Vehicle Activated Signs: An emerging treatment at high risk rural intersections

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Abstract

Vehicle Activated Signs (VAS) aim to improve safety by warning drivers to exercise caution and/or reduce their travel speeds at particular locations. This study examined the effect of VAS on the speeds of drivers approaching selected rural intersections in south-western Victoria. Six VAS were installed on rural undivided arterial approaches to T-intersections with limited sight distance from a side road. The VAS were activated by a movement sensor that detected the presence of vehicles on the side road. The speeds of main road drivers were recorded using pneumatic tubes. Arterial road speeds recorded at treatment sites were compared with speeds at selected comparison sites where standard static signs were present. Analysis of variance was used to compare mean speeds before and after treatment installation, controlling for any changes across comparison sites. At four sites, the treatment delivered statistically significant speed reductions of between 0.8 and 6.9 km/h. Increases in mean speeds of between 0.5 and 3.4 km/h were observed at the remaining two sites. The 85th percentile speeds followed mean speed trends. VAS may also deliver an increase in driver alertness. Other implications, including estimated crash reduction factors for this type of VAS application, are discussed further in this paper.

Introduction

Rural intersections are high crash risk locations, partly due to the high speed environment and potential for right-angle vehicle conflicts. This risk is further elevated where rural roads are steep or curved and driver sight distance may be restricted. Static signs are often used to warn main road drivers about approaching hidden side road intersections. However, standard static signs may be ineffective (Weidemann, Kwom, Lund & Boder 2011).

This paper describes the findings of an interim evaluation of the effectiveness of six vehicle activated signs (VAS). The VAS were trialled at selected rural sign-controlled T-intersections with restricted sight distance in south-western Victoria. The VAS were located on highways where an approaching intersection could not be seen easily, due to road curvature. Camera sensors detected side road vehicles approaching the stop line and activated a pair of flashing LED lights on the VAS. The type of VAS used in the present trial is shown in Figures 1 and 2.

Figure 1. Vehicle activated sign

Previous evaluations of VAS treatments indicated some success in achieving safer outcomes, depending on the treatment type. Treatment sites in this evaluation were selected on the basis of crashes across the years 2005 to 2009. Comparison sites were selected on the basis of their similarity with and proximity to the treatment sites. It was expected that an investigation into the speed behaviour of drivers under different conditions would provide insight into the ability of VAS to effectively instigate safer driver behaviour and safer outcomes on rural roads.

Method

Treatment design

The VAS lights on the main road approach were activated by a vehicle approaching the intersection on the side road. Vehicles approaching the side road were detected by a camera sensor that identified movement within a specific frame. Camera sensors were placed either opposite the side road intersection or in a corner of the intersection, depending on road features and the ability to obtain an unobstructed view (Figure 2). Note that the site detail shown in Figure 2 is typical of the layout and details for all sites in this study. When an approaching side road vehicle was detected, a wireless signal was sent to a control box mounted on the VAS. As long as a vehicle remained in the sensor zone, the VAS lights remained active. When a vehicle exited the sensor zone, a timing delay was initiated. This delay caused the VAS to flash for a fixed period of seconds after the vehicle exited the sensor zone. The time delay differed by site, according to the road environment (Table 1).

