New Zealand's Rural Intersection Active Warning System

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Abstract

This paper describes the development of NZ Transport Agency's rural intersection active warning system (RIAWS) and summarises key outcomes from trials at six high risk intersections from around New Zealand. The RIAWS has the aim of reducing fatal and serious crashes at high risk intersections by reducing traffic speed when potential for a collision exists. Side road and right-turn vehicles at the intersection trigger a variable speed limit of 70 km/h on the through road, thus reducing both the likelihood and energy of crashes. At two intersections a 'cross over' study design was used to evaluate the relative effectiveness of electronic 70 km/h variable speed limit signs and "Slow down" warning signs. Motorist behaviour and perceptions since the RIAWS have been operational have been positive. Traffic speeds at the intersections when the 70 km/h speed limit sign is activated have reduced significantly although the "Slow down" sign was much less effective. Based on driver feedback from the initial pilot site, most drivers both support and understand the RIAWS. The findings suggest that while motorists do naturally moderate their speed slightly through rural intersections in the presence of potentially conflicting vehicles, the variable speed limit causes a more substantial speed reduction and is likely to significantly reduce casualties at high speed intersections.

Introduction

Improving the safety of high risk intersections is a strategic priority under the New Zealand government's Safer Journeys Road Safety Strategy and the two action plans that have followed. The NZ Transport Agency's High Risk Intersection Guide outlines that intersection crashes accounted for 38% of all injury crashes on New Zealand roads between 2006 and 2010. The development, trial and implementation of a rural intersection active warning system (RIAWS) is part of this wider programme to address safety at high risk intersections.

In New Zealand, the RIAWS development began with a scoping study (Mackie 2010) to understand various intersection ITS based safety systems that have been developed overseas and the potential for the trial of such a system in New Zealand. The most compelling of the overseas examples was an intersection variable speed limit system that has been trialled by the Swedish Road Administration (SRA) between 2003 and 2007. At intersection locations where a permanent 90 km/h speed limit existed, a variable 70 km/h speed limit was activated by the presence of side road vehicles. At these sites, vehicle speeds reduced by 14 km/h on average, accepted gap time increased by 1-2 seconds and the system was perceived very positively by the motoring public (Lind 2009). Recently, vehicle activated signs at rural intersections were trialled in Australia (Bradshaw et al. 2013) and showed mean speed reductions between 0.8-6.9 km/h at some sites and speed increases of 0.5 and 3.4 km/h at others.

In New Zealand, RIAWS has the potential to reduce fatal and serious casualties at rural intersections by:

- Slowing motorists on major road intersection approaches and thus reducing crash likelihood (effectively increasing available stopping distance) and severity (less energy on impact)

- Increasing driver state awareness and therefore preparing motorists for a possible event (effectively reducing reaction time)
- Improving motorist gap judgement (accepting longer gaps) on minor road intersection approaches

Given the potential for RIAWS to improve safety at rural intersections, a trial was planned and carried out. The purpose of this trial was to demonstrate the development of a RIAWS in New Zealand and evaluate its effectiveness.

Rural intersection active warning System (RIAWS) development

A structured process was used to develop the RIAWS including the sign, trigger and control system architecture. This process included a small study identify a suitable variable speed limit for the system (Mackie 2011). The purpose of this study was to examine the role of speed in rural crashes in general and the likely effects of various speed limit options on rural intersection crashes. Key to this analysis was the considerable evidence that vehicle speed magnitude is highly related to crash risk and severity (Nilsson 2004, OECD 2006, Fildes and Lee 1993, Wramborg 2005, Richards and Cuerden 2009) and the distribution of speed has also been shown to affect crash risk (Aarts and Van Schagen 2006, Archer et al. 2008 and Garber and Gadiraju 1989). From the analysis it was determined that a variable speed limit of 70 km/h (within existing 100 km/h areas) for RIAWS would be appropriate, striking a balance between safety outcomes and overall compliance and acceptability. A “Slow Down” warning sign variation for the RIAWS was also developed for trial.

