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A Comparative Study between Vehicle Activated Signs and Speed Indicator Devices

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Abstract

Vehicle activated signs and Speed indicator devices are safety signs used to warn and remind drivers that they are exceeding the speed limit on a particular road segment. This article has analysed and compared such signs with the aim of reporting the most suitable sign for relevant situations. Vehicle speeds were recorded at different test sites and the effects of the signs were studied by analyzing the mean and standard deviation. Preliminary results from the work indicate that both types of signs have variable effects on the mean and standard deviation of speed on a given road segment. Speed indicator devices were relatively more effective than vehicle activated signs on local roads; in contrast their effectivity was only comparable when tested on highways.

Keywords: Vehicle activated signs; speed indicator devices; trigger speed; effect on drivers

1. Introduction

Vehicle activated signs (VASs) and Speed indicator devices (SIDs) are safety signs used to warn and remind drivers that they are exceeding the speed limit on a particular road segment. VAS and SID are activated by the speed of approaching vehicles (referred to as trigger speed from this point forward). In practice the threshold that activates the message to the driver is set to a constant value that corresponds to traffic agencies’ recommendations for the particular road segment.

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Such practices however do not consider the fact that an optimal trigger speed might exist, i.e. a trigger speed that has the most beneficial impact on driver behaviour. It is our belief that each sign may need a different setting of the trigger speed for different road segments. The signs display a warning message when drivers exceed a particular trigger speed. Note that the warning messages displayed by the VAS and SID signs are slightly different. VAS displays a warning message, typically a ‘slow down’ in combination with the current speed limit whereas SIDs displays vehicle speed in green or red colours to notify driver behaviour (Figure 1). Usage of either a smiley or a sad face on a SIDs is also not uncommon (Walter and Knowles 2010). Several studies have evaluated the effectiveness of the SID and VAS on driver behaviour. However studies reporting the effect of the different types of signs on different road segments are missing. Investigations studying the impact of different trigger speeds on road segments is yet another issue. Previous research studies have reported a speed reduction between 2 and 7 mph when the VASs and SIDs are used (Winnett and Wheeler 2003, Walter and Knowles 2008, Pesti and McCoy 2001, Sandberg et al. 2006, Walter and Broughton 2011, Poulter and McKenna 2005 and Cruzado and Donell 2009). Studies investigating trigger speed values of the signs are few. A recent study on the topic has shown that the optimal trigger speed of a VAS needs to be pre-determined according to the nature of the site and to the traffic conditions (Jomaa et al 2014). The aforementioned study also reported that the optimal trigger speed was approximately near the 85th percentile speeds i.e. one which had the desired effect of lowering the standard deviation. Another interesting area that can be lifted up in this context concerns studies investigating the environmental impact of speeding (Spellerberg 1998). In general, high speeds and large speed variation have a negative effect on the level of exhaust emissions, the level of traffic noise, fuel consumption and the quality of life for people living or working near the road (Panis et al. 2006, Lumbreras et al. 2008, Cen et al. 2016). However it is still unclear what type of sign should be considered when discussing usage and effectiveness on driver speed. In this paper a comparative study between VAS and SID has been done with an aim of reporting the most suitable signage for relevant usage by investigating the following:

- Effects of VAS and SID when installed on different sites
- Are their effects variable given different times of the day?
- Are their effects comparable in terms of the trigger speed? Does 85th percentile trigger speed of SID reduce the standard deviation of vehicle speed?

The rest of the paper is organised as follows. Section 2 describes the experimental design. Data analysis and results are described in section 3. The paper finally presents concluding remarks.

