Development and Evaluation of a Rural Intersection Active Warning System

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ABSTRACT

This study describes the development of a Rural Intersection Active Warning System (RIAWS) and the outcomes from the first two RIAWS pilot sites in New Zealand. The RIAWS trial is part of a wider programme by the NZ government to address safety at high risk intersections. The evaluation measures reported here include system performance, motorist speed and driver perception. 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 sensors trigger a variable speed limit of 70 km/h on major roads with existing 100 km/h speed limits. Motorist behaviour and perceptions since RIAWS implementation have been positive. Modal traffic speeds at the intersections when the 70 km/h speed limit sign is activated range from 68-72 km/h compared with modal speeds of 81-96 km/h before RIAWS installation, when potentially conflicting traffic is present. Driver feedback via a questionnaire suggests that most motorists understand the purpose of the system and believe the signs are conspicuous, legible and credible. The findings suggest that RIAWS is likely to significantly reduce the crash forces involved in collisions at high speed intersections and potentially reduce the likelihood of collisions.

Keywords: Road Safety, intersection, variable speed limit, human factors

INTRODUCTION

New Zealand's Safer Journeys Road Safety Strategy includes a strategic priority of improving the safety of high risk intersections. 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.

As part of the action plan to address high risk intersections in New Zealand, a scoping study was carried out (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 a system that has been trialled by the Swedish Road Administration (SRA) between 2003 and 2007 where variable speed limit (VSL) field trials were implemented at 19 locations in different parts of the country. Many of the installations were at intersections where the variable speed limit was triggered by the presence of a side road vehicle that may have the potential for a collision. At locations where a permanent 90 km/h speed limit existed, a variable 70 km/h speed limit was installed. 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).

It was determined that an intersection variable speed limit system triggered by potentially conflicting vehicles could be implemented in New Zealand. However, since no technical specifications for the system were available, it was designed from first principles.

DEVELOPMENT OF THE RURAL INTERSECTION ACTIVE WARNING SYSTEM

A structured process was used to develop the RIAWS. The sign design utilized a Delphi method, which involved an iterative improvement process via an expert group. This included key stakeholders and representatives from NZ Transport Agency (National office as well as regional representation), NZ Police and Automobile Association. A further step to determine the RIAWS sign design included focus groups administered in five regional centres around New Zealand. In total, 60 road safety experts participated in the process.

Following this process, the sign formats for RIAWS were agreed (Figure 1). A “Slow Down” sign option was included in the trial as some believed this format would be more appropriate than a variable speed limit.

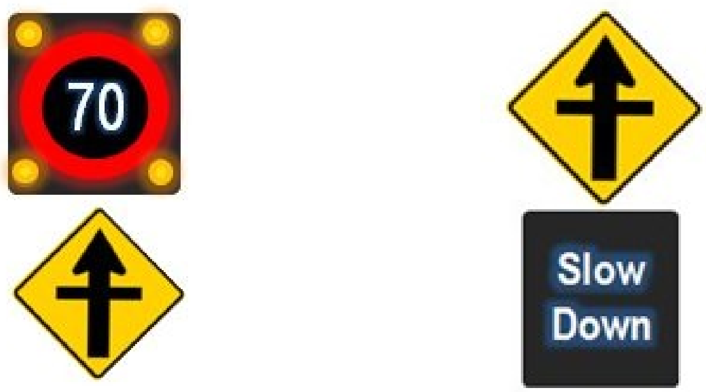

Figure 1. Signs developed for use as part of the RIAWS trial

A further small study was carried out to assist with the decision making process for setting the 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 then specifically examine the likely effects of various speeds 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), but 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 60 km/h would be a ‘Safe System’ solution for the RIAWS. However, further discussion among the project team and wider reference group resolved that a 70 km/h variable speed limit may have overall better compliance by motorists. Based on this, a 70 km/h variable speed limit was chosen for RIAWS by the project reference group and project team.

