Fullname Jane Jackson
Email [redacted]
What area does your submission relate to? Transportation & Infrastructure

Your comments
As Wicklow Co Co recently declared a climate and biodiversity emergency I think the county development plan should reflect this, especially in transport. Road Transport, of all sectors in Ireland, has seen the greatest increase in greenhouse gas emissions at 140% while all other sectors have reduced. As 80km/hr is regarded as the optimum speed for both fuel consumption and greenhouse gas emissions, I propose that the top speed limit be cut to 80km/hr across the county. The environmental and social benefits would be profound. With 85,000 registered vehicles in Co Wicklow this could equate to 85,000 tonnes of CO_2 being cut from the carbon budget. From a social perspective the reduction in deaths and catastrophic injuries on the road would be very welcome. It would also mean money saved from reduced fuel consumption would stay in the pocket and hence the local communities rather than be taken out by a carbon tax. Our group has been working for the past year asking people to pledge to cut their driving emissions by cutting their top speed on all roads to 80km/hr. We now have 1321 people pledged to keep to 80km/hr on all roads and countless more using our steering wheel sticker to remind them to slow down to cut their emissions. The response has been very encouraging. If implemented it would mean 85,000 drivers would become part of the solution for cutting our emissions. It is time for bold decisions to be taken. We now have less than 11 years to cut our emissions by 45% below 2010 figures. our website is www.80max.ie if you would like further information on what we are doing I can be reached at the above email or [redacted]

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Why slower is better

Pilot study on the climate gains of motorway speed reduction

Report
Delft, February, 2010

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CE Delft
Committed to the Environment

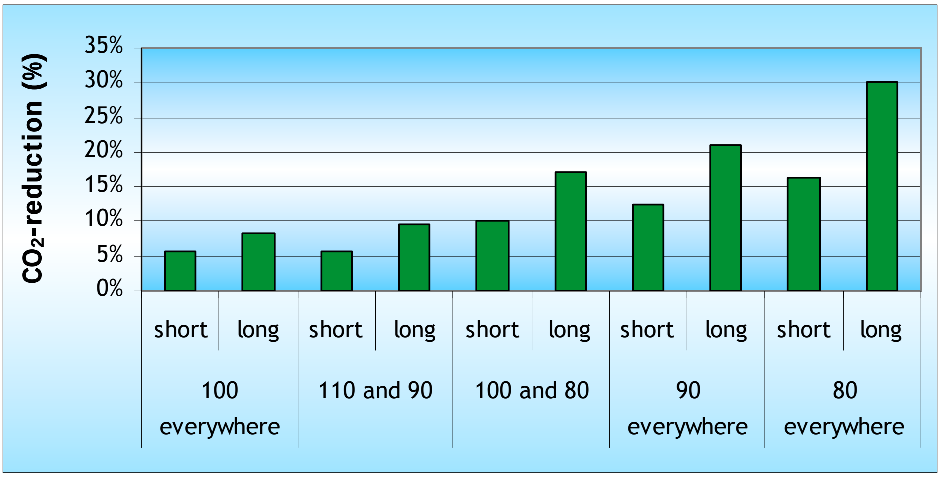
CE Delft is an independent research and consultancy organisation specialised in developing structural and innovative solutions to environmental problems. CE Delfts solutions are characterised in being politically feasible, technologically sound, economically prudent and socially equitable.

Contents

Summary

Driving at lower speeds is better for the climate. In this pilot study CE Delft has estimated the potential CO_2 savings in various scenarios with tighter motorway speed limits in the Netherlands. Lowering the speed limit for cars to 80 km/h can reduce transport CO_2 emissions on highways by 30% in the longer term (Figure 1).

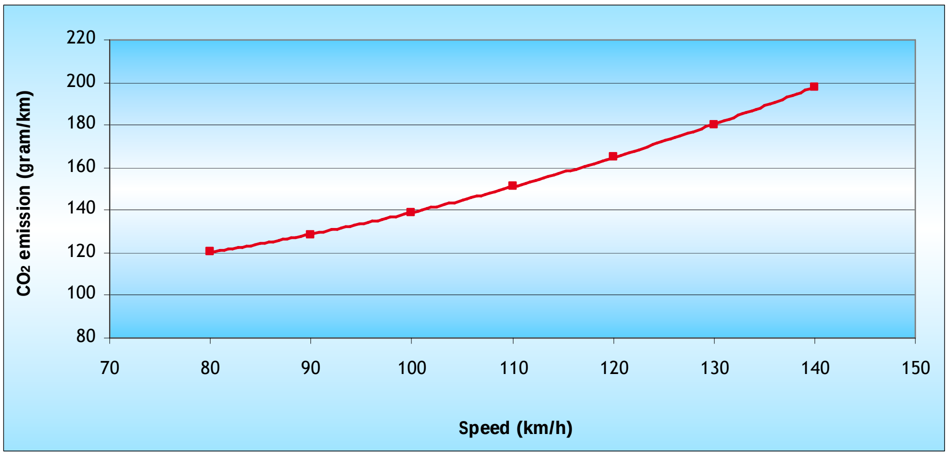
Figure 1 Short- and long-term CO_2 emission reductions as a share of total motorway CO_2 emissions by cars in various scenarios



Note: 100, 90 or 80 everywhere means that all highway speed limits that are higher than 100, 90 or 80 are reduced to 100, 90 or 80. Lower speed limits remain the same.

The maximum long-term CO_2 reduction is estimated to be 2.8 Mt for passenger cars and a further 0.2 Mt for delivery vans. In the case of passenger cars, this means a 30% reduction in motorway emissions. This maximum reduction is achieved with a uniform speed limit of 80 km/h together with strict enforcement. Less drastic tightening of speed limits result in modest emission cuts, but still leads to a 8 to 21% reduction in motorway car emissions depending on the scenario (Figure 1).

Figure 2 **Relationship between vehicle speed (km/h) and CO_2 emission (gram/km) at constant speed**



Source: TNO data, adapted by CE Delft.

It is common knowledge that, on average, vehicles burn less fuel per kilometre at lower speeds (Figure 2).
Less widely realised is the fact that, because of the longer travel times resulting, lowering motorway speed limits will also lead to less car-kilometres being driven and a certain shift from private car to public transport.

In the long term the CO_2 savings resulting from the reduction in car-kilometres will become increasingly pronounced, as structural behavioural change sets in (people moving closer to their workplace, shops relocating closer to consumers, etc.).

Reduced CO_2 emissions are just one of the benefits of lowering speed limits. There will also be improvements in terms of air pollution, noise nuisance, possibly congestion and traffic safety too. Lowering motorway speed limits also has its downside though. On average, people will be on the road for longer for a given journey and their annual mileage will be lower. From the perspective of economic welfare, both the lower speed and the reduced volume of traffic count as costs. A follow-up study on the social costs and benefits would enable calculation of 'optimal' speed limits.

Table 1 **Social costs and benefits of lower motorway speed limits**

Social costs	Social benefits
Longer travel times	Reduced CO_2 emissions
Reduced passenger vehicle kilometres	Reduced air-pollutant emissions
Enforcement costs	Reduced noise nuisance
	Improved traffic safety
	Reduced congestion
	Savings on infrastructure costs
	Fuel savings

1 Introduction

1.1 Background

The Dutch government has committed itself to the reduction of CO_2 emission to 30% below the level of 1990 by the year 2020. In order to meet this goal it will be necessary to bring about significant emission reduction in the transport sector as well. Important elements that contribute to this reduction are among other things, technical innovations in vehicles and fuels, better use of vehicle capacity and conscious decisions of consumers and corporations.

