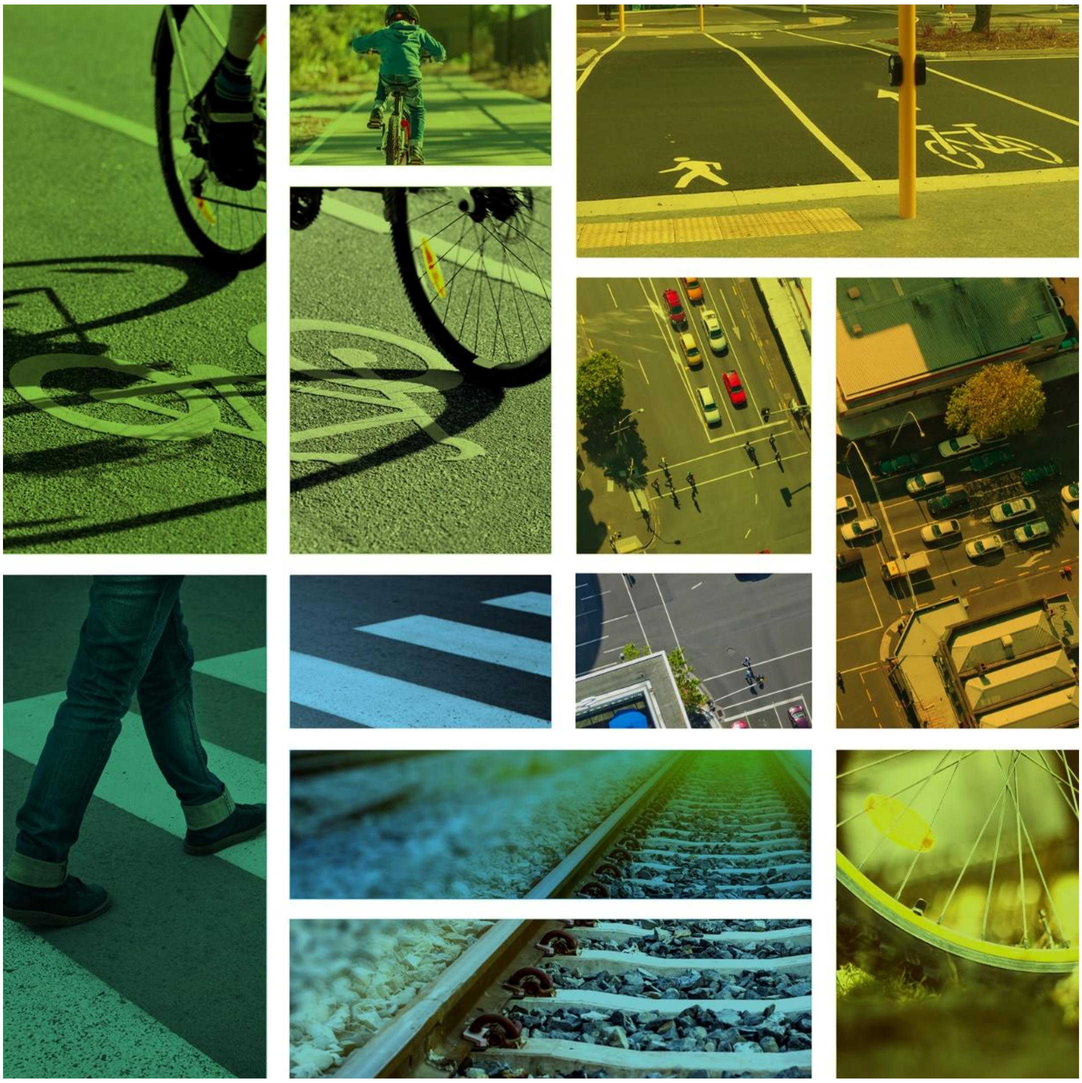

INTERSECTION SPEED ZONES

LONG-TERM OPERATIONAL AND SAFETY PERFORMANCE

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2	Revised report including updated New Site numbers	Hamish Mackie and Rebekah Thorne	05/06/20
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EXECUTIVE SUMMARY

Background and aim

Intersection Speed Zones (ISZs) have been in place at ten rural intersections around New Zealand for close to five years. Earlier evaluations of these ISZs found they were associated with substantial safety benefits, and they have since been rolled out to several more sites and also adopted in Australia.

