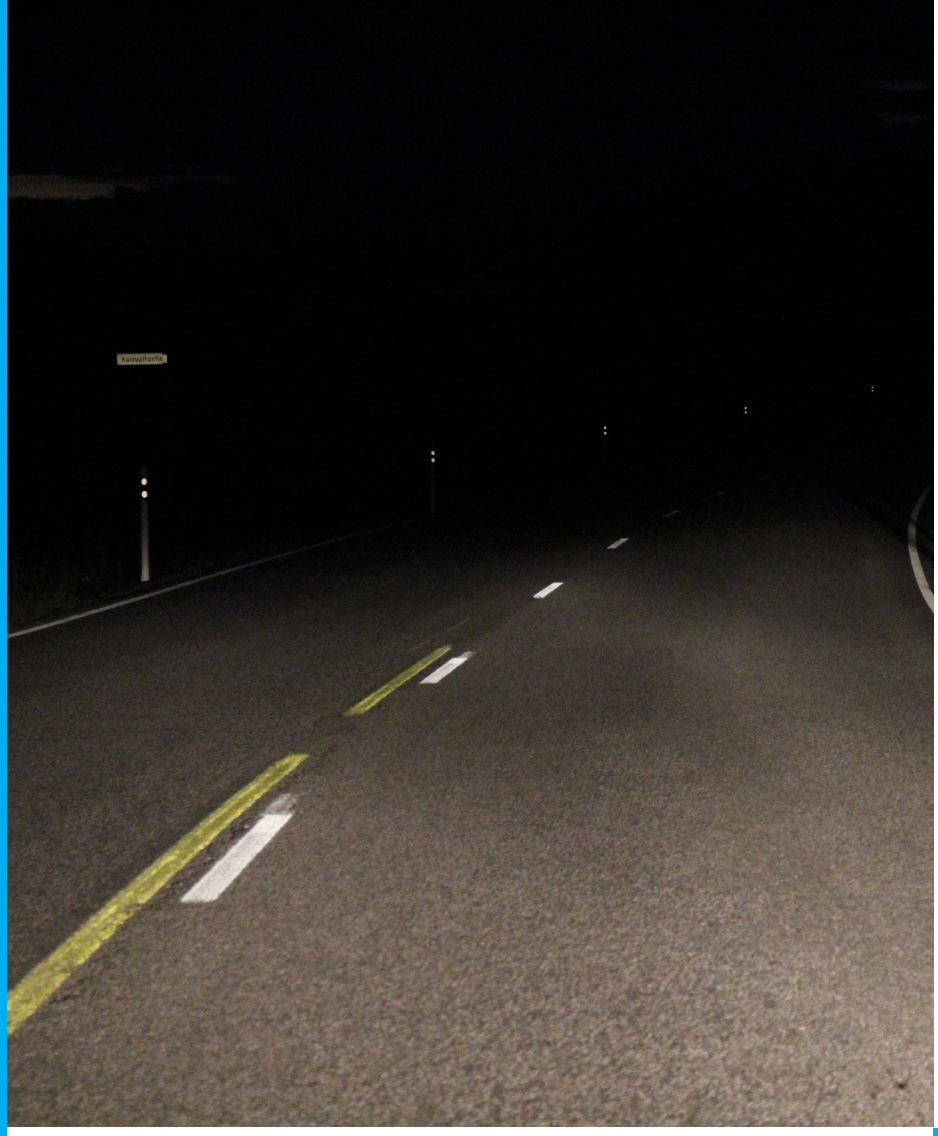

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Effects of delineator post density on vehicle speed, lateral position and driver acceptance

Riikka Rajamäki | Juha Luoma | Pirkko Rämä

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Effects of delineator post density on vehicle speed, lateral position and driver acceptance

Reunapaalujen vaikutus autojen nopeuteen, sivuasemaan ja kuljettajien mielipiteisiin.
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Abstract

This study was designed to validate simulator-study results concerning driving speeds with three different delineator post configurations based on post frequency. The distance between delineator posts was 25–50 m on curves and 50–100 m on straight road segments; in one configuration there were no delineator posts on the straight segments.

The test configurations were each installed on a specific road segment for about 2 weeks. During this time speed and lateral position of passing vehicles were measured at several sites along the road. Acceptance of these three delineator post configurations was examined in the lab by asking volunteers to compare nighttime pictures.

Nighttime spot speed with delineator posts was on average 0.5 km/h lower than before delineator post installation. Nighttime speed differences between delineator post configurations were small. One of the three configurations produced approximately 1 km/h higher average speed than the other two, regardless of the road curve radius at the measurement point. The results differed significantly from those obtained with the simulator: in the latter, delineator posts significantly increased the speed, and the speed differences between delineator post configurations were also substantial.

We found no statistically significant and consistent relationship between delineator post density and lateral positioning of vehicles. In the acceptance study, the volunteers expressed a preference for high delineator post density.

Keywords Road, visual conditions, speed

Reunapaalujen vaikutus autojen nopeuteen, sivuasemaan ja kuljettajien mielipiteisiin

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Tiivistelmä

Tällä tutkimuksella pyrittiin validoimaan ajosimulaattorissa saanut tulokset, jotka koskivat tienvarren heijastimella varustettujen reunapaalujen sijoittelun vaikutusta ajonopeuteen. Tutkitut kolme reunapaalujen sijoittelua erosivat toisistaan siinä, kuinka pitkä matka oli reunapaalujen välissä. Kaarteissa välimatka oli 25–50 metriä ja suorilla tieosuuksilla 50–100 metriä. Yhdessä sijoittelussa reunapaaluja ei ollut lainkaan suorilla tieosuuksilla.

Näitä kolmea reunapaalujen sijoittelua kokeiltiin vuorotellen samalla tieosuudella syksyllä 2012, kutakin kahden viikon ajan. Tänä aikana autojen nopeutta ja sijaintia kaistalla mitattiin useissa paikoissa. Lisäksi tutkittiin eri sijoittelujen hyväksyntää siten, että vapaaehtoiset koehenkilöt vertailivat näitä sijoittelutapoja valokuvien perusteella.

Yöajan pistemäisesti mitattu nopeus oli keskimäärin 0,5 km/h alempi reunapaalujen ollessa käytössä kuin ilman reunapaaluja. Erot yöajan ajonopeudessa olivat pieniä erilaisten reunapaalujen sijoittelujen välillä. Yhden sijoittelutavan ollessa käytössä ajonopeus oli noin 1 km/h korkeampi kuin muilla sijoittelutavoilla sekä mutkissa että suoralla tiellä. Kenttämittausten tulokset poikkesivat huomattavasti simulaattorissa saaduista tuloksista: simulaattorissa reunapaalujen käyttö kasvatti ajonopeutta merkittävästi, ja nopeuserot reunapaalujen sijoittelujen välillä olivat myös huomattavia.

Tässä tutkimuksessa reunapaalujen sijoittelulla ei havaittu tilastollisesti merkitsevää ja johdonmukaista yhteyttä auton sijaintiin ajokaistalla. Hyväksyttävyystutkimuksessa koehenkilöt pitivät eniten tiheimmistä reunapaalujen sijoitteluista.

Avainsanat Road, visual conditions, speed

Preface

This study was commissioned by the Nordic collaboration NMF (Nordic meeting for improved road equipment). It is the final phase of a larger project that began with a literature study and simulator studies conducted by the Swedish National Road and Transport Research Institute (VTI).

The study was carried out by VTT Technical Research Centre of Finland. The authors wish to thank Mikko Kallio for his assistance with collecting the field data, and Virpi Britschgi for her help with organizing the acceptance data. NMF participants provided helpful suggestions on an earlier draft of this paper. However, the authors are solely responsible for the final content and organization of this report.

Contents

1. Background and objectives

Delineator posts are designed to help drivers detect the direction of the road, especially in the dark and in otherwise poor visibility.

The regulations for delineator posts differ substantially between the Nordic countries in regard to both design and density. There are also differences in the criteria for delineator post placement, as summarized by Nygårdhs (2008). On straight roads, for example, the distance between posts varies between 50, 60 and 100 m depending on the regulation.

Kallberg (1993) showed that delineator posts along a winding road with an 80 km/h speed limit actually create a greater risk of accident in the dark because the driver increases speed. On roads with good geometry, however, delineator posts seem to improve safety. There is also older evidence indicating that delineator posts do not always promote safety (see Nygårdhs 2008).

In 2009, NMF commissioned a multi-stage research project with the main objective of delving into the delineator post issue. This would serve as a foundation for revising and perhaps harmonizing delineator post regulations in the Nordic countries. The project included a simulator study and a field study.

In 2011–2012, the Swedish National Road and Transport Research Institute (VTI) conducted simulator measurements with different delineator post configurations (Lundkvist et al. 2013). The last phase of the simulator study comprised six delineator placement configurations: three currently in use in the Nordic countries and three new ones. Overall, the results indicated that some of the new configurations could be promising. Speeds were lower for configurations with fewer delineators. However, drivers seemed to prefer dense configurations. The road had a 9 m wide pavement and included both very sharp (radius 250 m) and gentle (radius 1,000 m) curves. Fourteen test drivers took part in this final phase.

The present study was designed to validate simulator results for some delineator post configurations in a normal road environment with larger and more representative data. The main focus was on speed results because of the well-known association between mean speed and road safety. The speed results were complemented with findings on lateral position and acceptance of the compared options.

2. Method

In the field study, three different delineator post configurations were installed alternately at about 2-week intervals on the same segment of road. Vehicle speed and lateral position were measured in several places along the road. Comparison data for speed were obtained from another road with no delineator posts. If delineator posts have effects on driving speed, changes in speed should be greater on the experimental road than on the comparison road.

We assumed that delineator posts would have the strongest effect on nighttime traffic, when there is less other visual guidance, and that changes in speed on the experimental road would be greater at night than during the day.

Since the effects of delineator posts may vary with the road curvature, we measured spot speed, speed over distance and vehicle lateral position in several locations.

Acceptance of these three delineator post configurations was examined in the lab by asking volunteers to compare nighttime pictures.

2.1 Delineator post configurations

The three delineator post configurations chosen for the field study are shown in Table 1. They are the current Norwegian-Swedish configuration and two configurations with fewer delineator posts. Compared to the Norwegian-Swedish configuration, in the two new configurations post density depended on curve radius and included 100 m road segments before and after the curves with the same delineator post density throughout. The difference between the new configurations is that in the latter alternative there were no delineators on straight sections. A segment with no delineator posts was used as the baseline.

Table 1. Compared delineator post configurations in the field study. Configuration numbers are those used in VTI simulator studies. In configurations 9 and 12, the curve configurations covered 100 m of the straight road segment before and after the curves.

Configuration identification		Road section type	Delineator post spacing
VTI simulator study	This study		
Configuration G	None	Straight road and curves	No delineators
Configuration A	Traditional	Straight road	50 m
		Curves	25 m
Configuration E	Advanced	Straight road	100 m
		Curves with radius >600 m	50 m
		Curves with radius 600 m or less	25 m
Configuration F	Low	Straight road	No delineators
		Curves with radius >600 m	50 m
		Curves with radius 600 m or less	25 m

The delineator posts used in this study were Standard Finnish Posts (Figure 1). The specifics are described by Nygårdhs (2008).

Figure 1. Delineator posts on the test site in early November. The spot speed measurement device is faintly visible on the right of the picture.

2.2 Experimental road segment, field study

A 5.1 km-long segment of regional road 167 was chosen for this experiment. It is located in southern Finland approximately 100 km northeast of Helsinki (see Appendix A). The speed limit is 80 km/h and the annual average daily traffic (AADT) is 1,700. The pavement width varies from 7.0 to 7.4 m. There were no delineator posts before this field study.

This road segment was considered sufficiently comparable to the road section used in the simulator study. Specifically, our road section included curves with radii of approximately 300 m and 1,100 m (more detailed map in Appendix B), and the simulator study included curves with radii of 250 and 1000 m. The curve with a radius of 1,100 m was relatively short; therefore spot speeds were also measured on a curve with a radius of 600 m.

2.3 Procedure of the field study

Data collection was planned for September and October, when the nights are dark and before the onset of snowy and icy weather and interference from plough marker reflectors. However, collection was delayed and ended in early November. Table 2 shows the final schedule for delineator post configurations on the experimental road segment.

Table 2. Schedule for different configurations.

Time	Configuration
4–14.9.2013	**None (before)**: No delineator posts.
17–30.9.2013	**Traditional (vers1)**: Traditional configuration, but wrong delineator post density on 1,100 m radius curve at northern end of test site; density 50 m instead of correct 25 m.
2–14.10.2013	**Advanced** configuration
16–28.10.2013	**Low** configuration
31.10–4.11.2013	**Traditional (vers2)**: Traditional configuration on northern half of test site. No delineator posts on southern half of test site.
6–9.11.2013	**None (after)**: No delineator posts.

