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SPEED LIMITS, EFFECTS AND BENEFITS IN TERMS OF ENERGY EFFICIENCY AND REDUCTION OF EMISSIONS

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SUMMARY

The driving speed of a car influences the fuel consumption and emission of air-polluting substances. On 1 May 1988, a system of differentiated speed limits for passenger cars and light duty vehicles on motorways was introduced in the Netherlands, among other things for the purpose of reducing environmental pollution. On particular sections of the Dutch motorways a limit of 100 km/h is in force, on the rest one of 120 km/h. (Lorries 80 km/h on all motorways).

Prior to and after introduction of the new system of speed limits the fuel consumption and the NO_X, CO, CO_2 and hydrocarbon emissions from passenger cars and lorries on motorways have been calculated based on the actual driving speeds on both types of road sections. The emission behaviour at different vehicle speeds has been derived from field tests on roller-type test stands in combination with measurements on German motorways under actual driving conditions.

After an initial sharp decrease in driving speed after 1 May 1988, resulting in lower fuel consumption and emissions, the speeds have slowly increased again, with the result that benefits have largely disappeared already.

1. INTRODUCTION

On 1 May 1988, a new system of differentiated speed limits for passenger cars and light duty vehicles on Dutch motorways was introduced. The speed limits in force before that date were 100 km/h for passenger cars and light duty vehicles, and 80 km/h for lorries, but a large part of the drivers did not keep within the speed limits. The starting-point of the new policy was that the driving speeds could be influenced and controlled.
Its motivation was three-fold:

- to increase the sense of standards;
- to reduce the damaging effects of motor traffic on the environment;
- to improve or at least stabilize road safety.

The following measures were taken in order to reach that objective:

- the introduction of a system of differentiated speed limits;
- a full-scale information campaign for motorists, before as well as after the introduction of the new speed limits;
- a sharpened enforcement policy, by acting in a repressive way (justice) as well as by using preventive means (administrative support).

The differentiation of the speed limits implies that on particular road sections, i.e. on about 17% of the total amount of motorways on which about 30% of the vehicle kilometres is spent, the limit of 100 km/h for passenger cars and light duty vehicles is maintained. On the other sections of the motorways there is a limit of 120 km/h, while the limit for lorries remains an unchanged 80 km/h for all sections.

The policy aimed at a return to the speed situation as it was at the time of the coalition agreement of the Second cabinet Lubbers in 1985. The mean driving speed of passenger cars then was 106 km/h with a 85-percentile value lower than 120 km/h (1). When the new system was introduced the Dutch Lower House was promised that the situation would be evaluated one year after its introduction. At the same time, as a support of the policy implementation, the national speed development on motorways was to be presented monthly after 1 May 1988, and, moreover, the background of the speed behaviour of road users on motorways would be investigated in order to arrive at targeted enforcement and information campaigns.

The evaluation contained an investigation into the air pollution component. By means of model calculations the effect of the implementation of a differentiated set of speed limits on the fuel consumption and the following exhaust gas components: oxides of nitrogen (NO_x), carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbons (HC) of passenger cars and lorries on Dutch motorways was measured. For that purpose a comparison was made between the period May 1988 - May 1989 and a comparable period before the implementation (May 1987 - May 1988). The period May 1989 - May 1990 was also considered because the speed picture seems to be subject to continual changes.

Beside the influence of the average driving speed changes on the air pollution, the effects of increasing traffic during these periods, of more fuel-efficient and cleaner engines as well as of the possible changes in the speed distribution of cars were quantified.

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2. METHODS AND INTRODUCTION DATA

2.1 Driving speeds on motorways

Data concerning the speed on Dutch motorways is obtained by using the network of counting points with which also the intensities are measured. The equipment (ES-06) in this network measures continual driving speeds by means of induction with loops in the road and processes them to averages per hour and standard deviations per vehicle category and per traffic lane. The vehicle categories are determined by means of the detected (mass)length: passenger cars, lorries and trailers (1).