The RIAWS is designed to slow major road through traffic on approaches to an intersection when a potential collision risk exists. Variable speed limit signs on the major road intersection approaches are triggered by the presence of side road and turning traffic (Figure 2):

Figure 2. The RIAWS in operation at Himitangi with no conflict risk (left) and a potential conflict risk (right) with a side road vehicle present (circled).

A number of human factors questions arose from the RIAWS development process as follows:

- What conspicuity, comprehension and compliance would be associated with the RIAWS in a rural intersection setting?
- How might drivers respond to sudden activation or de-activation of the sign
- To what extent might risk homeostasis apply? Will crossing drivers compensate for the lower speed environment by taking more risks in gap selection?
- Will the system have novelty effects or will the affects be lasting?

SYSTEM 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

Further work is underway to understand the motorist gap selection patterns following RIAWS installation.

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 also provided data from which an analysis of sign activation time could be carried out.

Traffic 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.

A public perceptions survey was carried out for Himitangi only, 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.

RIAWS EVALUATION OUTCOMES

Sign activation performance

The proportion of time the variable speed limit signs spent on and off was measured and analysed, to check power demand and ensure that the system was not being overused or underused. Underuse might make the sign 'surprising' whereas overuse could lead to de-sensitization. An example of the sign activation patterns for one of the sites is shown in Figure 3. At times 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.

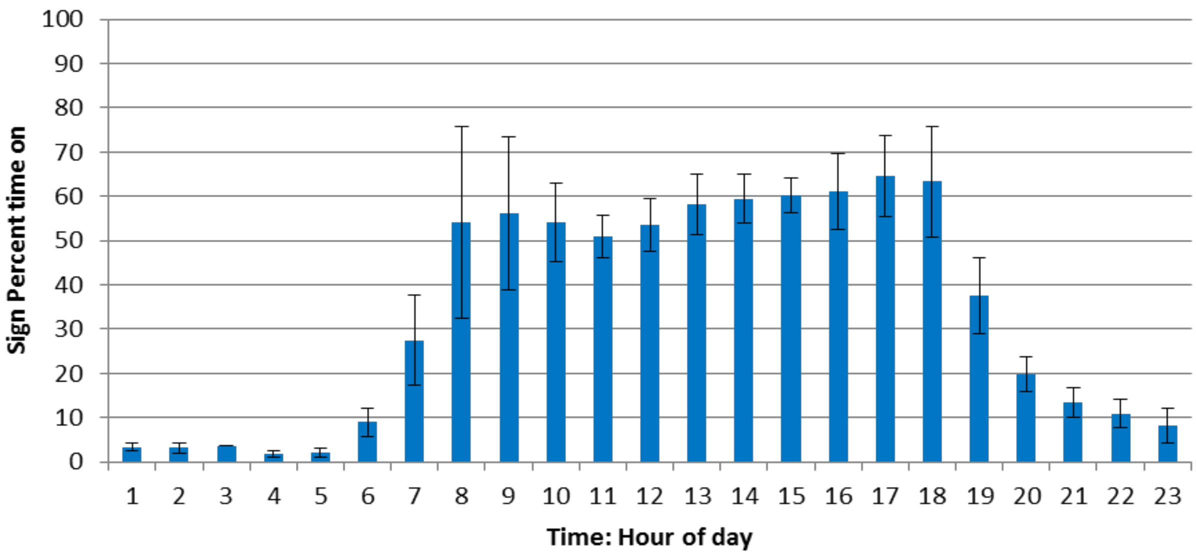

Figure 3. Average and standard deviation (error bars) percent time on for each hour of the day (for seven days) for the northbound direction at one of the pilot sites

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 now typically very close to the speed limit of 70 km/h and this effect has been maintained 9-months following system commissioning (Figure 4). Statistically it is clear that the RIAWS system has positively reduced traffic speed at the intersections. For example, a t-test comparing the mean speed at the Yaldhurst intersection before and after RIAWS installation (with the sign activated in the post condition) returns the following results:

Degrees of freedom = 16393, t statistic = 64.9, p = < 0.001 (very close to zero)

Further, effects sizes (Cohen's d statistic) for the intersection comparisons with the sign on were typically between 0.72 and 1.0 (Error: Reference source not found), reinforcing a strong real effect in reduced mean speed.