The period from 9:00 pm to 07:00 am was classified as nighttime; at the start of data collection sunset was at 20:12 pm and sunrise at 6:18 am. The period from 09:00 am to 04.00 pm was classified as daytime; sunrise was at 08:05 am and sunset at 3:56 pm when the data collection ended.

2.4 Speed measurements

2.4.1 Spot speed

Spot speeds were measured continuously at four points. However, because of technical problems the spot speed data from 31st October to 4th November were not collected.

Spot speeds were measured with four microwave detectors that record speed, length and bypass time of vehicles in both directions. The detectors were located as follows (see Appendix B):

- On a straight segment 130 m after the preceding curve in the south, and 315 m before the following curve northwards
- On the curve with radius 300 m
- On the curve with radius 600 m
- On the curve with radius 1,100 m.

Measurements on curves were conducted approximately in the middle of the curve. One detector was attached to a traffic sign and the others to a wooden post erected at the roadside (Figure 2). All observations of speeds from 20 to 120 km/h were included in the data.

Figure 2. Spot speed measurement device attached to a wooden post.

2.4.2 Speed over distance with plate number recognition

Speed over distance (i.e. average speed between two points on the roadway) was measured at the 1,100 m radius and 300 m radius outer curves (curves 1 and 2 respectively in Appendix B) with plate number recognition. The distance between cameras was 173 m and 268 m respectively. Cameras were placed at both ends of the curves on wooden posts (Figure 3). Speed over distance was measured for 2 nights and 1 day for each delineator post configuration. For traditional (vers1), advanced and low configurations the data were collected at least 1 week after the delineator post configuration was changed. For the traditional (vers2) configuration and situation post-delineator removal in November, measurement of speed over distance started sooner, roughly 1 day after the configuration change, due to time pressure to complete the data collection.

The cameras were barely detectable at night and differed in appearance from those used in Finnish automatic speed enforcement. Thus it is unlikely that drivers would have lowered their speed because of the devices, although some might have detected them in daylight.

Figure 3. Plate number recognition camera.

2.4.3 Speed over distance by combining spot speed observations

Speed over distance was also measured by combining spot speed observations. It was computed for both driving directions on the road segment between spot

speed sites on the 1,100 m radius curve and on the straight road section (see Appendix B). The centreline length of this road segment is 606 m.

The combination of spot speed observations was conducted as follows: For each vehicle approaching the first site on a given road segment, the time was calculated within which the vehicle should be detected at the second point if it was travelling at 20–120 km/h. If there was only one possible vehicle at the second point, and its length was within ±0.5 m of the vehicle length at the first site, these two observations resulted in a successful case. However, if there were several possible vehicles at the second point, the procedure was more challenging. In this case it was checked whether the same number of unpaired observations occurred at both sites between clear speed-over-distance observations (i.e. cases with only one possible vehicle at the second point), and whether the vehicle lengths matched. At most four consecutive observation pairs with matching vehicle lengths were accepted as sufficiently assured findings.

With this procedure, approximately 40% of spot speed observations were combined as speed over distance observations. This proportion does not include spot speed observations in one time period that was omitted from the final data because the measurement timers seemed to be insufficiently synchronized.

2.4.4 Control data and calculation methods

Data for controlling for seasonal speed trends was obtained from one of the Finnish Transport Agency's permanent automatic measurement points (#158). This site is located approximately 30 km southeast of the test site (see Appendix A) on a tangent of regional road similar to the test road and without delineator posts.

Spot speed changes after delineator post installation were compared to comparison road speed changes with the following formula:

$$\Delta\mu = \left(\mu_{E,a} - \mu_{E,b}\right) - \left(\mu_{C,a} - \mu_{C,b}\right) \quad (1)$$

where μ is the average speed, E is the experimental road, C is the comparison road, and b is the time period before delineator post installation, and a is the time period with some delineator post configuration on the experimental road.

Automatic measurement point #158 is located on a straight road section and is therefore best comparable to spot speed measurements on the experimental road's straight segment. The distance between comparison point and experimental road may also cause small differences in weather conditions. Therefore a supplementing calculation method was used. Delineator posts can be assumed to have a greater effect at night when drivers have fewer other means of guidance than they do in daylight. Therefore nighttime speed changes after delineator post installation were calculated by subtracting the daytime speed change from the nighttime change as follows:

$$\Delta\mu = \left(\mu_{N,a} - \mu_{N,b}\right) - \left(\mu_{D,a} - \mu_{D,b}\right) \quad (2)$$

where μ is the average speed, N is nighttime, D is daytime, and b and a are as in Formula 1.

Average speeds by configuration and by weather condition were compared to examine whether the effects of delineator posts on speed varied by curve radius or by weather condition. Confidence intervals for speed and vehicle position were calculated using a normal distribution assumption.

2.5 Lateral position measurements

The lateral position of vehicles was measured from pictures taken by plate number recognition cameras simultaneously with speed-over-distance measurement on the curves. Thus lateral position data were collected at both ends of both outer curves. The position of the licence number recorded by the camera was converted by a computer program to lateral positioning using small reference markings painted on the road centreline and shoulder line.

Some vehicles may have an unusual location of the licence plate, but the proportion of these vehicles is considered low.

2.6 Weather data

Weather and road condition data were obtained from the Finnish Transport Agency's road weather station (#1059), located approximately 15 km south of the test site (see Appendix A). This station provided no data for the period from 10th October at noon to 16th October at 1:30 pm. Therefore data from another weather station (#1021), 30 km southwest of the test site, were used for this period.

For this study, information provided by weather stations was merged into one single variable in the following order:

- Snow or sleet → snowing
- Rain → raining
- Visibility less than 1000 m → fog
- Hoarfrost on road → frost
- Wet or damp road → dry weather, wet road
- Dry road → dry weather, dry road.

Overall, October and the beginning of November were exceptionally rainy. During the period from 31st October to 4th November with configuration Traditional (vers2) there was only one single hour of dry road surface, and even some snowing occurred. From 6th to 9th November, when the road section was without delineator posts, it was snowing wet snow a substantial proportion of the time (Figure 4). During this last measurement period, the road remained mainly wet; to some degree this was due to road salting. The temperature was frequently below zero and some snow remained on the ground around the road, changing the scenery (as in Figure 1). Therefore, drivers may have expected some slipperiness.

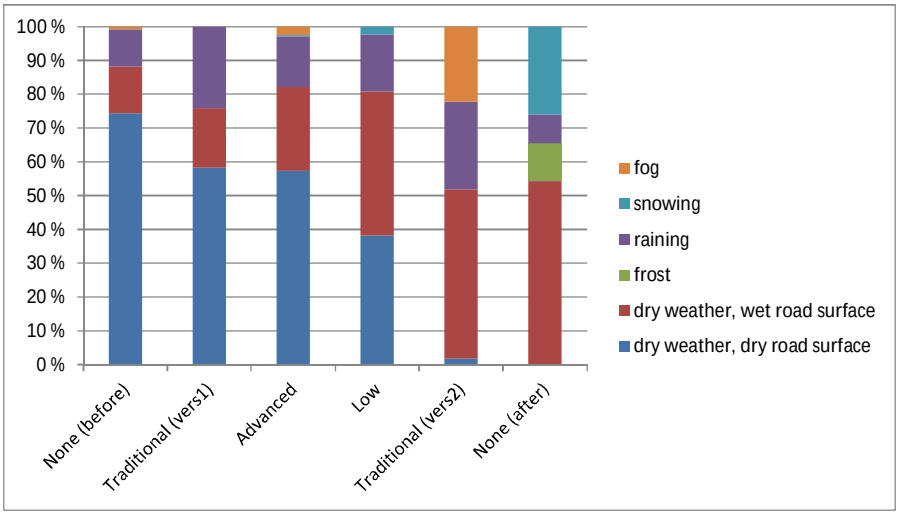


Figure 4. Weather and road conditions during field measurements.

2.7 Acceptance of configurations

Fifty volunteers (aged 24–64 years, mean 41 years) with a valid driving licence took part in the experiment. The 24 females and 26 males were recruited from among VTT employees and Aalto University students by an Internet announcement.

Two sessions were conducted in an auditorium, each of which was attended by 25 people. The volunteers were shown 19 pairs of pictures including a road view at night with various delineator post configurations or with no delineator posts. They were requested for each pair to select their preferred option. Each pair of pictures showed the same site from the perspective of a car driver at night with low beams on. The pictures were further edited so that the only visible difference between pairs was the delineator post configuration.

The following five sites were included in the tests:

1. Smooth (1,100 m radius) curve to the left, followed by a short straight segment and steep curve to the right
2. Straight road, followed by a distant sharp (300 m radius) curve to the right
3. Medium (600 m radius) curve to the right
4. Sharp (300 m radius) curve to the right
5. Straight road uphill, followed by a sharp curve to the left.

The pictures were projected on the screen so that the visual angle was approximately 18–40 degrees wide horizontally. The lateral order of picture pairs in the second session was opposite to that in the first. The pictures and their order in each session are shown in Appendix C.

3. Results

3.1 Effects of delineator posts on spot speeds

3.1.1 Spot speed data

There were 44,758 nighttime spot speed observations. The minimum amount of observations for a site by direction and delineator post configuration was 262 (Appendix D Table D1). The corresponding figures for daytime are 183,780 and 544.

The nighttime traffic volume on the experimental road section was relatively low, averaging 200 vehicles a night. During measurements after delineator post removal there was a somewhat higher traffic volume of 285 vehicles a night. Twelve per cent of the observed vehicles were more than 15 m long, suggesting that they were trucks with a semi- or full trailer. Seven per cent of vehicles were 7–15 m long, suggesting that they were trucks, buses or cars and vans with a trailer. This distribution remained roughly the same during the data collection.

The average traffic volume for the time period between 09.00–16.00 on this experimental road section was 850 vehicles, 5% of which were more than 15 m long.

3.1.2 Comparison road speed change removed

Table 3 shows the nighttime spot speed changes for different delineator post configurations calculated with Formula 1 (Chapter 2.3). This calculation removes the comparison road's speed change from that of the experimental road to account for seasonal trends in speed.

Nighttime spot speed with delineator posts was at minimum 2.6 km/h lower and at maximum 1.6 km/h higher with delineator posts than before their installation (Table 3). On average, the speed was 0.5 km/h lower with delineator posts than before their installation. The greatest difference between delineator post configurations was 2.2 km/h, observed between Advanced and Low on the inner edge of the 300 m radius curve. On average, the speed was 1.0 km/h higher with configuration Advanced than with configurations Traditional and Low.

Because comparison data were collected on a straight road, these data are best comparable with speed changes on a straight segment of the experimental road. Even here the nighttime speed was highest for configuration Advanced.

After delineator post removal, the speed was up to 5.6 km/h lower than before-situation speed, after subtracting the speed change on the comparison road. On the comparison road, the after-situation speed was 3.4 km/h lower than the before-situation speed.

Table 3. Nighttime average spot speed compared to speed before delineator post installation, speed change at comparison point subtracted (Formula 1).

Configuration	1,100m curve, outer	1,100m curve inner	Straight road south	Straight road north	300m curve, outer	300m curve, inner	600m curve, outer	600m curve. inner	Average for all measurement points
Traditional (vers1)	0.7	-1.1	1.4	-1.6	-2.0	0.5	-2.6	-2.4	-0.9
Advanced	0.6	0.4	1.6	-0.3	-0.9	1.2	-0.5	-0.4	0.2
Low	-0.5	-0.1	0.6	-0.9	-1.7	-1.0	-1.3	-1.1	-0.8
None (after)	-1.6	0.0	-2.6	-3.0	-4.4	-5.6	-1.7	-1.1	-2.5

The corresponding figures for daytime are listed in Table 4. Speed changes for delineator post configurations were between -1.5 km/h and +1.4 km/h compared to the situation before delineator post installation. The difference between delineator post configurations was at most 1.6 km/h, which was found on the inside of the 300 m radius curve between configurations Traditional and Low. On average, the speed was 1.0 km/h higher with configuration Traditional than with configuration Low, and configuration Advanced was in between.

Speed changes from the situation before delineator post installation to that after delineator post removal were greater than those between delineator post configurations, by up to 3.4 km/h, after subtracting the speed change on the comparison road. On the comparison road, the after-situation speed was 1 km/h lower than the before-situation speed. This suggests that there may be a remarkable difference in after-situation weather conditions between the experimental and comparison roads.

