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THE IMPACT OF DEMAND REDUCION ON CO_2 EMISSIONS AND CONGESTION

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1. INTRODUCTION

The Dutch Ministry of Infrastructure and Water Management is working on the improvement of accessibility, safety and sustainability in the Netherlands. With respect to sustainability, the climate change and the international agreements to reduce the worldwide increase in temperature, urge the government to work on the reduction of emission of greenhouse gasses, especially carbon dioxide (CO_2). In the Climate Agreement (Climate Consideration, 2019) it is agreed to reduce greenhouse gas emissions in the Netherlands in 2030 by 49% compared to 1990 levels. According to the emission registration, about 18% of the CO_2 emissions are due to traffic and transport, of which a large part can be contributed to road traffic (CBS, 2023a). Policy is aiming to reduce road traffic, for example by stimulating the use of sustainable transport modes, such as public transport and the bicycle. But reduction in traffic demand could also be achieved by other sustainable travel behaviour, such as carpooling (ride sharing) or teleworking.

Carpooling is sharing a ride between people living and working in the same area, especially for commuting. Carpooling was once popular and the government supported it by building a lot of carpool locations, where people could change cars. Due to relatively low fuel prices, individualism and more flexible working hours, carpooling became less popular, both for policy and the traveller. However, it is rediscovered by policymakers and it is seen as a promising measure to decrease vehicle kilometres driven and improve sustainability. This is supported by research (Bresciani *et al.*, 2018), although issues on non-work carpooling, digitalisation and perception of shared transport modes on the short, medium and long term need to be tackled (Aguiléra and Pigalle, 2021) and also psychological factors need to be taken into account (Hartl *et al.*, 2020; Julagasigorn *et al.*, 2021).

Also, hybrid working (partially working at the office and partially at home) or teleworking is considered promising. Staying at home to work has become a viable option for a lot of people as a result of the experience gained during the COVID-19 pandemic (Olde Kalter *et al.*, 2021). Also, more flexibility in meetings and other appointments led to an increase of commuting trips outside peak hours.

However, knowledge about the impact of both options to decrease demand is still scarce. This paper tries to fill a part of that gap. First, the potential of carpooling to decrease CO_2 emissions and congestion is researched and after that the potential impact of hybrid working on the congestion in a number of bottlenecks is determined using a traffic model.

2. IMPACT OF CARPOOLING

2.1 Impact on CO_2 emissions

For the impact of carpooling on CO_2 emissions, a quick analysis was done. The primary source for this was the national travel survey which is published by Statistics Netherlands (CBS, 2023b). In Table 1 the kilometres travelled for trip purposes and different modes are given. The numbers are kilometres per person (6 years and older) and per day for 2019. The year 2019 is used, because during more recent years the COIVD-19 pandemic had a big impact on traffic.

Table 1: Kilometres travelled for trip purposes and modes

Distance (km)	Total	Commute	Business	Services	Shopping
Total	36,00	9,72	3,27	0,73	3,13
Car driver	18,02	6,20	2,15	0,38	1,52
Car passenger	6,65	0,38	0,16	0,19	0,78
Train	4,08	1,35	0,21		0,22
Bus/tram/metro	1,06	0,31	0,03	0,03	0,09
Bicycle	3,01	0,65	0,05	0,06	0,33
Walking	0,88	0,06	0,01	0,01	0,09
Other	2,30	0,78	0,67	0,03	0,1
	Education	Visiting	Go out	Go for a ride	Other
Total	2,05	5,85	6,69	1,62	2,93
Car driver	0,37	2,69	2,57	0,33	1,80
Car passenger	0,19	1,91	2,26	0,23	0,56
Train	0,66	0,77	0,59		0,20
Bus/tram/metro	0,29	0,11	0,14		0,04
Bicycle	0,42	0,20	0,63	0,51	0,15
Walking	0,04	0,04	0,21	0,39	0,03
Other	0,08	0,13	0,28	0,10	0,13