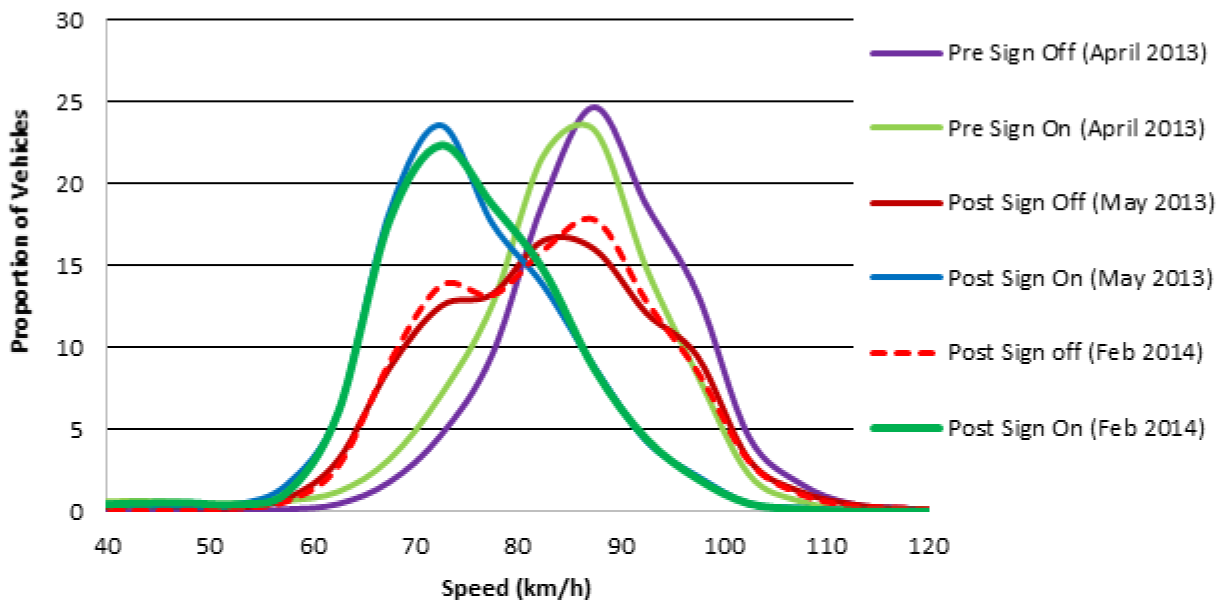

Figure 4. Speed profiles for Yaldhurst RIAWS site

However, statistical significance is less relevant here because it is very obvious that the system has positively affected mean speed. More importantly is whether RIAWS has had sufficient effect to improve road safety at high risk intersections. Prior to RIAWS, modal intersection speeds ranged between 81-96 km/h across the Himitangi and Yaldhurst sites. Following RIAWS, when the sign was active, modal intersection speeds ranged between 68-72 km/h.

It is also important to note that there is not a perfectly clear distinction between those motorists exposed to the 70 km/h speed limit, compared with those who were not. A proportion of motorists who passed the sign (approx. 150m from the intersection) will have assumed the speed limit is either 100 km/h if the sign was ‘off’, or 70 km/h if the sign was activated, but then before they reached the intersection speed loops the signs will have been either activated or turned off. For example, a motorist could pass the sign without it being activated and so the motorist will consider the speed limit to be 100 km/h. Meanwhile a side road or turning vehicle triggers the system and signs are activated. By the time the major road vehicle triggers the speed loops at the intersection, the data will be recorded as ‘sign on’ data, yet the motorist will have assumed the speed limit is still 100 km/h. So in reality, the ‘sign off’ traffic speed data is likely to be slightly lower than the actual speed of those motorists who were exposed to the sign being inactive. Likewise, the ‘sign on’ data is likely to be slightly higher than the actual speed of those motorists who were exposed to the sign being active. For this reason, it is recommended that the modal speeds provide the best indication of the change in motorist speed behaviour before and after the installation of the RIAWS system.