2. Experimental design

The experimental design in this paper has investigated two key issues namely site selection and sign selection; careless choice of which might lead to inconsistent and biased data. Past studies indicated that site selection should be based on either an area known as speeding area i.e. road segments notorious for speeding and or with a history of accidents where inappropriate speeds were the initial problem (Winnett and Wheeler 2002). In the current study two test sites were selected in Borlänge, Sweden with two different road characteristics; referred to as Mjälga and Djurås sites from this point forward. Mjälga site is restricted to 40km/hr and is one of the local roads (under the authority of the local municipality) in Borlänge. Djurås site is restricted to 60km/hr and is located on a highway segment (E16) between Borlänge and Djurås in central Sweden. It should be noted that choice of relatively small number of sites in the current case is due to the pragmatic limitations involved in installing VAS alongside roads which requires permission from transport authorities and so on. The idea is to be able to verify proof of concept using a small number of sites before large scale experimentation. Note that both areas have known safety problems as a result of which speed limits on the segments have been reduced from 50km/hr to 40km/hr in Mjälga and from 90km/hr to 60km/hr in Djurås. Proper care was taken in
selecting the sites to be able to collect relatively consistent speed data. In both the cases road segments were free of sharp bends (before and after), pedestrian crossings, roundabouts and other traffic calming measures that usually have an effect on speed.

As mentioned above, two warning signs VAS and SID were installed and used for collecting data. Both signs are activated by the speed of the approaching vehicles and a warning message is displayed when drivers exceed a particular threshold speed. VAS and SID differ in the type of displayed message (see Fig. 1, best viewed in colour). VAS display a reminder of the posted speed limit (40km/hr or 60km/hr) and a reduce speed (SÄNK FARTEN in Swedish) message. In contrast SID displays the speed of all the vehicles passing the signs in green or red colours depending on set threshold speed i.e. speed is displayed in green if the vehicle speed is under the threshold and in red otherwise (Walter and Knowles 2010).

Bearing in mind issues such as traffic intensity together with road and weather conditions in addition to the site and sign, trigger speeds for each sign were randomly assigned with an aim of collecting consistent and unbiased data. At this point it is worth mentioning that trigger speeds were randomly assigned each day at Djurås; but a single trigger speed was assigned over a three day period at Mjällga bearing in mind the variation of site characteristics in terms of flow, influence on vehicle speed and so on. Speed limit on the road and the 85th percentile speed were mainly used as the threshold values. The fact that it is a normal practice to use the speed limit as a trigger speed in Sweden motivates our choice; in contrast 85th percentile speed is a common setting used by traffic engineering and transport planners and is defined as the speed at or below which 85% of all vehicles are observed to travel past a nominated point under free flowing conditions. Choice of the trigger speed varies between different countries. As example traffic authorities in Britain mainly consider the 85th percentile as the trigger speed. It was shown in our previous work that 85th percentile is a good first approximation for the optimum trigger speed for VAS (Jomaa et al. 2014).

![Fig.1](image1.png)

Fig.1. (a) SID is turned on in green; (b) SID is turned on in red indicating high vehicle speed; (c) VAS is turned off (d) VAS is turned on

3. Data collection

Data was collected in two stages using Doppler radars. In the first stage two Doppler radars were deployed and data was collected for a week. Note that data collection in the first stage was carried out prior to the installation of SID and VAS. In the second stage data was collected for another week using the SID and VAS (at different time periods) on top of the already two existent Doppler radars. Note that the SID and VAS were installed at the same location but in different time periods. For the sake of simplicity data collection periods will be referred to as ‘before’ and ‘during’ from this point forward. It
should also be noted that the two Doppler radars were left in place i.e. 100m before the respective sign and are referred to as pre-SID/pre-VAS and at-SID/at-VAS from this point forward. The pre-SID/pre-VAS Doppler radars (100m) are deployed to capture driver behavior before encountering the sign. A distance of 100m should not be regarded as standard but relatively as one that can account for the acceleration and deceleration aspects and is largely dependent on the site under investigation. Vehicle speeds, trigger speed, the direction of travel together with date and time stamps were collected for further investigation. A total of 5488 observations were made.

The data are summarised in table 1. The number of observations per day, mean speed, 15th percentile speed, 85th percentile speed and standard deviation of vehicle speed are presented.