An increase in carpooling means that the total distance travelled as a car driver decreases and the distance travelled as a car passenger will increase. For the analysis some other assumptions are made:

- It is assumed that there is no generation of car kilometres, but that there is a shift from other modes to car passenger. This shift comes from the modes car driver, train, bus/tram/metro and bicycle, proportional to the share of these modes. So, for these modes the kilometres are decreasing. We are not taking into account the modes and kilometres to reach a carpool location.
- The trip purposes 'commute' and 'business' are summed as one purpose 'commute' and the other ones are taken together as one purpose 'other'.
- It is assumed that the CO_2 emissions are linear with the kilometres travelled.

On the basis of an assumed growth of the car occupancy rate, these assumptions and the data from table 1, it can be determined how large the reduction in car kilometres driven will be. It is also known that the total emissions for car traffic is 16.9 megatons CO_2 (PBL, 2021). Based on the total and reduced car kilometres and the other assumptions, it is possible to calculate the decrease in megatons CO_2 emission.

Based on table 1, the occupancy rate for commuting in the Netherlands in 2019 was 1.06. For the other purposes it was 1.63. In 1996 these figures were 1.19 and 1.96 respectively. Now suppose that the occupancy rate of vehicles can be increased. That means that kilometres as a car driver decrease. For commuting the calculations were done for desired occupancy rates of 1.075, 1.10, 1.15, 1.20, 1.25 and 1.30. For the other trip purposes occupancy rates of 1.75, 1.80, 1.85, 1.90, 1.95 and 2.00 were used. The results are shown in figure 1.

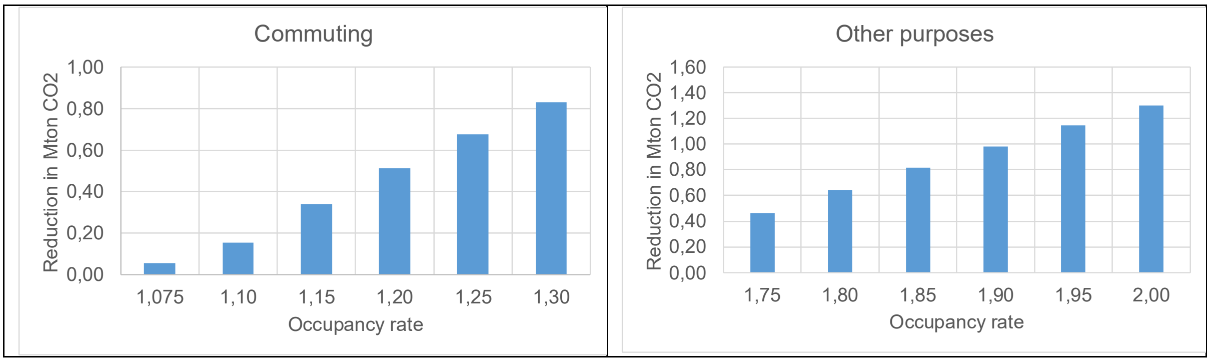

Figure 1: Reduction in CO_2 emissions for commuting and other trip purposes

From the graphs although small, an effect can be expected if the occupancy rate of vehicles is increased. For example, if it is increased from 1.06 to 1.075 for commuting and from 1.63 to 1.75 for other trip purposes, the decrease in CO_2 emissions of car traffic is 3%. For the maximum scenario the decrease is 13%. However, some remarks must be made.

- Only the emissions of car traffic were considered. A general emission factor per kilometre driven was applied. In this way a simple translation from a reduction in car kilometres to a reduction in CO_2 emissions could be done.
- The assumed increase in vehicle occupancy due to carpooling is not connected to certain policy measures. It is certainly not easy to obtain such increase in vehicle occupancy.
- It is assumed that there is no increase in vehicle kilometres driven. However, an increase is possible because of the latent demand. If there is less traffic on the roads and less congestion due to carpooling, other people can choose to take the car again, instead of using public transport. Therefore, the impact on vehicle kilometres driven (and on emissions) can be smaller.

