FREEWAY WORK ZONE CAPACITY
Empirical Research on Work Zone Capacity in the Netherlands

Thijs Homan

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Graduation committee:
E.C. van Berkum
T. Thomas
S.J. Stegeman (ARCADIS)
M.E.J. Loot (ARCADIS)

Organisation:
ARCADIS

People in the Netherlands are constantly on the move and this will grow in the following years. Between 2005 and 2020, the transport of people will increase by 20% and the increase of the transport of goods will be even higher, between 40% and 80% according to the Nota Mobiliteit (Ministerie van Verkeer & Waterstaat, 2006). To cope with this growth in mobility, the infrastructure in the Netherlands is being improved constantly.

The necessary adjustments on the existing road network have an impact on the traffic flow and cause hindrance for road users, because the capacity of that road section is reduced during the road works. Freeway work zones have a significant impact on the congestion and traffic queue delays on freeways, thus knowledge about freeway work zone capacity is essential for traffic planners.

There is a lack of empirical research on the effect of freeway work zones on the capacity of a freeway in the Netherlands. This research paper tries to fill this gap by researching the capacity of freeway work zones and the conditions that affect this capacity in real situations in the Netherlands. The goal of this research is as follows:

> The main goal of this research is to develop more knowledge about the capacity at freeway work zones in the Netherlands by gaining insight in the capacity of different freeway work zone lay-outs and how differences in capacity between work zones can be explained.

This main research goal can be split in different research objectives:

1A Empirical estimation of the capacity of different freeway work zones lay-outs.
1B Estimation of the difference in capacity for different freeway work zone lay-outs compared to the standard situation.
2 Explaining differences in capacity by analyzing situation-specific variables.
3 Analysis of the effect of external variables on freeway work zone capacity.

The work zone lay-outs that are the most frequently present in the Netherlands in recent years and thus are analyzed in this research are:

- closure of the hard shoulder;
- lane narrowing on a two lane freeway;
- lane narrowing on a three lane freeway;
- 3 – 1 lane shift system;
- 4 – 0 lane shift system;
- 4 – 2 lane shift system.

For every work zone lay-out two or three locations are analyzed, which are located across the Netherlands.

The capacity of every work zone is estimated using the Empirical Distribution Method, which is the standard method for estimating capacity at bottlenecks since this method estimates the capacity flow. The estimated capacities are shown in the table beneath. The results show that work zone capacity differs a lot.The decrease in capacity caused by work zones differs from 11% to 43% compared to the standard capacity of a freeway. The biggest decrease can be found by work zones with the 3 – 1 and the 4 – 2 lane shift system, which are, in respective order,-31.7% and -35.1%, and -35.2% and -43.2%. The relative decrease in capacity of the 3- 1 and the 4 – 2 lane shift system is significantly bigger than the other work zones and the only thing that both work zones differentiate from the others is that the lanes of these two work zone lay-outs are split. Thus, from this can be concluded that the capacity of work zones with split lanes is lower than the capacity of work zones where the lanes are not split.

Location	Work zone lay-out	Capacity	Relative difference with CIA work zone	Relative difference with CIA standard
A9 Uitgeest – Alkmaar	Lane narrow.2 lane	3744	+17,0%	-10,9%
A12 Zoetermeer – Zevenhuizen	4 – 0 shifted	3660	+7,7%	-12,9%
A58 Batadorp – Oirschot	Clos. hard shoulder	3636	+1,0%	-13,4%
A2 Lage Weide – Utrecht Centrum	Lane narrow.3 lane	5292	+17,6%	-16,0%
A2 Zaltbommel – Kerkdriel	4 – 0 shifted	3516	+3,4%	-16,3%
A12 Zevenhuizen – Zoetermeer	4 – 0 non-shifted	3366	-1,0%	-19,9%
A28 Hattemerbroek – Zwolle Zuid	4 – 2 non-shifted	4896	+8,8%	-22,3%
A15 Klaverpolder – ‘s Gravendeel	4 – 2 non-shifted	4704	+4,5%	-25,3%
A50 Heteren – Renkum	3 – 1 non-shifted	3105	-8,7%	-26,1%
A2 Roosteren – Echt	Clos. hard shoulder	3048	-15,3%	-27,4%
A7 Zaandijk – Zaandam	Clos. hard shoulder	3030	-15,8%	-27,9%
A12 Zevenhuizen – Gouwe	Lane narrow.2 lane	3018	-5,7%	-28,1%
A12 Zoetermeer Centrum – Nootdorp	Lane narrow.3 lane	4518	+0,4%	-28,3%
A2 Kerkdriel – Empel	3 – 1 shifted	2868	-4,4%	-31,7%
A50 Renkum – Heteren	3 – 1 shifted	2724	-9,2%	-35,1%
A28 Zwolle Zuid – Hattemerbroek	4 – 2 shifted	4080	-5,1%	-35,2%
A16 ‘s Gravendeel – Klaverpolder	4 – 2 shifted	3576	-16,8%	-43,2%