In the early part of 1988 62 ES-06 measurement locations were installed of which 41 with an in principle undisturbed traffic passage (32 on roads with a limit of 120 km/h and 9 on 100 km/h roads) were selected to determine the national speed developments. At these points normally no build-up of traffic occurs. Situations with incidental disturbances were avoided as much as possible as to allow a good comparison between the monthly calculated speeds. To the same effect a period of one week was selected out of each month in which there were no particular holidays nor extreme weather conditions. Per period all hours of that week were included to calculate the monthly speed average and its 85-percentile. In the presentation a distinction will be made based on speed limits and vehicle categories:

- road sections with a limit of 100 km/h, passenger cars and light duty vehicles;
- road sections with a limit of 120 km/h, passenger cars and light duty vehicles;
- road sections with a limit of 100 km/h, lorries;
- road sections with a limit of 120 km/h, lorries.

Fig. 1 represents the mean monthly values of the driving speeds of passenger cars and lorries on both road sections (2) measured since April 1988.

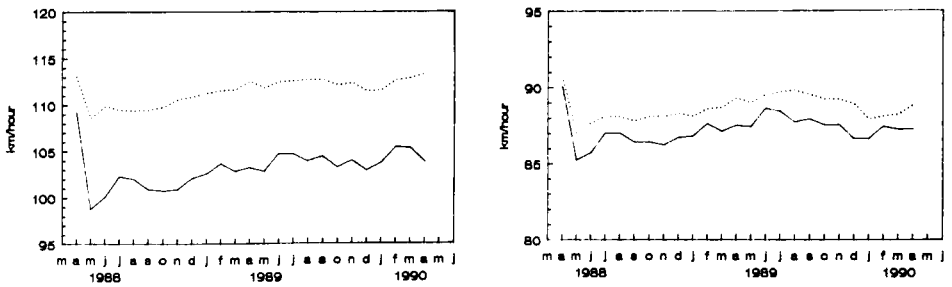

Fig. 1. Mean monthly values of the driving speed on road sections with a limit of 100 km/h (———) and 120 km/h (·····) from april 1988 up to and including april 1990. (a) Passenger cars and light duty vehicles. (b) Lorries.

In May 1988, as a result of the change in speed limits, a striking decrease of the mean driving speed occurred, both on the 100 km/h and the 120 km/h sections. In the months that followed a steadily increasing driving speed was observed both for passenger cars and lorries, which does not seem to have come to a stop.

Figure 2 shows the weighed mean and the 85-percentile (V-85) of the driving speeds of passenger cars on both sections of the motorways. The policy's aim, i.e. an average speed of 106 km/h, was only reached in May 1988, and after that it moved further and further away from the goal. This also counts for the aim of a V-85 speed of 120 km/h.

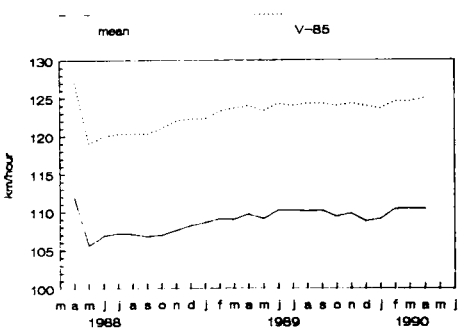

Fig. 2. Mean monthly values (——) and V-85 (·····) of the speeds of passenger cars on all sections of the motorways.

The speed distribution hardly changed after the implementation of the new speed limits. The V-85 value (15% fastest vehicles) appears to change in exactly the same manner as the mean driving speed does.

Table 1 represents the yearly average driving speeds of passenger cars (incl. light duty vehicles) and lorries before and after the implementation of the new speed limits.

TABLE 1
Overall picture of the mean driving speeds of passenger cars and lorries on 100 en 120 km/h road sections (2).

	Passenger cars [a]			Lorries		
Period	100 km	120 km	mean	100 km	120 km	mean
	Driving speed in km per hour					
1-5-87 / 1-5-88	b	b	112.6	c	c	90.3
Policy's aim	99.0	109.0	106.0	86.0	86.0	86.0
1-5-88 / 1-5-89	101.6	110.3	107.7	86.6	88.2	87.7
1-5-89 / 1-5-90	104.0	112.4	109.9	87.5	89.0	88.6

[a] including light duty vehicles.
[b] No exact figures known. In april 1988: 109.1 (100 km sections) and 113.0 (120 km sections), mean 111.8 km/h.
[c] Idem. In april 1988: 90.0 (100 km), 90.7 (120 km), mean 90.5 km/h.