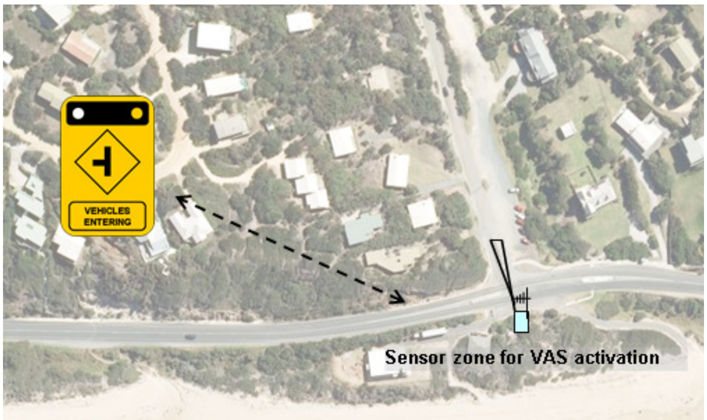

Figure 2. Example of vehicle activated sign arrangement

Table 1. VAS activation delay timeframe and sensor zone length by site

Site number	**Treatment site name**	**Delay (sec)**	**Sensor zone (m)**	**Mean speed before VAS installed (km/h)**
1	Great Ocean Road/Yarringa Road, Fairhaven	10	17	66.74
2	Hamilton Highway/Burnside Road, Murgheboluc	12	32	85.57
3	Cobden–Port Campbell Road/Cooriemungle Road, Cooriemungle (northbound)	18	50	89.35
4	Cobden–Port Campbell Road/Cooriemungle Road, Cooriemungle (southbound)	18	50	71.12
5	Cobden–Port Campbell Road/New Cooriemungle Road, Cooriemungle (northbound)	18	35	72.41
6	Cobden–Port Campbell Road/New Cooriemungle Road, Cooriemungle (southbound)	18	35	90.25

Before and after-treatment data collection occurred 17 months apart. This delay was primarily due to vandalism at site 2. A change to the initial after-data collection method was also required when technological difficulties were encountered.

There were three comparison sites in total: one in Fairhaven, one in Murgheboluc and a third in Cooriemungle. Each comparison site was within 10 km of its matched treatment site and similar in terms of speed limits, steepness, curvature and presence of nearby intersections. Although close replication of the above factors across sites was sought, it was not always possible to replicate such features. All before and after speed movements were undertaken outside school holiday periods.

Before-treatment data collection

Pneumatic tubes and traffic counters were placed at treatment and comparison sites where baseline speed data (Table 1) was collected for comparison with after-treatment mean speed data. Before-treatment data was collected between 5 – 28th May, 2010.

After-treatment data collection

Data collection at sites 3 – 6 and the Cooriemungle comparison site occurred between 18th October and 23rd November, 2011. This was an extended period due to tube outages and lower traffic volumes. Data collection for sites 1 and 2 (and each corresponding comparison sites) began on 19th October until 15th November, 2011.

Two sets of tubes on side roads were used to detect the arrival and departure of side road vehicles in the camera sensor zone. One set of tubes was placed upstream of the intersection, to indicate the beginning of a sensor zone. Another set of tubes was placed immediately at the intersection with the main road, to detect when a vehicle exited the sensor zone. Effective sensor zones on side roads were measured on site by monitoring when the VAS activated and deactivated in accordance with the presence of a vehicle in the zone. Main road tubes were placed approximately 30 metres downstream of the VAS. Figure 3 provides a schematic of the final after-treatment data collection method.

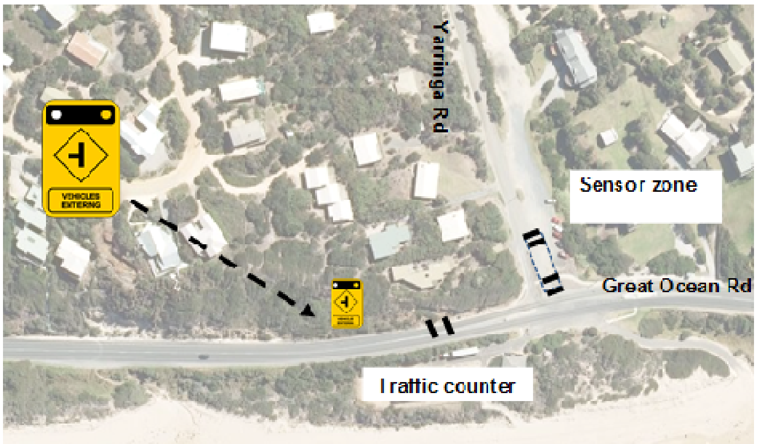

Figure 3. Example of revised data collection set-up at treatment sites

At each treatment site, testing of VAS operation was conducted prior to data collection. Tube counters were also tested to ensure that vehicle types and speeds were recorded reliably. Placement of the side-road tubes at the beginning and end of the sensor zones assisted confirmation of the VAS operation timeframes. The times of the main and the side road tube counters were synchronised to enable the research team to identify which drivers on the main road saw the operating VAS and which saw only the inactive VAS.