The RIAWS consists of the following elements:

- Side-road radar sensors (high definition radar) to detect approaching side road traffic approximately 150m from the intersection and activate signs
- Side-road limit line sensors (cut loops) to detect waiting traffic and trigger the end of sign activation following a delay
- Right turn bay sensors 50-66m from limit line, to activate signs, plus limit line sensors to detect queuing traffic and terminate sign activation following a delay
- Variable speed limit signs approximately 150m from intersection
- A central control system box to manage the system and accommodate data collection equipment

Selection criteria were then developed to aid the decision making progress for RIAWS implementation at candidate high risk intersections. Through this process, an initial two pilot sites were chosen for trial at Himatangi (Manawatu) – SH1/Highway 56/Himatangi Beach Rd; and at Yaldhurst (Canterbury) – SH73/Buchanans Rd. Initial indicators of success at these sites determined the further roll-out of RIAWS at a further four sites around New Zealand:

- SH1/SH10 Pakaraka, Northland
- SH10/SH11 Puketona, Northland
- SH1/Kennington Rd, Invercargill
- SH3/SH54, Newbury, Palmerston North

Figure 1 below shows the RIAWS in operation at the first pilot site at Himatangi.

Figure 1. The RIAWS in operation at Himatangi with no conflict risk (left) and a potential conflict risk (right) with a side road vehicle present (circled).

Evaluation method

Because it will take some time to determine the safety improvement benefits of RIAWS, surrogate safety measures have been developed to evaluate short to medium-term effectiveness. Therefore, the more immediate objectives of the RIAWS trial are to evaluate the feasibility and indicative safety benefits of RIAWS. This study evaluated the following outcomes:

1. RIAWS development and operational performance
2. Major road traffic speed through the intersection
3. Public perception and understanding of the system

To understand the operational performance of RIAWS, the project team attended a 'launch' of each system and observed it operating. Further, a regional engineer carried out a structured audit of various characteristics of the system shortly afterwards. The data collection system provided data from which an analysis of sign activation time and traffic speed could be carried out.

At the pilot sites, speed was measured for each direction on the major road, both at the sign (using radar) and at the intersection (using inductive loops). A target of 14 days of data collection prior to, and following RIAWS commissioning, was set. In reality, eight days of data were collected before and after RIAWS commissioning at the pilot sites. With such large sample sizes (traffic volume), statistical significance is reached very easily with speed reductions of only one or two km/h (possibly within the measurement error of the system). A more meaningful measure of effectiveness for speed changes is effect size (Cohens d), as it considers the change in mean and the standard deviation of the data to estimate meaningful changes in speed.

A public perceptions survey was carried out for the initial pilot site (Himatangi), by capturing number plate information for vehicles passing through the intersection using automatic number plate recognition (ANPR) and then accessing vehicle owner address details through the motor vehicle registry (following NZ Transport Agency approval). A paper survey was then mailed to vehicle owners, with an option of completing the survey online. The survey asked motorists a range of questions related to the meaning, conspicuity and legibility of the signs and any perceived hazards and suggested changes associated with the system.

A substantial amount of video footage at the pilot intersections were also gathered for initial subjective analysis, but also for a quantitative gap analysis which will be completed at a later time. The video data were collected via a waterproof video camera fixed to a lighting pole at the intersection.

For the further four trial sites speed was only collected at the intersection and video data were not collected. At two of these sites (in Northland) the “Slow Down” sign format was evaluated in addition to the 70 km/h VSL sign using a ‘cross-over’ study design. For an initial period the VSL sign was used at SH1/10 (Pakaraka) and the “Slow Down” sign at SH10/11 (Puketona). After a monitoring period, the signs were swapped and a further period of monitoring was carried out (Figure 2). By using this study design any order or location effects were removed from the comparison, allowing a robust understanding of the merits of each sign option.