After the implementation of the new set of speed limitations there was a decrease of the average driving speed on all road sections. However, the policy's aim will not be reached. The following year showed a steadily increase again.

2.2 Fuel consumption and emissions at different speeds

Increased driving speeds on motorways cause an increase in both fuel consumption and the emissions of air-polluting substances. This increase is not the same for all components. The emission data of passenger cars at high speeds is best known, mainly because of field tests on roller-type test stands (3). The emission of NO_X, CO and HC is less for diesel engines than for petrol engines. The relative dependence of the speed, however, appears to be exactly the same. From the results of these measurements (3) the relation between the emissions and the fuel consumption and the speed was deducted for passenger cars with the for the Netherlands valid share of diesel engines of 15%. LPG (share in the Dutch traffic of about 20%) was not considered in this study, yet it may be assumed that the relation emission and fuel consumption with the speed will not essentially deviate from other fuels. The model calculations in fact use this relative dependence, but with regard to the absolute emission factors, the fuel consumption of petrol, diesel and LPG, and the actual compilation of vehicles on the Dutch motorways.

The connection between emissions and fuel consumption on the one hand and the driving speed on the other as is deduced from (3), is drawn in Figure 3. The remark should be made here, that not the emissions at constant speeds were considered, but the emissions for an actual driving cycle with said speed as the average speed, as corrected after measurements on motorways in Western Germany (4). The increase of the average driving speed in the speed area of 100 to 115 km/h seems to be about equal for NO_X, CO and the fuel consumption. The HC emission is roughly constant at these speeds.

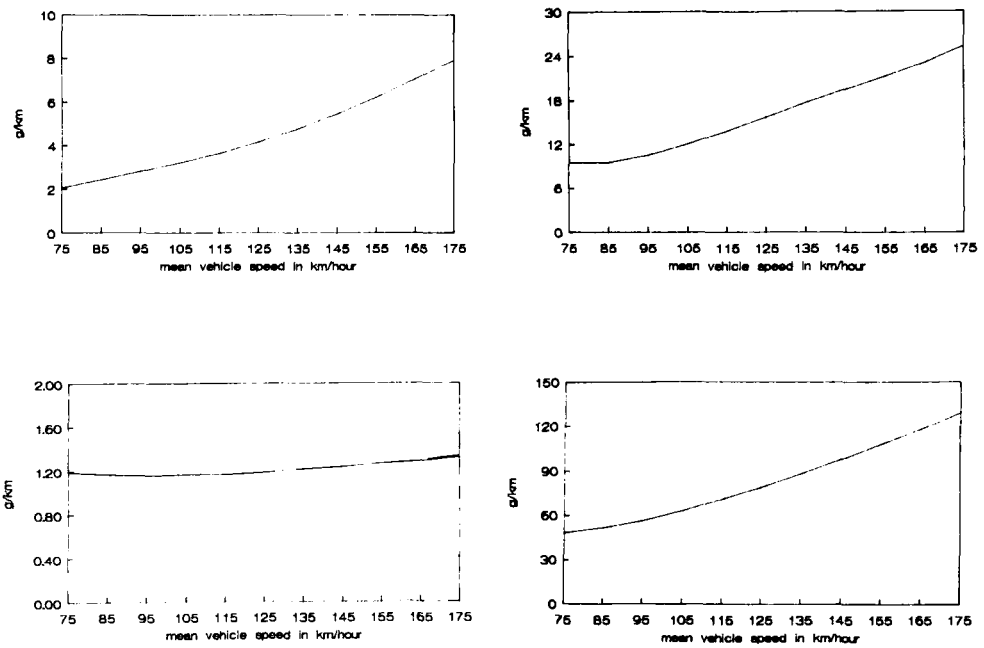

Fig. 3. Speed dependence of the emissions of NO_x (a), CO (b), HC (c), and the fuel consumption (d) of passenger cars on motorways with a diesel contribution of 15% (1985).