2.2 Impact on congestion

During the COVID-19 pandemic there was much less traffic on the roads then normal. Less traffic meant less congestion. To get an impression of the relation between distance travelled and congestion on the Dutch main road network, data for the period 2019-2022 was plotted in a graph (see figure 2). Each dot represents one week of data.

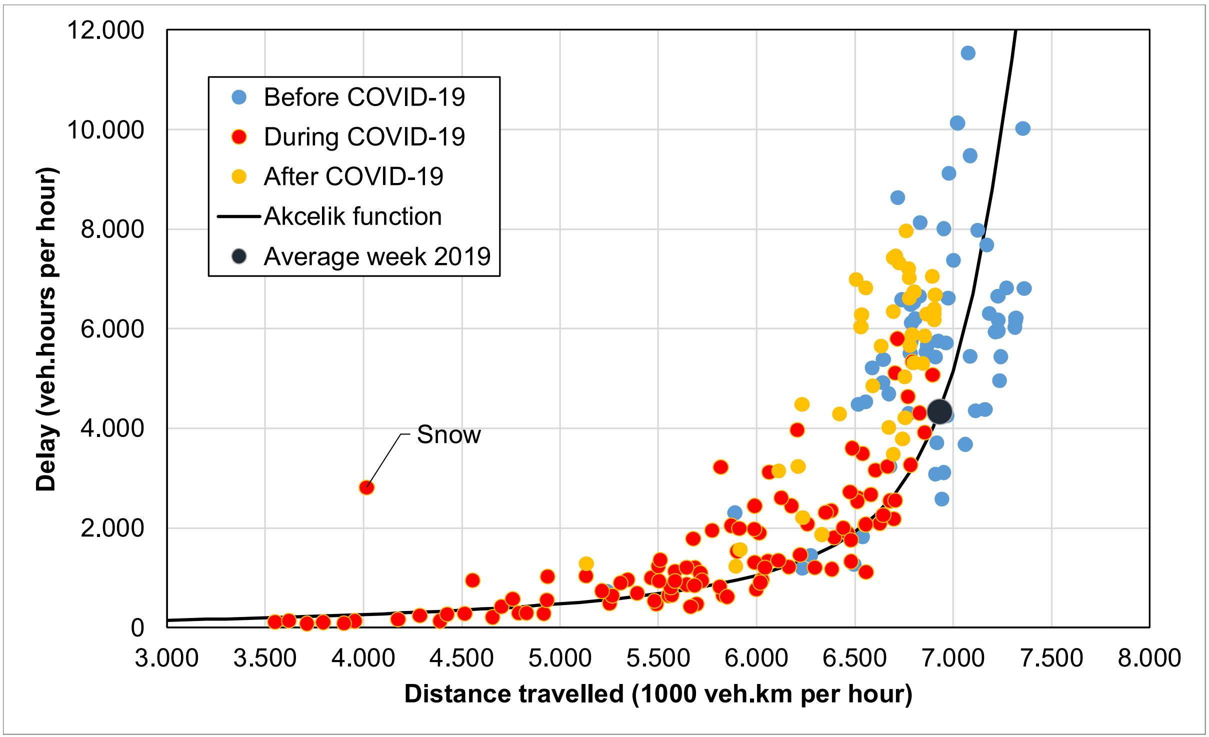

Figure 2: Relation between distance travelled and delay

The graph shows that for the period before COVID-19 the measurements are mainly at the right and upper side of the graph and the same holds for the measurements for the period after COVID-19 (until the end of 2022). During COVID-19 the lower left branch of the graph appears and together the measurements show first a slightly increasing, but further on a steep relationship between distance travelled and delay. An exponential function was tested, but that didn't quite fit. However, the relation looks very similar to the one Akçelik derived for estimating travel times on normal links (Akçelik, 1991, 2003), using the coordinate transformation technique (Akçelik, 1989). Therefore, we use a similar function:

$$D = 0.25 \cdot T_f \left[x - 1 + \sqrt{(x-1)^2 + \frac{8 \cdot k \cdot x}{Q \cdot T_f}} \right],$$

for which D is the delay, T_f a time parameter, x is the distance travelled divided by the network capacity Q (capacity in terms of maximum distance travelled without severe delays), and k is a parameter to calibrate. If this function is fitted on the data, we get the black line shown in figure 2.