The aim of this study was to assess the long-term crash, speed, and operational performance of the original ten ISZs, the short-term performance of newer ISZs, and to understand any operational and design issues which may have allowed fatal or serious crashes to happen at ISZ sites, or which have been raised by stakeholders.

Method

The performance of ISZs was assessed through:

- Analysis of pre/post-ISZ crash rates at the 10 original sites using Traffic Crash Reports (TCRs)
- Deeper review of post-ISZ fatal and serious injury crashes at all current and previous ISZ sites, as well as minor and non-injury crashes at new ISZ sites using TCRs
- Analysis of current ISZ speed performance compared to earlier reported speed performance using speed data collected continuously through speed loops at intersections
- Analysis of feedback from engineers, ISZ operators, and other stakeholders on ISZ design and performance.

Findings

The key study findings were that:

- ISZs are associated with a 69% reduction in fatal and serious injury crashes and a 28% reduction in total crashes since installation at the original sites between 4 and 7 years ago. Hence it appears that ISZ reduce both the severity and likelihood of crashes happening.
- Crash reductions at ISZ sites run counter to a comparison group of similar intersections and to national trends across all rural intersections, at which crashes have been increasing since 2013.
- Mean speeds at ISZ intersections are between 3km/h and 10km/h lower when the ISZ signs are active compared to when they are not active.
- Speed reductions at ISZ intersections remain consistent over time (no evidence of reduction in compliance), with some variability between sites.
- Some operational issues have been raised by motorists and internal stakeholders, but some issues are not supported by objective data.

Conclusion

Overall, the Intersection Speed Zones are continuing to demonstrate effectiveness in reducing speed, high severity crashes, and to a lesser extent all crashes at high-speed rural intersections. On this basis and their relative cost-effectiveness, ISZs should be considered for further widespread application. Recommendations are provided at the end of this report.

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1. INTRODUCTION

1.1. Background

Intersection Speed Zones (ISZs), formerly known as Rural Intersection Active Warning Systems (RIAWS), are part of the Waka Kotahi NZ Transport Agency's Safer Journeys road safety strategy to improve safety at high-risk rural intersections. ISZs are intersections along high-speed priority roads such as state highways where electronic Variable Speed Limit (VSL) signs temporarily reduce the legal speed limit to for vehicles travelling along the priority road when there are vehicles turning into and out of side roads.

The system aims to reduce impacts speeds to survivable levels at high speed priority-controlled intersections, by reducing the speed limit to 60 or 70 km/h when intersecting vehicles exist. With braking, collisions should then be no greater than 50 km/h, which should be survivable. The system includes a control system, sensors, and variable speed limit (VSL) signs on the priority road approaches in each direction. Almost all priority roads on which ISZs have been installed have permanent speed limits of 100km/h.

Figure 1: Northbound VSL sign at Brynderwyn Intersection Speed Zone

ISZs were first introduced to New Zealand in 2013. This followed a scoping study completed in 2010 which recommended a form of speed limit-based intersections safety systems based on a Swedish model as a cost-effective measure to reduce fatalities and serious injuries at these intersections. A design process was then completed and an ISZ model developed for the NZ context. A trial was completed at two pilot sites, in Himatangi, Manawatu, and Yaldhurst, Canterbury, following which ISZs were rolled out at a further eight sites around the country. The effectiveness of the ISZs with regard to speed, vehicle gap selection, road user perceptions, preliminary crash outcomes, and system performance was evaluated before and after ISZ installation in two studies; one completed in 2015, and a longer-term follow-up in 2016. For further information and context on the earlier trial and evaluation processes, see previous reports[1,2].

The trial evaluations found there was a dramatic decrease in the incidence of fatal and serious injury crashes at intersections with ISZs, as well as a reduction in total crashes, and that ISZs had lasting speed-reducing impacts on vehicles travelling through the intersections[2]. The frequency of small gap selection by vehicles exiting side roads was also found to decrease, and driver perceptions were generally positive at the Himatangi intersection where these were studied[1].