The CO_2, lead and SO_2 emissions can be calculated directly from the fuel consumption. In this study the following conversion factors were used for CO_2 (grammes CO_2 per gram fuel) (5):

petrol	: 3.12
diesel fuel	: 3.12
LPG	: 3.04

Relatively few emission measurements are known of lorries driving at speeds exceeding 80 km/h. It is certain that the emissions increase with higher speeds (6 - 7). The calculations here depart from the same relative speed dependence as is valid for passenger cars. Based on the data of a study by Rijkeboer (8), which shows a relative increase of fuel consumption with an increasing driving speed similar to the one of passenger cars, the fuel consumption at higher speeds was estimated.

Both the emission factors and the fuel consumption of vehicles are constantly liable to changes. Increasingly cleaner engines are being produced because of legal measurements, mainly on the EC directives. The built-in catalysts in new passenger cars have resulted in a decrease of the regulated emissions. The fuel consumption and the CO_2 emission have slightly decreased as well due to the ever more fuel-efficient engines. This implies that the 1985 data which was mentioned before, cannot be applied without alterations on the period May 1987 - May 1988.

The data on this particular period primarily departed from the fuel consumption from (8), and the CBS-based emission factors from (5), as is shown in Table 2.

TABLE 2
Emission factors and fuel consumption of passenger cars and lorries on motorways in the period May 1987 till May 1988.

Component	Passenger cars < 3.5 ton	Lorries > 3.5 ton
NOx in g/km (1987)	3.3	19.4
CO in g/km (1987)	4.9	2.2
HC in g/km (1987)	1.0	2.6
Petrol in g/km	56.5 [a]	-
Diesel in g/km	58.4 [a]	195.0
LPG in g/km	55.4 [a]	-

[a] passenger cars; for light duty vehicles the following values apply: gasoline 96.2, diesel 98.5, LPG 89.0 g/km.

A comparison between the data on passenger cars and Figure 2, while taking into consideration a decrease of the emission factors and the fuel consumption since 1985, shows that the emission factor for CO as given by the CBS rather deviates. The reason for this is that the CBS data is based on emissions at constant speeds. For CO, (3) considers this a serious underestimation of the emission factor. Therefore, the calculations have been made with an emission factor for CO of 10 g/km, a figure closer to reality.

After the implementation of the new motorway speeds the emission factors and the fuel consumption (FC) have developed as follows, as the CBS data (5) shows (Table 4):

TABLE 4
Changes of the emission factors and fuel consumption in terms of percentage (%) compared to the period May 1987 - May 1988.

	Passenger cars				Lorries			
Period	NO_x	CO	HC	FC	NO_x	CO	HC	FC
1/5'88-1/5'89	-5	-5	-5	-1	0	0	0	-1
1/5'89-1/5'90	-10	-10	-10	-2	0	0	0	-2

2.3 Kilometres spent on motorways

The amount of vehicle kilometres spent on motorways increases yearly. Two effects are responsible here, an increase of the traffic intensity and the extension of the road system. Table 5 shows the spent vehicle kilometres on Dutch motorways in 1987, as provided by the CBS (5), and the increase in 1988 and 1989 (preliminary figures).

TABLE 5
Amount of vehicle kilometres (in millions) spent on motorways in 1987 and the increase in 1988 and 1989 compared to 1987.

	1987	1988	1989
Vehicles < 3.5 ton	25044	+6%	+12%
Vehicles > 3.5 ton	2527	+11%	+22%
total	27571	+6.5%	+13%

Table 5 shows that the lorry traffic on motorways increases faster than the traffic of passenger cars.

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3. RESULTS

The results of this study are represented in two ways for a sound judgement on the effects of the implementation of the new motorway speed limits. On the one hand there is the result of the changed driving speeds, and on the other the totality of influences of driving speeds, emission factors, and spent vehicle kilometres.

Table 6 presents data on the emissions and fuel consumption of passenger cars (including light duty vehicles) and lorries of the period prior to the introduction of the new speed limits, as well as of the changes due to the fluctuations in speed.

TABLE 6
Effects of changes in vehicle speeds on the emissions and fuel consumption, expressed as tons per year compared with the period prior to introduction of the new system of speed limits.

