European transport: emission trends and policy responses

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ABSTRACT

This paper describes the trends in the main emissions to air by European road transport. Following this overview, policy options are discussed which can bring the emissions down to levels which meet environmental targets.

Of the so called "classical" pollutant emissions (NO_x, HC, CO, particulates and SO_2) HC, CO and SO_2 can both quite well be tackled by technical measures. The current trend towards lower emissions will continue, provided extra policy measures will be taken. NO_x is a more persistent problem. A strong technical effort improvement of diesel technology is required to bring this emission to acceptable levels.

Policy instruments are emission and fuel standards. Stringent fuel standards and check of conformity of vehicles in use become increasingly important. Special emphasis is required for cold start standards, two wheelers and off road machinery.

The trend in CO_2-emissions from road transport shows a different picture: an annual growth of 2 to 3%. This might slow down a little in the coming decades, because traffic growth could diminish somewhat. For CO_2 technical progress is clearly slower than traffic growth.

A strong government interference in the car sales market is suggested to achieve a reduction in CO_2-emissions. A 'downsizing' trend of the car can be forced and/or high

additional costs are needed for the car. Both consequences are expected to reduce mobility growth somewhat.

For freight transport the answer is a drastic increase in efficiency of road haulage. Load factors are currently rather low and should go up. Next, the growth in transport intensity of economic production should be slowed down. Higher prices for road haulage seem the best policy instrument to achieve this.

1. CLASSICAL POLLUTANTS: NO_x, HC, CO, Pm, SO_2

1.1. Introduction

This chapter describes the development of the so called 'classical' emissions from mobile sources in Europe. These are the emissions that are covered by regulation: NO_x, HC, CO, Pm (particulate matter) and SO_2.

It describes the original emission situation, the current regulatory and technological developments and it gives an outlook to the future.

Volume developments will not be explicitly addressed in this chapter as they are treated in the next chapter on CO_2 emissions. It must be said that, as long as engine and fuel technology are not into play, measures to reduce CO_2 emissions mostly bring the same reduction of the 'classical' emissions. The measures discussed in this chapter must therefore be considered as *additional* to the measures presented in the 'CO_2' chapter.

1.2. Developments in new vehicle technology

Gasoline (petrol) cars

Historically the *gasoline car* has been the primary source of traffic pollution, due to the large share of total kilometers driven and the high emissions per kilometer driven.

Regarding the latter aspect, the reduction of emissions per kilometer from new SI (Spark Ignition, i.e. gasoline, LPG and CNG) vehicles is quite spectacular. The application of the three way catalyst on this type of engines has made over 90% emission reduction per km possible (except, of course, for CO_2). The first generations of catalyst equipped cars in the 80's faced quite some problems in the area of driveability and durability, increased fuel consumption and odd phenomena like a 'rotten egg' smell with certain catalyst types. The Dutch 'in use compliance' testing program shows that improvements in catalyst technology, fuel injection and engine management systems have largely eliminated these initial shortcomings.

The emissions of NO_x and HC from a modern well functioning gasoline car with a warm catalyst are practically negligible, a few *hundredths* of grams per kilometer (compared to a few grams per km in the early 80's). This equals to a few tenths of grams per liter of gasoline burnt. New emission standards as proposed by the European Commission for the year 2000 and 2005 are even 60 to 70% stricter.

However, the cold start emission behavior of gasoline cars is still poor, especially at low ambient temperatures, when an excess of fuel is injected into the cylinders to get enough evaporation. As a result even modern cars have excess HC and CO emissions in the first 2 kilometers after a cold start at lower ambient temperatures. The effect can be noticed very well on winter mornings in traffic peaks. Inclusion of a special cold test in the type approval procedure, which makes fuel pre-heating at low temperatures necessary, is therefore most desirable. This item is currently under discussion in Europe, but the outcome is still uncertain. The United States already have a low temperature test but the standards are fairly weak.

The costs of emission reduction of new gasoline cars amount to about 5 to 10 ECU's per kg of NO_x and HC emission reduced.