Table 4. Daytime average spot speed compared to speed before delineator post installation, speed change at comparison point subtracted (Equation in Chapter 2.3).

Configuration	1,100m curve, outer	1,100m curve inner	Straight road south	Straight road north	300m curve, outer	300m curve, inner	600m curve, outer	600m curve. inner	Average for all measurement points
Traditional (vers1)	0.5	1.4	1.0	0.7	-0.1	0.8	0.0	0.2	0.5
Advanced	-0.1	0.6	0.5	0.7	-0.4	0.5	-0.1	-0.3	0.2
Low	-0.6	0.2	0.2	-0.3	-1.5	-0.8	-0.6	-0.9	-0.5
None (after)	-0.4	-0.8	-0.8	-2.5	-3.4	-2.9	-1.1	-0.9	-1.6

3.1.3 Nighttime speed change, daytime change subtracted

At night, in most cases the spot speed was slightly lower with different delineator post configurations than prior to their installation, after subtracting the corresponding daytime speed change (Table 5). The effect varied from a decrease of 1.9 km/h to an increase of 1.2 km/h. The average over all sites was the same (0.5 km/h reduction) for all configurations. The largest difference between configurations was 1.4 km/h, occurring between configurations Traditional and Low on the inside of a 600 m radius curve.

After delineator post removal, the nighttime average speed dropped by 1.6–5.1 km/h more than the average daytime speed compared to the situation before installation.

Table 5. Nighttime average spot speed (km/h) compared to speed before delineator post installation, daytime speed change subtracted (Formula 2).

Configuration	1,100m curve, outer	1,100m curve, inner	Straight road south	Straight road north	300m curve, outer	300m curve, inner	600m curve, outer	600m curve, inner	Average for all measurement points
Traditional (vers1)	0.9	-1.7	1.2	-1.5	-1.1	0.5	-1.8	-1.9	-0.5
Advanced	0.2	-0.7	0.5	-1.6	-1.1	0.1	-1.0	-0.6	-0.5
Low	-0.3	-0.7	0.0	-0.9	-0.5	-0.5	-1.1	-0.5	-0.5
None (after)	-3.7	-1.6	-4.3	-3.0	-3.4	-5.1	-3.1	-2.6	-3.7

3.1.4 Confidence intervals and weather conditions at night

Overall, nighttime spot speeds for different delineator post configurations included only minor differences. The largest difference in average spot speed was 2.3 km/h on the 300 m radius curve between configurations Advanced and Low (Figure 5). There were no differences between nighttime spot speeds with different delineator post configurations on a dry road surface (Figure 6). In dry weather and wet road surface conditions the average speed was lower with configuration Low than with configuration Traditional in three out of eight cases; the maximum difference was 2.9 km/h.

At every site in both directions the spot speed was lower after delineator post removal than with any delineator post configuration or before delineator post installation (Figure 5). However, this may be due to weather conditions, as described in Chapter 2.6.

Nighttime spot speeds in dry weather and dry road surface conditions remained roughly the same or increased slightly with delineator post configurations compared with the before-situation without delineator posts (Figure 6). In dry weather and wet road surface conditions the average speed with delineator posts was 0–5 km/h lower than before (Figure 7).

When spot speeds for vehicles over 7 m long were considered separately, the only statistically significant difference (at each site) was that the speed during the after-situation was lower than at other times.

Tables of spot speed averages, standard deviations and 95% confidence intervals are given in Appendix D, together with corresponding daytime figures.

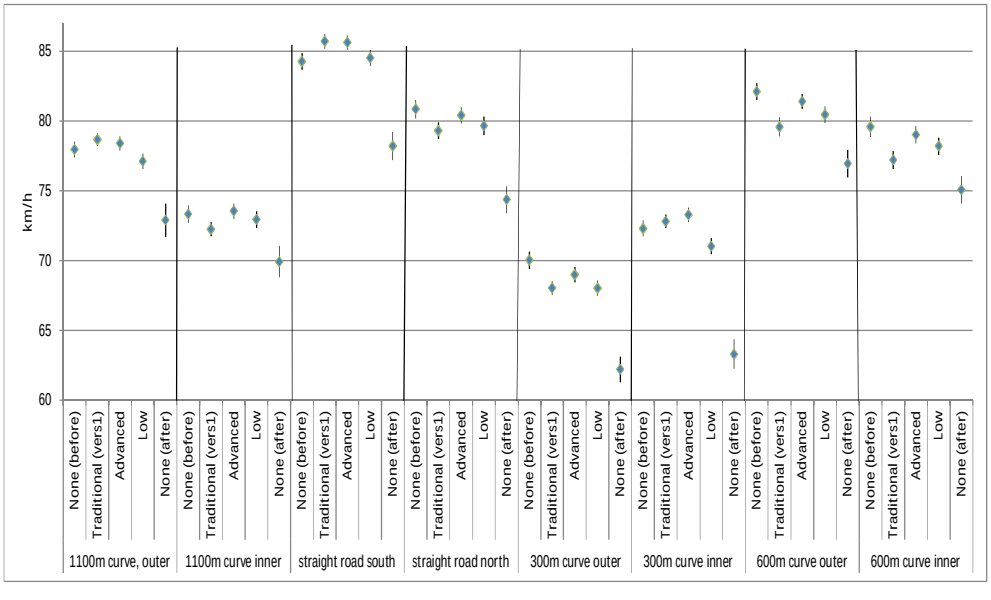


Figure 5. Average spot speeds and 95% confidence intervals by configuration at night.

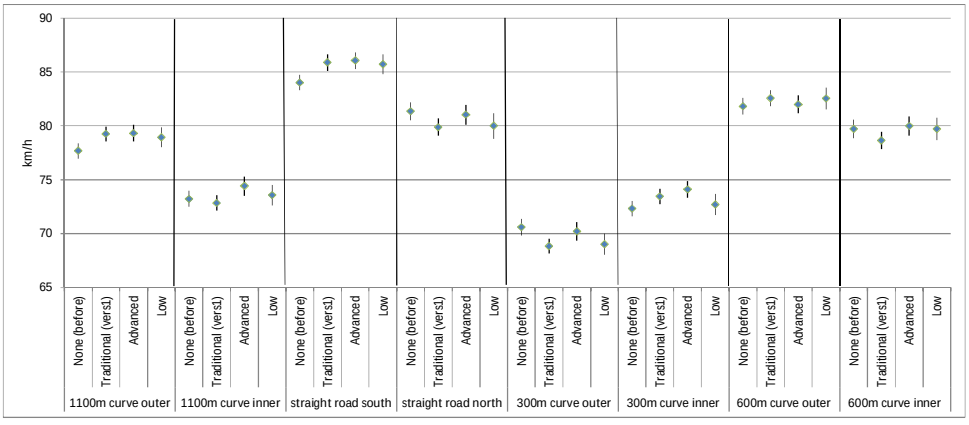


Figure 6. Average spot speeds and 95% confidence intervals by configuration at night in dry weather and dry road surface conditions.

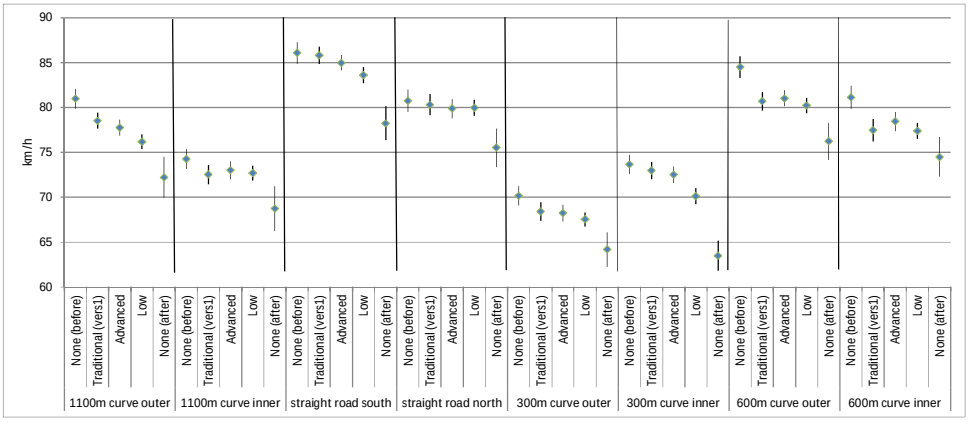


Figure 7. Average spot speeds and 95% confidence intervals by configuration at night on in dry weather and wet road surface conditions.

3.2 Effects of delineator posts on speed over distance

3.2.1 Speed over distance data

The speed over distance data collected with plate number recognition comprises 14,302 observations: 7,288 at the outer edge of the 1,100 m radius curve and 7,014 at the outer edge of the 300 m radius curve. Of these, 1,123 observations occurred at a time defined as nighttime in this study.

When looking at observations for the same time periods, approximately 31% of vehicles detected by the spot speed measurement device were also detected by

both number plate recognition cameras, and were thus included in the speed-over-distance data. For nighttime the percentage was 26.

Based on licence plate numbers there are 6,925 separate vehicles in the data. Seventy per cent of speed-over-distance observations were vehicles that were observed at least twice, and 20% were vehicles that were observed at least eight times – indicating that a remarkable share of vehicles travel this road segment often.

The speed-over-distance data obtained by combining spot speed observations comprised 13,701 observations. Of these, 8,439 were to the south and 5,262 to the north; 3,589 were nighttime observations.

Average spot speeds calculated using only the spot observations that form this speed-over-distance data were somewhat higher than the whole spot speed data (Chapter 3.1). This is due to the way the data was formed. Vehicles outside queues were easier to identify reliably at two sequential sites and also had higher speed on average.

3.2.2 Nighttime speed-over-distance change, daytime change subtracted

At night, speed over distance on outer curves, measured with plate number recognition, was 1.3–3.9 km/h higher with different delineator post configurations than prior to installation, when the corresponding daytime speed change is subtracted (Table 6). This speed increase was greatest for configuration Advanced, on average 1.6 km/h higher than for configuration Traditional and 0.9 km/h higher than for configuration Low.

Table 6. Nighttime average spot speed (km/h) compared to speed before delineator post installation, daytime speed change subtracted (Formula 2).

Configuration	1,100m curve, outer	300m curve, outer	Average for both curves
Traditional (vers1)	1.3	2.6	1.9
Traditional (vers2)	1.2	2.3	1.7
Advanced	3.9	3.0	3.4
Low	1.7	3.3	2.5
None (after)	3.5	4.5	4.0

Speed over distance on a 606 m road segment between spot speed measurement points was from 1.7 km/h lower to 1.0 km/h higher with different delineator post configurations than before (Table 7). The biggest difference between configurations was 2.5 km/h and was detected between Traditional and Low to the south. Average speed over distance was 0.8 km/h higher for Advanced than for Low, and 0.6 km/h higher than for Traditional.

Table 7. Nighttime average speed over distance (km/h) on a 606 m road segment, compared to speed before delineator post installation, daytime speed change subtracted (Formula 2).

Configuration	South	North	Average for both directions
Traditional (vers1)	0.8	-1.2	-0.2
Advanced	0.5	0.3	0.4
Low	-1.7	1.0	-0.4
None (after)	-2.4	0.5	-0.9

3.2.3 Confidence intervals and weather conditions in nighttime

When nighttime speed over distance was measured in outer curves with register plate recognition, it was significantly higher with delineator posts than without them (Figure 8). When speed over distance was calculated for a 606 m road segment by combining spot speed observations, it was the same or lower than before delineator post installation in one driving direction, and slightly higher than before in the other direction (Figure 9).

Differences between delineator post configurations were small. Speed over distance was higher with configuration Advanced than configuration Traditional on the 1,100 m radius curve (Figure 8). However, this difference is not statistically significant when dry and wet road surfaces are considered separately. On the 300 m radius curve there were no differences in speed between delineator post configurations. On the 606 m road segment, speed over distance was lower to the south with configuration Low than with Traditional and Advanced (Figure 9). This is true even when limited to dry weather observations. There were no differences between delineator post configurations to the north.

Speed-over-distance averages, standard deviations and 95% confidence intervals are tabulated in Appendixes E and F, together with corresponding daytime and weather condition figures.