<table>
<thead>
<tr>
<th>Site</th>
<th>Speed limit</th>
<th>Observations per day</th>
<th>Mean speed (km/hr)</th>
<th>15th percentile (km/hr)</th>
<th>85th percentile (km/hr)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mjälga</td>
<td>40</td>
<td>1108</td>
<td>43</td>
<td>36</td>
<td>50</td>
<td>8</td>
</tr>
<tr>
<td>Djurås</td>
<td>60</td>
<td>4380</td>
<td>66</td>
<td>57</td>
<td>77</td>
<td>12</td>
</tr>
</tbody>
</table>

4. Methodology

Two measures were used to be able to study the effect of both signs. The first measure was based on the detectable effect of the sign (Walter and Broughton, 2011). The detectable effect was calculated as the difference between the mean speeds of vehicles ‘before’ and ‘during’ periods at the sign (at-VAS or at-SID); and the mean speeds ‘before’ and ‘during’ periods 100m before the sign (pre-VAS or pre-SID). The mean speed at before period was assumed not to be influenced by the presence of the sign and thus controlling for baseline speeds at each location of the radar. It was necessary to consider the mean speeds 100m before the sign as this assumed to reduce the chance of a speed difference being due to an external random effect rather than the presence of VAS/ SID. The detectable effect was detailed as follows (see equation (1)):

\[ \delta_2(t) = (\mu_2(t) - \mu_2(before)) - (\mu_1(t) - \mu_1(before)) \]  

Where \( \delta_2(t) \) the effect for time period \( t \) at the sign is, \( \mu_2 \) is the mean speeds at the sign and \( \mu_1 \) is the mean speed 100m before the sign. The second measure concerned the coefficient of variation which was an appropriate way to find the extent of variability in relation to the mean speed (Jomaa et al. 2015). The coefficient of variation was defined as the ratio of the speed standard deviation to the mean speed. This measure is presented in equation (2) where \( CV_2(t) \) the coefficient of variation for time period \( t \) at the sign is, \( \sigma_2(t) \) is the standard deviation at the sign for time period \( t \), \( \mu_2(t) \) mean speeds at the sign.

\[ CV_2(t) = \left( \frac{\sigma_2(t)}{\mu_2(t)} \right) \]  

5. Analysis and results

Data were pre-processed to exclude all the vehicles travelling in the other direction relative to the sign. The data were divided into day/night periods bearing in mind the difference in traffic flow
volumes at different times of the day (see Fig. 2). Note that daylight saving has not been accounted for and data division was carried out strictly on the basis of the number of the observations with respect to the division into day and night periods. The day period was defined as 0700 to 1959 hrs and the night period was defined as 2000 to 0659 hrs.

Fig. 2. Traffic flow (number of vehicles per hour) respective to the time of the day at Mjälga site and Djurås

Fig. 3 and Fig. 4 show the speed distribution at Mjälga and Djurås sites when SID and VAS were activated. As per the figures SID had in general more effect than the VAS at Mjälga site whereas at Djurås both signs had approximately similar effect on shifting the curves to the left, indicating that drivers reduce their speeds.

Fig. 3. Speed distribution and density of speeds at Mjälga site pre- and at- the SID and the VAS
Effects of VAS and SID when installed on different sites

The effects of SID and VAS on vehicle speeds are detailed in Table 2. An overall reduction in mean speeds and standard deviation was observed. In particular a reduction in mean vehicle speeds of 9.0 km/hr was observed at Djurås site when VAS was active during night with the 85th percentile as the trigger speed. In contrast SID had a larger effect in reducing speed (5.8 km/hr in the current case) when compared to VAS in Mjälga with 85th percentile as the trigger speed. SID had a low coefficient of variation at Mjälga but VAS had a low coefficient of variation at Djurås indicating that the signs have variable effects on different sites. The results indicate that the impact of the SID and VAS are statistically significant; the same can be observed when one examines the difference in speed distribution between the pre- and at- the SID and the VAS (see Fig 3 and Fig. 4).

Fig.4. Speed distribution and density of speeds at Djurås site pre- and at- the SID and the VAS

Are their effects variable given different times of the day?

Using SID, no overall detectable differences on the effect of mean speeds were observed during night and day time at both sites. However, the results were different when VAS was installed; an increase in mean speeds and coefficient of variation were observed at night. During day periods the lowest coefficient of variation was observed when VAS was activated with trigger speed equal to 85th percentile; whereas during night periods, the lowest coefficient of variation was observed when VAS was triggered with the speed limit on the road segment. The low coefficient of variation during the night could also be attributed to the fact that the total numbers of day and night observations were uneven.
Are their effects comparable in terms of the trigger speed?