In addition, reduction of the maximum speed limit can contribute to CO_2 reduction in the transport sector. To establish an indication of the potential of this measure, Milieudefensie (Friends of the Earth Netherlands) has requested CE Delft to conduct a pilot study on the CO_2 reduction of a lower speed limit on the motorway.

1.2 Speed and CO_2 emissions of traffic

Reduction of maximum speed has effects on CO_2 emissions caused by transport in several ways. The fact that a car is more fuel-efficient at 80 km/h than at 120 km/h is commonly known. Reducing the maximum speed limit results in the effect of cars consuming less fuel per kilometre.

Less widely realised is the fact that there is a clear correlation between transport speed and transport volume. In the long term, increasing travel speed will lead to an increase in travel volume (for an example see the box below). Reversely, reduction of speed will result in a (relative[1]) decrease in transport volume.

Additional commuting because of construction TGV Paris - Lyon

With the introduction of the TGV on the Paris – Lyon route in 1981 it became possible to cover this distance in less than two hours. For many people this gave the possibility to work in Paris and live, for instance, in Lyon (approx. 450 km). In 2006 the TGV was used by 45.000 people for long distance commuting.

Source: French embassy in the United Kingdom, www.ambafrance-uk.org.

1.3 Objective of this pilot study

Goal of this pilot study is to calculate the effect of lowering the speed limits on the motorway on CO_2 emission of road traffic. In addition, this pilot study aims to give insight in other effects of speed limit reduction such as air pollution, noise pollution and loss of travel time.

1 In this instance we mean relative in relation to autonomous development of traffic volume; if traffic volume grows, reducing speed limits can still lead to growth in traffic volume. However, growth will be less than had there not been a lowering of speed limits.

2 Overview of effects of speed limit reduction

2.1 Introduction

In this chapter we will give an overview of the most important effects of lowering the speed limit. In the light of the goal of this pilot study we will mainly look at the effect on CO_2 emissions. Reduction of speed limits has effect on CO_2 emissions in several ways. These different mechanisms will be discussed in section 2.2 and will be further elaborated on in chapter 3.

Apart from CO_2 emission reduction, lowering the speed limit has other effects as well. For instance, it affects traffic safety, noise and air polluting. Furthermore, speed limit reduction leads to an increase in travel time and thus effects the economy. In section 2.3 an overview is given of these other kinds of effects.

2.2 Influence of traffic on CO_2 emissions

Decreasing the maximum speed on the motorway influences CO_2 emissions of passenger cars in different ways. The most important effects are:

1. Decrease of emission per vehicle-kilometre
   There is a decrease in emission per vehicle-kilometre because fuel consumption decreases at lower (constant) speed.
2. Decrease in amount of car-kilometres
   In the long term people will drive less kilometres. This is caused by the fact that people in general are unwilling to spend more than 60 to 70 minutes on transportation. Therefore, in the long term people will choose to live closer to their work for example or be more selective on the journey they undertake.
3. Increase in kilometres of other modes of transportation
   People will be more willing to choose alternative modes of travel like train and bicycle (for short distances) because road travel becomes relatively less attractive compared to these other modes of transport.
4. Change in congestion level
   Lowering the speed limit on motorways can have effects on traffic congestion. Whether congestion will decrease or increase depends on several factors. The level of congestion affects emissions of traffic: on the one hand emissions will increase during congestion because emissions per kilometre increase, on the other hand emissions decrease because congestion increases travel time and therefore causes in the long term a decrease in transport volume.

In the next sections these effects will be further discussed.

Besides the aforementioned effects for passenger cars, also other road users will change their behaviour. For delivery vans too, lowering the speed limits will affect emission per kilometre. In chapter 3 this emission reduction will be taken into account. The effect on the amount of vehicle-kilometres of delivery vans is more diffuse and is more dependent on financial costs than on travel time. The effects of volume reduction, therefore, have not been taken into account.

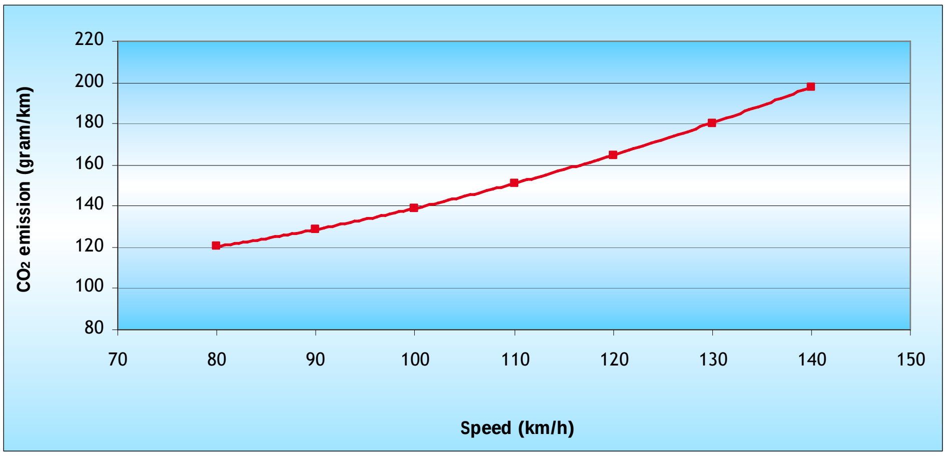
A decrease or increase in congestion will influence travel time for trucks and therefore the costs of cargo transport by road. In the long term this can have its effect on the quantity of cargo transport and the 'modal split' of freight traffic. Such secondary effects have not been examined in this pilot study. However, these effects are expected to be minimal compared to the four aforementioned effects.

2.2.1 Decrease of emission per vehicle-kilometre

CO_2 emissions of a passenger car are directly related to fuel consumption. The fuel consumption of a passenger car depends, among other things, on driving speed and driving pattern. This also includes driving behaviour.

The level of CO_2 emissions as a function of (constant) speed varies between cars, but for all cars the same type of correlation is observed. In Figure 3 this correlation is depicted for a typical passenger car on highways.
Fuel consumption of a car increases at higher speeds. The main reason is that with increasing speed the wind resistance increases exponentially. As a result fuel consumption (litre/km) increases too.