The relation can be used to estimate the relative difference in delay from the relative difference in distance travelled. For this a reference point is needed, which was chosen to be the average week in 2019 (the black dot in the graph). Therefore, the results for the different scenarios in occupancy rate are relative to that average week and are shown in figure 3. Only the results for commuting are shown, because the impact will mostly be in peak periods and traffic for other purposes is driving outside peak hours for a large part.

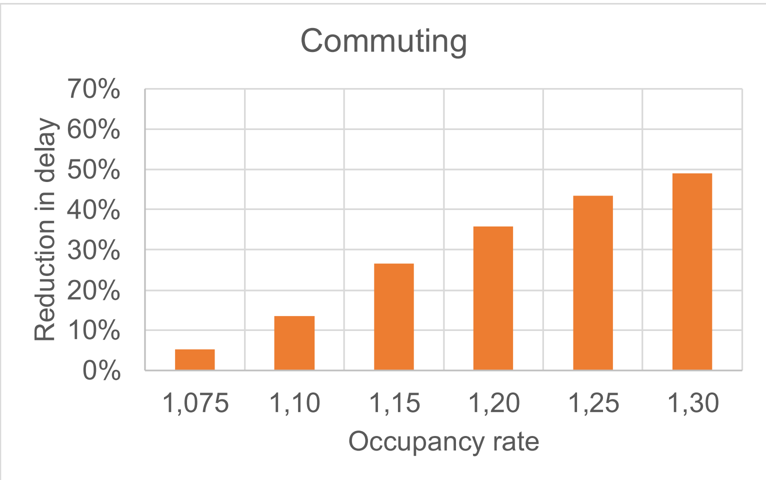

Figure 3: Reduction in delay for commuting

It is clear from the results, that increasing the occupancy will lead to less distance travelled and therefore to less delay and that small increases could have considerable impact. However, also these results should be considered with care. It was assumed that the reduction in car kilometres for the whole of the Netherlands is also valid for the main road network and that the total demand does not change. Normally, less congestion leads to more traffic (latent or induced demand) and this effect is not considered. Also, the differences between peak periods and off-peak periods and days of the week are not considered, including the variances that occur from week to week.

3. IMPACT OF HYBRID WORKING

The potential impact of hybrid working on the congestion was determined for several bottlenecks using a traffic model. Based on literature, it was formulated what hybrid working could mean for a reduction of vehicles on a certain location, looking at the location itself, work sectors (public, industrial, etc.) and travel distance. This was translated to a demand reduction for that location and with a traffic model it was determined what the impact on congestion and travel time could be.

From the literature it was found that hybrid working could lead to a reduction of distance travelled by car for the whole day varying between 1.1% and 3.6% (Hamersma *et al.*, 2021). A modal shift between car, public transport and other modes could not be confirmed. A decrease in distance travelled is distributed differently over the day. The effect is stronger in the morning peak (7.0% - 10.0%) than in the evening peak (3.5% – 6.0%) and bigger on Wednesday and Friday (Hamersma *et al.*, 2021). For different work sectors different hybrid working possibilities exist. For ICT related work the possibility to work at home can vary between 25% en 80%. For agriculture related work this is much lower, between 0.5% and 1.5%.

Based on these figures the demand reduction for eight bottlenecks was determined. The bottlenecks are shown in figure 4. For every bottleneck aspects such as the peak period, the type of bottleneck, the distribution between sectors and the location of offices was taken into account. The demand reduction is only applied for commuting car traffic, other trip purposes are not changed, except business traffic, which was decreased by 1%.