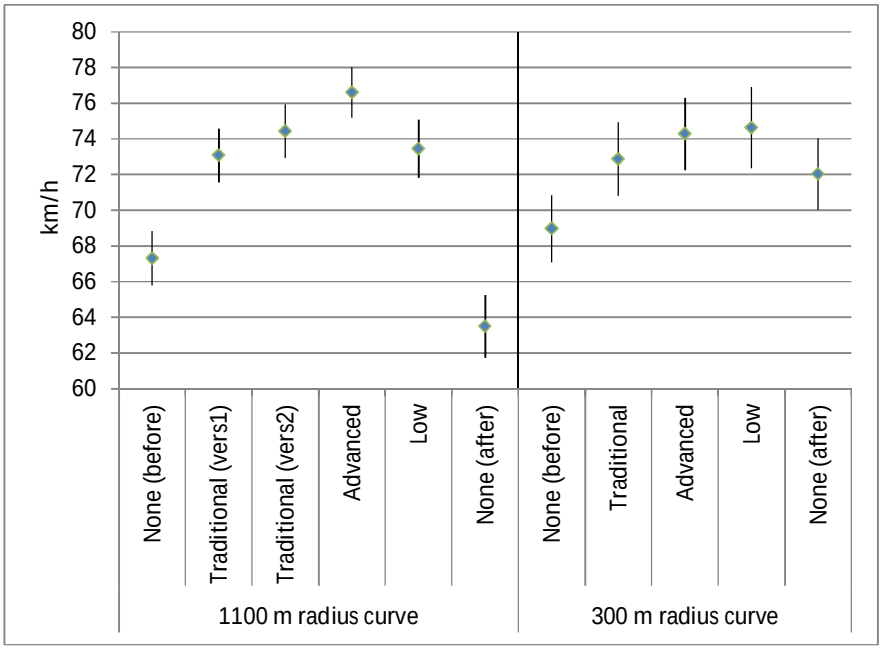


Figure 8. Speed over distance by configuration on outer curves at night.

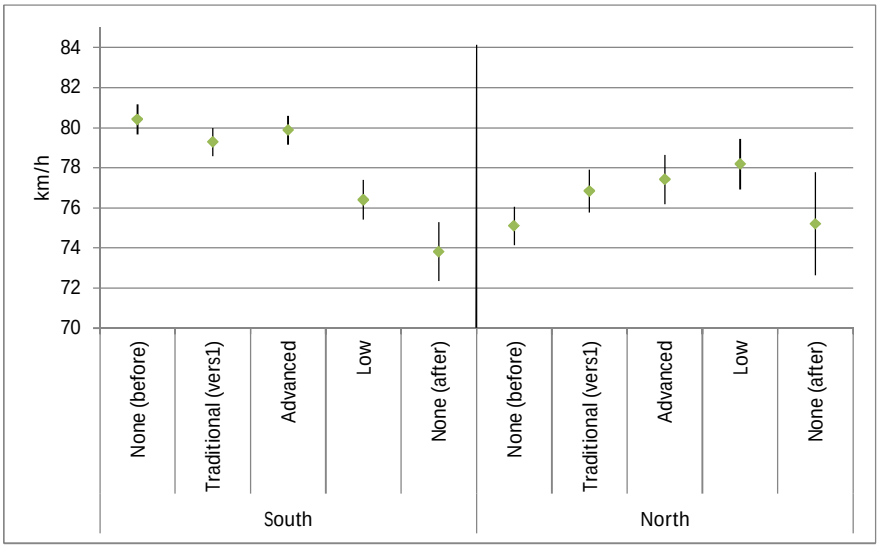


Figure 9. Speed over distance by configuration on a 606 m road segment at night.

3.3 Lateral position

There were 3,036 nighttime lateral position observations.

Lateral position with delineator posts did not differ significantly from the situation before delineator post installation. There were few differences between delineator post configurations, and they varied between positive and negative.

Going into the 1,100 m curve, the only difference between delineator post configurations was that on a dry road vehicles were nearer the centreline with configuration Advanced than with Low (Figure 10).

Exiting the 1,100 m curve, vehicles were 15 cm nearer the centreline with configuration Traditional (vers2) than with Advanced (Figure 11). This difference was not statistically significant when focusing on wet road surface conditions (Figure 12).

Going into the 300 m radius curve, vehicles were nearer (20 cm) the centreline with configurations Advanced and Low than with Traditional.

Exiting the 300 m radius curve, there were no differences in lateral position.

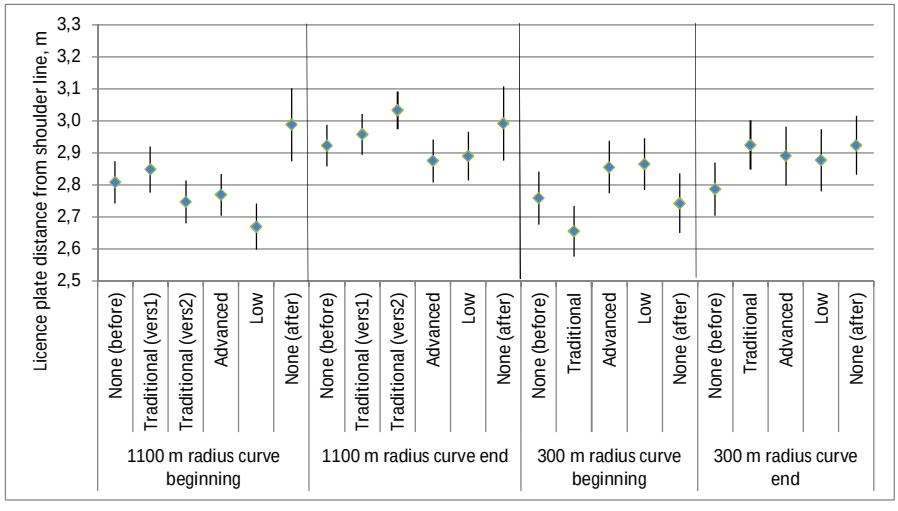


Figure 10. Average lateral position and confidence interval by configuration at night.

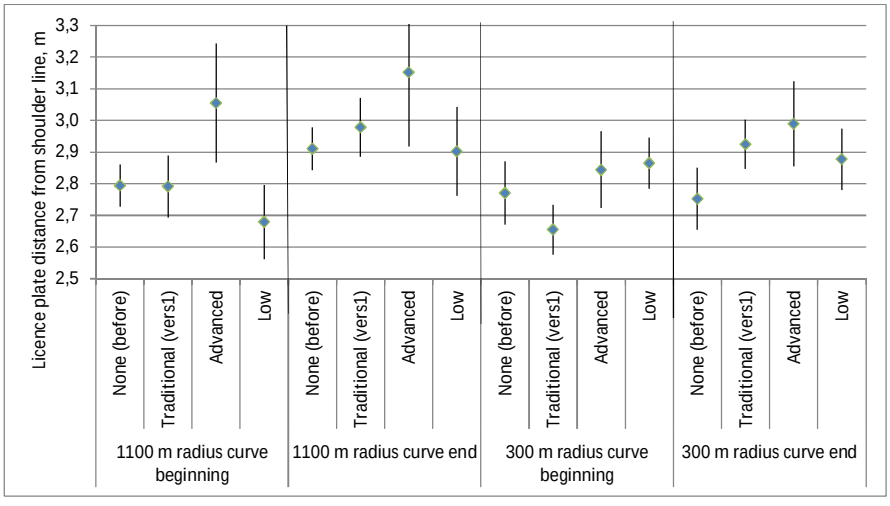


Figure 11. Average lateral position and confidence interval by configuration at night in dry weather and dry road surface conditions.

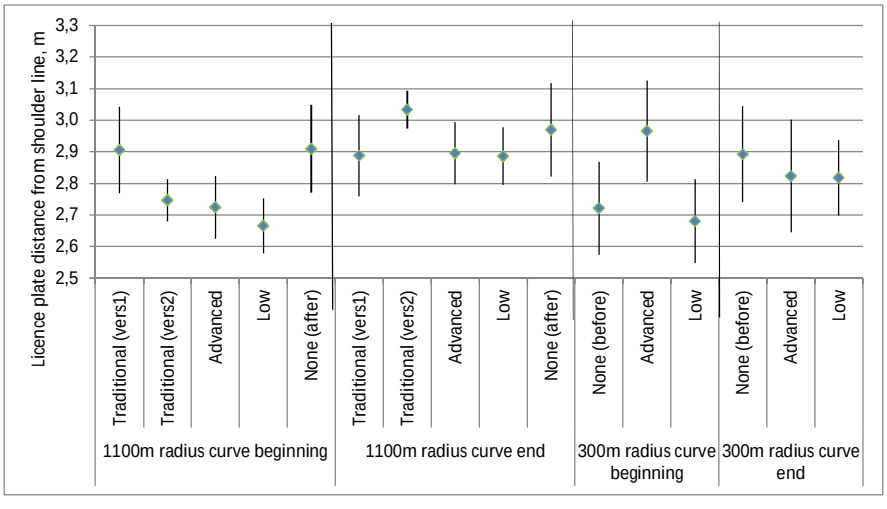


Figure 12. Average lateral position and confidence interval by configuration at night in dry weather and wet road surface conditions.

3.4 Configuration acceptance

In general, the test volunteers preferred the pictures with the densest delineator post placements. Where there was only a minor difference in the number of posts, preferences were divided fairly evenly.

Sites 1 and 3 were on curves, and configurations Advanced and Low were similar on both. For site 1, 54% of the volunteers preferred configuration Traditional and 46% preferred configurations Advanced and Low (Figure 13). For site 3, 90% of the volunteers preferred the denser configuration Traditional over configurations Advanced and Low.

Sites 2 and 5 were on a straight road. At site 2, configuration Traditional was preferred, 74% of the volunteers choosing it over configuration Low and 60% favouring it over configuration Advanced. Here 78% of the volunteers preferred configuration Advanced over configuration Low.

At site 5, Advanced was the most preferred configuration, 60% of the volunteers choosing it over Traditional and also over Low. When comparing configurations Traditional and Low, both got a 50% share.

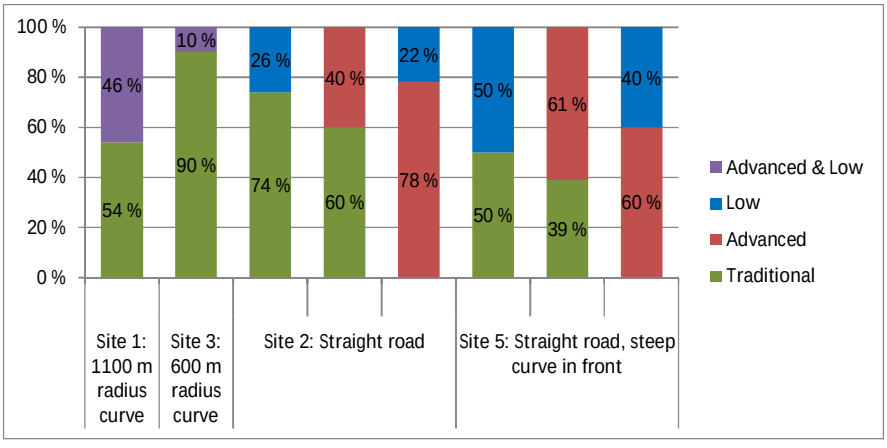


Figure 13. Volunteer preferences for different delineator post configurations.

For picture pairs including a scene with and without delineator posts, the vast majority (97%) of volunteers preferred the delineator post configuration (Table 8).

Table 8. Picture pairs and preferences expressed by volunteers. Picture pair numbering as used in the first session.

Picture pair	Place and configuration	Pref.	Place and configuration	Pref.
1	Site 5 Advanced	50	Site 5 None	0
2	Site 1 None	0	Site 1 Traditional	50
3	Site 3 Traditional	45	Site 3 Advanced&Low	5
4	Site 4 None	1	Site 4 Traditional&Advanced&Low	49
5	Site 5 None	0	Site 5 Low	50
6	Site 3 Advanced&Low	49	Site 3 None	1
7	Site 2 Low	44	Site 2 None	6
8	Site 5 Traditional	19	Site 5 Advanced	30
9	Site 2 Traditional	37	Site 2 Low	13
10	Site 5 Traditional	50	Site 5 None	0
11	Site 1 Advanced&Low	23	Site 1 Traditional	27
12	Site 1 None	1	Site 1 Advanced&Low	49
13	Site 2 Advanced	20	Site 2 Traditional	30
14	Site 5 Low	25	Site 5 Traditional	25
15	Site 3 None	1	Site 3 Traditional	49
16	Site 2 Advanced	39	Site 2 Low	11
17	Site 2 None	1	Site 2 Advanced	49
18	Site 5 Low	20	Site 5 Advanced	30
19	site 2 None	3	Site 2 Traditional	47

4. Summary of the results

4.1 Speed

Overall, the effects of delineator posts on speed were small. Typically different delineator post configurations seemed to change spot speeds at night by ± 1 km/h on average, and the largest observed effect was a 2.6. km/h decrease compared to pre-installation. In daytime there was no significant effect.