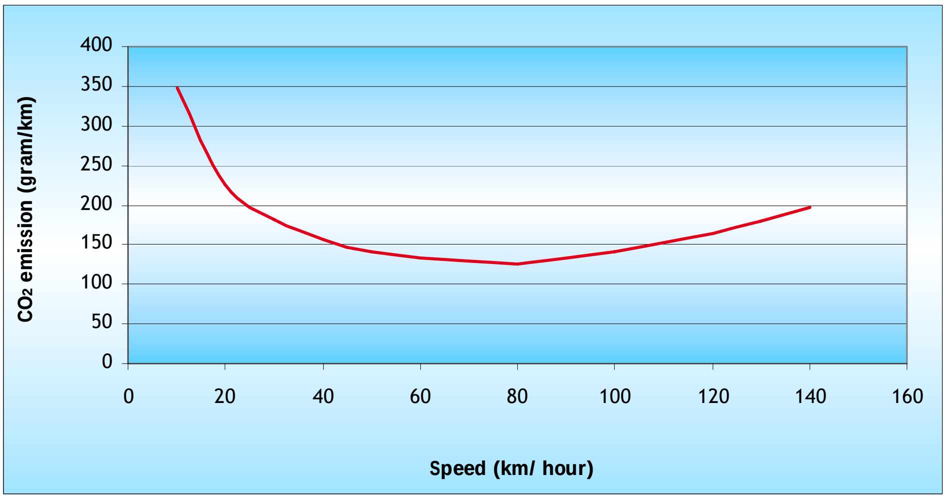
Figure 3 Relationship between vehicle speed (km/h) and CO_2 emission (gram/km) at constant speed



Source: TNO data, adapted by CE Delft.

As mentioned before, the driving pattern is of influence on fuel consumption too. For instance, fuel consumption during congestion is higher as compared to driving at constant speed. Figure 4 depicts how CO_2 emission per kilometre depend on speed when vehicle dynamics (stop-and-go) are taken into account. At lower speed stop-and-go behaviour increases, which results in an increase in fuel consumption and therefore in an increase in CO_2 emission. The most favourable speed limit for a minimum of CO_2 emissions per vehicle-kilometre lies at approximately 80 km/h. When a speed limit guarantees that the driving speed of passenger cars decreases from, for instance, 100 km/h to 80 km/h, CO_2 emissions will decrease.

Figure 4 **Correlation average speed (km/h) and CO_2 emission (gram/km) including vehicle dynamics**



Source: TNO data, adapted by CE Delft.

2.2.2 Reduction of total traffic volume and shift to public transport

In the previous section it was shown that speed limit reduction influences the average fuel consumption of passenger cars on the road. However, speed limit reduction also influences the amount of passenger car traffic and indirectly the use of other modes. In this section these two effects are discussed in relation to each other.

When speed limit reductions on the motorway are affected, travel time for a journey will increase. In principle, two reactions of drivers can be expected:
1. Covering a distance will cost drivers more time but they will continue to travel that distance.
2. Drivers will travel less or less far in order to loose no more time on travelling.

In practice it turns out that in the long term the second option prevails. In addition, the use of other modes of transport somewhat increases and some traffic will shift to secondary roads. The question is to what extent these effects will occur. The correlation between total traffic volume and travel time is expressed in so-called elasticities. Before going into this, the concept of constant travel time budget will be discussed, which gives insight in the applied elasticities.

Constant travel time budget

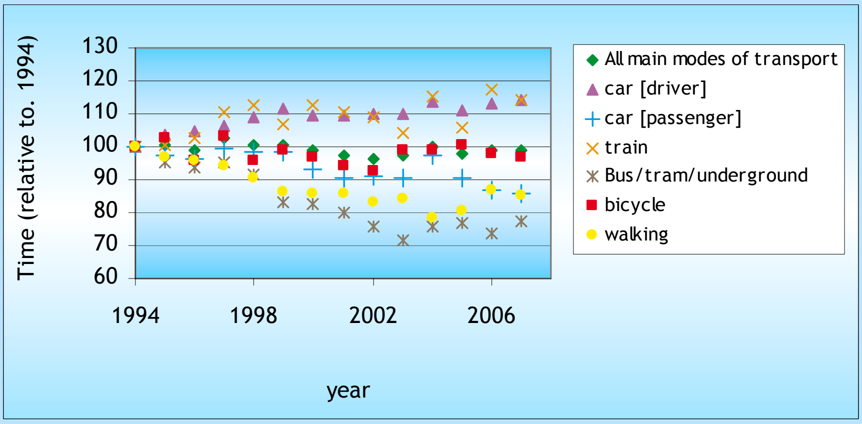
Different studies (Levinson, 1995; Lawton, 2001) show that the average amount of time per person spend on travelling remains more or less constant (60-70 minutes per 24 hours) over the years and is even more or less constant in different countries. This constant amount of time spent on travelling appears to be independent of the transportation facilities and has been constant over decennia. It seems that the average person is unwilling to spend more than about an hour per day on travelling. This phenomenon is known as the law of constant travel time budget.

The consequence of the constant travel time budget is that an increase in speed results in covering greater distances; in the same 60 or 70 minutes longer distances can be travelled. In fact, the rise of better and faster means of transport have resulted in covering longer distances and making more journeys rather than in a decrease in time spent on travelling (Lawton, 2001; Duany, 2000; Cervero, 2001).

Travel time spending in the Netherlands

Figure 5 depicts the average travel time spending per day for an average person for the period 1994-2007 in the Netherlands. It is shown that the total average time spent on travelling (all primary means of transport) indeed has practically remained constant (in 1994 61.6 minutes, in 2007 60,7 minutes). Travel time spent in a car as a driver and in the train has slightly increased over this period at the cost of transportation with tram/bus, as passenger in a car and walking. Also the average speed of travelling by car and train shows a slight increase over this period (approx. 4 and 0.3 % respectively). This, together with the increase of time spent on driving a car and using the train has led to an increase in kilometres of respectively 18% for cars and 14% for trains. Comparing the average for all modes of transportation of 2007 with 1994, there was a 6% increase in kilometres per person per day with a 7% increase in speed.

Figure 5 Development of average travel time spending per 24 hours per person (1994 = 100)



Source: CBS-figures: Mobility of the Dutch population per region revealing motif and means of transport.

From the textbox above it can be concluded that over the years 1994-2007 in the Netherlands the travelling behaviour is in accordance with the law of constant travel time budget: there has hardly been a change in travel time per person per day (-1%). The average travelling speed has increased 7% which is almost equal to the increase in travelled distance: 6%.

It is to be expected that the law of constant travel time budget will equally work the other way around: when the time per journey increases (speed decreases) the average distance travelled will decrease, since less kilometres can be covered within the 60 or 70 minutes travel time per day.

On a short term basis decreasing the maximum speed limit will probably lead to a (partial) increase in time spent on travelling, as it is difficult to immediately adjust travelling habits adequately. However, in the long term there are a number of changes that can be made which will lead to less kilometres. In Table 2 a few changes in travelling habits are summed up which lead to a structural change in travelling habits and therefore in less car kilometres (Litman, 2007).

Table 2 **Possible effects of decreasing the maximum speed limit which lead to less road use.**

Term	Behavioural changes leading to less car-kilometres
Short term	Working at home
	Teleconferencing instead of face-to-face meetings
	Shortest route instead of the fastest
	Choosing destinations closer to home
Medium term	Public transport / bicycle instead of car
	Less journeys, combining destinations
	Public transport season tickets, electric bicycle, scooter
Long term	Move to live closer to the workplace
	Improved bicycle and public transport infrastructure as effect of a higher demand
	Building in more advantageously located places in relation to transport possibilities (car as well as train)
	Increase in locally oriented business and industry

Elasticities - Correlation between changes in travel time and traffic volume

Changes in the amount of travelled kilometres as a result of changes in travel time can be expressed in elasticities. The elasticities give the correlation between the relative change in travel time and the resulting relative change in transport volume.
Based on the law of constant travel time budget, the average travel time elasticity of the amount of kilometres equals -1, (average for all modalities) (Van Wee, 1998; Pfleiderer, 2003). This means that a 1% increase in travel time leads to a 1% decrease in travelled kilometres. A decrease of maximum speed on the motorway will not only lead to a decrease in travelled kilometres by car, but will also partially result in a modal shift. The use of public transport and cycling will become relatively more favourable options. The car travel time elasticity of the amount of car-kilometres will therefore be less than -1.