Bottleneck	Period	Type	Offices nearby	Demand reduction
A12 Galecopperbrug East	Evening peak	Road works	Yes	4.1%
A12 German border – Arnhem	Morning peak	Structural	Yes	7.8%
A20 Gouda - Rotterdam	Evening peak	Structural	Yes	4.1%
A27 Houten - Hooipolder	Evening peak	Road works	No	6.0%
A1 Barneveld - Hoevelaken	Morning peak	Structural	No	9.3%
A58 Tilburg - Eindhoven	Morning peak	Structural	Yes	9.3%
A2 Den Bosch – Empel/Deil	Morning peak	Structural	No	9.3%
A10 Zuidasdok West	Morning peak	Road works	Yes	8.5%

Figure 4: Bottlenecks studied

Two scenarios were simulated for every bottleneck: the estimated reduction and a reduction which is three times higher (based on a low and high estimate per sec of the number of people who could work at home), just to see how that impacts congestion and travel times. The simulations were done with the dynamic macroscopic model Streamline (Mein *et al.*, 2010). The input was derived from Dutch national strategic models, for which the OD matrix was made dynamic using traffic counts for the specific locations. Using the network and OD matrix as input, the normal situation was calibrated using information on the location, length and duration of the congestion.

In this paper the results for one bottleneck are shown: the A20 between Gouda and Rotterdam, which is a structural bottleneck for the evening peak. For this location the distribution of trip purposes is 32% commuting and 11% business, and more than average trips are related to transport and logistics. This leads to a reduction of 4.1% in commuting and 1% in business traffic. Overall, the decrease in demand is 1.5% for scenario 1 and 4.4% for scenario 2.

If this bottleneck is simulated with the normal demand profile and the demands for scenario 1 and 2, the results in travel time are shown in figure 5. The overall delay is decreasing with 20% in scenario 1 and 56% in scenario 2. The simulations were done for all eight bottlenecks (Stemerding and Birnie, 2022) and the reduction in delay varied between 20% (A20 Gouda – Rotterdam) and 72% (A58 Tilburg – Eindhoven).

The results of the simulation for scenarios 1 and 2 were checked with an estimation using the Akçelik function of figure 2 and the results are given in figure 6. Overall, the results show a remarkable resemblance, although it has to be considered that the simulated results are for specific bottlenecks, while the estimated results are for the Netherlands as a whole.