Also the differences in spot speed between delineator post configurations were small. The nighttime speed was slightly higher for configuration Advanced than for Traditional and Low; the difference in average spot speed was 1.1 km/h between Traditional and Advanced, and 1.0 km/h between Low and Advanced. The difference was approximately the same regardless of the road curve radius at the measurement point. There were no marked nighttime speed differences between configurations Traditional and Low.

After delineator post removal, the spot speed was markedly lower than before installation. Weather conditions in the after-phase were almost wintery, which probably had an effect on speed.

Speed over distance was measured in two ways: by plate number recognition and by combining spot speed observations. Speed over distance results measured by combining spot speed results were consistent with spot speed results, while measurements with plate number recognition showed that delineator posts increased speed in curves by 2–3 km/h. The difference between nighttime spot speeds and speed over distance collected by number plate recognition is probably due to vehicle selection. Number plate recognition found a speed over distance for approximately 26% of passing vehicles, and this sample may be somewhat skewed.

4.2 Vehicle lateral position

Lateral position with delineator posts did not differ significantly from the situation before delineator post installation. There were few statistically significant differences in the lateral position of vehicles between delineator post configurations,

and they varied between positive and negative. We thus conclude that delineator post density had no applicable effects on the lateral position of vehicles.

4.3 Acceptance of delineator post configurations

Overall, high delineator post density was preferred. If the difference between densities was small, the preferences were fairly evenly divided. Specifically, test volunteers preferred configuration Traditional on a 600 m radius curve and on a long straight road segment. At a site with a smooth curve followed by a sharp curve, preferences were almost equally divided between the three tested delineator post configurations. At a site ending a straight segment and entering a sharp curve, configuration Advanced was slightly preferred over other configurations.

4.4 Comparison with simulator results

The simulator study showed 2–12 km/h higher speeds with delineator posts than without them (Lundkvist et al. 2013). The speed was lowest for delineator post configuration Low, and approximately equally high for configurations Traditional and Advanced.

This field study did not confirm the simulator results, since the speed was highest for configuration Advanced and slightly lower for configurations Traditional and Low. Simulator results showed substantial differences between speeds with different delineator post configurations. The difference between average speeds for configurations Traditional and Low varied from 5 to 12 km/h depending on the road geometry. This field study found at most 2 km/h differences in speed between delineator post configurations.

The simulator study test volunteers gave a subjective estimation of difficulty driving with the different delineator post configurations. Configurations Traditional and Advanced were roughly at the same level. In the acceptability part of the present study, configuration Traditional was preferred over Advanced in four out of five sites. The simulator study volunteers estimated configuration Low to be more difficult than Traditional and Advanced, which is consistent with the present study.

5. Discussion

The simulator results showed remarkable differences in speed for different delineator post configurations, while in the field study the differences were small or non-existent. One explanation could be the difference in road characteristics. In the simulator study, the paved road was 9 m wide (7.0–7.4 m in the field study), the speed limit was 90 km/h (80 km/h in the field study), and there were longer straight segments, which gives more choice in terms of speed. The field studies in Finland could not be conducted in similar road conditions to those in the simulator studies because the speed limits are different (in Sweden 70, 90 or 110 km/h, in Finland 80 or 100 km/h), and wide roads (pavement width 9 m in the simulator study) with steep curves (250 m radius in the simulator study) could not be found on Finnish roads with speed limit 80 km/h or higher. Therefore we suggest that road features should better comply with reality in future simulator studies. Furthermore, in the simulator study there was no visual guidance from the surrounding landscape.

A notable share of vehicles in the field test drove along those roads fairly regularly and probably knew the road well. It could be that delineator post density affects speed less on a familiar road than it would otherwise.

The comparison point for spot speed data was located somewhat nearer the coast than the experimental road. Therefore differences in speed between these locations may partially be due to different weather, especially when the temperature is near zero and a small difference turns rain to snow. This applies in particular to measurements with configuration Traditional(vers2) in late October and after-phase measurements in early November. However, results for configuration Traditional(vers2) did not differ from those for configuration Traditional(vers1) measured in September. After-phase results were mainly omitted from the comparisons because of their uncertain comparability.

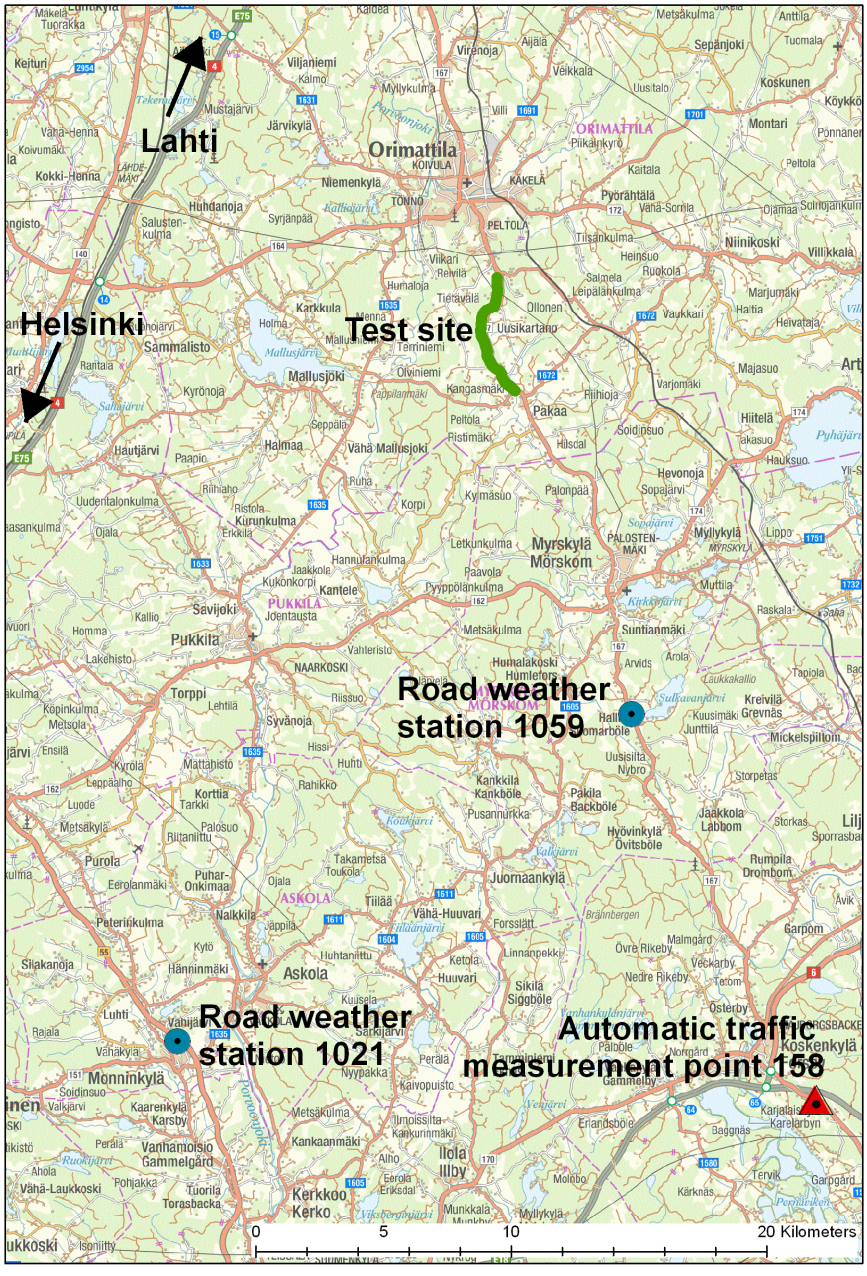
References

Kallberg, V. (1993). Reflector posts – signs of danger? Transportation Research Record. 1993, nr 1403, s. 57–66.

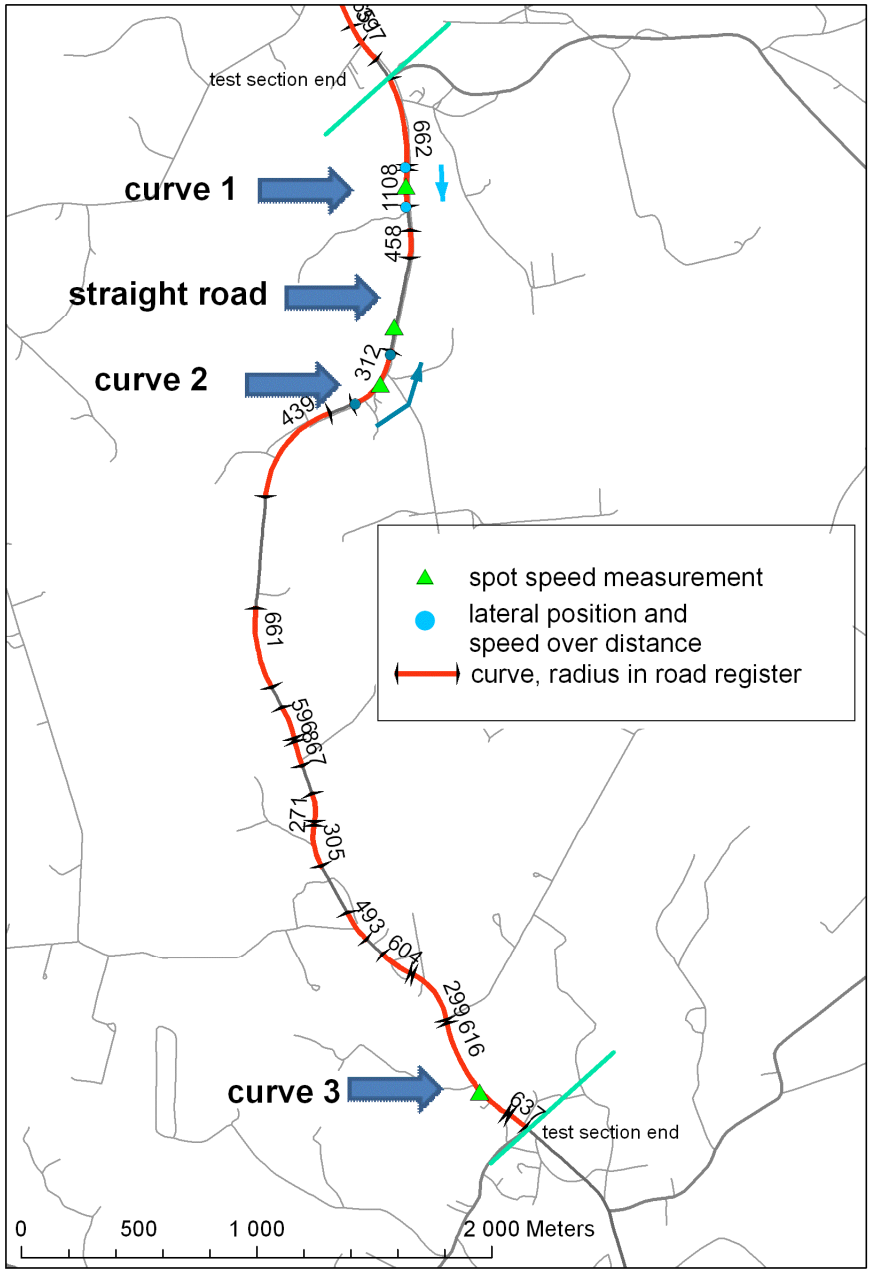
Lundkvist, S., Engen, T., Rajamäki, R., Helmers, G., Nygårdhs, S. (2013). Effekten av kantstolpar på trafikantbeteendet. VTI Rapport 795.

Nygårdhs, S. (2008). Kantstolpar. En litteraturstudie utförd på uppdrag av NMF. VTI notat 18-2008. http://www.vti.se/sv/publikationer/pdf/kantstolpar--en-litteraturstudie-utford-pa-uppdrag-av-nmf.pdf.

Appendix A: Test site location



Appendix B: Measurement sites



Appendix C: Pictures in the preference test

Figure C1. Site 1 with no delineator posts.