In 1999 the European project TRACE was conducted in which, among other things, elasticity between car travel time on the one hand and number of journeys and vehicle kilometres on the other hand have been determined. The car travel time elasticities and cross-elasticities of vehicle-kilometres and number of journeys for the Netherlands are given in Table 3 (TRACE, 1999). In this analyses a distinction has been made between short and long term elasticities. For the long term indeed car travel time elasticity of car-kilometres smaller than -1 have been found.

Table 3 **Car travel time elasticity's of car kilometres and public transport kilometres**

		Vehicle kilometres (by car/public transport)	Number of journeys (by car/public transport)
Short term	Car	-0.35	-0.20
	Public transport	1.55	0.95
Long term	Car	-1.34	-0.33
	Public transport	0.65	0.51

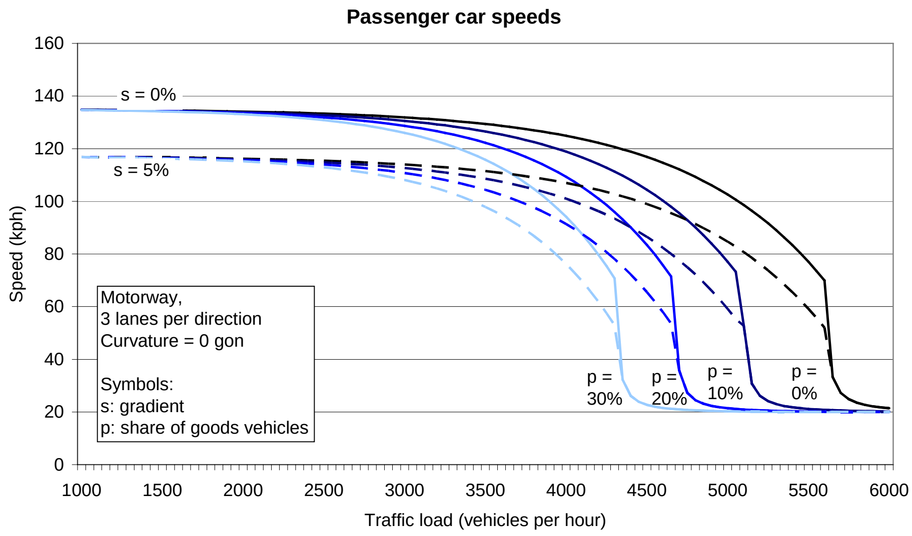
Above mentioned elasticities can be used to calculate the effects which arise in transport volumes of different modes of transport at different speed limits of road traffic. These elasticities have been used in the scenarios calculated in

Chapter 3. More information on the method of calculation with use of elasticities can be found in Appendix A.

2.2.3 Effects on Congestion

Congestion occurs when traffic volume on a road approaches the maximum road capacity. The correlation between traffic volume and traffic flow is expressed in so-called speed flow curves. An example is given in Figure 6.

Figure 6 Speed flow curves for passenger cars on a three-lane motorway



Source: 'Recommendations for the Economic Appraisal of Roads' EWS (FGSV, 1997).

If traffic volume is significantly below the maximum road capacity on a particular road then the speed of the road user is hardly affected by other road users. In that case there is no congestion. This situation is generally described as 'free flow'. When traffic volume approaches the maximum road capacity free flow decreases gradually. This situation is generally called 'forced traffic'. At a certain point, traffic volume is so high that traffic speed diminishes rapidly. At that point traffic experiences serious congestion also known as 'stop and go traffic'.

Maximum speed on the road mostly has its effects on driving speed outside congestion. Congestion speed is namely determined mostly by congestion levels. Nevertheless, maximum speed limit can have some effect on the extent of congestion although this effect is not singular. For instance, introducing 80-kilometre zones in the Dutch agglomeration Randstad induced an increase in congestion in some places and a decrease in others. Local situations play a large role in the outcome of these measures. At the Utrechtse Baan in The Hague congestion increased. This is mostly due to the fact that the maximum speed limit is lowered twice over a short distance: from 120 to 100 and a little further on from 100 to 80. In addition, close to the 80-kilometre zone is a merger lane because several roads conjunct.

It is not possible within the scope of this analysis to calculate the exact effects of reducing speed limitation on congestion. However, it is to be expected that total congestion in case of an uniform speed limit will decrease compared to the current situation of varying speed limits.

At a speed of 90 km/h traffic flow is optimal. A maximum speed limit of 90 km/h or 100 km/h is therefore expected to be most favourable for congestion reduction. A maximum speed limit of 90 km/h has the additional advantage of disappearing speed differences between trucks and passenger cars (the speed limiters of trucks are generally set at 89 km/h).

2.3 Additional effects of speed limit reduction

Besides reducing CO_2 emission and possible congestion reduction, lowering the maximum speed limit also has other effects. The most important effects are:
- Economical effects of longer travel time.
- Effects on air quality.
- Effects on noise pollution.
- Traffic safety effects.

In the subsections below we shortly touch upon these different effects.

2.3.1 Economical effects of extended travel time

Reducing the maximum speed limit has as the consequence that on average people will spend more time in transit in order to make a specific journey. In section 2.2.2 we have seen that on the long term total travel time of people hardly increases because increase in travel time is for a large part compensated by a decrease in distance.

Both effects (increased travel time for a specific journey and a decrease in distance covered) involve costs from the perspective of economical welfare. The extra time spent in the car and the decrease in travelled kilometres represent for the consumer a loss in economical welfare. There are also economical gains such as the reduced fuel consumption per kilometre. Quantifying these effects is outside the scope of this study.

The lower speed limit measure is expected to have hardly any effect on cargo transport because the maximum speed limit for trucks is already set at 80 km/h. Congestion reduction as a result of a uniform speed limit of, for instance, 90 km/h could have economical benefits for this sector. For passenger travel too, congestion reduction can have economical benefits.

2.3.2 Effects on air quality

Transport has important effects on air quality. In the case of road traffic these effects are connected to the emission of PM_{10} (particle matter) and NO_x (nitrogen oxides). As with CO_2, the emission of these particulates will decrease when a lower speed limit is established. However, there will be an even greater decrease than for CO_2. The reason for this is that at higher speeds and larger driving dynamics the emission of PM_{10} and NO_x increase faster than fuel consumption and CO_2 emission.

2.3.3 Effects on noise pollution and noise damage

Road traffic causes noise pollution. Besides nuisance this also brings health damage along with it.

Lower speeds and a reduction of traffic volumes both result in less noise pollution. In order to make a substantiated estimation of the size of this reduction further study is necessary.