A previous study by the authors revealed that the trigger speed for VAS had an effect on lowering the standard deviation on local roads in Sweden (Jomaa et al. 2015). Results obtained in the current study reinforce such previous findings where a lower coefficient of variation was observed during day periods at both sites; when the trigger speed of VAS was set to the 85th percentile. In contrast SID with trigger speed equal to the speed limit on the road segment was more effective at both sites. On the contrary in terms of mean effects the trigger speed of the SID had no effect on mean speed at both sites.

Table 2 presents the coefficient of variation and the effect of SID and VAS with different trigger speeds observed at Mjälga and Djurås sites at two day/night time.

Hypothesis testing

The aforementioned questions were also investigated by comparing the mean speeds when each sign (SID or VAS) was activated with different trigger speeds at the sites. Two-way analysis of variance (ANOVA) has been used to evaluate the effect of trigger speed on driver behaviour according to the time of the day and at different sites.

In general the two-way ANOVA is used to determine whether the main effects and interaction effect are statistically significant. The null hypothesis for a main effect is that the response mean for all factor levels are equal. The null hypothesis for an interaction effect is that the response mean for the level of one factor does not depend on the value of the other factor. To determine whether each main effect and the interaction effect were statistically significant, table 3 compared the p-values for each term to a significance level 0.01 to assess each null hypothesis. The p-value for trigger speed of SID was greater than 0.01 indicating that the levels of trigger speeds were not statistically significant with the mean speed of drivers.

Table 2. Coefficient of variation at the sign and effect of VAS and SIS at both sites

<table>
<thead>
<tr>
<th>Coefficient of variation CV&lt;sub&gt;2&lt;/sub&gt;</th>
<th>Mjälga site (speed limit 40km/hr and 85th percentile speeds 50km/hr)</th>
<th>Djurås site (speed limit 60km/hr and 85th percentile speeds 70km/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day time (7:00 – 19:59)</td>
<td>Night time (18:00 – 6:59)</td>
<td>Day time (7:00 – 19:59)</td>
</tr>
<tr>
<td>SID-SL</td>
<td>SID-85</td>
<td>SID-SL</td>
</tr>
<tr>
<td>0.14</td>
<td>0.15</td>
<td>0.14</td>
</tr>
<tr>
<td>VAS-SL</td>
<td>VAS-85</td>
<td>VAS-SL</td>
</tr>
<tr>
<td>0.14</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>VAS-85</td>
<td>VAS-85</td>
<td>VAS-SL</td>
</tr>
<tr>
<td>0.14</td>
<td>0.16</td>
<td>0.15</td>
</tr>
<tr>
<td>Effect δ&lt;sub&gt;2&lt;/sub&gt;</td>
<td>-5.4</td>
<td>-8.2</td>
</tr>
<tr>
<td>-5.6</td>
<td>-3.3</td>
<td>-8.0</td>
</tr>
<tr>
<td>-2.4</td>
<td>-5.3</td>
<td>-8.6</td>
</tr>
<tr>
<td>-5.8</td>
<td>-2.6</td>
<td>-8.4</td>
</tr>
<tr>
<td>-1.9</td>
<td>-8.1</td>
<td>-9.0</td>
</tr>
</tbody>
</table>

**SID-SL**: Speed Indicator Device with a message “Your Speed” and with trigger speed set to speed limit

**SID-85**: Speed Indicator Device with a message “Your Speed” and with trigger speed set to 85th percentile speeds

**VAS-SL**: Vehicle Activated Sign with a message “Slow Down” and with trigger speed set to speed limit
**VAS-85: Vehicle Activated Sign with a message “Slow Down” and with trigger speed set to 85th percentile speeds**

In contrast there was strong evidence that trigger speed of VAS was statistically significant on the mean speed of drivers. For the two signs the main effect of the two factors; type of site and the time of the day were statistically significant on driver speed but the interaction between the two factors was not significant. Trigger speed neither interacted with the type of site nor the time of the day despite the fact that site and the time of the day exhibited strong interaction (see table 3). In fact we cannot interpret the main effects of vehicle speeds without considering the interaction effect between time of the day and type of site.