Diesel cars

The emissions from new diesel cars, especially NO_x and Pm_{10}, are generally considered more problematic than those from new gasoline cars. A modern passenger car diesel engine produces about 10 grams of NO_x per liter of diesel fuel burnt, about two thirds of the older generations' emissions. For the next five years only a 20% reduction in new cars is foreseen and this is not enough to compensate for the rapid growth in diesel car use.

Several NO_x after treatment technologies are currently under development but they are not expected to enter the market before about 2002. The other diesel car problem, the Pm_{10} emission, will be treated later on in this article. This emission gives especially rise to worries in countries with a large share of cars running on diesel, like France.

HC and CO emissions from diesel cars are not of great concern.

It must be said that the diesel car offers about 15% fuel consumption/CO_2 emission advantage compared to gasoline cars. However, careful analysis points out that this CO_2 advantage of diesel cars does not fully compensate for their NO_x and Pm_{10} disadvantage|1|.

The costs of emission reduction of new diesel cars amount to about 5 ECU's per kg of NO_x emission reduced.

Heavy trucks and buses

Without any new legislative measures the heavy truck will without competition be the main polluter on the road in the year 2010. The modern 'Euro 2' truck engine's NO_x emission is about 30 grams per liter of diesel fuel burnt, which is three times as much as the diesel passenger car and about 40% lower than the 80's generation of truck engines. Basic calculations indicate that traffic growth will more than compensate for this reduction, resulting in an unacceptable rise of total NO_x emissions from trucks and a 'market share' for trucks in NO_x emissions from road traffic in 2010 of about 70%. It is clear that either major technology steps or major volume reductions are necessary to move towards environmental targets for ozone formation, acidification and eutrophication.

The most promising concept currently under development to achieve a very substantial reduction of NO_x emission per unit of fuel burnt is Selective Catalytic Reduction or SCR. The technology is almost in the demonstration phase of development and seems to have about a 60 to 70% NO_x reduction potential over the current generation of trucks. It gives this performance without sacrifices in terms of fuel consumption or particulate emission.

Besides the uncertainty about the 'on the road' performance, this technology faces two main obstacles for a rapid and massive penetration on the market. The first obstacle is probably the need of an *extremely* low sulphur diesel fuel and the second obstacle is the need of a reducing agent like urea. This implies a substantial effort from the refining industry, the introduction of an extra product in the fuel distribution system and anti-tampering provisions. It must be ensured that a) the trucker will not 'forget' to fill the urea tank when driving in the EU, and b) is not prohibited from driving in non-EU states where no urea is sold.

Strong joint action of engine designers, catalyst manufacturers, oil industry and policy makers is needed to overcome these obstacles.

The costs of emission reduction of new trucks and buses amount to about 2 ECU's per kg of NO_x emission reduced.

Mopeds and motorcycles

Two wheelers (mopeds and motorcycles) deserve far more attention than they are currently given.

Mopeds, especially the two stroke versions, are a serious threat for urban air quality. Measurements show that HC emissions from mopeds can rise up to 10 grams per km and they can even double when the engine has been tampered with. This is about a hundred times more than a modern gasoline car with a hot catalyst. Combining this with the knowledge that mopeds mostly drive in urban areas it is clear that they are a key factor in future urban air quality improvement. This is especially the case in southern parts of Europe where mopeds are used extensively in cities.

The motorcycle problem is a bit different. They cover more kilometers in total but the emissions per kilometer are lower and they drive less in urban areas. BMW shows that low motorcycle emissions are very well possible by offering bikes equipped with injection engines and closed loop three way catalyst systems. Other manufacturers however still use carburetor systems and do not use any catalytic conversion.

Off road equipment

This extensive category of machinery includes ships, trains, tractors, shovels, forklift trucks, cranes etcetera. Altogether they have a surprisingly high emission 'market share' in the EU. They emit about 30% of NO_x emissions and 40% of Pm_{10} from mobile sources. For example, the NO_x emission from Dutch inland vessels is about one third of the NO_x emission from Dutch trucks.

Technically the off road diesel engines' emissions can be reduced in the same way as the truck emissions. However, these sources are not subject to any form of emission regulation yet. As volume growth rates are not likely to be smaller than those of road traffic it is expected that the share of total EU emissions will grow quite rapidly.