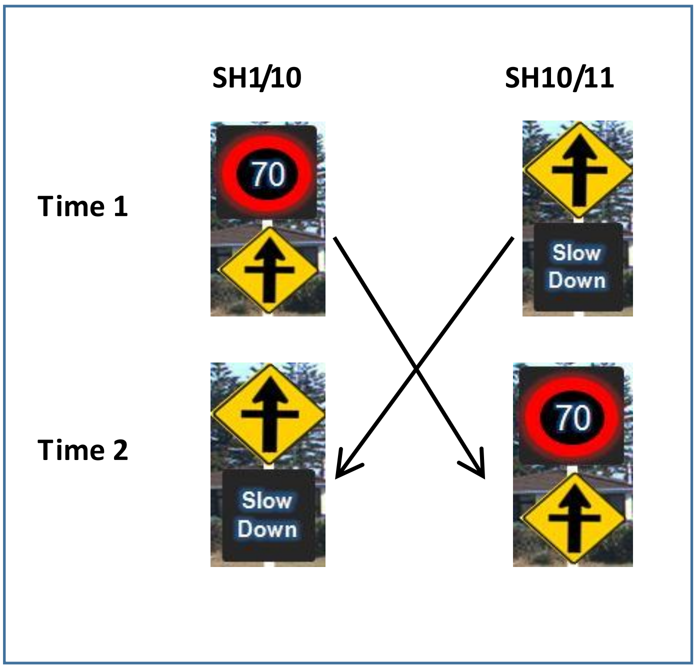

Figure 2: Cross-over study design to evaluate two Northland RIAWS sign options

Evaluation outcomes

For this paper, key examples of the data are presented. For a full explanation of the trial findings at each of the sites, refer to the project report (Mackie and Scott 2014).

System utilisation

The proportion of time the VSL signs spent on and off was measured and analysed to check power demand and ensure that the system was not being overused or underused. An example of the sign activation patterns is shown in Figure 3, for Yaldhurst. At both Himitangi and Yaldhurst the sign was active for over 50% of the time for large parts of daylight hours, transitioning to minimal activation at night. The project team has concluded that this activation pattern is acceptable as it reflects the periods of demand and does not unduly slow through vehicles when there is no collision risk. This may be particularly beneficial for trucks at night.

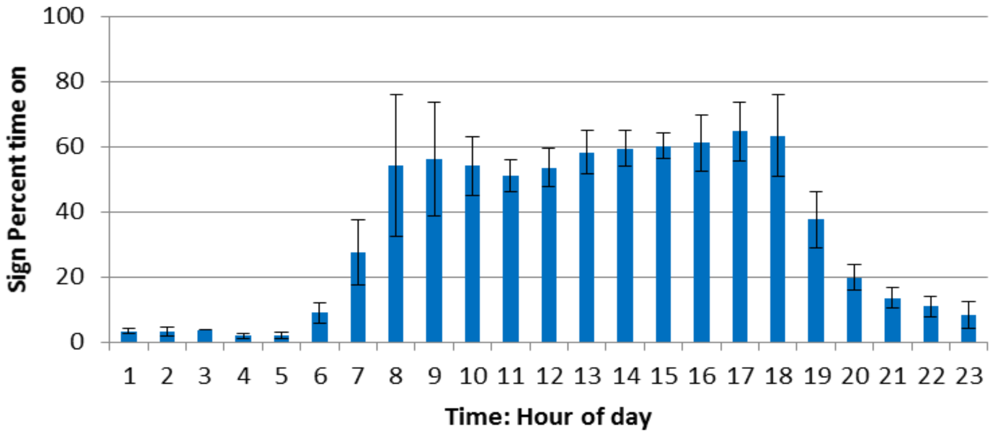

Figure 3. Average and standard deviation (error bars) sign utilisation at Yaldhurst

Major road traffic speed through the intersection

The RIAWS has been effective in reducing traffic speed through the intersections. When the signs are activated by potentially conflicting traffic, modal speeds are typically very close to the speed limit of 70 km/h (Figure 4), and the speed reductions caused by the RIAWS have been sustained for at least 14 months following installation. At Yaldhurst, before the electronic signs were made operational, it was possible to categorise the pre-RIAWS speed data in the same way as the post-RIAWS speed data, using the sign triggers to determine whether the sign *would* be on or not, without them actually being illuminated. This allows motorist speed behaviour, when potential conflict situations exist, to be differentiated from motorist speed when there are no potentially conflicting vehicles and allows a direct comparison with the RIAWS 'sign on' and 'sign off' data. Table 2 shows descriptive statistics for the short-term Yaldhurst evaluation.