**Table 3. Hypothesis testing for speed variances using two-way ANOVA**

<table>
<thead>
<tr>
<th>Effect of mean speeds based on factors</th>
<th>factor</th>
<th>SID</th>
<th>VAS</th>
<th>Null hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger speed (TS) and sites</td>
<td>TS</td>
<td>F= 0.05, p&lt;0.01</td>
<td>F= 230, p&lt;0.01</td>
<td>H0: μ(TS=SL) = μ(TS=85th)</td>
</tr>
<tr>
<td>Site</td>
<td>Site</td>
<td>F=32851, p&lt;0.01</td>
<td>F=17192, p&lt;0.01</td>
<td>H0: μ(site=Mjälga) = μ(site=Djurås)</td>
</tr>
<tr>
<td>TS:site</td>
<td>TS:site</td>
<td>F=1.4, p&lt;0.01</td>
<td>F=1.2, p&lt;0.01</td>
<td>H0: no interaction between trigger speed and site</td>
</tr>
<tr>
<td>Trigger speed (TS) and time</td>
<td>TS</td>
<td>F=4.2, p&lt;0.01</td>
<td>F=138, p&lt;0.01</td>
<td>H0: μ(TS=SL) = μ(TS=85th)</td>
</tr>
<tr>
<td>time</td>
<td>Time</td>
<td>F=12.3, p&lt;0.01</td>
<td>F= 9.6, p&lt;0.01</td>
<td>H0: μ(time=day) = μ(time=night)</td>
</tr>
<tr>
<td>TS:time</td>
<td>TS:time</td>
<td>F=0.6, p&lt;0.01</td>
<td>F=6.5, p&lt;0.01</td>
<td>H0: no interaction between trigger speed and time of</td>
</tr>
<tr>
<td>Site and time</td>
<td>Site</td>
<td>F= 22310, p&lt;0.01</td>
<td>F= 5820, p&lt;0.01</td>
<td>H0: μ(site=Mjälga) = μ(site =Djurås)</td>
</tr>
<tr>
<td>Time</td>
<td>Time</td>
<td>F= 949, p&lt;0.01</td>
<td>F= 368, p&lt;0.01</td>
<td>H0: μ(time=day) = μ(time=night)</td>
</tr>
<tr>
<td>Site:time</td>
<td>Site:time</td>
<td>F= 76, p&lt;0.01</td>
<td>F=10.6, p&lt;0.01</td>
<td>H0: no interaction between site and time</td>
</tr>
</tbody>
</table>

### 6. Conclusions

SID and VAS are two speed warning signs that can be used to reduce driver speed to the speed limit. This study has compared and analysed the effect of VAS and SID in terms of the nature of the site (local/highway), the time of the day (day/night) and the trigger speed of each of the sign. Our preliminary results showed that SID had larger effect than VAS in local roadways but in contrast their effectivity was comparable when tested on highways. The use of SID might be the best, most appropriate in local area but the decision whether to adopt SID instead of VAS in highway might require other measures such as operational and capital costs. A cost benefit analysis is planned to be done in a future study.

The results obtained from ANOVA tests proved the hypotheses that when studying the effect of VAS and SID on driver speed, the time of the day and the type of site are significant. However, it was also proven that trigger speed of the VAS had effect on driver speed particularly at local road; the 85th percentile speed could be appropriate trigger speed for VAS in lowering the coefficient of variation. Another interesting finding was that the trigger speed of SID had no effect on driver behaviour in order to lower the mean speed. This finding might be related to the type of the warning messages displayed on this sign. SID showed the speed of each driver passing the sign. The colour of the message (in red colour) was the only difference in the information presented to the drivers who exceeded the trigger speed. VAS displayed to the contrary the message when driver exceeded otherwise the sign was a black dashboard. A preliminary conclusion is therefore that SID devices require less tuning and measurement.
of traffic data as compared to VAS (where selection of the trigger speed is important for maximum effect). In our future work, we plan to investigate more sites with different road geometric to draw more general conclusions.

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