The first EU legislation on mobile machinery is expected to come into force from 1998. However, it does not cover ships, diesel trains and agricultural and forestry tractors. This leads to the odd conclusion that from the NO_x emission point of view it could in 2005 be better to transport goods by a new truck than by a new inland vessel !

This indicates that a lot of policy work will have to be done in the coming years.

The costs of emission reduction of new mobile machinery are relatively low. Even the first cheap emission measures have not been taken yet. However, cost effectiveness is highly dependent on the area of engine application. For example emission reduction of new engines of inland vessels is very cheap, about 0.4 ECU's per kg of NO_x emission reduced.

1.3. The issue of particulate emission

The issue of the emission of particulate matter (Pm) requires some extra attention. Pm emission is caused by poor fuel combustion, poor fuel quality, especially a high sulphur content, and by lube oil burn. Pm consists of soot (unburnt C atoms) and sulphate (from sulphur), often with very large polycyclic aromatic hydrocarbons (PAH) sticking to it.

In the earlier generation of trucks the problem is very much visible: thick black clouds of smoke coming from the exhaust pipes of diesel cars and trucks, especially in acceleration. The particulate emission factor from earlier generation diesel engines is about 3 grams per liter of diesel fuel burnt.

At first sight an enormous progress has been made in reducing particulate emissions. Current truck engines emit only about half a gram of particulates per liter of diesel fuel, which is 80 to 90% less than before. This progress is mainly caused by a spectacular improvement of combustion circumstances: a much higher injection pressure and electronic injection timing and quantity control, resulting in a much better air/fuel mixing. Also the lower diesel fuel sulphur content made a substantial contribution.

However, closer analysis points out that mainly the particulate *size* has been reduced, not so much the *number* of particulates. Evidence is growing that especially these small particulates can cause great health damage as they enter the lungs very deeply. Some people even say that gasoline engines' particulate emissions (which are fairly negligible in terms of mass) are therefore at least as harmful as the diesel engines' particulate emissions.

If the relationships as described above appears to be true the classical way of measuring and regulating emissions (by mass) would be not effective at all. The particulate problem becomes a very hard nut to crack. It is yet very unclear how emission policy is going to react to this phenomenon. Size related emission limits could be a consequence.

1.4. Control of 'in use' emissions

With increasing complexity of emission control equipment to be installed on new vehicles it becomes increasingly important to check whether the 'on the road' or 'in use' performance of the technology is still satisfactory. In the case of advanced emission technology (as applied in gasoline cars) the emissions from a malfunctioning vehicle can be ten or twenty times higher than the emissions from a correctly tuned and maintained vehicle.

There is a wide range of possible measures to ensure that every vehicle on the road remains well below the emission limits for that vehicle type. There are two main categories of measures.

In the first category every vehicle is inspected individually once in a while. These so called 'Inspection and Maintenance' (I&M) programs are generally quite costly. Mostly the costs are passed to the consumer. This makes these programs politically sensitive and therefore practically every country has got its own regime. It is obvious that these programs are potentially the key to ensure low emissions in every day reality. A major technology currently being implemented on new vehicles in the US and planned to be implemented in the EU in the year 2000 is the so called OBD (On Board Diagnostics) system. This system gives information on the functioning of the emission control devices. With this information checks and repairs in the I&M program become much easier. Probably the main effect of the OBD system is a more careful and robust design of emission control technology, as every manufacturer will try to avoid any fault indication.

In the second category a statistical sampling method is used to check a limited number of vehicles of every vehicle type. Generally this is called an In Use Compliance (IUC) procedure. If any systematic production faults appear to occur within a certain vehicle type appropriate measures can be taken. In the most extreme case a recall campaign could be the consequence with major costs for the manufacturer. This makes a IUC strategy a very effective tool to improve the quality of emission control devices, at the same time being a form of consumer protection.

Both types of, programs to control 'in use' emissions play a crucial role in actually *ensuring* low emission performance of vehicles 'on the road'. Limitations to the stringency of such programs are determined more by economics and politics than by technology.

1.5. The role of fuel quality

The role of fuel quality in attaining low emission performance is often not very well understood. Fuel quality influences a vehicle's emission performance in multiple ways.

The first way is the one-on-one link between fuel quality and vehicle emissions, *independent* of vehicle technology. This is the case for carbon/sulphur content of the fuel and CO_2/SO_2 emissions respectively.