Following the success of the trial, Waka Kotahi has rolled these out to several more rural intersections and Network Operating Contracts are starting to include them more routinely. City Councils have also started to adopt them for use on local roads.

As the first ten ISZ installations have now been operational for close to five years, a further assessment of the safety benefits of ISZs is warranted, along with ongoing speed reduction performance, any ISZ design considerations that may have allowed fatal or serious crashes to occur, and their continued operational performance.

As well as giving further confidence to their use in New Zealand, this analysis will also be useful for Australian States who have started to roll out their own versions of the ISZ.

1.2. Purpose

The purpose of this study is to assess the ongoing crash, speed, and operational performance of ISZs and understand design considerations that may have allowed fatal or serious crashes to occur.

The project scope involves:

- analysis of crash performance before and after ISZ installation at the 10 original trial sites compared to 10 control sites
- preliminary analysis of crash performance before and after ISZ installation at 11 new Waka Kotahi ISZ sites
- examination of fatal and serious injury crashes occurring after ISZ installation at all current and decommissioned ISZ sites
- analysis of mean and 85th percentile speeds at all ISZ sites for which data is available, compared to earlier reported speed performance
- analysis of current speed distributions at the 10 original trial sites compared to earlier report speed distributions
- analysis of design and operational issues at ISZ sites.

[1] Mackie, H., Scott, R., Hawley, G. (2015) Rural Intervention Active Warning System (RIAWS) Trial. A report prepared for the NZ Transport Agency.
[2] Mackie, H., & Scott, R. (2016) Long-term update of RIAWS performance. A report prepared for the NZ Transport Agency.

2. METHOD

2.1. Sites

A total of 21 active ISZ sites were analysed for speed, crash, and operational performance, comprising the 10 'original' sites included in the previous report[3] and a further 11 'new' sites at which ISZs have since been installed (Table 1). Two decommissioned sites were also included.

Table 1: Original Intersection Speed Zone sites

#	Site name	Intersection	District	ISZ live date	VSL (km/h)
		Original ISZ sites			
1	**Himatangi**	SH1/Hwy 56/Himatangi Beach Rd	Manawatu	Dec-12	70
2	**Yaldhurst**	SH73/Buchanans Rd	Christchurch City	May-13	70
3	**Kennington**	SH1/Kennington Rd	Invercargill City	Oct-13	70
4	**Newbury**	SH3/SH54	Manawatu	Oct-13	70
5	**Pakaraka**	SH1/SH10	Far North	Oct-13	60
6	**Puketona**	SH10/SH11	Far North	Oct-13	70
7	**Burnham**	SH1/Burnham Rd/Aylesbury Rd	Selwyn	Oct-14	70
8	**Longlands**	Railway Rd S/Longlands Rd E	Hastings	Oct-14	70
9	**Kaiapoi**	SH1/Williams St	Waimakariri	Nov-14	70
10	**Puketaha**	Holland Rd/SH1B	Waikato	Jan-15	70
		New ISZ sites			
11	**Brynderwyn**	SH1/SH12	Kaipara	Dec-16	60
12	**Oakleigh**	SH1/Mangapai Rd	Whangarei	Apr-19	60
13	**Waipu**	SH1/Shoemaker Rd	Whangarei	Apr-19	60
14	**Kopu**	SH25/Hauraki Rd	Hauraki	Jul-19	60
15	**Gordonton**	SH1B (Gordonton Rd)/Taylor Rd	Waikato	Apr-19	60
16	**Te Puninga**	SH27/Horrell Rd	Matamata-Piako	Jul-19	70
17	**Hinuera**	SH29/SH27	Matamata-Piako	Apr-19	60
18	**Hopkins**	SH29/Hopkins Rd	Matamata-Piako	Jul-19	60
19	**Piarere**	SH1/SH29	Matamata-Piako	Aug-19	60
20	**Luggate**	SH6 (Wanaka-Luggate Hwy)/SH8A	Queenstown-Lakes	Apr-19	70
21	**Moeraki**	SH1/Moeraki Boulders Rd	Waitaki	Jun-17	70
		Decommissioned ISZ sites			
	Thomas Rd	Gordonton Rd/Thomas Rd	Hamilton City	Oct-17	60
	Waterholes Rd	SH1/Dawsons Rd/Waterholes Rd	Selwyn	May-16	70

Note the priority road affected by ISZ variable speed limits (VSLs) is listed first in the intersection column.