2.3.4 Traffic safety effects

In 2008 there were 750 road fatalities in the Netherlands as a result of traffic accidents. Statistics on the number of people injured are less recent: in 2005 17,760 victims of traffic accidents had to be admitted to the hospital.
A reduction of the maximum speed limit influences traffic safety in several ways:

- Lower speed limits and fewer dissimilarities in speed between passenger cars and trucks increases traffic safety.
- A decrease in traffic volume results in a decrease of the amount of road casualties. Although in general this decrease is relatively less than the decrease in traffic volume.
- A shift to other modes of transport affects traffic safety.
- A shift of traffic from motorways to secondary roads will worsen traffic safety.

The overall effect of a reduction of the maximum speed limit is difficult to assess. It is expected that overall traffic safety improves. For instance, speed limit reduction on the A13 from 100 km/h to 80 km/h resulted in more than 50% drop in the number of injured people (Beek et al., 2007).

2.4 Enforcement

The effectiveness of a speed limit depends strongly to which extent traffic participants comply to it. Enforcement is an important condition for this. Strict enforcement like speed cameras that track drivers over long distances by measuring average speed (route control) currently in use at the 80-kilometre zones in the Dutch agglomeration Randstad proves to be effective. Of course, these kinds of systems bring along costs.

2.5 Overview social costs and benefits

In the previous section a variety of effects has been discussed of lowering the speed limit on the motorway in combination with strict enforcement. These effects result in a variety of social costs and benefits. For instance, prolonged travelling time and less vehicle kilometres lead to social costs. After all, a traveller attributes positive value to making a journey, otherwise he would not undertake it. Therefore, travelling less results in social costs. On the other hand, the reduction of CO_2 emissions, air and noise pollution and traffic casualties represent social benefits.

The most important social costs and benefits (for the society as a whole) are given in Table 4.

Table 4 Overview of social costs and benefits of lower motorway speed limits

Social costs	Social benefits
Prolonged travel time	Reductions of CO_2 emissions
Reduction vehicle kilometres of passenger cars	Reduction of air polluting emissions
Enforcement costs	Reduction of noise pollution
	Improvement of traffic safety
	Congestion reduction
	Saving infrastructure costs
	Savings fuel

Performing a complete cost-benefit analysis falls outside the scope of this study.

In the past such analyses have been made. In an article of Rietveld et al. (Rietveld et al., 1996) the effects of climate change, air pollution, accidents, fuel consumption, and travel time have been quantified and economically valued (expressed in monetary terms)in a cost-benefit analysis. In this analysis it was concluded that from the point of view of total welfare, the most beneficial maximum speed limit on the motorway lies somewhere around 90 km/h. For other types of road too, the most beneficial speed limits have been determined. The Rietveld analysis is over a decennium old and needs to be interpreted with some care. An actualization is recommended.

Recently, Transport and Mobility Leuven (TML) commissioned by the Bond Beter Leef Milieu (Confederation Better Living Environment) issued a report 'Impact van maximumsnelheid op autosnelwegen' (Impact of maximum speed limit on motorways) (TML, 2009). In this report a cost-benefit analysis has been made for speed limit reduction on the Belgium motorways in which the effects of climate change, air pollution, traffic safety and travel time are incorporated. This study concludes that the most beneficial maximum speed limit of 110 km/h based on these effects. TML notes that in this study the volume effects of speed limit reduction are not taken into account. Other important effects not taken into account are the benefits of reduced fuel consumption and reduced expenses on infrastructure. Perhaps taking into account these effects in the cost-benefit analysis will bring the most beneficial speed limit closer to 90 km/h as in the study of Rietveld et al. (1996).

3 Estimation of climate gain of different scenarios

3.1 Overview of calculated scenarios

In this chapter the CO_2 reduction for different speed limit scenarios have been calculated. The scenarios concern implementing a reduction of the maximum speed limit on all motorways of the Netherlands with current speed limits of 120 or 100 km/h.

The following scenarios have been calculated:

1. **100 everywhere**: Max. 120 -> Max. 100.
2. **110 en 90:** Max. 120 -> 110 en Max. 100 -> 90.
3. **100 en 80:** Max. 120 -> 100 en Max. 100 -> 80.
4. **90 everywhere:** Max. 120 -> 90 en Max. 100 -> 90.
5. **80 everywhere:** Max. 120 -> 80 en Max. 100 -> 80.

For all scenarios applies that motorways with a maximum speed limit of 80 km/h are not included in the scenario; in other words the speed limit on these motorways remains unaltered at 80 km/h in all scenarios.

3.2 Method of calculation

Table 5 shows the share of vehicle-kilometres on motorways divided over different enforced maximum speed limits. It also shows the average speed on these motorways.

Table 5 Average speed and share in maximum vehicle kilometres per maximum speed category on the motorway

Maximum speed category	Average speed	Share in vehicle kilometres
50	46	3%
70	68	2%
80	70	5%
100	81	30%
120	90	60%
Average	**83**	**100%**

The average speed for other roads is given in Table 6, with an average speed on all roads of 45 km/h (see also Table 8 in Appendix B).

Table 6 Average speed and vehicle kilometres per road category

Type of road	Average speed	Number of kilometres
Motorway	83	43,162
Secondary road	55	34,922
City	20	20,161
Average/total	45	98,245
Average CBS	44.5	

For each scenario the influence of a reduction of the maximum speed limit on the average speed of Dutch passenger car traffic is calculated. In order to do this it has been estimated for each scenario how the average speed changes as a result of a reduction of the maximum speed limit, as depicted in Table 7 (see also Table 9 in Appendix B).

Table 7 Average speed and emission as a result of lowering the maximum speed limit

	Maximum speed scenario	Average speed (km/uur)	CO_2 emission (gram/km)
Scenario for current 100-km/u roads (high level enforcement)	80	66	152
	90	72	158
	100	79	166
Scenario for current 120-km/u roads (high level enforcement)	80	69	149
	90	76	155
	100	83	163
	110	86	171
	120	89	178
Current situation (current control)	80	70	157
	100	81	172
	120	90	178

The ratios of the new average speed of the total Dutch passenger car traffic in relation to the old (45 km/h) are calculated (see Appendix B, Table 11). Aided with the elasticities in Table 3, the decrease in car-kilometres and the increase in public transport kilometres haves been calculated. The effects are calculated both for the short and for the long term. For those kilometres avoided it is assumed that 80% of them are saved on the motorways and 20% on other roads.

Subsequently, for the remaining passenger car kilometres it has been determined how much CO_2 emissions will be saved due to the lower average speeds by applying the emission factors in Table 7. In Figure 7 the CO_2 reduction as a result of slowing down delivery vans is also given.

Background data and sources for the calculations are included in Appendix B.