The sulphur content of the EU main transport fuels has been reduced substantially to 0.03%m for gasoline and 0.04%m for diesel respectively. New desulphurization steps will be taken (see below). With these values the SO_2 emission from road traffic is not a major issue any more.

The carbon content cannot be influenced substantially. Therefore CO_2 is a very persistent problem which will be treated in the next chapter.

The second way is a direct influence of fuel quality on vehicle emissions, *dependent* on vehicle technology. Typical parameters here are benzene content, aromatics content, volatility (for gasoline) and cetane number, density and aromatics (for diesel fuel). The emission effects of changes in these parameters are different for every vehicle type but reductions achievable are as high as about 20%. These effects may be counterbalanced by increases in energy use (CO_2 emissions) by refineries. Studies have led to the introduction of cleaner burning RFG (reformulated gasoline) in certain zones in the United

States and the EU wide introduction of a set of environmental specifications for gasoline and diesel fuel by the year 2000.

A third way is the fuel quality being a prerequisite for proper functioning of emission abatement technology. This effect is most important when catalysts come into play. For example lead in gasoline used to be a main issue in relation to poisoning of the three way catalyst. At the moment sulphur in gasoline as well as in diesel fuel is widely discussed for its effect on the three way catalyst and on future diesel $DeNO_x$ catalyst systems. Especially the latter category of catalysts seems to be very sensitive to fuel sulphur, as described in an earlier paragraph.

1.6. Conclusions per emission

NO_x

From the description in the previous paragraphs it appears that in the future NO_x will be about the most persistent of the 'classical' emissions. Though gasoline vehicles' NO_x emissions are decreasing with several per cents per annum total NO_x emissions from traffic only slowly decrease. The diesel engine is responsible for this unsatisfactory development.

First, there still is a technical problem. The non-catalytic NO_x reduction techniques for diesel engines do not offer enough potential and there is quite some uncertainty about the future success of catalytic systems. Therefore it is not expected that NO_x emissions from diesel cars and trucks will decrease substantially until 2005.

Secondly, there is a political problem. A major part of today's heavy duty diesel engine sales does not face any emission legislation at all. Introduction of legislation for all types of diesel engines will at least take 5 more years. It will take about 10 more years before any substantial reduction of total NO_x emissions from these yet unregulated engines will be seen.

Summarizing, total NO_x emissions from mobile sources will decrease by only about 30% till the year 2005 and a 50% reduction will not be seen before 2010. Under the conditions that technology develops well and that continuous stringent regulation is applied to all new diesel engines NO_x emission targets (80% reduction) could be attained in the long term, about 2020 or 2025.

Particulate matter

This emission gives rise to worries for other reasons. In terms of tons of total emissions per annum a satisfactory improvement can be seen due to technical progress of the diesel engine. However, scientific evidence is growing that human health effects do not seem to correspond with the total load in tons of emission but merely with a combination of total load and particle size. Is therefore very uncertain whether the *effects* of particulate emissions are decreasing as well.

HC and CO

Currently the HC and CO emissions from historically the most important source, the gasoline car, are decreasing by about four per cent per annum as a result of the very low emissions of new gasoline vehicles entering the market. As a result, today's total HC and CO emissions from mobile sources are already about 50% lower than 15 years ago.

A lot of people are convinced that CO air quality targets will be met with the existing regulation only. HC emissions are more dangerous because these can have long term health effects and cause the quite persistent ozone problem.

Future strategies to reduce HC emissions from mobile sources are:

- controlling 'cold start' emissions from gasoline vehicles, especially at low ambient temperatures.
- keeping the existing fleet in good emission shape by a stringent inspection and maintenance policy and by 'in use compliance' monitoring.
- reducing the (urban) HC emissions from two wheelers.

If these issues will be tackled effectively the necessary 80% HC and CO emission reduction from 1990 levels could be met somewhere around 2010 or 2015.

SO_2

This issue has quite effectively been tackled by the desulphurization of diesel fuel. Emissions will be further reduced as a result from new desulphurization steps in 2000 and 2005. Emissions from combustion of high sulphur heavy fuel oil in marine diesel engines give most rise to worries.

