	0,03	232	17,5	1,9	0.01
Vans, diesel	0,81	5,4	0,36	913	3,6	1,1	0
Buses	0,67	15,1	1,62	753	8,5	3,2	0
Trucks	2,18	42,5	5,17	2454	21,5	7,0	0
Other fuels-related emissions 1)	8.9	1.37	0.41	1410	0.87	5.6	0
Petrol; 1986 kt	5.6	1.0	0.30	910	0.56	5.2	0
Diesel; 1542 kt	3.3	0.37	0.11	500	0.31	0.5	0
Road traffic, total	14,26	159	11,60	12619	406	67,00	0,19
Other dom. tot. 2)	242.0	169.0	84.18	47600	125.1	123.5	0.11
Grand total	256,3	328,0	95,78	60219	531,1	190,5	0,30
Exhaust gases, %	2,1	48,0	11,7	18,6	76,3	32,2	63.3
Whole chain, %	5,6	48,5	12,1	21,0	76,4	35,2	63.3

1) Covers emissions from the refinery, storage and distribution of road traffic fuels in Finland. Emissions from domestic transports are included in the 'emissions from consumption' figures. As regards carbon dioxide, the figure covers emissions abroad caused by the production and transport of the oil used for refinery of Finnish road traffic fuels and emissions from the refinery, storage and distribution of road traffic fuels in Finland. Emissions from domestic transports are included in the 'emissions from consumption' figures.
2) Covers emissions from energy production and industry, etc.
3) Covers only exhaust gas emissions (and other fuel emissions) and not, for example, dust lifted up by road traffic (resuspension)

Table L2. *Estimate of Finnish emissions into the air in 2000 (MOBILE Report), 1000 tonnes*

Sector	SO_2	NO_2	Particles	CO_2	CO	HC	Pb
Road traffic			3)				
Emissions from consumption	0.6	56	8	12640	181	59	0
Passenger cars, petrol	0.12	19.7	2.3	7415	145.7	42.1	0
Passenger cars, diesel	0.09	1.0	1.4	1145	1.3	2.0	0
Vans, petrol	0.003	2.8	0.1	199	13.7	4.9	0
Vans, diesel	0.06	3.6	1.4	783	3.0	2.0	0
Buses	0.05	8.4	0.7	509	3.2	1.9	0
Trucks	0.24	20.5	2.1	2590	14.6	6.1	0
Other fuels-related emissions 1)	2.5	1.37	0.20	740	0.40	3.92	0
Petrol; 1986 kt	1.6	1.0	0.15	540	0.26	3.58	0
Diesel; 1542 kt	0.9	0.37	0.05	200	0.14	0.34	0
Road traffic, total	3.1	57.4	8.2	13380	181.4	62.9	0
Other dom. tot. 2)	112.9	153.6	60	46860	144.6	96.1	0
Grand total	116	211	68.2	60240	326	159	0
Exhaust gases, %	0.5	26.5	11.7	21.0	55.2	37.1	-
Whole chain, %	2.7	27.2	12.0	21.9	55.6	39.6	-

1) Covers emissions from the refinery, storage and distribution of road traffic fuels in Finland. Emissions from domestic transports are included in the 'emissions from consumption' figures. As regards carbon dioxide, the figure covers emissions abroad caused by the production and transport of the oil used for refinery of Finnish road traffic fuels and emissions from the refinery, storage and distribution of road traffic fuels in Finland. Emissions from domestic transports are included in the 'emissions from consumption' figures.
2) Covers emissions from energy production and industry, etc.
3) Covers only exhaust gas emissions (and other fuel emissions) and not, for example, dust lifted up by road traffic (resuspension)

Table L3. Estimated (this study) damage caused by road traffic fuel emissions and dust lifted up by road traffic in Finland and estimated global economic effects caused by carbon dioxide emissions from Finnish road traffic, FIM million/a (1990). The estimates of the previous study made for Finnish National Road Administration, FIM million/a (1989) are in parenthesis.