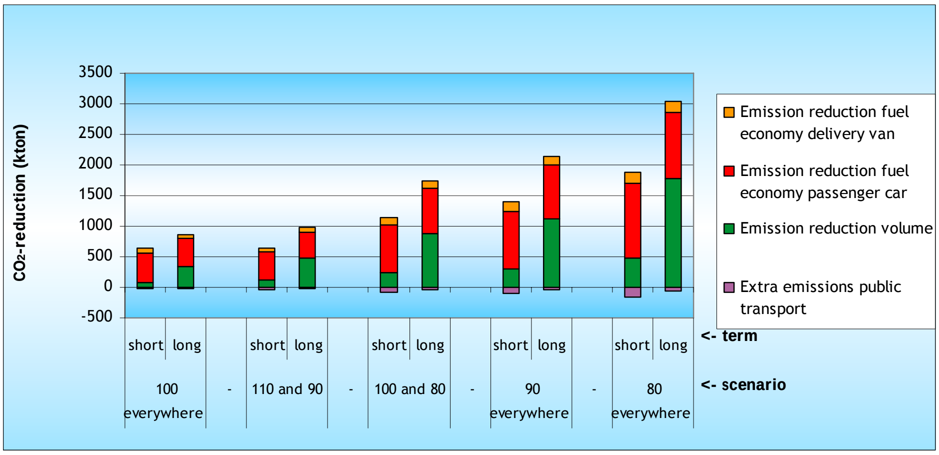
3.3 Results

The results are depicted in Figure 7, Figure 8 and Figure 9 in different ways. It concerns both CO_2 emissions of the car's exhaust and emissions of oil refineries and transport (well-to-wheel emissions).

These figures prove that a uniform decrease of the speed limit with strict enforcement can offer substantial CO_2 reductions. The volume of the reduction

strongly depends on the scenario. A stronger speed limit reduction leads to a stronger reductions in CO_2 emissions. The largest reduction is obtained for the scenario in which the speed limit on all 100 km/h and 120 km/h roads is lowered to 80 km/h.
Figure 7 shows that on the short term CO_2 emission reduction is mainly realized through improved fuel economy and, to a lesser extent, through a decrease in transport volume. On the long term the emphasis shifts to a decrease in transport volume. For delivery vans, as mentioned before, only reductions as a result of improved fuel economy are taken into account.

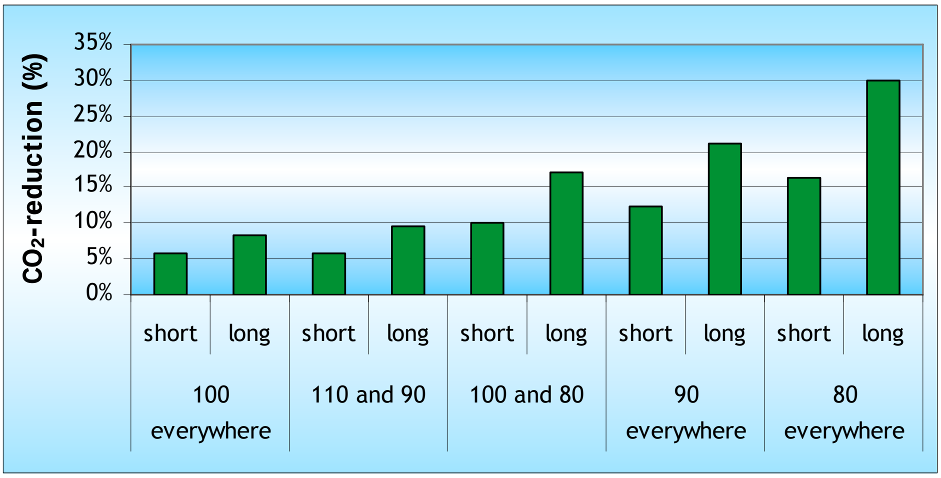
Figure 7 **CO_2 reduction for the scenarios on the short and the long term (passenger cars and vans)**



In Figure 8 and Figure 9 emission reductions for passenger cars are set against total emissions of passenger cars on the motorway and the total emissions of passenger cars in the Netherlands.

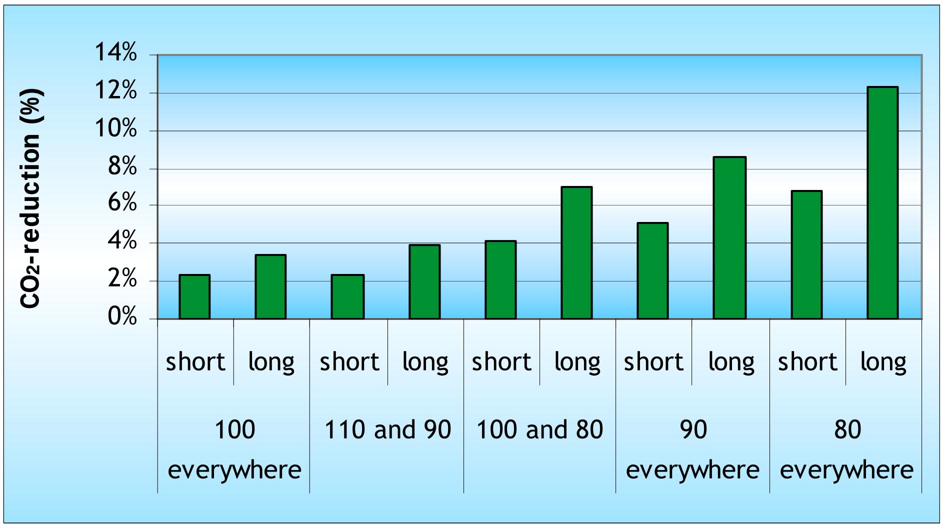
On the short term speed limit reduction will lead, depending on the scenario, to a 6 to 16% decrease of CO_2 emissions of passenger cars on the motorway. On the long term a 8 to 30% decrease will be realized.

Figure 8 **Short and long term CO_2 emission cuts as a share of total CO_2 emissions by cars on motorways (various scenarios)**



In relation to the total emissions of passenger cars this means a CO_2 reduction of 2 to 7% on the short term and 3 to 12% on the long term.

Figure 9 Short and long term CO_2 emission cuts as a share of total CO_2 emissions by cars s in the Netherlands (various scenario's)



4 Conclusions and recommendations

4.1 Conclusions

A reduction of the maximum speed on the motorways can yield significant CO_2 reductions of passenger cars. In this survey CO_2 reductions have been estimated by quantifying the changes in fuel consumption both on the level of vehicles and on the level of traffic volume. Also, an estimate has been made of the shift toward other modalities. Reduction of maximum speed can also result in a decrease in congestion, however, this effect has not been quantified in this study.

The maximum long-term CO_2 reduction was estimated to be 2.8 Mt for passenger cars and a further 0.2 Mt for delivery vans. In the case of cars, this means a 30% reduction of emissions on motorways, which equals 12% of all CO_2 emissions of passenger cars in the Netherlands. This maximum reduction is attained at a uniform speed limit of 80 km/u. A less drastically lowered speed limit attains a smaller amount of reduction but, depending on the scenario, it still leads to a reduction of emissions of passenger cars on the motorway of 8 to 21%, which equals 3 to 9% of all CO_2 emissions of passenger cars in the Netherlands.

Aforementioned reductions demand strict enforcement, for example with route control. Perhaps the technique which will be used for kilometre pricing can be applied.

Next to reducing $C0_2$ emissions, lowering maximum speed also has positive effects on air pollution, noise pollution, and possibly congestion and traffic safety.

Lowering the maximum speed limit also has disadvantages. On average people will need to spend more time to make a specific journey and they will travel less kilometres. From the perspective of economic welfare both the reduced speed and the reduction in traffic volume count as costs. Quantifying these effects is outside the scope of this pilot study. The measure is expected to have hardly any effect on cargo transport because there the maximum speed limit is already set at 80 km/h.