2. CO_2-EMISSIONS

2.1. Introduction

The UN Framework Convention on Climate Change (FCCC - signed by most European countries - states as its main aim to stabilize the atmospheric concentration of green house gases on a level which avoids dangerous anthropogenic distortions of the climate system. The UN Intergovernmental Panel on Climate Change (IPCC) is a little more specific and concludes that the rise in global temperature should be limited to 2° C, with a maximum increase per decade of 0.1° C |2|. With these limits it is estimated that the industrialized countries need to reduce their emission of green house gases with 1 to 2% each year |3|. For this estimate it is assumed that developing countries have some scope to increase their emissions, while industrialized countries have to cut back. This paper takes the desired reduction in green house gases with 1 to 2% per year as starting point.

Current trends, however, reveal a growth in CO_2 emission in the industrialized world. For Europe the trend can be roughly estimated at an annual growth of 1% |4|. Road transport has a higher growth rate than average, which can be estimated at around 2-3% per year (see next sections).

2.2. Trends in passenger transport

The CO_2 emissions from passenger traffic increase by 2 to 3% each year. The main underlying trends in the distinguished factors will be discussed hereafter |4|.

Population size

Although the population in Europe has grown in the last decades - and centuries - this is not a major factor in explaining the fast growing environmental pressure from passenger transport. According to current trends for the coming years the European population grows with roughly 0.3% per annum, for both West and Central Europe.

Travel distance per person (per day)

Statistics from the ECMT show that the volume of passenger kilometers in Europe has grown on average with 3.1% per year in the period 1970-1994. Part of this growth, however, is caused by population growth, estimated at 0.7% per year in this period. This results in a trend in growth of travel distance per person of around 2.4%.

Modal split

The share of car traffic in total passenger traffic has increased from around 76% in 1970 to 82% in 1994 (excluding walking, cycling and aviation). This implies that the share of car traffic rose each year on average with 0.3 to 0.4%. Assuming that emissions per passenger kilometer of public transport are roughly half of those of cars, this modal shift corresponds with an annual increase in emissions of around 0.1 to 0.2%.

Occupancy

Because car traffic is dominant with respect to pollution from passenger transport, only the load factor of cars will be discussed.

It seems that the occupancy of cars tends to decline slowly. This can be illustrated by data for The Netherlands. In 1980 on average 1.73 persons were seated in a car, which went down to 1.65 in 1994. This correspond with an average reduction of the occupancy by 0.3% per year in this period. The average fuel consumption per passenger kilometer went up almost the same rate.

Efficiency

Again, only the efficiency of cars will be reviewed. Efficiency improvements of the cars have been achieved and resulted in a reduction of specific energy consumption of 0.5 to 1.0% per annum. This outcome is, however, a combination of two opposite trends. For it is well known that cars have become faster, heavier and more comfortable over time. This development can be summarized as upgrading. Several studies estimate that this upgrading trend results in 0.5% higher specific fuel consumption per year. This implies that technical progress is around 1 to 1,5% per year, but that roughly half of the technical achievements are offset by upgrading of the car.

Overview

Table 1 summarizes the main influences resulting in an annual growth of CO_2 emissions from passenger traffic of 2 to 3% per year. The dominant factors are the growth in travel distances and the efficiency improvement of the car. Next, the upgrading of cars is important as well. The other factors - population size, modal split and load factor - only explain the growth in CO_2 emissions for a small part.

Table 1

Estimated main trends behind the growing CO_2 emissions from passenger traffic.

Factor	Impact on CO_2 emissions
Population size	+0.3%/year
Travel distance per person	+2.0 - 2.5%/year
Mobility	*+2.3 - 2.8%/year*
Modal shift	+0.1 - 0.2%/year
Occupancy car	+0.2 - 0.3%/year
Upgrading car	+0.5%/year
Technological improvement car	-1.0 - 1.5%/year
CO2 emissions passenger traffic	*+2.1 - 2.8%/year*

Underlying forces

Two important underlying forces behind the growth in CO_2-emissions can be identified |4|. The first is increased travel speed. The introduction of the car and later of the aircraft allowed for higher travel speeds. This did, however, not result in time savings, but instead in increased travel distances, as economic research shows |5|. There appears to be a roughly Constant Travel Time Budget implying that a higher speed generates longer average travel distances. This is in the long run the main force behind the growth in mobility.