The VAS configurations at the Cooriemungle location were different. There were two intersections with both north and south facing VAS, resulting in four VAS sign installations for two intersections in close proximity. The other sites had one VAS per intersection and were not near to any other VAS treatments.

Site observations were conducted on the same day as the installation of after-treatment data collection tubes. Observations included testing of the VAS activation, the functionality of tubes and of observations of road users. Testing the VAS involved replicating the situation of a driver entering the side-road sensor zone and activating the VAS to warn main road drivers. The tube testing included checking the speed data received by the portable computer after a vehicle passed over the tubes at a known speed.

Observations of road user behaviour were conducted at each treatment site, with a focus on changes in speed. Observers' presence was not obvious to main road drivers.

Background to data preparation and statistical analyses

Several actions were taken to ensure only valid data was included in the analyses. The data exclusions made are shown in Table 2.

Table 2. Data excluded from statistical analyses

What was excluded	Reason for exclusion
Duplicate records	Non-meaningful data
< 6 s headway	To ensure that the speed behaviour of main road drivers at treatment sites was not affected by downstream vehicles. The headway rules were also applied at comparison sites
Unknown vehicle class	Risk of false or inaccurate data
Records with false direction of travel	Inaccurate
Records with zero number of vehicle axles	Inaccurate
Records with a wheelbase of zero	Inaccurate
Comparison site data not on intersection approach	Does not best replicate the conditions at the treatment site
Not full day of data collection	Speeds vary as a function of time of day. Days with only partial data collection completed could bias results
Days with unusually low mean speeds for certain times of a day that were inconsistent with expected speeds	Slowed traffic conditions due to road works, manoeuvring or other reasons could bias results

When the VAS was inactive, vehicles on the main road were exposed to the large static sign and included in the treatment (VAS inactive) group. The numbers of drivers who saw the active VAS or the large static sign varied by site, depending largely on the traffic volume of the side road.

Final data preparation and analysis was completed in IBM SPSS Statistics version 19. This involved both descriptive and inferential analyses. These analyses were applied to evaluate the interim effectiveness of the VAS devices for three treatment scenarios:

1. a standard static sign compared to an operating VAS

2. a standard static sign compared to a large static sign
3. a large static sign compared to an operating VAS.

SPSS was used to apply a factorial analysis of variance (ANOVA). ANOVA specifically compares means and not percentiles. The factorial ANOVA was able to cater for the treatment including both an operating VAS and a large static sign. The two factors in the factorial ANOVA were 'site' and 'condition'. The two levels of 'site' were comparison and treatment. The three levels of 'condition' were the before-treatment speed data (both at comparison and treatment sites), main road drivers who saw the large static sign (inactive VAS) and main road drivers who saw the active VAS.

The statistical analysis completed for each VAS

An overall factorial ANOVA was conducted for each VAS to indicate whether the reduction in speeds at the treatment sites was greater than any change in speeds at the comparison sites. Further detail about differences between treatment and comparison sites was gathered via a second ANOVA, where the comparison was focused on the before-treatment speed data and the speeds of main road drivers who saw the operating VAS. This analysis tested whether the reduction in speeds of drivers who saw the lights flashing was significantly greater than any changes in speeds of drivers who travelled through the sites before the treatment was installed.

A third factorial ANOVA investigated whether there were significant differences in travel speeds between drivers who saw the standard static sign and drivers who saw the large static sign (the inactive VAS). Finally, a fourth ANOVA compared speeds of main road drivers who saw the operating VAS with the speeds of drivers who saw the large static sign. This comparison focused on the effect of the flashing lights only and would indicate whether there were significant differences in speeds between these two groups.