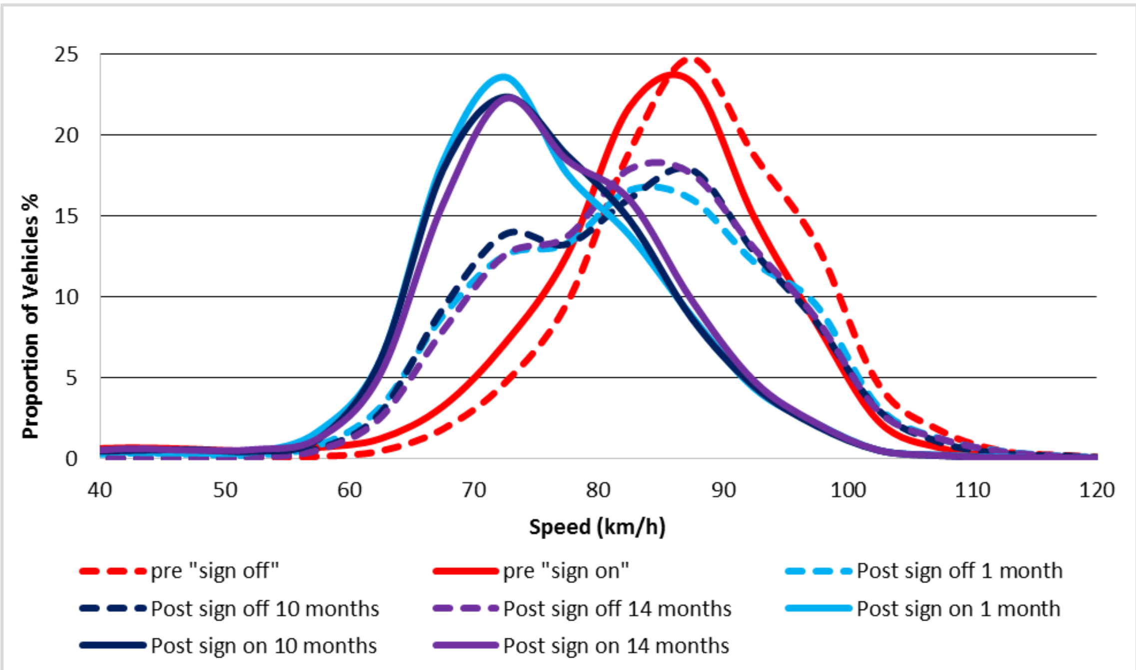

Figure 4. Example of speed profile changes at Yaldhurst in the northbound direction before and after RIAWS Installation.

Table 1. Speed data for Yaldhurst pre and post RIAWS installation

Northbound Intersection							
		Vehicle Count	**Mean Speed (km/h)**	**Standard Deviation**	**85th % speed**	**Effect Size (Cohen's d)**	**Modal speed**
Pre	**sign off**	10971	88	9	98	-	90
	sign 'on'	16410	84	12	94	-	81
Post	**sign off**	12448	83	13	95	0.50	81
	sign on	16394	76	11	86	0.72	72
Southbound Intersection							
		Vehicle Count	**Mean Speed (km/h)**	**Standard Deviation**	**85th % speed**	**Effect Size (Cohen's d)**	**Modal Speed**
Pre	**sign off**	11227	90	9	99	-	95
	sign 'on'	14858	88	10	98	-	90
Post	**sign off**	11469	85	12	98	0.47	81
	sign on	16435	77	10	88	1.01	71

The effects sizes for the RIAWS 'sign on' data were large, indicating a meaningful change in the speed profile following RIAWS activation. The mean and 85% speeds did not decrease as much as modal speed. This is due to some motorists not being exposed to the VSL, but by the time they are at the intersection, the system has been activated and their understandably higher speed is categorised with the 'sign on' data.

Figure 5 shows examples of the signs that were used in the 'cross-over' study for the Northland intersections. For the VSL sign, alternating beacons supported the speed limit sign, whereas for the Slow Down sign the words flashed to catch drivers' attention.