The second underlying force is income growth. Since 1965 real income per person has increased by around 2,5% a year in Western Europe, resulting in roughly doubling the total real income. The income growth generated both the large penetration of the (faster) car and allowed for a continuous 'upgrading' of the car. Maximum speed, acceleration, weight and size of the average car have increased over the last decades and are expected to continue to do so.

2.3. Trends in freight transport

The most familiar trend in the realm of freight transport is probably that the number of ton kilometers of all modes of transport is growing at the same rate as GDP. This means that the ton kilometers of road transport are growing faster than GDP, since the relative share of road transport is increasing. However, there are variety of factors behind this trend.

Growing transport distances

The underlying causes of the growth in freight transport can be illustrated with a description of trends in the UK food and drink sector |6|. The logistical changes taking place between 1983 and 1991 are shown in figure 1.

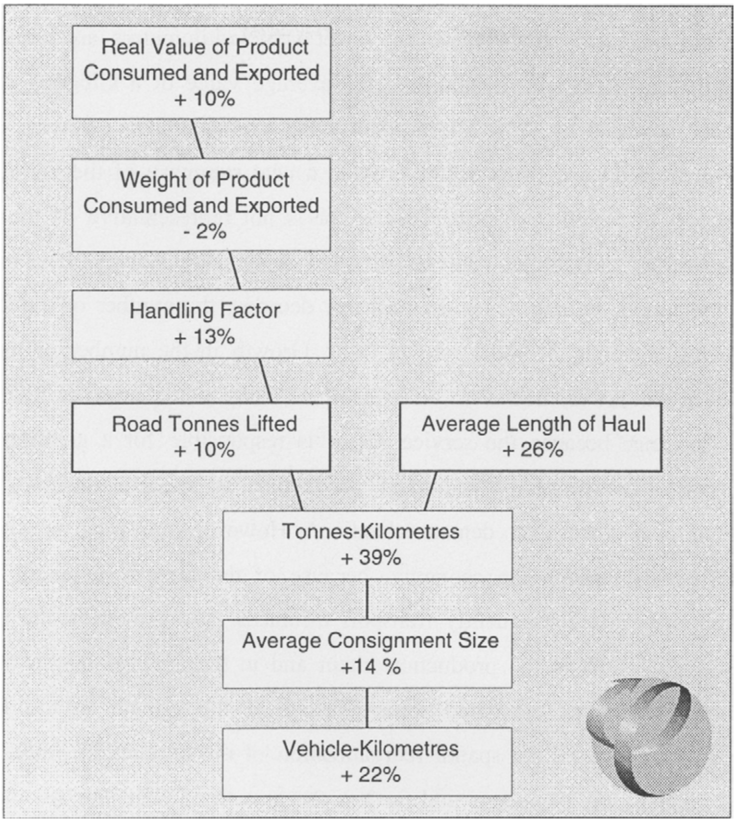

Figure 1. Logistical changes in the UK food and drink sector, 1983-1991 (Source: McKinnon and Woodburn, 1995)

It can be seen from the figure that the ultimate growth of 22% in the number of vehicle-kilometers is the result of trends in opposing directions. The main cause of the growth is a 26% increase in the average length of haul: an average increase of 3% per annum. A secondary cause of the growth in vehicle-kilometers is the increase in the number of hauls involved in the production chain as a whole, reflected in the 13% rise in the handling factor. This is due to the fact that the production process has become more complex and takes place at various different locations. Taking these two causes together, growth in freight transport is the result of more and longer hauls per unit end product.

This growth is tempered by two other trends, however. In the first place, the average load per haul has increased by 14%, so that fewer vehicle-kilometers are required for a given number of ton kilometers. In addition, the average value of a kilogram of product (food and drink) increased by 12%. The product value is tied to GDP (growth).