Results

Site observations

Table 3 presents the key observations made regarding driver behaviour at the six VAS sites. Multiple contributing factors appeared to impact on driver speed decisions in these locations, including road curvature, responding to other driver's movements and preparing to turn at approaching intersections. Dog-leg movements as depicted in Figure 5 occurred frequently at the Cooriemungle locations. Overall, it was not clear if speed reductions occurred as a direct response to the VAS.

Table 3 Observations of driver behaviour in response to active and inactive VAS

Site number	Observations
1	• No sudden braking or confusion evident • Occasionally observable change in driver speed in response to active VAS • Potential slowing due to slight road curvature • No easily observable consistency in behaviour regarding the large static sign
2	• No sudden braking or confusion evident • Noticeable presence of heavy vehicles, some of which experienced decreased speeds due to steep incline on the approach to Burnside Road • No obvious consistency in behaviour regarding the active VAS or large static sign
3, 4, 5, 6	• Noticeable presence of heavy vehicles • More northbound travel compared to southbound • Difficult to know whether changes in speed were due to active VAS, road curvature or preparing to turn at approaching intersections • No obvious consistency in behaviour regarding the large static sign • Frequent dog-leg movements

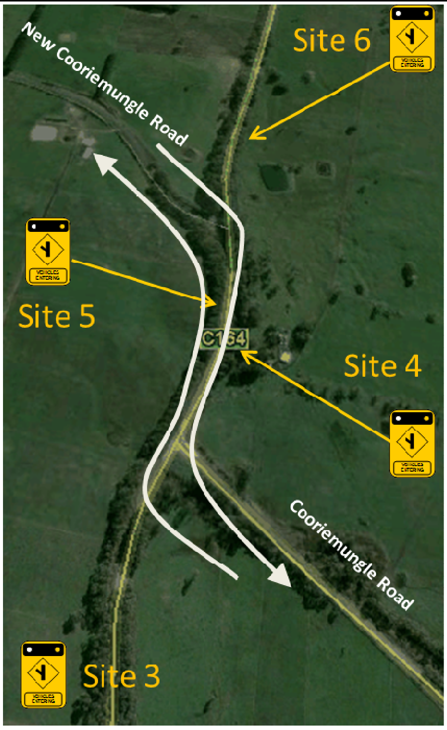

Figure 5. Cooriemungle VAS sites and the observed side road movements

Key findings from statistical analysis

Table 4 summarises the comparisons based on the site by condition interaction for each of the analyses of variance for each of the VAS. Interactions which indicate a significant increase in speed are shown in italics. Non-significant interactions are not included in the table. The overall conclusion from the statistically significant results on mean speed differences is that upgrade of a standard static sign to a VAS (active lights or not) acted to reduce highway intersection approach speeds at most VAS sites.

Table 4 Summary of statistically significant interaction effects between site and condition (cells in italics indicate significant speed increases)

Comparison	Number of statistically significant interactions	Behaviour observed	Site number where interaction was recorded
Standard static sign versus operating VAS	4/6 or 67%	Lower speeds when exposed to operative VAS	1, 2, 3, 6
Standard static sign versus operating VAS	*1/6 or 17%*	*Higher speeds when exposed to operative VAS*	*4*
Standard static sign versus large static sign	4/6 or 67%	Lower speeds when exposed to large static sign	2, 3, 5, 6
Standard static sign versus large static sign	*1/6 or 17%*	*Higher speeds when exposed to large static sign*	*4*
Large static sign versus operating VAS	3/6 or 50%	Lower speeds when exposed to operating VAS	1, 2, 3

There was often a greater reduction in mean speeds between the standard static sign and large static sign (inactive VAS) compared to the reduction between the large static sign and active VAS. The greatest mean speed reduction was 6.9 km/h at Cobden–Port Campbell Road/Cooriemungle Road, Cooriemungle for northbound traffic. The smallest mean speed reduction was 1.7 km/h at Hamilton Highway/Burnside Road, Murgheboluc. Similarly, the greatest and smallest reductions for the standard static sign to large static sign comparison were a 4.4 km/h reduction for northbound traffic at Cobden–Port Campbell Road/Cooriemungle Road, Cooriemungle, and a mean speed reduction of 0.8 km/h at Hamilton Highway/Burnside Road, Murgheboluc.