Capacity does not only differ between different work zone lay-outs but also between researched work zone locations with the same lay-out. When comparing the guidelines for capacity of work zones from the “Capaciteit Infrastructuur Autosnelwegen” (CIA) handbook (Ministerie van Infrastructuur en Milieu, 2011)and the estimated capacities for the work zones part of this research, this dispersion is very clear shown. Only four of the seventeen estimated capacities are not significantly different from the guideline from the CIA handbook. The others are significant different from the CIA handbook guideline and these differences range between -17% and +18%.Thus can be concluded that there is great variation possible in work zone capacity.

From a sensitivity analysis on estimated capacities can be concluded that the dispersion of the estimated capacities is caused by the work zones them self. The dispersion is not attributable to the used method for capacity estimation when looking at the expected influence of traffic related aspects of a work zone. The sensitivity analysis found that or work zones with a high number of capacity measurements the Empirical Distribution Method is a better method than the Product Limit Method and for work zones with a low number of capacity measurements both methods are equal, when respecting the traffic related aspects of the work zones.

The differences found in the capacity estimation are input for the analysis of the situation-specific variables that have influence on freeway work zone capacity. For this analysis seven situation-specific variables are distinguished from previous literature. With these situation specific variables a multiple linear regression analysis is carried out for work zones in general and per work zone system.

This analysis resulted in four situation specific variables that have significant influence on work zone capacity. These four variables are: the percentage of heavy vehicles, the presence of a nearby ramp upstream, the presence of a nearby ramp downstream and the length of a work zone. The percentage of heavy vehicles has a negative influence on work zone capacity when increasing. Also the presence of nearby ramps upstream and downstream have a negative effect on capacity and an increasing work zone length has a positive effect on work zone capacity.

Another finding of the analysis of the differences between estimated capacities is that there are no peculiarities when looking at the differences in capacity for one work zone system only. From this analysis the conclusion can be drawn that in most cases the measurements belonging to a specific work zone system are not significantly different from the model for work zones in general. For two work zone types the percentage of heavy vehicles and the presence of a nearby ramp downstream had a significant influence on the differences in capacity. The degree of influence of these variables changed per system, but the coefficient of determination and the number of measurements was quite low for both work zone types, thus drawing a conclusion on the degree of influence per system is not feasible. The absence of the other variables can most of the times be addressed to insignificance caused by the low number of cases per work zone system. Hence the conclusion is drawn that for none of the work zone systems there are other variables with significant influence on capacity than the four that have significant influence on work in general.

A goodness of fit analysis showed that the four variables with significant influence are all important for explaining differences in estimated capacities and together these variables explain the most of the variance. Other combinations of these variables explained at least 4% less of the variance. The coefficient of determination of these four variables together is 0.375, which means that these four variables explain 37.5% of the variance in the difference between the CIA guidelines and the estimated capacities. There can be concluded that these four variables explain a considerable part of the variance in capacity, but the majority of the variance is explained by other influences than the distinguished situation-specific variables of this research. Because of the uncertainty caused by the low coefficient of determination, determining the degree of effect of the variables is not plausible in this research.

For two external variables, which were fixed in the first parts of the research, the effect on work zone capacity is also estimated. These two variables are rain and duration of work zones.

The finding of the research on the effect of rain is that rain causes a drop in capacity between 4% and 9% in the work zones studied in this research. The literature review shows that the effect of rain on capacity in normal situations is between -5% and -10%. The conclusion of this research is that the effect of rain on the capacity of work zones is the same as the effect of rain on capacity in normal situations, there is no reason to assume otherwise.

The findings of the research on the effects of duration of a work zone on the capacity of that work zone are not clear. After more than one month almost all cases show no significant difference in capacity and after more than two months half of the cases show an increase in capacity and the other half of the cases show no significant difference. Thus a clear conclusion on the effect of duration of a work zone on the capacity of that work zone is not found in this research.