These trends in the food and drink sector provide a neat summary of the various factors behind the growth of freight transport. This sector is not representative of the economy as a whole, however, and similar analyses of other sectors are lacking. It is possible to give a rough indication, though. Over the past few decades, the number of ton kilometers has been growing at about the same rate as GDP. Growth in the number of tons of end product has been far lower, however: at an estimate, only one-quarter of GDP growth. This is not surprising, because the service sector is responsible for a growing share of economic activity. The share of industrial production is steadily declining and the economy is thus in a process of 'dematerialization'. However, this trend is not reflected in the flow of goods through the economy, because of the growth in length of supply and distribution lines and consequently transport distances. The growth in the number of links and associated hauls in the production chain and in the average length of haul are together responsible for an estimated three-quarters of the growth in ton kilometers observed. It is thus above all the spatial reorganization of the production process that has caused the increase in ton kilometers and far less the growth of GDP *per se*.

Several underlying economic and logistical trends contribute to the growth of transport distances|7|: The main factors are:

- less stocks (Just-in-Time)
- upscaling in production and distribution
- larger geographical market areas (both for resources and products).

Rising share of road transport

Another trend that can be discerned is the rising share of road transport. In the ECMT countries the share of road transport grew from 45% in 1970 to almost 60% in 1989. Assuming that road transport (long distance) uses 2 to 3 times more energy per ton kilometer than rail freight and inland waterways, this modal shift implies an annual 0.5 to 0.8% increase in CO_2-emissions. A further illustration is provided by the case of the

UK, where the share of road transport increased from 42% to 68% over the period 1953-1989 (measured in ton kilometers). Under the assumption of unchanged policy, all future projections indicate a continuation of this trend. An underlying reason is that little further growth is anticipated for bulk transport - much of which is transported by rail and waterway - while 'Other goods' will continue to grow substantially. Moreover, the aforementioned logistical trends also point towards further growth of the share of road transport.

Load factor

The average load factor of trucks has not changed substantially over the last decades and thus did not influence growth in CO_2 emissions.

Truck size

The average truck size tends to increase. Although statistical data are lacking, it is estimated that this development towards larger trucks reduces CO_2 emissions by around 0.5% per year.

Energy efficiency

Truck fuel consumption can be reduced by improving engine and drivetrain efficiency, reducing aerodynamic drag, lowering empty weight, and lowering rolling resistance. Statistical material gives not the right information to exactly calculate this technical improvement rate, but it can quite well be estimated from existing market knowledge. The fuel consumption per 100 km driven by a fully loaded 40 ton truck evolved from about 50 liters in 1970 to about 40 liters in 1980 (about 2% p.a.) to about 35 liters in the second halve of the 80's (1.5% p.a.). Since then progress has slowed down further to the current 1% per annum.

Overview

Table 2 summarizes the main trends behind the growth in CO_2-emissions from freight transport of 2 to 3% a year.

Table 2

Estimated main trends behind the growing CO_2-emissions from freight transport.

Factor	Impact on CO_2-emissions
GDP	+ 0.8% / year
Transport distance	+ 2.2% / year
Ton kilometers	*+ 3.0% / year*
Modal split	+ 0.6% / year
Load factor	0% / year
Truck size	- 0.5% / year
Efficiency truck	- 1.0% / year
CO_2-emissions freight transport	*+ 2.1% / year*

Table 2 shows that the growth in annual transport distance is the dominant factor. The main cause seems to be the decrease in the price of road freight transport. For The Netherlands the real price decrease is estimated at 1.6% per year for the period 1984-1992. In the same period other production factors, as labor and storage, have become more expensive. These changes in relative prices promote a shift towards transport and away from other production factors. The transport intensity of the economy increases.

2.4. Policy recommendations

Passenger traffic

A reduction in CO_2-emission from passenger traffic can only be achieved with the use of fierce policy instruments and thus after clear political choices. The reason for this is that a reduction of CO_2-emissions conflicts with two powerful trends: faster transport and growing income. The main effective policy instruments to counterbalance these forces are:

- strong government interference in the car sales market, to force the introduction of the very fuel efficient car against existing consumer preferences. Two main options are available. The first is a - possibly modified - version of the standards for Corporate Average Fuel Economy (CAFE), which have been successfully applied in the USA. The second policy option is a drastic increase in the fuel price, by e.g. doubling or tripling the current level of fuel excise duty in Europe. This will mainly promote the introduction of cars with a better fuel economy, but will also reduce mobility growth somewhat;
- reduced average speed of car traffic will bring specific energy consumption down by around 10%, counteracts the 'upgrading' trend in the car market and slows mobility growth. This combination of effects makes speed management a powerful policy instrument. Setting and enforcing proper speed limits - probably with the use of electronic speed limiters in the vehicle - is the main element of such a policy.