Effect	Ghg	SO_2	CO	NO_x	Pb	HC	O_3	Part	Res	Σ
Health effects total	- (-)	35 (9,7)	- (-)	144 (68)	46 (-)	478 (32)	- (-)	833 (160)	500 (sis. ed.)	2036 (260)
Cancer mortality risk		-		- (1,3)	-	478 (6,6)		- (5,3)	- (sis. ed.)	478
Other mortality risk		8 (-)		32 (-)			-	201 (-)	121 (-)	362
Other health effects		27 (9,7)	-	112 (67)	46	- (25)	-	632 (150)	379 (sis. ed.)	1196
Material damages, total		18 (15)		- (21)				62 (410)	246 (sis. ed.)	326 (450)
Construction material		18 (15)		- (21)		-	-	-		18
Fouling		-				-		62 (410)	246 (sis. ed.)	308
Forest damages		6 (9,6)		8 (85)		- (23)	32 (77)	- (27)	- (sis. ed.)	46 2) (220)
Crop losses		- (2,5)		- (55)	-	- (25)	63 (130)	- (13)	- (sis. ed.)	63 (220)
Climate change 3)	99-2103 (-)	-	-	-				-	-	99-2103 (-)
Total	99-2103 (-)	59 (37)	- (-)	152 (230)	46 (-)	478 (80)	95 (130)	895 (610)	746 (sis. ed.)	4574 1) (1150)

1) Estimated using climate change costs of FIM 2103 million/a.
2) Discount rate of 3% has been used to estimate forest damages and climate change-induced damage. If a discount rate of 0% is used, forest damages rise to FIM 56 million/a.
3) Two approach methods have been used to estimate economic effects of greenhouse gas emissions; Assessment of damage (lower estimate) and economic control instruments needed for halting the growth in emissions (higher estimate). If a discount rate of 0% is used, climate change-induced damages rise to FIM 833 million/a.

In addition to this, road traffic fuel emissions cause damages abroad ("exported effects"), which are valued at FIM 240-910 million (the best estimate about FIM 870 million).

Table L4. *Damage caused by light and heavy traffic emissions (exhaust gases/upper line, emissions from distribution and production/lower line) per kilometrage and per amount of fuel consumed in population centres (health and materials effects)*

Damage	**Light traffic, no cat.**	**Light traffic, w/cat.**	**Heavy traffic, 90**	**Heavy traffic, 95**
HC, Part. and SO_2, p/km	3,05 0,27	0,54 0,27	61,44 0,60	29,26 0,60
CO_2, p/km	3,42 0,57	3,20 0,57	19,19 1,92	18,44 1,92
Total, p/km	6,47 0,84	3,74 0,84	80,63 2,52	47,70 2,52
HC, Part. and SO_2, p/l	30,53 2,67	5,38 2,67	145,95 1,43	69,51 1,43
CO_2, p/l	30,17 5,74	32,00 5,74	45,57 4,57	43,79 4,57
Total, p/l	60,70 8,41	37,38 8,41	191,52 6,00	113,30 6,00

The figures do not include damages caused by resuspension (particulates lifted up by road traffic). When these damages are divided by the estimated kilometrage of 1990, the average damage is 4,9 p/km. A fairer division would be based, not only on the kilometrage, but also on the weight and speed of vehicles.

The damage due to emissions from light and heavy traffic (exhaust gas/upper line, emissions from distribution and production/ lower line) per kilometrage and per amount of fuel consumed in the rural area (ecological effects).