In Table 1, ‘sign off’ and ‘sign on’ sub-conditions exist for the pre-RIAWS condition. 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.

The data shows that even without the RIAWS, traffic speed through the intersections were slightly slower when potentially conflicting vehicles were present. However, the RIAWS has caused traffic speed to reduce even further, with modal speeds during RIAWS sign activation being 68-72 km/h across each direction and both sites.

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

		Vehicle Count	Mean Speed (km/h)	Standard Deviation	85th % speed	Effect Size (Cohen's d)	Modal speed
Northbound							
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
	sign on	19208	82	10	92	0.90	81
Southbound							
		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
	sign on	16611	82	10	93	1.77	82

Public perception and understanding of the system

In total 307 survey responses were collected (297 posted paper surveys and 10 online) representing a 31% response rate. Overall, based on the driver feedback, the RIAWS has been positively received. A minority of negative comments elude to various deficiencies 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 Himitangi, 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.

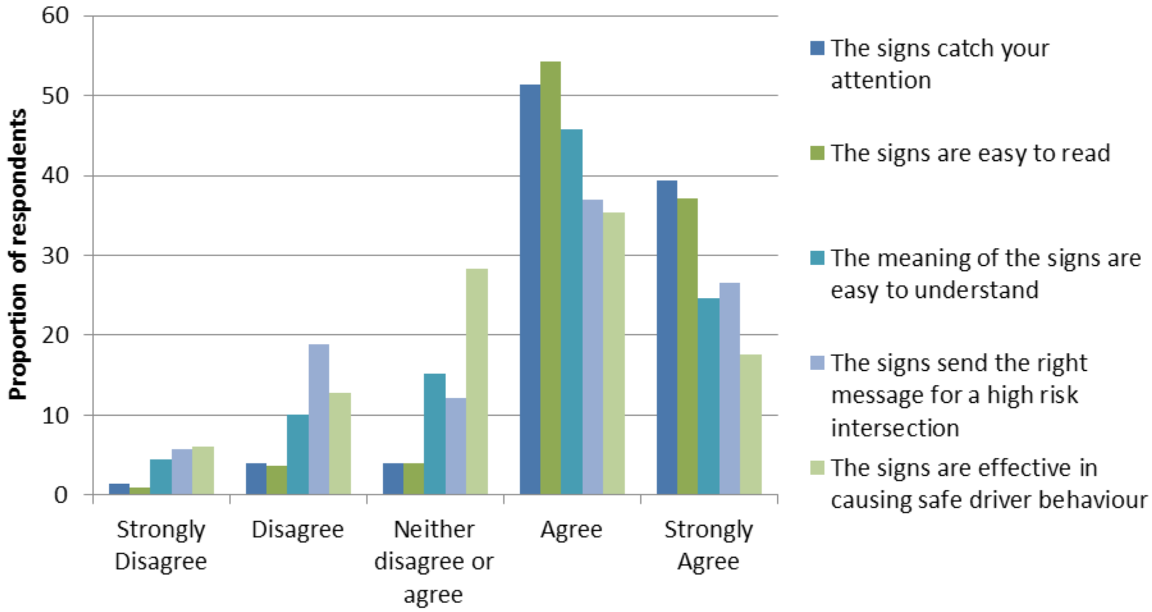

Figure 5. Survey response to question: "*For the signs shown in the picture, and from the perspective of a motorist driving through this intersection, please circle the number that most closely matches your level of agreement with each statement*"

DISCUSSION

From the data it is clear that generally, motorists slow down slightly at rural intersections when the potential for a collision exists, although this was clearer at Yaldhurst than at Himitangi. However, it appears that most motorists do not adjust their speed sufficiently to mitigate the effects of a potential collision situation, possibly 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 simply represents an extension of reasonable precautionary behaviour at rural intersections. It could be said that RIAWS helps motorists by extending their existing precautionary behaviour, in line with current evidence of the survivability of crash situations at various speeds.