Other policy instruments can support these two main approaches, but can not replace them [4].

It is clear that both policy lines are currently not political acceptable. Main reason for this is the 'price' attached to a reduction of CO_2 emissions: reduced growth in mobility and travel speed a substantial downgrading of the car and/or higher prices for mobility e.g., caused by the use of advanced environmental technology.

Freight transport

Reduction of CO_2 emissions from freight transport can mainly be achieved by some further improvements of the trucks, by changes in logistics (higher load factor) and by a higher transport efficiency of the economy (less transport per unit of GDP) [7]. Only for technical improvements direct regulation might be considered as policy instrument, although the effectiveness seems limited for the promotion of energy efficiency.

The other two options to reduce CO_2 emissions - logistics and transport efficiency - can mainly be promoted by the use of financial incentives. An increase in fuel price is attractive because it stimulates all types of CO_2 reduction, including driving behavior. It is estimated that the average price of diesel in the EU should be roughly doubled to come in line witch the total marginal costs of a truck kilometer in rural areas |8|. An alternative policy option is to introduce an electronic kilometer charge for trucks, based on registration of the number of kilometers driven in each country. This assures that the country where the truck has driven, and thus caused the costs, receives the revenues, which is not fully the case with the diesel tax.

Additional to these general cost related charges for trucks, it is needed to have extra charges in urban areas. Because congestion is higher and more people are exposed to air pollution and noise nuisance in urban areas, the marginal costs in urban areas are roughly twice as high as in rural areas |8|. Systems of urban road pricing can incorporate these additional urban costs.

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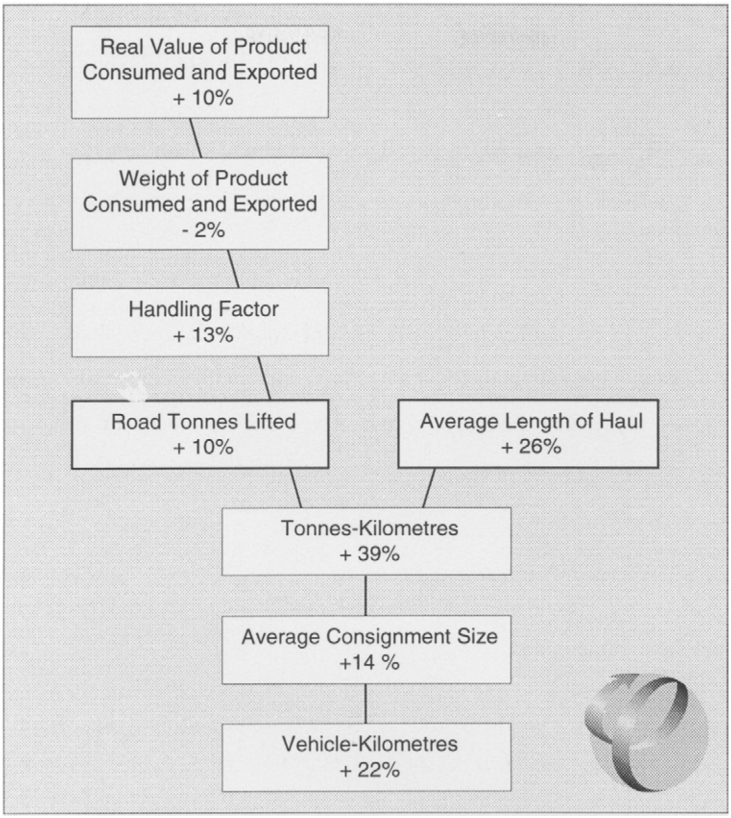
Real Value of Product Consumed and Exported + 10%
Weight of Product Consumed and Exported - 2%
Handling Factor + 13%
Road Tonnes Lifted + 10%
Average Length of Haul + 26%
Tonnes-Kilometres + 39%
Average Consignment Size +14 %
Vehicle-Kilometres + 22%