Performing a cost-benefit analysis fell outside the scope of this study. A study conducted in the late 1990s concluded after reviewing all costs and benefits that the most favourable speed limit on the motorway is approximately 90 km/h.

4.2 Recommendations

In this pilot study a first step has been taken to map out the effects of speed limit reduction on motorways. Because of the substantial climate gain involved, it is recommended to further research these measures. Especially an analysis of social costs and benefits appears to be interesting, which allows to calculate the most optimal maximum speed limit. Considering the current discussion on tests with dynamic speed limits it might be of interest to have a look into optimal speed limits for various situations. For instance, the time of day (day/night), actual air quality and/or congestion level could be of interest.

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Annex A Definition of travel time elasticity

The time elasticity (ε_t) of the number of vehicle-kilometres is defined as follows:

$$\varepsilon_t = (\delta km/km_0)/(\delta t/t_0) \quad (1)$$

with δkm standing for a small change in the number of vehicle-kilometres in relation to the number of vehicle-kilometres in the starting situation (km_0) and δt for a small change in the average travel time in relation to the average travel time in the starting situation (t_0). When the elasticity is constant at different starting situations, the following also counts:

$$(km_n/km_0)= (t_n/t_0)^{\wedge}\varepsilon_t \quad (2)$$

with km_n and t_n standing for the number of kilometres and the travel time, respectively, in the new situation.

Annex B Background data and calculations

To estimate the total amount of car-kilometres driven on roads with a speed limit of 120 km/h and 100 km/h the starting values in Table 7 have been used. The average speed on the road calculated with the help of velocity based on TNO-data and the amount of vehicle-kilometres per road type results in 45 km/h. This average car speed is in good agreement with the value of 44.5 km/h according to CBS (CBS, 2008).

Table 8 Average speed and vehicle kilometres per road category

Type of road	Estimation speed	Source	Number of vehicle kilometres (mln)	Source
Motorway	83	DVS (MoNiCa)	43,162	Taakgroep 2008
Secondary road	55	Op basis van TNO, 2008	34,922	Taakgroep 2008
Urban road	20	Op basis van TNO, 2008	20,161	Taakgroep 2008
Average/total	45		98,245	Taakgroep 2008
Average CBS	44.5	CBS		

As depicted in Table 8 the average speed on the motorway is approx 83 km/h. For determining the average actual speed per maximum speed limit category (Table 9), data from the MoNiCa system of DVS[2] have been used. The data concern actual speeds per road section, transport performances per road section and maximum speed limit per road section. The amount of vehicle-kilometres (vkm) per maximum speed category on the motorway (Table 9) have been determined using data of the Directorate General of Public Works and Water Management (Rijkswaterstaat, source dataportal). The data concern vehicle intensities, maximum speed limits and road section lengths.

Table 9 Average speed and share vehicle kilometres per maximum motorway speed category

Maximum speed category	Average speed	Share in vehicle kilometres
50	46	3%
70	68	2%
80	70	5%
100	81	30%
120	90	60%
Average	**83**	**100%**

The average speed of 83 km/h is the kilometre-weight average of the given speeds per maximum speed category.

The MoNiCa-data give the average speed and transport performances per 15 minutes per road section. Using these data, an estimation has been made of the speeds driven per road category (in %vkm) and how this distribution changes when the speed limit is adjusted. In the three lower rows of Table 10

[2] Many thanks to Arnold van Veluwe and Peter Schout of DV for making available MoNiCa data.

the vehicle-kilometre share for different speeds are given per maximum speed limit category. In the rows above, it is depicted how this distribution changes for the current 100 km/h and 120 km/h roads by applying different maximum speeds limits (assuming strict enforcement).

Table 10 Distribution op speeds after % vehicle kilometres

	Maximum speed limit	<70 (32,5)	70	80	90	100	110	120	130	140	Average speed
Scenario at current 100-km/u roads (high level of enforcement)	80	12%	27%	53%	6%	2%					66
	90	12%	4%	28%	48%	7%	1%				72
	100	12%		2%	26%	50%	9%	1%			79
Scenario at current 120-km/u roads (high level of enforcement)	80	8.5%	28%	55%	7%	2%					69
	90	8.5%	4%	29%	50%	8%	1%				76
	100	8.5%		2%	27%	53%	9%	1%			83
	110	8.5%		1%	18%	32%	36%	5%			86
	120	8.50%		1%	5%	32%	35%	18%	1%		89
Current situation (low level of enforcement)	80	11.00%	22%	38%	14%	9%	5%	2%			70
	100	12.00%		4%	15%	36%	25%	6%	2%		81
	120	8.50%		1%	5%	31%	33%	17%	4%	1%	90

In Table 10 it is shown how the average speed changes by adjusting the maximum speed limit. By applying these adjusted speeds on 100 and 120 km/h roads to the calculation of the average speed (starting situation 45 km/h) the ratio between new and old average speed can be determined.

The ratios of the new speed and the old (V_n/V_0), the consequent relative change in kilometres (km_n/km_0) and the kilometre reduction (in mln) are depicted in the tables below. Data are given for both long and short term.

Table 11 Ratio's of new average speed measured against old (V_n/V_0) and the consequential kilometres in short term

Scenario	V_n/V_0	km_n/km_0	Reduction in km (mln)
120-> 110	0.9928	0.9975	247
120-> 100	0.9905	0.9967	368
120-> 90	0.9743	0.9909	996
120-> 80	0.9608	0.9861	1,528
100 -> 90	0.9905	0.9967	366
100 -> 80	0.9839	0.9943	624
120 -> 110/ 100 -> 90	0.9861	0.9951	536
120 -> 110/ 100 - 80	0.9795	0.9928	792
120 -> 100/ 100 -> 90	0.9811	0.9934	730
120 -> 100/ 100 -> 80	0.9746	0.9910	985
120 -> 90/ 100-> 90	0.9679	0.9886	1,249
120 -> 90/ 100 -> 80	0.9615	0.9864	1,500
120 -> 80/ 100 -> 80	0.9483	0.9816	2,022

Table 12 **Ratio's of new average speed measured against old (Vn/V0) and the consequential kilometres in the long term**

Scenario	V_n/V_0	km_n/km_0	Reduction km (mln)
120-> 110	0.9928	0.9904	941
120-> 100	0.9905	0.9872	1,402
120-> 90	0.9743	0.9657	3,766
120-> 80	0.9608	0.9478	5,737
100 -> 90	0.9905	0.9873	1,394
100 -> 80	0.9839	0.9784	2,371
120 -> 110/ 100 -> 90	0.9861	0.9815	2,036
120 -> 110/ 100 - 80	0.9795	0.9727	3,003
120 -> 100/ 100 -> 90	0.9811	0.9748	2,769
120 -> 100/ 100 -> 80	0.9746	0.9661	3,724
120 -> 90/ 100-> 90	0.9679	0.9572	4,707
120 -> 90/ 100 -> 80	0.9615	0.9488	5,632
120 -> 80/ 100 -> 80	0.9483	0.9314	7,543

For the number of vehicle-kilometres we have used data of the Taakgroep verkeer en vervoer (Taskforce traffic and transport) (Taakgroep, 2008), as depicted in Table 13.