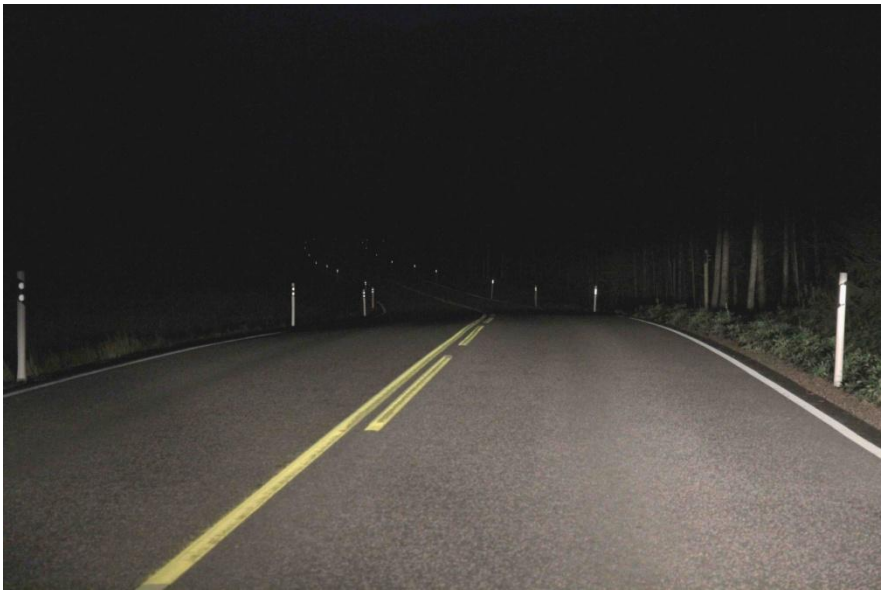


Figure C2. Site 1 with configuration Traditional.

Figure C3. Site 1 with configurations Advanced and Low.

Figure C4. Site 2 with no delineator posts.

Figure C5. Site 2 with configuration Traditional.

Figure C6. Site 2 with configuration Advanced.

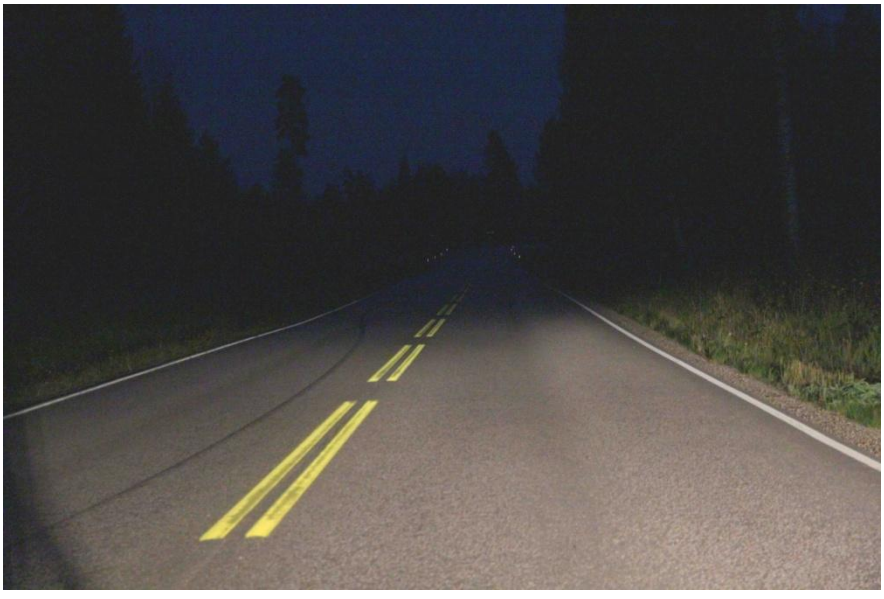


Figure C7. Site 2 with configuration Low.

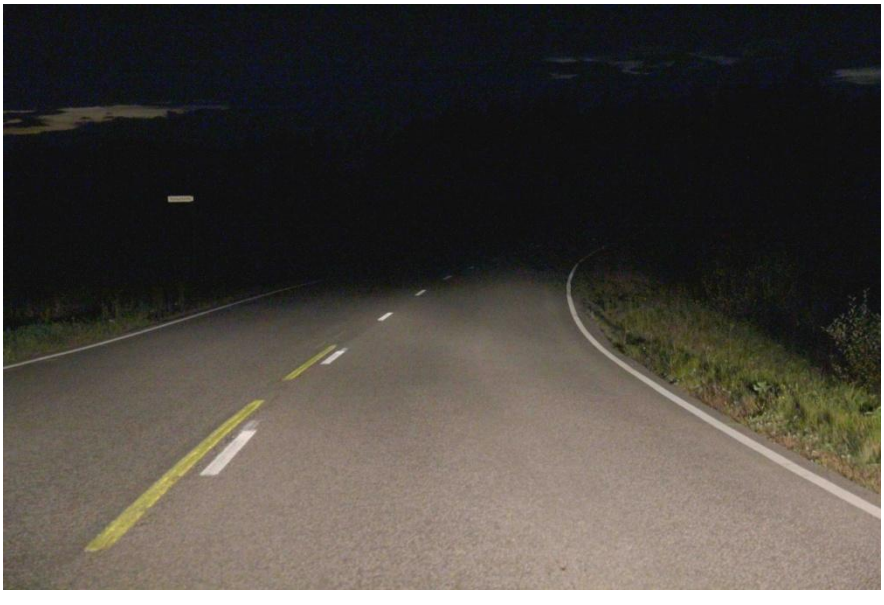


Figure C8. Site 3 with no delineator posts.

Figure C9. Site 3 with configuration Traditional.

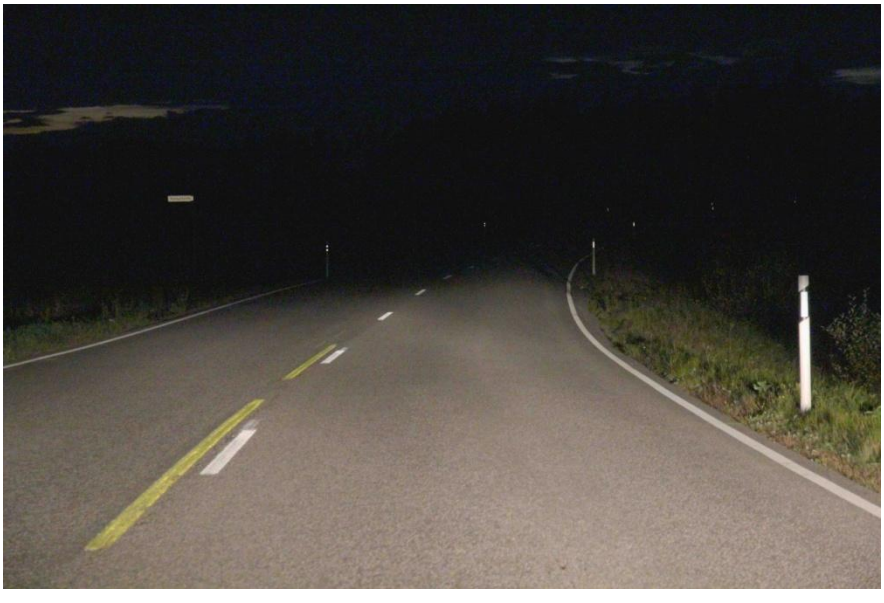


Figure C10. Site 3 with configurations Advanced and Low.

Figure C11. Site 4 with no delineator posts.

Figure C12. Site 4 with all configurations.

Figure C13. Site 5 with no delineator posts.

Figure C14. Site 5 with configuration Traditional.

Figure C15. Site 5 with configuration Advanced.

Figure C16. Site 5 with configuration Low.

Table C1. Picture order in auditorium sessions.

Picture pair	First session		Second session	
	Left	Right	Left	Right
1	Site 5 Advanced	Site 5 None	Site 5 None	Site 5 Traditional
2	Site 1 None	Site 1 Traditional	Site 1 Traditional	Site 1 Advanced&Low
3	Site 3 Traditional	Site 3 Advanced&Low	Site 1 Advanced&Low	Site 1 None
4	Site 4 None	Site 4 Traditional& Advanced&Low	Site 2 Traditional	Site 2 Advanced
5	Site 5 None	Site 5 Low	Site 5 Traditional	Site 5 Low
6	Site 3 Advanced&Low	Site 3 None	Site 3 Traditional	Site 3 None
7	Site 2 Low	Site 2 None	Site 2 Low	Site 2 Advanced
8	Site 5 Traditional	Site 5 Advanced	Site 2 Advanced	Site 2 None
9	Site 2 Traditional	Site 2 Low	Site 5 Advanced	Site 5 Low
10	Site 5 Traditional	Site 5 None	Site 2 Traditional	Site 2 None
11	Site 1 Advanced&Low	Site 1 Traditional	Site 5 None	Site 5 Advanced
12	Site 1 None	Site 1 Advanced&Low	Site 1 Traditional	Site 1 None
13	Site 2 Advanced	Site 2 Traditional	Site 3 Advanced&Low	Site 3 Traditional
14	Site 5 Low	Site 5 Traditional	Site 4 Traditional& Advanced&Low	Site 4 None
15	Site 3 None	Site 3 Traditional	Site 5 Low	Site 5 None
16	Site 2 Advanced	Site 2 Low	Site 3 None	Site 3 Advanced&Low
17	Site 2 None	Site 2 Advanced	Site 2 None	Site 2 Low
18	Site 5 Low	Site 5 Advanced	Site 5 Advanced	Site 5 Traditional
19	Site 2 None	Site 2 Traditional	Site 2 Low	Site 2 Traditional

Appendix D: Spot speeds

Table D1. Nighttime spot speed.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1 100m curve outer					
None (before)	78.0	9.9	1 136	77.4	78.5
Traditional (vers1)	78.7	9.7	1 589	78.2	79.1
Advanced	78.4	9.7	1 423	77.9	78.9
Low	77.1	9.7	1 260	76.6	77.7
None (after)	72.9	9.9	262	71.7	74.1
1 100m curve in-curve					
None (before)	73.3	10.5	1 187	72.7	73.9
Traditional (vers1)	72.2	10.3	1 474	71.7	72.8
Advanced	73.5	11.0	1 441	73.0	74.1
Low	72.9	10.6	1 244	72.4	73.5
None (after)	69.9	9.9	290	68.8	71.0
Straight road south					
None (before)	84.3	10.3	1 129	83.7	84.9
Traditional (vers1)	85.7	10.5	1 561	85.2	86.2
Advanced	85.6	9.9	1 389	85.1	86.1
Low	84.5	10.2	1 238	83.9	85.1
None (after)	78.2	10.0	372	77.2	79.2
Straight road north					
None (before)	80.9	11.5	1 183	80.2	81.5
Traditional (vers1)	79.3	11.9	1 489	78.7	79.9
Advanced	80.4	11.7	1 429	79.8	81.0
Low	79.7	12.1	1 242	79.0	80.3
None (after)	74.4	10.9	483	73.4	75.3
300 m curve outer					
None (before)	70.0	10.5	1 154	69.4	70.6
Traditional (vers1)	68.0	9.9	1 436	67.5	68.5
Advanced	69.0	10.2	1 372	68.4	69.5
Low	68.0	10.0	1 187	67.4	68.6
None (after)	62.2	10.1	471	61.3	63.1
300 m curve inner					
None (before)	72.3	9.7	1 100	71.7	72.9

Traditional (vers1)	72.8	9.8	1 546	72.3	73.3
Advanced	73.3	9.7	1 381	72.8	73.8
Low	71.0	10.3	1 212	70.4	71.6
None (after)	63.3	10.4	375	62.2	64.3
600 m curve outer					
None (before)	82.1	10.1	1 065	81.5	82.7
Traditional (vers1)	79.6	13.9	1 534	78.9	80.3
Advanced	81.4	9.8	1 336	80.9	81.9
Low	80.5	10.4	1 177	79.9	81.0
None (after)	76.9	8.9	308	75.9	77.9
600 m curve in-curve					
None (before)	79.6	12.2	1 092	78.9	80.3
Traditional (vers1)	77.2	12.1	1 377	76.6	77.8
Advanced	79.0	11.2	1 321	78.4	79.6
Low	78.2	10.8	1 129	77.6	78.8
None (after)	75.1	9.5	364	74.1	76.0

Table D2. Nighttime spot speed in dry weather, dry road surface.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1,100m curve outer					
None (before)	77.7	10.0	778	77.0	78.4
Traditional (vers1)	79.3	10.3	829	78.5	80.0
Advanced	79.3	9.7	623	78.6	80.1
Low	78.9	9.5	427	78.0	79.8
None (after)					
1,100m curve in-curve					
None (before)	73.2	10.4	744	72.5	74.0
Traditional (vers1)	72.9	10.3	795	72.1	73.6
Advanced	74.4	11.3	618	73.5	75.3
Low	73.6	10.5	469	72.6	74.5
None (after)					
Straight road south					
None (before)	84.0	10.2	765	83.3	84.7
Traditional (vers1)	85.9	10.9	808	85.1	86.6