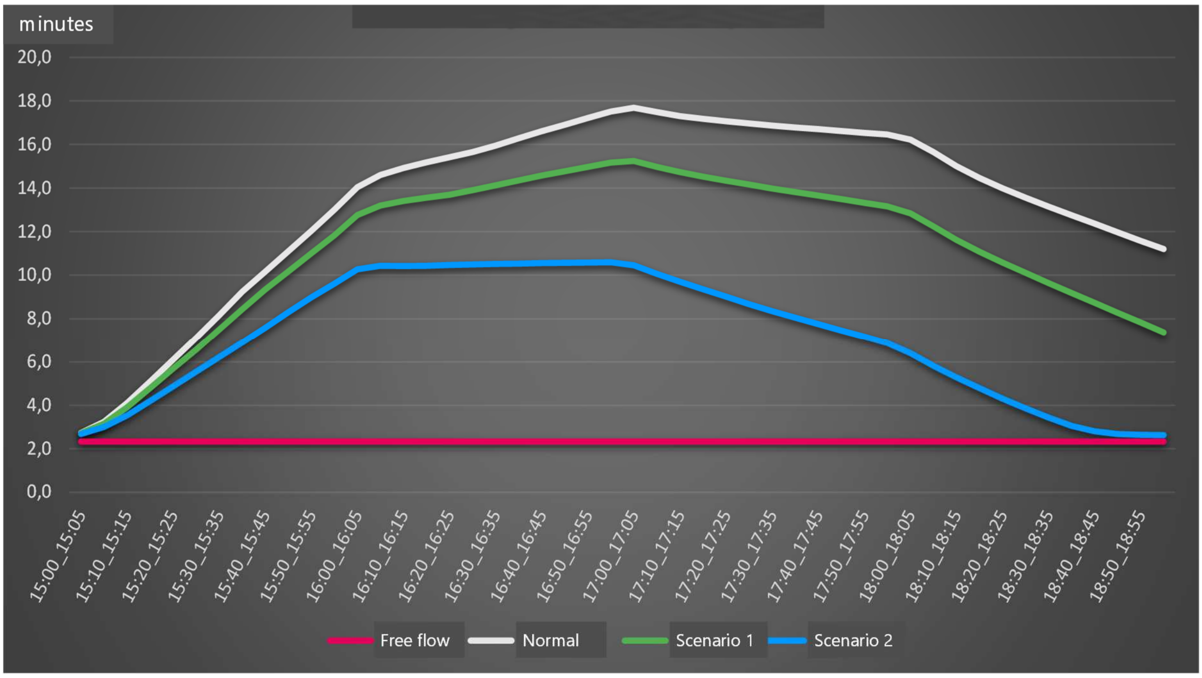

Figure 5: Simulated travel times A20 Gouda - Rotterdam

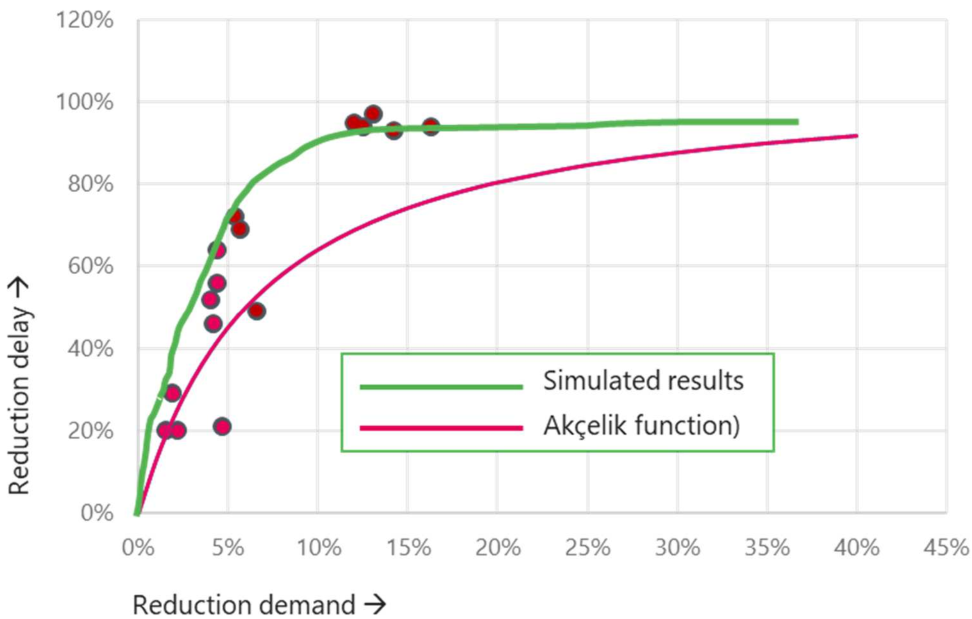

Figure 6: Simulated results and estimation with other method.

4. CONCLUSIONS

Both analyses showed that measures to reduce traffic demand are effective on both reducing congestion as on reducing CO_2 emissions. Of course, the results shown are highly dependent on the assumptions made, but a small reduction in demand could lead to considerable positive impacts. And whether this reduction in demand and kilometres travelled is due to increasing the occupancy rate of vehicles or due more hybrid working is not relevant.

However, it will not be easy to convince people to carpool more often or to work at home. Ride sharing is not popular in the Netherlands and policy must put effort in stimulating this form of demand reduction. And although teleworking has become more normal due to COIVD-19, there is a trend the people to their working places, especially on specific days (Tuesday and Thursdays). Measures to get a better distribution over the weekdays should have a positive impact.

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