	Period			
	1-5-87 / 1-5-88	Policy's aim	1-5-88 / 1-5-89	1-5-89 / 1-5-90
NOx-emissions				
Passenger cars	83,800	-6.000	-4,500	-2,500
Lorries	49,100	-2,300	-1,400	-900
total	132,900	-8,300	-5,900	-3,600
CO-emissions				
Passenger cars	250,000	-18,000	-13,000	-7,000
Lorries	10,000	-500	-300	-200
total	260,000	-18,500	-13,300	-7,200
HC-emissions				
Passenger cars	21,700	-	-	-
Lorries	6,600	-	-	-
total	28,300	-	-	-
CO_2-emissions				
Passenger cars	4,530,000	-320,000	-245,000	-136,000
Lorries	1,870,000	-90,000	-53,000	-34,000
total	6,400,000	-410,000	-298,000	-170,000
Fuel consumption				
Passenger cars	1,460,000 [a]	[b]	-79,000	-44,000
Lorries	600,000	[b]	-17,000	-11,000
total	2,060,000	[b]	-96,000	-55,000

[a] petrol 914,000, diesel fuel 244,000, LPG 304,000 tons per year.
[b] not included in the policy's aim.

Due to the introduction of the new system of speed limits on motorways on May 1, 1988 the emissions and fuel consumption appear to have decreased, except in the case of HC for which the emission hardly depends on speed (Table 6). The aim of the policy, in which a sharper decrease was anticipated, did not come true. In the second year after the implementation the emissions and fuel consumption on motorways increased again due to an increase of the mean driving speeds.

When beside changes in driving speed also the changes in emission factors and amount of spent vehicle kilometres are taken into consideration a comparison of the situation prior to and after the introduction of this new speed system shows another picture. Table 7 presents an overview of the effects on emissions and fuel consumption one year and two years after the implementation of the new speed limits.

TABLE 7
Emissions and fuel consumption of passenger cars (incl. light duty vehicles) and lorries on Dutch motorways prior to and after introduction of a new system of speed limits on 1 May, 1988, in tons per year.

	Period 1/5'87-'88	1/5'88-'89	1/5'89-'90
NOx-emissions			
Passenger cars	83,800	80,000	83,000
Lorries	49,100	53,000	59,000
total	133,000	133,000	142,000
CO-emissions			
Passenger cars	250,000	239,000	248,000
Lorries	10,000	11,000	12,000
total	260,000	250,000	260,000
HC-emissions			
Passenger cars	21,700	21,900	22,100
Lorries	6,600	7,300	8,000
total	28,300	29,200	30,100
CO_2-emissions			
Passenger cars	4,530,000	4,510,000	4,800,000
Lorries	1,870,000	2,020,000	2,200,000
total	6,400,000	6,530,000	7,000,000
Fuel consumption			
Passenger cars	1,460,000	1,450,000	1,550,000
Lorries	600,000	650,000	700,000
total	2,060,000	2,100,000	2,250,000

Table 7 shows that there is an increase, mainly because of lorry traffic (a sharp increase in vehicle kilometres at steady emission factors). The CO figures show a decrease for the first year after implementation.

All calculations are based on mean speeds. For two particular road sections calculations have been made with the actual speed distribution. Only for CO, the emission turns out to be higher (about 8%). The speed distributions before and after 1 May 1988 show no differences. Therefore, the method to calculate the means does not influence the size of the calculated effects (Table 6).

Because the aim of the policy has not been reached as far as the speeds are concerned, either the number of road sections with a maximum speed of 100 km/h might be enlarged, or the limit on these sections might be lowered to 90 km/h. The decision should yet be taken. The enforcement of the speed limits is the major problem here.

4. CONCLUSIONS

- The introduction of a new system of speed limits and the related changed speed pattern caused a decrease in emissions and fuel consumption on Dutch motorways. In the second year after implementation these effects partly perished, because the mean driving speed slowly increased again.

- The amount of spent vehicle kilometres on motorways has increased sharply in the last few years, especially for lorries, and consequently, the fuel consumption and emissions have increased in total, the CO emissions excepted.

- The introduction or tightening up of speed limits is a means to reduce emissions and fuel consumption. The introduction, however, requires an active enforcement policy and it should be presented extensively to the public. A permanent improvement will require need measurements to restrict motoring.