Advanced	86.1	10.0	613	85.3	86.8
Low	85.7	9.9	422	84.8	86.7
None (after)					
Straight road north					
None (before)	81.3	11.5	737	80.5	82.2
Traditional (vers1)	79.9	11.4	792	79.1	80.7
Advanced	81.0	11.6	616	80.1	81.9
Low	80.0	13.2	475	78.8	81.2
None (after)					
300 m curve outer					
None (before)	70.6	10.6	714	69.8	71.4
Traditional (vers1)	68.8	9.9	772	68.2	69.5
Advanced	70.2	10.4	594	69.4	71.1
Low	69.0	10.6	451	68.0	70.0
None (after)					
300 m curve inner					
None (before)	72.3	10.1	758	71.6	73.0
Traditional (vers1)	73.4	10.2	807	72.7	74.2
Advanced	74.1	9.8	606	73.3	74.9
Low	72.7	10.0	412	71.7	73.7
None (after)					
600 m curve outer					
None (before)	81.8	10.4	725	81.1	82.6
Traditional (vers1)	82.6	10.7	780	81.8	83.3
Advanced	82.0	10.1	579	81.2	82.8
Low	82.5	10.5	405	81.5	83.6
None (after)					
600 m curve in-curve					
None (before)	79.7	11.8	681	78.8	80.6
Traditional (vers1)	78.7	11.1	724	77.8	79.5
Advanced	80.0	11.2	571	79.1	80.9
Low	79.7	10.8	429	78.7	80.7
None (after)					

Table D3. Nighttime spot speed in dry weather, wet road surface.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1,100m curve outer					
None (before)	81.0	8.4	221	79.9	82.1
Traditional (vers1)	78.5	8.9	392	77.6	79.4
Advanced	77.7	9.4	458	76.9	78.6
Low	76.2	10.1	579	75.4	77.0
None (after)	72.2	10.9	86	69.9	74.5
1,100m curve in-curve					
None (before)	74.3	10.3	328	73.1	75.4
Traditional (vers1)	72.5	10.5	376	71.5	73.6
Advanced	73.0	10.7	438	72.0	74.0
Low	72.7	10.5	589	71.8	73.5
None (after)	68.7	9.5	55	66.2	71.2
Straight road south					
None (before)	86.1	9.3	226	84.9	87.3
Traditional (vers1)	85.8	9.5	390	84.9	86.7
Advanced	85.0	9.1	440	84.1	85.8
Low	83.6	10.5	567	82.7	84.5
None (after)	78.2	9.8	103	76.3	80.1
Straight road north					
None (before)	80.7	11.3	332	79.5	82.0
Traditional (vers1)	80.3	11.5	375	79.1	81.5
Advanced	79.9	11.6	437	78.8	81.0
Low	80.0	10.8	581	79.1	80.8
None (after)	75.5	9.8	80	73.4	77.7
300 m curve outer					
None (before)	70.2	10.0	328	69.1	71.2
Traditional (vers1)	68.4	10.1	364	67.4	69.4
Advanced	68.2	9.8	418	67.3	69.2
Low	67.5	9.5	565	66.7	68.3
None (after)	64.2	8.6	77	62.3	66.1
300 m curve inner					
None (before)	73.7	8.3	216	72.5	74.8
Traditional (vers1)	73.0	9.6	386	72.0	73.9

Advanced	72.5	9.7	437	71.6	73.4
Low	70.1	10.6	557	69.2	71.0
None (after)	63.5	8.4	97	61.8	65.2
600 m curve outer					
None (before)	84.5	9.3	218	83.3	85.7
Traditional (vers1)	80.7	10.2	374	79.6	81.7
Advanced	81.0	9.3	423	80.1	81.9
Low	80.2	10.3	540	79.3	81.1
None (after)	76.2	10.3	94	74.2	78.3
600 m curve in-curve					
None (before)	81.1	11.3	303	79.8	82.4
Traditional (vers1)	77.5	11.6	350	76.3	78.7
Advanced	78.5	11.0	398	77.4	79.5
Low	77.4	10.7	537	76.5	78.3
None (after)	74.5	9.9	77	72.3	76.7

Table D4. Nighttime spot speed when raining.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1,100m curve outer					
None (before)	73.8	10.6	108	71.8	75.8
Traditional (vers1)	77.5	9.0	368	76.6	78.4
Advanced	77.5	10.4	255	76.3	78.8
Low	76.6	9.1	212	75.4	77.8
None (after)	74.7	6.6	29	72.3	77.1
1,100m curve in-curve					
None (before)	71.1	10.9	88	68.8	73.3
Traditional (vers1)	70.3	9.9	303	69.2	71.4
Advanced	72.9	10.2	287	71.7	74.1
Low	71.9	10.9	168	70.2	73.5
None (after)	65.3	6.9	19	62.2	68.4
Straight road south					
None (before)	81.9	12.4	109	79.6	84.2
Traditional (vers1)	85.3	10.5	363	84.2	86.4

Advanced	85.4	10.6	250	84.1	86.8
Low	84.9	9.5	208	83.6	86.2
None (after)	82.1	8.5	64	80.0	84.2
Straight road north					
None (before)	77.5	11.0	87	75.2	79.8
Traditional (vers1)	76.7	13.0	322	75.3	78.1
Advanced	80.3	11.3	278	79.0	81.6
Low	77.7	13.3	169	75.7	79.7
None (after)	77.0	9.3	79	75.0	79.1
300 m curve outer					
None (before)	65.6	10.5	86	63.3	67.8
Traditional (vers1)	65.5	9.1	300	64.5	66.5
Advanced	67.9	9.8	268	66.7	69.1
Low	66.9	10.1	158	65.4	68.5
None (after)	63.7	11.1	77	61.2	66.2
300 m curve inner					
None (before)	68.9	8.8	97	67.2	70.7
Traditional (vers1)	71.2	8.7	353	70.2	72.1
Advanced	72.2	9.2	252	71.1	73.3
Low	70.3	10.0	206	68.9	71.6
None (after)	68.3	7.1	64	66.5	70.0
600 m curve outer					
None (before)	78.6	8.9	96	76.8	80.4
Traditional (vers1)	72.3	19.2	380	70.4	74.2
Advanced	80.2	9.9	250	79.0	81.5
Low	77.5	9.6	197	76.2	78.9
None (after)	78.6	8.3	64	76.6	80.7
600 m curve in-curve					
None (before)	74.6	14.3	85	71.6	77.6
Traditional (vers1)	73.4	14.1	303	71.9	75.0
Advanced	77.8	11.6	261	76.3	79.2
Low	77.0	10.8	152	75.3	78.7
None (after)	75.6	7.1	71	73.9	77.3

Table D5. Daytime spot speed.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1,100m curve outer					
None (before)	74.4	9.4	4 992	74.1	74.6
Traditional (vers1)	74.1	9.3	6 099	73.9	74.4
Advanced	74.6	9.1	5 655	74.4	74.8
Low	73.8	9.2	5 380	73.6	74.1
None (after)	73.0	8.9	603	72.3	73.7
1,100m curve in-curve					
None (before)	69.7	9.2	5 236	69.5	70.0
Traditional (vers1)	70.4	9.1	6 421	70.2	70.6
Advanced	70.7	9.4	5 972	70.4	70.9
Low	70.0	9.2	5 781	69.8	70.3
None (after)	68.0	8.3	544	67.3	68.7
Straight road south					
None (before)	79.7	10.0	4 880	79.4	80.0
Traditional (vers1)	79.9	9.7	6 030	79.7	80.2
Advanced	80.5	9.5	5 587	80.3	80.8
Low	79.9	9.5	5 327	79.7	80.2
None (after)	77.9	9.6	1 167	77.3	78.4
Straight road north					
None (before)	78.4	10.1	5 093	78.1	78.6
Traditional (vers1)	78.3	9.8	6 370	78.1	78.6
Advanced	79.5	9.7	5 950	79.2	79.7
Low	78.1	9.8	5 753	77.8	78.3
None (after)	74.8	9.8	1 119	74.2	75.4
300 m curve outer					
None (before)	68.8	9.7	5 065	68.5	69.1
Traditional (vers1)	68.0	9.4	6 284	67.7	68.2
Advanced	68.8	9.0	5 888	68.6	69.1
Low	67.3	9.0	5 623	67.1	67.6
None (after)	64.4	8.6	1 085	63.9	64.9
300 m curve inner					
None (before)	69.1	9.3	4 720	68.9	69.4
Traditional (vers1)	69.2	9.8	5 860	68.9	69.4
Advanced	70.1	9.5	5 410	69.8	70.3
Low	68.4	9.5	5 136	68.1	68.6
None (after)	65.2	9.0	1 104	64.7	65.8

600 m curve outer					
None (before)	78.5	10.7	4 570	78.2	78.8
Traditional (vers1)	77.7	10.2	5 535	77.4	78.0
Advanced	78.7	10.0	5 216	78.5	79.0
Low	77.9	9.5	4 855	77.6	78.2
None (after)	76.4	9.2	793	75.8	77.0
600 m curve in-curve					
None (before)	77.3	10.3	4 869	77.0	77.6
Traditional (vers1)	76.7	9.8	5 990	76.5	77.0
Advanced	77.3	10.4	5 680	77.0	77.6
Low	76.4	9.8	5 344	76.1	76.7
None (after)	75.3	9.9	794	74.7	76.0

Table D6. Daytime spot speed in dry weather, dry road surface.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1,100m curve outer					
None (before)	74.3	9.6	4 057	74.0	74.6
Traditional (vers1)	74.2	9.2	4 021	74.0	74.5
Advanced	75.0	9.2	3 760	74.7	75.2
Low	74.1	9.7	2 352	73.7	74.5
None (after)					
1 100m curve in-curve					
None (before)	69.8	9.4	4 206	69.5	70.1
Traditional (vers1)	70.5	9.1	4 185	70.3	70.8
Advanced	71.1	9.6	3 780	70.8	71.4
Low	70.8	9.4	2 355	70.4	71.2
None (after)					
Straight road south					
None (before)	79.7	10.1	3 943	79.4	80.0
Traditional (vers1)	79.8	9.6	3 971	79.5	80.1
Advanced	80.7	9.6	3 702	80.4	81.0
Low	80.3	9.9	2 319	79.9	80.7
None (after)					
Straight road north					
None (before)	78.6	10.2	4 062	78.3	78.9
Traditional (vers1)	78.3	9.9	4 148	78.0	78.6
Advanced	79.9	9.9	3 706	79.5	80.2

Low	78.6	9.9	2 328	78.2	79.0
None (after)					
300 m curve outer					
None (before)	69.0	9.9	4 063	68.7	69.3
Traditional (vers1)	68.1	9.5	4 067	67.8	68.4
Advanced	69.3	9.1	3 660	69.1	69.6
Low	68.2	9.3	2 275	67.9	68.6
None (after)					
300 m curve inner					
None (before)	69.2	9.5	3 828	68.9	69.5
Traditional (vers1)	69.1	9.8	3 859	68.8	69.5
Advanced	70.4	9.5	3 593	70.1	70.7
Low	69.2	9.7	2 241	68.8	69.6
None (after)					
600 m curve outer					
None (before)	78.5	10.9	3 719	78.1	78.8
Traditional (vers1)	77.9	10.3	3 620	77.6	78.3
Advanced	79.0	10.2	3 471	78.7	79.3
Low	78.8	9.7	2 099	78.3	79.2
None (after)					
600 m curve in-curve					
None (before)	77.4	10.4	3 888	77.0	77.7
Traditional (vers1)	76.9	10.0	3 860	76.6	77.2
Advanced	77.6	10.8	3 537	77.2	77.9
Low	77.4	10.0	2 161	77.0	77.8
None (after)					

Table D7. Daytime spot speed in dry weather, wet road surface.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1,100m curve outer					
None (before)	73.9	8.6	659	73.3	74.6
Traditional (vers1)	72.7	9.9	835	72.0	73.3
Advanced	74.8	9.0	885	74.2	75.4
Low	74.0	8.6	1 739	73.6	74.4
None (after)	73.3	8.8	544	72.5	74.0
1,100m curve in-curve					
None (before)	69.3	8.4	726	68.7	70.0