[3] Mackie, H., & Scott, R. (2016) Long-term update of RIAWS performance. A report prepared for the NZ Transport Agency.

At all sites except Thomas Rd (decommissioned), the speed limit along the priority road is 100km/h when the ISZ signs are inactive.

Crash performance at ISZs was also compared to ten control sites (Table 2). Control sites were rural intersections selected for their similar layout and (non-VSL) speed limit to sites with ISZs. Note only two of these intersections are the same high-risk intersections used as control sites in a previous study[4], as significant layout changes or lower speed limits have since been implemented at the remaining control sites used previously, as would be expected.

This does mean that this cohort of intersections has a lower existing crash rate than the ISZ sites, as shown later, but it at least provides a comparison with untreated or 'business as usual' intersections.

Table 2: Control sites used in crash performance analysis

Site name	Intersection	District
Brixton	SH3 (Devon Rd)/Raleigh St	New Plymouth
Hikuai	SH25A (Kopu-Hikuai Rd)/SH25 (Tairua Rd)	Thames-Coromandel
Kairanga	Longburn Rongotea Rd/Number 1 Line	Palmerston North
Kinleith	SH1/SH30 (near Forestry Rd)	South Waikato
Mangatarata	SH27/SH2 (Cross Rd)	Hauraki
Milton	SH1 (Milton Hwy)/SH8 (Manuka Gorge Hwy)	Clutha
Netherton	SH2 (Wilson Rd)/Awaiti Rd	Hauraki
Newstead	SH26 (Morrinsville Rd)/SH1B (Hoeka Rd)	Waikato
Pukaki	SH8 (Tekapo-Twizel Rd)/SH80 (Mt Cook Rd)	Mackenzie
Takapau	SH2/SH50	Central Hawke's Bay

Note the first road listed in the intersection column is the 100km/h priority road; the second road(s) are controlled by stop or give way signs.

Table 3 shows the analyses conducted for each site type.

Table 3: Analyses of each site type conducted to assess crash, speed, and operational performance

	Analyses	Site types			
		Original	New	Decomm -issioned	Control
Crash performance (CAS data)	Summary of post-ISZ crash numbers	Y	Y	-	Y
	Pre-post crash rate comparison	Y	Y	-	Y
	Review of post-ISZ fatal and serious crashes	Y	Y	Y	-
Speed performance (speed loop data)	Current speeds with sign on/off compared to earlier pre-post speeds	Y	Y*	-	-
	Current speed distribution graphs	Y	-	-	-
Operational performance	Assessment of ISZ issues and optimal design	Y	Y	Y	-

*For new sites where speed data is available: excludes Moeraki.

[4] Mackie, H., Brodie, C., Scott, R., Hirsch, L., Tate, F., Russell, M., Holst, K. (2017) The signs they are a-changin': Development and evaluation of New Zealand's rural intersection active warning system. Journal of the Australian College of Road Safety – Volume 28 No. 3, 2017.

2.2. Crash performance

Crash performance was assessed using traffic crash reports (TCRs) recorded in the Crash Analysis System (CAS). All crashes recorded within 50m of the centre of each intersection were included in the analysis. At the Hinuera site, all crashes recorded within 50m of *either* of the two intersections (located approximately 70m apart) of SH27 and SH29 were included. In keeping with the Safe System approach, fatal and serious crashes were also analysed separately.

Due to changes in CAS output, crash data from the current version of CAS are not comparable to data from the previous version. This meant recent crash data were not able to be compared to those reported in earlier studies. All crash analyses were therefore re-conducted in the current version of CAS; no data from previous studies are reported. The overall longer-term crash performance was however, compared with the overall crash performance for all sites reported earlier.

All original, new, and control sites were assessed for layout changes and major upgrades using Google Street View and other intelligence, and posted speed limits were confirmed before including them in the study.