Figure 5: The two RIAWS sign variations used in Northland

The modal speeds for the 'cross-over' study, showing the 70km/h VSL sign relative to the "Slow down" sign are shown below in Figure 6. The "Slow down" signs are clearly less effective than the 70km/h signs with higher modal speeds at each location when the "Slow down" signs were operational.

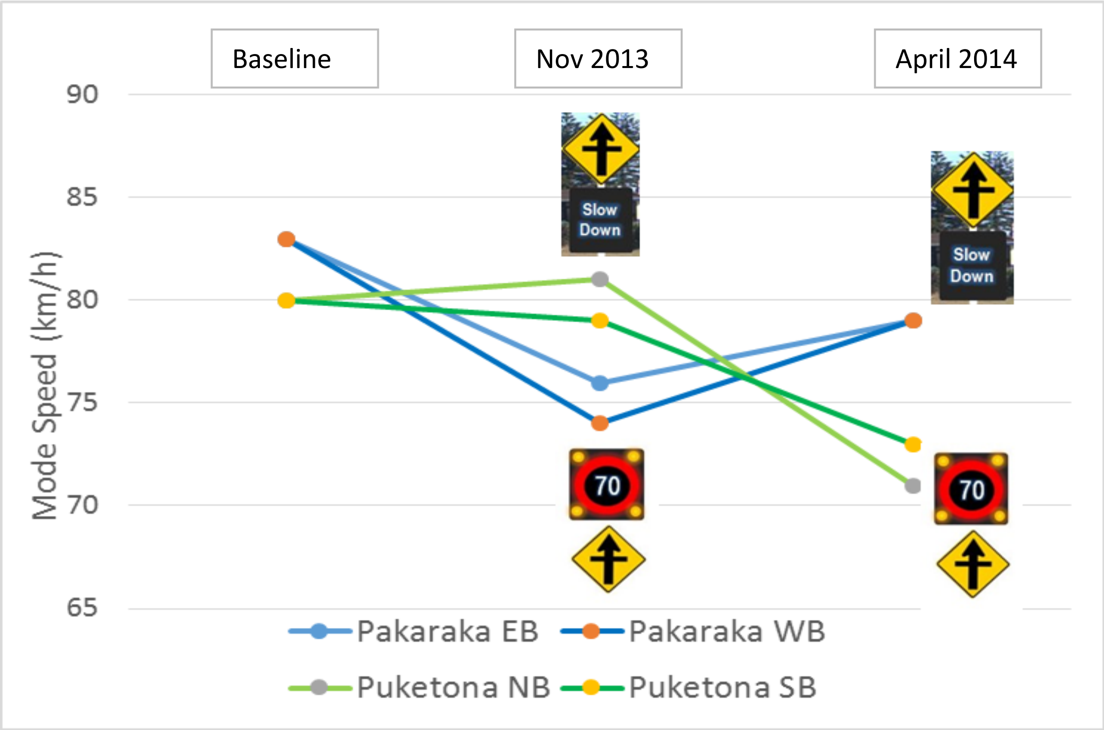

Figure 6: Modal speeds and sign type

Clearly the actual safety effects (reduced crashes and severity of injury) of RIAWS will take time to emerge. However, given the effects of the system on reducing traffic speed and the absence of any serious operational or user issues to date, the system shows promise for improving safety at rural intersections.

Public perception and understanding of the system

For the Himatangi perceptions survey a total of 307 survey responses were collected (297 posted paper surveys and 10 online) representing a 31% response rate. Overall, based on the survey responses, the RIAWS has been positively received. There have been a minority of negative comments regarding the system however it is important to distinguish between drivers' opinions of the system as opposed to their actual behaviour, which generally appears to be positive to date. Nevertheless, some of the feedback can be used to further improve the RIAWS at future sites. The majority of respondents correctly understood the key message from the RIAWS at Himatangi, although a minority did not understand the regulatory nature of the signs or why they were being instructed to slow down by the signs. More conspicuous signage indicating the up-coming intersection and the potential for conflict could be considered.