It was the location at Great Ocean Road/Yarringa Road, Fairhaven where the greatest reduction in mean speeds was recorded for drivers who saw the operating VAS compared to drivers who saw the large static sign (4.9 km/h). The smallest reduction of 0.9 km/h was recorded at Hamilton Highway/Burnside Road, Murgheboluc.

At Cobden–Port Campbell Road/Cooriemungle Road (southbound), Cooriemungle, there was a statistically significant increase in mean speeds. The increase in mean speed was 3.4 km/h in the comparison between the standard static sign and the large static sign, and 2.2 km/h between the standard static and the operating VAS. While this result does not follow the overall trend of the other sites of a speed reduction in response to VAS, there are key differences at the Cooriemungle sites compared to the other VAS sites. As noted in Table 3 and outlined in Figure 5, frequent dog-leg movements occurred between the two intersections, which caused altered speed behaviour in comparison to when a driver intends to continue past an intersection on the arterial road. It is possible that the dog-leg movements and altered traffic volumes impacted differentially on drivers' speeds, in comparison to other sites in this analysis. It is also noted that the Cooriemungle sites were atypical with four VAS placed in proximity to each other, rather than there being one VAS at one intersection in one direction only.

Table 5 shows changes in mean speeds and corresponding estimates of changes in fatal, serious injury and minor injury crash likelihood. A negative number indicates a reduction in speed, where speeds associated with the standard sign were taken from the speeds associated with the treatment under investigation.

At the four sites where the operating VAS treatment was effective in reducing speeds, there was the potential to reduce fatal crashes by an average of approximately 18% (7–26% range across the four sites). Serious injury crashes could be reduced by an average of approximately 12% (4–17% across the four sites). Similarly, casualty crashes could be reduced by an average of approximately 8% (3–11% across the four sites). The estimates were calculated using Elvik's (2009) power model of crash changes in response to mean speed changes. This estimation was based on the statistically significant mean speed reductions only and related to the standard static sign to operating VAS comparison (i.e. before and after). Data from sites 4 and 5 were not included in the crash reduction estimations, because the mean speeds recorded at these sites were atypical.

It should be noted that these preliminary estimates are based on observed mean speed reductions of a few sites. A broader review of similar VAS before- and after-treatment evaluations would be required to verify if these estimates are transferable to other locations.

Discussion

This project provided an interim evaluation of the effectiveness of VAS in warning main road drivers on rural roads about approaching sight-restricted intersections. At four sites, there were statistically significant reductions in mean speeds between 0.8 and 6.9 km/h. Although driver alertness was not measured in this study, it is expected that the VAS did also increase alertness which could further increase the crash reduction factors. At site 4, there was a statistically significant increase in speed when drivers saw the operating VAS and when drivers saw the large static sign compared to the standard static sign. Although not significant, the same trends were apparent at site 5.

Several potential explanations exist for the increased speeds recorded at sites 4 and 5. Both VAS were the preceded by another VAS, as shown in Figure 5. As such, there were four VAS installed to cover two T-intersections that were only 300 metres or so apart. This resulted in a driving experience where there was exposure to two consecutive signs a short distance apart, if the driver continued on the main road past the first intersection. It is possible that a second sign caused the warning effect to decline for the second intersection being approached. Another confounding aspect to this site was that many drivers completed a dog-leg manoeuvre by leaving one side road and entering another. This movement resulted in initially slow-moving traffic from the side roads, followed by acceleration along Cobden–Port Campbell Road past the sites of both midblock VAS. The two midblock VAS sites on Cobden–Port Campbell Road produced inconsistent results, with a mix of increases and decreases in speeds after the installation of the VAS treatment. As such, these VAS did not achieve the expected aim.

There were also smaller sample sizes at the Cooriemungle sites (including sites 4 and 5) compared to the other sites, both for the sample of drivers who saw the operating VAS and for drivers who saw the large static sign. The smaller sample sizes probably resulted from low traffic volume, reflecting long-term traffic patterns, but may be indicative of more transient factors, such as roadwork detours or driving preference.