2.2.1. Pre-post crash analysis

For each original site, analyses were carried out on crashes which occurred in the 5-year period pre-ISZ installation (using the same time periods as the previous study[5]), as well as all crashes occurring post-ISZ installation, up to the end of June 2019. Control site crashes were also analysed using a 'pre-ISZ' period of 2009-2013 and a 'post-ISZ' period of July 2014 to June 2019. In addition, pre-post crash rates across all T-junction, Y-junction and crossroad intersections on rural arterial, major, and medium roads in the country were calculated to assess whether changes in crash rates at ISZs were representative of national trends at rural intersections.

Crashes occurring after June 2019 were excluded as there is a delay between crash occurrence and TCR reporting in CAS; excluding the most recent six months ensures CAS data are reliable and comparable to earlier periods. Both absolute crash numbers and monthly crash rates are reported to enable comparison across the different length time periods analysed.

Brief pre-post casualty analyses were conducted for original and control sites using the same time frames as above. Death and serious injury (DSI) equivalents[6] were also calculated for pre- and post-ISZ crashes at original sites to understand how ISZs affect crash severity. These were determined using 2014-2018 severity ratios for each crash type at rural crossroad and T-junction intersections[7].

Pre-post crash and casualty analyses were also conducted for new sites, however, insufficient post-ISZ data for most sites means the results should be interpreted extremely cautiously. Given most new sites were only installed in 2019, post-ISZ data were reported from the month following installation through to the end of 2019 to provide some indication of early trends. All crash numbers for new sites were updated in May 2019, by which time CAS data through to the end of 2019 should be reasonably complete, to increase the reliability of the analysis. In addition, minor and non-injury crashes at new sites were reviewed to understand the nature of the crashes and whether ISZ did or should have influenced the outcome.

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[5] Mackie, H., & Scott, R. (2016) Long-term update of RIAWS performance. A report prepared for the NZ Transport Agency.

[6] NZ Transport Agency (2013) High-risk intersection guide. Wellington: Author.

[7] Durdin, P. (2019) Development of Revised Severity Indices. A report prepared by Abley for the NZ Transport Agency.

2.2.2. Fatal and serious injury crash review

For all 'serious' and 'fatal' severity crashes which occurred at an original or new site post-ISZ installation, the individual TCRs were reviewed to understand more context around the crash, what factors were likely to have been involved, and whether it did or should have influenced the crash outcome. Such crashes include those occurring at the relevant intersection, involving more than one vehicle, and in which at least one vehicle travelled along the priority road and was exposed to the ISZ speed limit signs (regardless of whether they were active or not). A single vehicle loss of control crash, for example, is likely to be unrelated to the crashes ISZ is seeking to mitigate.

2.3. Speed performance

Speed performance was assessed using speed data from speed loops cut into the road at the intersection of all original and 10 of the 11 new ISZ sites. The speed loops produce individual vehicle speeds, but the logic controller uses rounding to produce data that are not continuous, rather they are grouped into certain speed values that are 1 to 4 whole numbers apart.

At several sites, the logic controller also cuts off speeds below 40km/h and above 120km/h. At two of the remaining sites, Himatangi and Yaldhurst, substantial congestion was apparent in the data, with speeds frequently falling below 20km/h. At these sites, data below 40km/h and above 120km/h were manually removed to facilitate comparison between sites and with earlier speed data.

7-day data from Monday 7 October to Sunday 13 October 2019 were used to assess current speed performance at all original and new sites for which data was available (excludes Moeraki). Data were separated by direction and by ISZ sign status (on vs off, i.e. VSL active vs inactive).

2.3.1. Sign on-off speed analysis

Vehicle counts, mean speeds, standard deviations, and 85th percentile speeds in each direction were calculated for each site. These are reported together with data from previous analyses[8] to enable examination of speed trends over time.

2.3.2. Speed distributions

For each original site, the speed data were grouped into 5km/h histogram bins and graphed to enable comparison of the current speed distributions when the VSL is active ('on') compared to when it is inactive ('off').

2.4. Operational performance

The operational performance of RIAWS was qualitatively and briefly evaluated, by analysing customer and internal stakeholder feedback. An interview was also conducted with the supplier who has been involved with RIAWS since its inception. Note that this analysis did not involve an in-depth evaluation of how each installation is functioning, but rather a general scan of trends that seem to be emerging based on feedback to date. Also note that this feedback does not necessarily cover the whole country and may be skewed towards installations that have

[8] Mackie, H., & Scott, R. (2016) Long-term update of RIAWS performance. A report prepared for the NZ Transport Agency.

received the most attention or concern. A more systematic check would be needed to see if some of the operational issues are emerging at most sites around the country, or whether they are isolated to a few locations with unique characteristics.