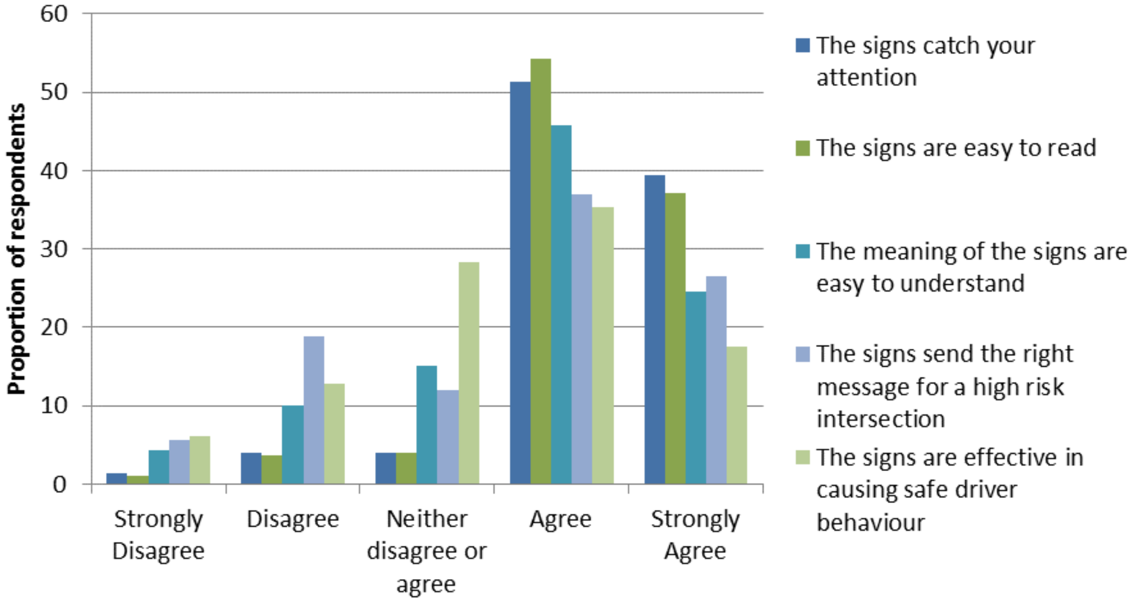

Figure 1. Survey response to question: "For the signs shown in the picture, and from the perspective of a motorist driving through this intersection, please circle the number that most closely matches your level of agreement with each statement"

Discussion

There is some evidence that motorists slow down slightly at rural intersections when the potential for a collision exists. However, most motorists do not adjust their speed sufficiently to mitigate the effects of a potential collision situation, no doubt trading off safety with convenience, or perhaps being unaware of the consequences of an intersection collision at 80-100 km/h. The relatively high level of compliance with RIAWS suggests that the system is highly credible to most motorists and the variable speed limit of 70 km/h may help motorists by extending their existing precautionary behaviour, in line with current evidence of the survivability of crash situations at various speeds.

It seems clear that the "Slow down" sign is not as effective as the VSL sign in reducing traffic speeds. This finding is supported by the findings of Bradshaw et al. (2013) who found variable results from a warning sign that was not associated with a speed limit changes. Other New Zealand trials of VSL signs at rural schools and on school buses have been highly effective and lend further support to VSL signs at highly credible locations. Together these findings suggest that in order to achieve 'safe speeds' at high risk intersections, VSL signs are needed as they send a clear instruction about the behaviour that is required of motorists.

Although a trial has not yet been carried out for rural intersections, it may be that a VSL of 60 km/h is more appropriate at locations where operating speeds are lower than 100 km/h due to road geometry constraints. Such a scenario has been trialled for a rural school where the operating speed was approximately 80 km/h and very good compliance with the 60 km/h VSL was achieved.

Following the success of the trial, RIAWS are currently being installed at another four sites. Work is also underway to establish standard operating procedures for RIAWS as part of New Zealand's suite of road safety countermeasures.

Conclusion

A rural intersection active warning system (RIAWS) has been developed and evaluated in New Zealand. The findings to date suggest that the RIAWS performs well in a diverse range of intersections and has the potential to significantly reduce fatal and serious casualties at rural high risk intersections by extending drivers' natural intersection risk management strategies. The study findings suggest that a variable speed limit sign results in lower traffic speed through high risk intersections than a "Slow down" warning sign.

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Acknowledgement

This work was funded by the NZ Transport Agency.