Damage	**Light traffic, no cat.**	**Light traffic, w/cat.**	**Heavy traffic, 90**	**Heavy traffic, 95**
NO_x, HC ja SO_2, p/km	1,63 0,15	0,22 0,15	10,00 0,42	4,54 0,42
CO_2, p/km	2,85 0,46	2,67 0,46	14,62 1,92	14,05 1,92
Total, p/km	4,48 0,61	2,89 0,61	24,62 2,34	18,59 2,34
NO_x, HC and SO_2, p/l	20,38 1,84	2,80 1,84	23,75 0,99	10,78 0,99
CO_2, p/l	35,63 5,74	33,34 5,74	34,72 4,57	33,38 4,57
Total, p/l	56,01 7,58	36,14 7,58	58,48 5,56	44,16 5,56

Table L5. *Dose-response functions of nitrogen oxides*

Study	Dose-response function
Ostro 1994	Change in respiratory symptom days a year = 0.0054 · change in annual average NO_2 concentrations (μg/m^3)
Leksell & Löfgren 1994	Percentage of people experiencing disturbing air pollutants daily or nearly daily in the town centre = - 4 + 0.64 · winter average NO_2 concentrations (μg/m^3) in the town centre at concentrations of over 10 μg/m^3
Leksell & Löfgren 1994	Percentage of people experiencing disturbing air pollutants daily or nearly daily in residential areas = - 3 + 0.4 · winter average NO_2 concentrations(μg/m^3) in the town centre
Leksell & Löfgren 1994	Percentage of people experiencing disturbing air pollutants (all disturbance reactions) daily or nearly daily in residential areas = 0.4 · winter average NO_2 concentrations (μg/m^3) in the town centre
Leksell & Löfgren 1994	Percentage of people experiencing disturbing air pollutants daily or nearly daily in the whole population centre = 0.7 · winter average NO_2 concentrations (μg/m^3) in the town centre

Table L6. *Mortality risk caused by particles, summary*

	MOBILE Report	Sensitivity analysis
Direct emissions (particles 83%, SO_2 - sulphate 3%, NO_x - nitrate 13%)		
A Change in mortality (%) as PM_{10} concentration changes by 10 µg/m^3	0.5	0.5-0.64
B PM_{10} concentration (µg/m^3)	15	12-15
C Proportion of road traffic in concentrations (%)	20	20-25
D People exposed (million)	3.983	3.08-3.983
E Value of a statistical life (FIM million)	6.7	4.5-6.7
Damage caused by direct emissions, total - Minimum - maximum values - Best estimate - MOBILE study	69-458, average FIM 264 million FIM 241 million/a FIM 415 million/a	
Resuspension		
Proportion of road traffic in damages (%)	-	30-40
Hazardousness of resuspension (%) in relation to hazardousness of direct emissions per µg/m^3	-	50
Damage caused by resuspension, total - Minimum - maximum values - Best estimate	26-229, average FIM 128 million/a FIM 121 million/a	
Damage, total - Minimum - maximum values - Best estimate - MOBILE study	95-687, average FIM 391 million/a FIM 362 million/a FIM 415 million/a	

The best estimate indicates that direct particle emissions and particle-forming emissions would cause 54 statistical cases.

Table L7. *Health risk caused by particles, summary*

	MOBILE Report	Sensitivity Analysis
Direct emissions (particles 83%, SO_2 - sulphate 3%, NO_x - nitrate 13%)		
A People being exposed to concentration (million)	3.983	3.08-3.983
B PM_{10} concentration (μg/m^3)	15	12-15
C Proportion of road traffic in concentrations (%)	20	15-25
D Finnish unit damages (%) of American unit damages (%)	100	70-100
Damage caused by direct emissions, total - Minimum - maximum value 246-948, average FIM 597 million/a - Best estimate FIM 758 million/a - MOBILE study FIM 1104 million/a		
Resuspension		
Proportion of road traffic in damages, (%)	-	30-40
Hazardounsess of resuspension (%) in relation to hazardousness of direct emissions per μg/m^3	-	50
Damage caused by resuspension, total - Minimum - maximum values 92-474, averge FIM 283 million/a - Best estimate FIM 379 million/a		
Damage, total - Minimum - maximum values 338-1422, average FIM 880 million/a - Best estimate FIM 1137 million/a - MOBILE study FIM 1104 million/a		