Applying the analysis that was carried out earlier (Mackie, 2011), it could be interpreted that the RIAWS is likely to significantly reduce the crash forces involved in collisions at the intersection and potentially reduce the likelihood of collisions. Applying the RIAWS speed outcomes to the risk of KSI curve for side impacts (adapted from Richards and Cuerden 2009), it is clear that in theory the RIAWS system should have substantial effects on intersection safety (Figure 6). But only the crash behaviour of the intersections over time (minimum five years) will determine if this eventuates in reality.

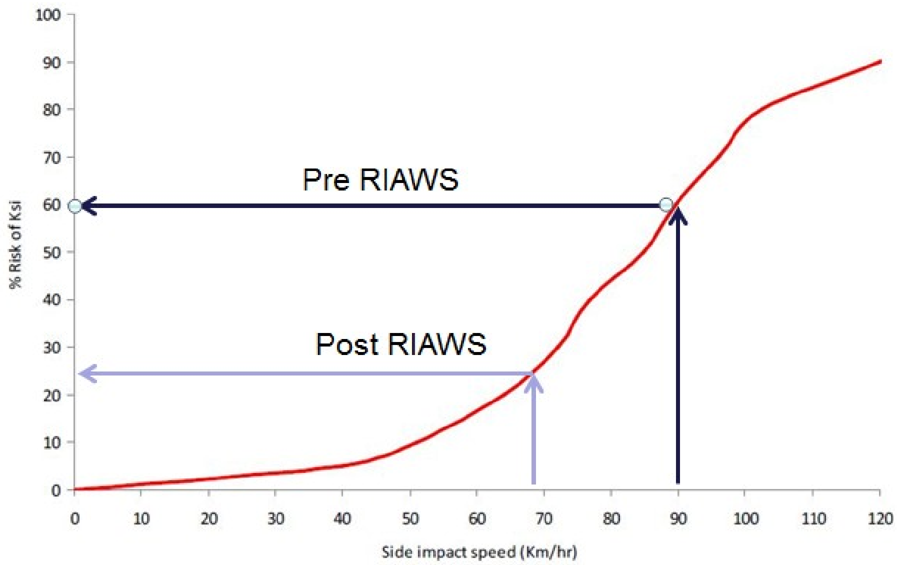

Figure 6. Estimated improvements to risk of death or serious injury following RIAWS installation

Following the application of the selection criteria outlined earlier, four more RIAWS sites have been chosen, are currently in operation and are being evaluated. Further analyses of motorist gap selection at Himitangi (using video collected at the intersection) and evaluation of the further four trial sites will also help to confirm the merits of RIAWS (or otherwise). There are a number of considerations for the wider use of RIAWS in New Zealand including cost, the nature of the problems present at specific intersections and the potential programming of 'Safe System' physical infrastructure such as a rural roundabout.

There may be a case for using RIAWS when a high risk intersection warrants transformational remediation such as a rural roundabout, but funding does not allow this to happen for a number of years. In such situations RIAWS may provide a useful and relatively cost effective interim countermeasure until transformational works are implemented. At other intersections, the prioritisation process might identify that an intersection ranks relatively high in terms of road safety risk but it doesn't quite meet the threshold for significant infrastructure works. In such a situation, RIAWS might also provide a useful road safety solution.

The human factors questions that were posed at the beginning of the project have mostly been positively answered and there do not appear to be any significant risks associated with the system. A minority of people did find the meaning of the system confusing so it will be important to monitor the sites for any behavioural signs of driver confusion. Also, the side road gap study will help to determine whether RIAWS improves or worsens motorist gap judgement.

CONCLUSION

A RIAWS has been developed and evaluated in New Zealand. The findings to date suggest that the system performs well and has the potential to significantly reduce fatal and serious casualties at rural high risk intersections by extending drivers' natural intersection risk management strategies. Longer-term evaluation of crash data from the pilot sites and further trial sites will help to confirm the efficacy of RIAWS in New Zealand.

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