Table 13 **Vehicle kilometres passenger cars per road type in 2007**

Road type	V-km (passenger cars) (mln)
Motorway	43,162
Secondary road	34,922
Urban	20,161
Total	98,245

The emission factors (Table 14) that have been used for calculating the saved emissions through less kilometres and more economical driving are determined by the data supplied by TNO[3] for cars which typically populate the motorways (Euro 4/Euro 5). The CO_2 data in Table 14 concern both the exhaust CO_2 emissions and the CO_2 emissions from the refinery and transport of the fuel (well-to-wheel).

Table 14 **The emission factors for motorway based on data of TNO for motorway**

	Maximum speed	CO_2 emission (gram/km)
Scenario at current 100-km/u roads (high level of enforcement))	80	152
	90	158
	100	166
Scenario at current 120-km/u roads (high level of enforcement)	80	149
	90	155
	100	163
	110	171
	120	178
Current situation (low level of enforcement)	80	157
	100	172
	120	178

3 With thanks to Norbert Ligterink and Ronald de Lange for making the data available.

For public transport an average emission factor of 79 gram per passenger kilometres (well-to-wheel) has been used. The change in public transport kilometres is based on a current number of 22,200 million passenger kilometres (based on CBS, 2008).

The final results are eventually scaled to the CO_2 emission caused by passenger cars, as reported by CBS (CBS, 2009).

Annex C Supplementary scenarios worked out

Besides the scenarios described in the main body of the report the scenarios shown below have been computed too.

1. a. Max. 120 -> Max. 110
   b. Max. 120 -> Max. 100
   c. Max. 120 -> Max. 90
   d. Max. 120-> Max. 80
2. a. Max. 100 -> Max. 90
   b. Max. 100 -> Max. 80
3. a. Max. 120 -> 110 en Max. 100 -> 90
   b. Max. 120 -> 110 en Max. 100 -> 90
4. a. Max. 120 -> 100 en Max. 100 -> 90
   b. Max. 120 -> 100 en Max. 100 -> 80
5. a. Max. 120 -> 90 en Max. 100 -> 90
   b. Max. 120 -> 90 en Max. 100 -> 80
6. Max. 120 -> 80 en Max. 100 -> 80

The results for these scenarios are represented in Figure 10, Figure 11, Table 15 and Table 16.

Figure 10 **CO_2 savings for short term scenarios**

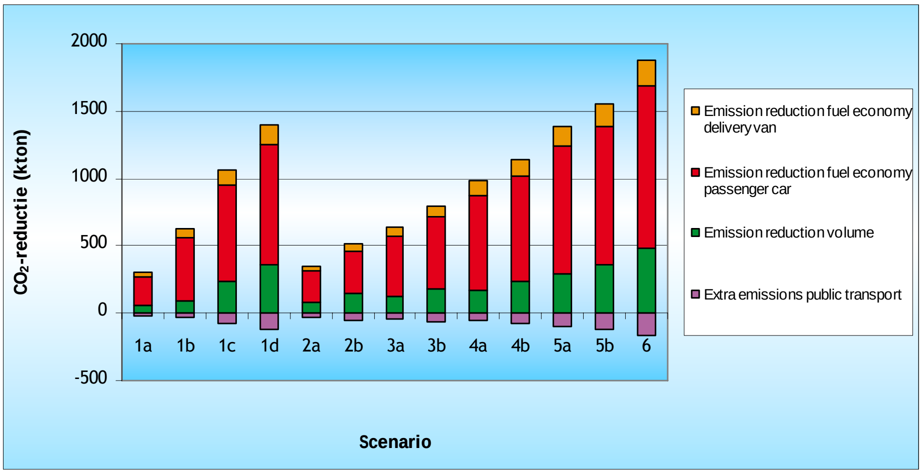

Figure 11 CO_2 savings for long term scenarios

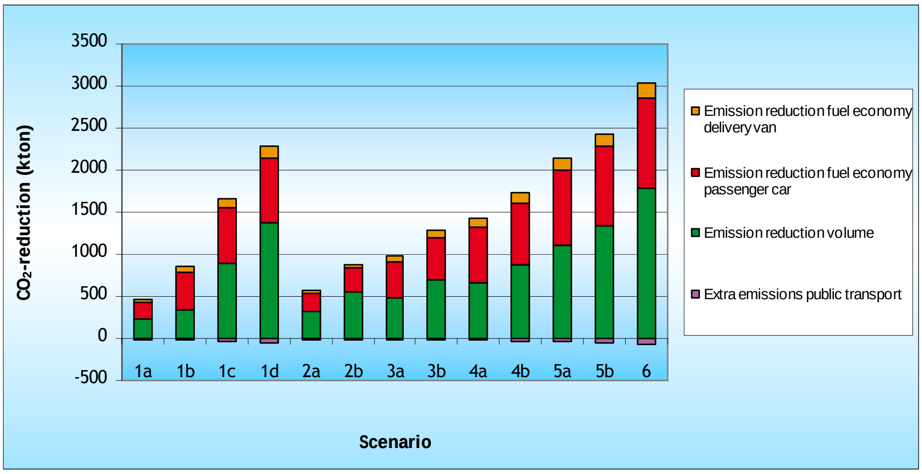

Table 15 CO_2 savings for short term scenarios

Scenario	CO_2-reduction Passenger cars (kton)		Extra CO_2 emissions (kton)	Total CO_2 reduction through reduced speed passenger cars			CO_2 reduction delivery vans (kton)
	Volume	Fuel economy	OV	(kton)	% measured against total of emissions passenger car		Fuel economy
					On motorway	Total NL	
1a	59	214	-22	252	3%	1%	32
1b	88	472	-29	531	6%	2%	71
1c	238	717	-79	876	9%	4%	110
1d	364	893	-123	1,135	12%	5%	139
2a	85	230	-29	287	3%	1%	35
2b	146	316	-49	413	4%	2%	49
3a	126	445	-42	529	6%	2%	67
3b	186	532	-63	655	7%	3%	81
4a	172	702	-58	817	9%	4%	106
4b	232	788	-78	942	10%	4%	120
5a	296	950	-100	1,146	12%	5%	145
5b	355	1,036	-121	1,270	14%	6%	159
6	479	1,213	-165	1,527	16%	7%	188

Table 16 CO_2 savings for long term scenarios

Scenario	CO_2-reduction passenger cars (kton)		Extra CO_2 emissions (kton)	Total CO_2 reduction through reduced speed passenger cars			CO_2 reduction delivery vans (kton)
	Volume	Fuel economy	OV	(kton)	% measured against total of emissions passenger car		Fuel economy
					On motorway	Total NL	
1a	224	210	-9	425	5%	2%	32
1b	334	457	-12	779	8%	3%	71
1c	898	654	-33	1,519	16%	7%	110
1d	1,368	771	-51	2,089	22%	9%	139
2a	325	215	-12	528	6%	2%	35
2b	553	280	-20	813	9%	4%	49
3a	479	428	-18	890	10%	4%	67
3b	705	495	-26	1,174	13%	5%	81
4a	653	672	-24	1,302	14%	6%	106
4b	876	738	-32	1,582	17%	7%	120
5a	1,116	878	-41	1,953	21%	9%	145
5b	1,332	945	-50	2,228	24%	10%	159
6	1,788	1,066	-67	2,787	30%	12%	188