Table L8. *Cancer risk caused by hydrocarbon compounds, summary*

	MOBILE Report	Sensitivity Analysis
A VOC-caused cases due to road traffic emissions/a	108	62-94
B Value of a statistical life (FIM million)	6.7	4.5-6.7
C Study cited	Törnqvist	Törnqvist
Damage caused by hydrocarbons		
- Minimum - maximum values	279-630, average FIM 455 million/a	
- Best estimate	FIM 478 million/a	
- MOBILE study	FIM 1137 million/a	

The best estimate indicates that hydrocarbons would cause 73 statistical cancer cases, all of which have been priced according to the value of a statistical life.

Table L9. *Damage estimates in this study, summary (FIM million/a)*

Effect	Ghg	SO_2	CO	NO_x	Pb	HC	O_3	Particles	Res	Σ
Health effects total	-	35 12-49	-	144 52-198	46 23-69	478 279-630	-	833 264-1172	500 118-703	2036 748-2821
Cancer mortality risk		-		-	-	478 279-630		-		478 279-630
Other mortality risk		8 2-15		32 8-61			-	201 59-382	121 26-229	362 95-687
Other health effects		27 10-34	-	112 44-137	46 23-69	-	-	632 205-790	379 92-474	1196 374-1504
Material damages, total		18 13-22		-				62 49 - 74	246 157-296	326 219-392
Construction material		18 13-22		-		-	-	-		18 13-22
Fouling		-				-		62 49 - 74	246 157-296	308 206-370
Forest damages		6 3-21		8 4 - 26		-	32 19-86	-		46 26 - 133
Crop losses		-		-	-	-	63 44-84	-		63 44 - 84
Climate change	99-2103		-				-	-		99-2103
Total	99-2103	59 28-92	-	152 56-224	46 23-69	478 279-630	95 63-170	895 313-1246	746 275-999	2471 1) 1032-3430

1) The figures in this field do not include the contribution of greenhouse gases.

In addition, emissions from road traffic fuel chains cause damage abroad ("exported effects"), the estimated value being FIM 240-910 million (the best estimate about FIM 870 million).

Table L10. *Estimating damages caused by road traffic noise using the Hedonic Price Method*

Pricing according to noise levels	**55 -65 dB (av. 60 dB)**	**65-70 dB (av. 67.5 dB)**	**>70 dB (av. 75 dB)**
Number of people living along highways in noisy areas	266138	41480	10662
Number of people living in noisy areas along streets and planned roads	399207	62220	15994
Number of people living in noisy areas of road traffic	306065	103700	26656
Households in noisy areas of road traffic (average 2.1 people)	14602	49381	12693
Decrease in value of dwelling/dB as noise level exceeds 55 dB	0.36 %		
Average size of dwellings Average price of dwellings	74.8 m^2 FIM 5248/m^2		
Total decrease in value, FIM million/a (sum FIM 3. 5 billion/a)	2238	872	359

Table L11. The emission coefficients (g/km) of vehicles used in the calculations (Laurikko 1996).

Taajama-ajo (g/km)	CO_2	SO_2	NO_2	HC	Hiukk.
Henkilöautot, ei-kat	205	0,017	1,7	1,3	0,03
Henkilöautot, kat	192	0,008	0,28	0,12	0,01
Raskaat ajoneuvot '90	1151	1,298	28	2,7	1,7
Raskaat ajoneuvot'95	1106	0,012	14	1,89	0,85

Maaseutuajo (g/km)	CO_2	SO_2	NO_2	HC	Hiukk.
Henkilöautot, ei-kat	171	0,015	3,2	0,95	0,03
Henkilöautot, kat	160	0,007	0,43	0,15	0,01
Raskaat ajoneuvot '90	877	0,989	18	2	1
Raskaat ajoneuvot'95	843	0,01	9	1,4	0,5

ISSN 0788-3722
ISBN 951-726-323-6
TIEL 3200457E