Overall, it is apparent that VAS were most effective at reducing driver speeds where there were no major complications in the road environment, except for restricted sight distance. It is possible that dog-leg movements, multiple VAS signs in close proximity to one another and road curvature or steepness may contribute to inconsistent speed results, render the VAS less effective. Therefore, these results suggest that VAS are more effective at simpler intersection sites, where the presence of other factors (other intersections, dog-leg traffic movements) may detract from the intended effect of VAS.

Limitations

Differences between the comparison and treatment sites in road alignment, intersection positioning, direction of travel and traffic volumes may act as extraneous variables, affecting driver behaviour and the speeds at which they travelled. Data collection may be affected by maintenance activities (grass mowing, pavement or utilities maintenance, line marking), traffic events (breakdowns or crashes), weather and delays between before and after data collection. It was not possible to capture the potential presence and effect of such events on the data. However, quality measures were applied during data cleaning. The accuracy of speed measurement by pneumatic tubes may be affected by road alignment and surface.

Conclusions

VAS were effective in reducing the speeds of main road drivers at most sites; estimates based on Elvik's (2009) model suggest that VAS could reduce fatal crashes by an average of 18% and serious injury crashes by an average of 12% at similar sites.

VAS were observed to be most effective when the driving task and road environment were reasonably simple. Factors that impacted on the driving task included steep grade, road curvature, the presence of nearby intersections and other VAS, and dog-leg traffic movements across intersections.

This study found that speed reduced at four sites where VAS were positioned in 'simpler' driving environments and increased at two sites where other factors made the driving task more complex. The extent of speed changes due to VAS varied from site to site. Future work could look to investigate these effects further, to better understand the impact of the road environment on the effectiveness of VAS. Specifically, the following issues warrant further investigation:

- At what distance can a VAS be placed in proximity to another VAS without impacting on the effectiveness of either VAS, and whether VAS message content impacts this effect
- How the presence of other intersections, slowing and accelerating and dog-leg traffic movements influence a driver's ability or tendency to attend to VAS
- Impact of road curvature on the driving task in relation to VAS effectiveness
- Impact of road steepness on the driving task in relation to VAS effectiveness.

Table 5. Changes in mean speed and estimated changes in crash likelihood based on Power Model (Elvik 2009)

Site number	Condition		Estimated change in crashes (%)			
		Change in mean speed (km/h)	Fatal crashes	Serious injury crashes	Minor injury crashes	Casualty crashes
1	Standard static versus operating VAS	-5.1	-19	-13	-6	-8
	Standard static versus large static sign	-0.2^	-1	-1	0	0
	Large static versus operating VAS	-4.9	-19	-12	-5	-8
2	Standard static versus operating VAS	-1.7	-7	-4	-2	-3
	Standard static versus large static	-0.8	-3	-2	-1	-1
	Large static versus operating VAS	-0.9	-4	-2	-1	-1
3	Standard static sign versus operating VAS	-6.9	-26	-17	-8	-11
	Standard static sign versus large static sign	-4.4	-17	-11	-5	-7
	Large static sign versus operating VAS	-2.5	-10	-6	-3	-4
4	Standard static sign versus operating VAS	+2.2	+10	+6	+2	+4
	Standard static sign versus large static sign	+3.4	+15	+9	+4	+5
	Large static sign versus operating VAS	-1.2^	-5	-3	-1	-2
5	Standard static sign versus operating VAS	+0.5^	+2	+1	+1	+1
	Standard static sign versus large static sign	-0.9	-4	-2	-1	-1
	Large static sign versus operating VAS	+1.4^	+6	+4	+2	2
6	Standard static sign versus operating VAS	-5.7	-21	-14	-6	-9
	Standard static sign versus large static sign	-3.7	-14	-9	-4	-6
	Large static sign versus operating VAS	-2.1^	-8	-5	-2	-3

^ indicates a non-significant mean speed difference between conditions

References

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