Traditional (vers1)	69.6	9.4	1 008	69.0	70.1
Advanced	71.2	9.0	1 083	70.7	71.7
Low	70.4	9.0	2 034	70.0	70.8
None (after)	68.2	8.4	483	67.4	68.9
Straight road south					
None (before)	78.8	9.5	661	78.1	79.6
Traditional (vers1)	79.1	10.2	829	78.4	79.8
Advanced	81.1	9.4	875	80.5	81.8
Low	79.9	8.7	1 730	79.5	80.4
None (after)	78.6	9.9	724	77.9	79.3
Straight road north					
None (before)	77.3	9.4	727	76.6	78.0
Traditional (vers1)	78.4	9.6	985	77.8	79.0
Advanced	79.8	9.1	1 063	79.2	80.3
Low	78.8	9.7	2 015	78.3	79.2
None (after)	74.8	9.7	690	74.1	75.6
300 m curve outer					
None (before)	67.7	8.8	711	67.1	68.4
Traditional (vers1)	67.7	8.9	977	67.2	68.3
Advanced	69.1	8.8	1 059	68.6	69.6
Low	67.7	8.6	1 966	67.3	68.1
None (after)	64.7	8.6	669	64.0	65.3
300 m curve inner					
None (before)	68.3	8.9	627	67.6	69.0
Traditional (vers1)	68.4	10.1	808	67.7	69.1
Advanced	70.6	9.5	851	70.0	71.3
Low	68.2	9.1	1 665	67.8	68.7
None (after)	66.3	9.4	689	65.6	67.0
600 m curve outer					
None (before)	77.9	10.3	598	77.1	78.7
Traditional (vers1)	77.5	9.8	772	76.9	78.2
Advanced	79.0	9.7	816	78.4	79.7
Low	77.9	9.4	1 573	77.4	78.4
None (after)	76.4	9.0	654	75.7	77.1
600 m curve in-curve					
None (before)	76.6	10.1	699	75.9	77.4
Traditional (vers1)	76.5	9.5	933	75.9	77.1
Advanced	77.3	10.3	1 038	76.7	78.0
Low	76.5	9.4	1 860	76.1	77.0
None (after)	75.2	10.1	643	74.4	76.0

Table D8. Daytime spot speed when raining.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1,100m curve. outer					
None (before)	75.7	8.2	276	74.7	76.7
Traditional (vers1)	74.7	9.1	1 243	74.2	75.2
Advanced	73.2	8.7	971	72.6	73.7
Low	74.3	8.5	1 126	73.8	74.8
None (after)					
1,100m curve in-curve					
None (before)	69.8	8.5	304	68.9	70.8
Traditional (vers1)	70.6	9.0	1 228	70.1	71.1
Advanced	68.6	8.6	1 051	68.0	69.1
Low	69.2	8.8	1 167	68.7	69.7
None (after)					
Straight road south					
None (before)	81.3	7.9	276	80.4	82.3
Traditional (vers1)	80.9	9.6	1 230	80.3	81.4
Advanced	79.6	9.3	971	79.0	80.2
Low	80.5	9.2	1 122	80.0	81.1
None (after)					
Straight road north					
None (before)	77.7	9.5	304	76.6	78.8
Traditional (vers1)	78.4	9.5	1 237	77.9	78.9
Advanced	77.9	9.7	1 124	77.4	78.5
Low	77.2	9.0	1 191	76.6	77.7
None (after)					
300 m curve outer					
None (before)	68.5	8.3	291	67.5	69.4
Traditional (vers1)	67.7	9.1	1 240	67.2	68.2
Advanced	66.8	8.5	1 114	66.3	67.3
Low	66.7	8.4	1 172	66.2	67.2
None (after)					
300 m curve inner					
None (before)	70.7	8.0	265	69.7	71.7
Traditional (vers1)	69.8	9.5	1 193	69.3	70.4
Advanced	68.2	9.3	930	67.6	68.8
Low	68.5	8.6	1 084	68.0	69.0
None (after)					

600 m curve outer					
None (before)	79.5	9.6	253	78.3	80.7
Traditional (vers1)	77.1	10.2	1 143	76.5	77.7
Advanced	77.4	9.5	892	76.8	78.1
Low	77.6	8.5	1 041	77.1	78.1
None (after)					
600 m curve in-curve					
None (before)	77.5	9.7	282	76.4	78.6
Traditional (vers1)	76.5	9.5	1 197	76.0	77.0
Advanced	76.4	9.5	1 052	75.9	77.0
Low	76.0	9.4	1 122	75.5	76.5
None (after)					

Appendix E: Speed over distance on outer curves with plate number recognition

Table E1. Nighttime speed over distance on curves.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1,100m radius curve					
None (before)	67.3	8.3	114	65.8	68.8
Traditional (vers1)	73.1	9.0	136	71.6	74.6
Advanced	76.6	8.1	125	75.2	78.0
Low	73.4	8.6	108	71.8	75.1
Traditional (vers2)	74.4	8.8	132	72.9	75.9
None (after)	63.5	5.4	36	61.7	65.2
300m radius curve					
None (before)	69.0	9.7	101	67.1	70.8
NS	72.9	10.7	104	70.8	74.9
Advanced	74.3	10.5	103	72.3	76.3
Low	74.6	10.5	83	72.4	76.9
None (after)	72.0	9.2	81	70.0	74.0

Table E2. Daytime speed over distance on curves.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1,100m radius curve					
None (before)	67.5	9.7	489	66.7	68.4
Traditional (vers1)	72.0	8.8	387	71.1	72.9
Advanced	73.0	7.1	539	72.4	73.5
Low	72.0	7.7	399	71.2	72.7
Traditional (vers2)	73.5	7.9	444	72.7	74.2
None (after)	60.2	5.6	41	58.5	61.9
300m radius curve					
None (before)	71.2	8.5	610	70.6	71.9
NS	72.5	7.2	525	71.9	73.2

Advanced	73.5	8.1	528	72.8	74.2
Low	73.6	7.8	507	72.9	74.3
None (after)	69.8	7.4	236	68.9	70.8

Table E3. Nighttime speed over distance on curves in dry weather and dry road surface conditions.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1,100m radius curve					
None (before)	66.8	8.3	103	65.2	68.4
Traditional (vers1)	76.0	7.7	37	73.5	78.4
Advanced	79.7	9.6	19	75.4	84.1
Low	76.2	8.5	29	73.1	79.3
300m radius curve					
None (before)	68.7	9.8	94	66.7	70.7
NS	72.9	10.7	104	70.8	74.9
Advanced	76.1	10.4	59	73.4	78.7
Low	74.6	10.5	83	72.4	76.9

Table E4. Nighttime speed over distance on curves in dry weather and wet road surface conditions.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
1,100m radius curve					
Traditional (vers1)	76.0	9.5	34	72.8	79.2
Advanced	75.4	7.3	82	73.8	77.0
Low	72.4	8.5	79	70.5	74.3
Traditional (vers2)	74.4	8.8	132	72.9	75.9
None (after)	62.2	4.1	23	60.5	63.9
300m radius curve					
Advanced	73.9	9.8	22	69.8	78.0
None (after)	71.2	10.1	35	67.9	74.6

Appendix F: Speed over distance between spot speed measurement sites

Table F1. Nighttime speed over distance between spot speed measurement sites.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
South					
None (before)	80.4	10.1	711	79.7	81.2
Traditional (vers1)	79.3	9.8	744	78.6	80.0
Advanced	79.9	9.4	621	79.1	80.6
Low	76.4	13.5	715	75.4	77.4
None (after)	73.8	8.7	138	72.4	75.3
North					
None (before)	75.1	10.4	440	74.1	76.1
NS	76.8	11.9	465	75.8	77.9
Advanced	77.4	11.6	343	76.2	78.7
Low	78.2	13.3	425	76.9	79.4
None (after)	75.2	13.0	98	72.6	77.8

Table F2. Daytime speed over distance between spot speed measurement sites.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
South					
None (before)	76.5	11.0	1354	74.1	75.1
Traditional (vers1)	74.6	9.6	1364	74.9	76.1
Advanced	75.5	10.2	1024	73.5	74.9
Low	74.2	13.6	1618	70.9	73.6
None (after)	72.3	8.3	150	74.1	75.1
North					
None (before)	73.3	11.0	841	72.6	74.1
NS	76.3	10.1	930	75.6	76.9
Advanced	75.4	12.1	639	74.4	76.3
Low	75.5	13.7	978	74.6	76.3
None (after)	73.0	10.8	103	70.9	75.0

Table F3. Nighttime speed over distance between spot speed measurement sites in dry weather and dry road surface conditions.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
South					
None (before)	79.8	9.7	486	78.9	80.6
Traditional (vers1)	79.5	11.1	411	78.5	80.6
Advanced	80.2	9.1	279	79.1	81.2
Low	76.2	10.2	243	74.9	77.5
North					
None (before)	75.1	10.6	292	73.9	76.3
NS	78.4	9.8	277	77.3	79.6
Advanced	78.5	10.8	164	76.8	80.1
Low	80.2	13.2	154	78.1	82.2

Table F4. Daytime speed over distance between spot speed measurement sites in dry weather and wet road surface conditions.

Row Labels	Average	StdDev	n	95% confidence interval for the average	
				Lower limit	Upper limit
South					
None (before)	85.4	8.9	119	83.8	87.0
Traditional (vers1)	79.6	7.3	146	78.4	80.8
Advanced	79.0	10.4	177	77.5	80.5
Low	78.9	15.7	357	77.3	80.5
None (after)	70.7	8.8	48	68.2	73.2
North					
None (before)	75.9	8.8	91	74.1	77.7
NS	76.8	12.7	100	74.3	79.3
Advanced	75.0	12.0	72	72.2	77.8
Low	75.4	12.7	225	73.7	77.1
None (after)	75.3	11.0	32	71.5	79.2

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Author(s)	Riikka Rajamäki, Juha Luoma & Pirkko Rämä
Abstract	This study was designed to validate simulator-study results concerning driving speeds with three different delineator post configurations based on post frequency. The distance between delineator posts was 25–50 m on curves and 50–100 m on straight road segments; in one configuration there were no delineator posts on the straight segments. The test configurations were each installed on a specific road segment for about 2 weeks. During this time speed and lateral position of passing vehicles were measured at several sites along the road. Acceptance of these three delineator post configurations was examined in the lab by asking volunteers to compare nighttime pictures. Nighttime spot speed with delineator posts was on average 0.5 km/h lower than before delineator post installation. Nighttime speed differences between delineator post configurations were small. One of the three configurations produced approximately 1 km/h higher average speed than the other two, regardless of the road curve radius at the measurement point. The results differed significantly from those obtained with the simulator: in the latter, delineator posts significantly increased the speed, and the speed differences between delineator post configurations were also substantial. We found no statistically significant and consistent relationship between delineator post density and lateral positioning of vehicles. In the acceptance study, the volunteers expressed a preference for high delineator post density.
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Nimeke	**Reunapaalujen vaikutus autojen nopeuteen, sivuasemaan ja kuljettajien mielipiteisiin**
Tekijä(t)	Riikka Rajamäki, Juha Luoma & Pirkko Rämä
Tiivistelmä	Tällä tutkimuksella pyrittiin validoimaan ajosimulaattorissa saanut tulokset, jotka koskivat tienvarren heijastimella varustettujen reunapaalujen sijoittelun vaikutusta ajonopeuteen. Tutkitut kolme reunapaalujen sijoittelua erosivat toisistaan siinä, kuinka pitkä matka oli reunapaalujen välissä. Kaarteissa välimatka oli 25–50 metriä ja suorilla tieosuuksilla 50–100 metriä. Yhdessä sijoittelussa reunapaaluja ei ollut lainkaan suorilla tieosuuksilla. Näitä kolmea reunapaalujen sijoittelua kokeiltiin vuorotellen samalla tieosuudella syksyllä 2012, kutakin kahden viikon ajan. Tänä aikana autojen nopeutta ja sijaintia kaistalla mitattiin useissa paikoissa. Lisäksi tutkittiin eri sijoittelujen hyväksyntää siten, että vapaaehtoiset koehenkilöt vertailivat näitä sijoittelutapoja valokuvien perusteella. Yöajan pistemäisesti mitattu nopeus oli keskimäärin 0,5 km/h alempi reunapaalujen ollessa käytössä kuin ilman reunapaaluja. Erot yöajan ajonopeudessa olivat pieniä erilaisten reunapaalujen sijoittelujen välillä. Yhden sijoittelutavan ollessa käytössä ajonopeus oli noin 1 km/h korkeampi kuin muilla sijoittelutavoilla sekä mutkissa että suoralla tiellä. Kenttämittausten tulokset poikkesivat huomattavasti simulaattorissa saaduista tuloksista: simulaattorissa reunapaalujen käyttö kasvatti ajonopeutta merkittävästi, ja nopeuserot reunapaalujen sijoittelujen välillä olivat myös huomattavia. Tässä tutkimuksessa reunapaalujen sijoittelulla ei havaittu tilastollisesti merkitsevää ja johdonmukaista yhteyttä auton sijaintiin ajokaistalla. Hyväksyttävyystutkimuksessa koehenkilöt pitivät eniten tiheimmistä reunapaalujen sijoitteluista.
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