3. CRASH PERFORMANCE

3.1. Pre-post crash summaries

3.1.1. Original and control sites

Absolute crash numbers

Overall, since the ISZs were installed, there have been fewer total crashes, much fewer injury crashes, and in particular fewer serious injury crashes at the original sites than before the ISZs were installed. In the 5 years prior to ISZ-installation, there were a total of 137 crashes, including 1 fatal and 20 serious crashes across the ten original sites (Table 4).

Table 4: Pre-ISZ crash history across ten original sites

#	Site name	Analysis period	Months	Fatal	Serious	Minor	Total injury	Non-injury	Total
1	**Himatangi**	2007-2011	60	0	3	5	8	6	**14**
2	**Yaldhurst**	2008-2012	60	1	2	1	4	4	**8**
3	**Kennington**	2008-2012	60	0	2	2	4	2	**6**
4	**Newbury**	2008-2012	60	0	2	5	7	11	**18**
5	**Pakaraka**	2008-2012	60	0	3	5	8	4	**12**
6	**Puketona**	2008-2012	60	0	1	2	3	5	**8**
7	**Burnham**	2009-2013	60	0	1	7	8	5	**13**
8	**Longlands**	2009-2013	60	0	2	2	4	8	**12**
9	**Kaiapoi**	2009-2013	60	0	2	4	6	11	**17**
10	**Puketaha**	2010-2014	60	0	2	9	11	18	**29**
	Total			**1**	**20**	**42**	**63**	**74**	**137**

Since the ISZs have been active, there were a total of 102 crashes, including 1 fatal and 6 serious crashes across the original sites (Table 5). Note that the periods of time for which reliable post-ISZ crash data is available vary across the sites due to different installation dates, making the absolute numbers post-ISZ not directly comparable with the 5-year periods analysed pre-ISZ.

Table 5: Post-ISZ crash history across ten original sites

#	Site name	Analysis period	Months	Fatal	Serious	Minor	Total injury	Non-injury	Total
1	**Himatangi**	1/1/2013 - 30/6/2019	78	0	1	2	3	9	**12**
2	**Yaldhurst**	1/6/2013 - 30/6/2019	73	0	0	1	1	4	**5**
3	**Kennington**	1/11/2013 - 30/6/2019	68	1	0	3	4	0	**4**

4	**Newbury**	1/11/2013 - 30/6/2019	68	0	0	4	4	17	**21**
5	**Pakaraka**	1/11/2013 - 30/6/2019	68	0	1	4	5	7	**12**
6	**Puketona**	1/11/2013 - 30/6/2019	68	0	0	2	2	1	**3**
7	**Burnham**	1/11/2014 - 30/6/2019	56	0	2	2	4	5	**9**
8	**Longlands**	1/11/2014 - 30/6/2019	56	0	0	0	0	8	**8**
9	**Kaiapoi**	1/12/2014 - 30/6/2019	55	0	1	1	2	8	**10**
10	**Puketaha**	1/2/2015 - 30/6/2019	53	0	1	5	6	12	**18**
	Total			**1**	**6**	**24**	**31**	**71**	**102**

In contrast, while there are fewer crashes occurring overall at the control sites compared to the original ISZ sites, crashes at the control sites increased from a total of 47 during the pre-ISZ period to 88 during the post-ISZ period (Table 6). Injury crashes at these sites have also increased from 15 to 31 crashes.

Table 6: Aggregated crash history across all ten control sites during average pre- and post-ISZ periods

Matched time period	Analysis period	Months	Fatal	Serious	Minor	Total injury	Non-injury	Total
Pre	2009-2013	60	1	2	12	**15**	32	**47**
Post	1/7/2014 - 30/6/2019	60	2	5	24	**31**	57	**88**

Crash rates

By calculating the average number of crashes occurring per month across the pre- and post-ISZ periods, crash rates can be compared across intersections at which ISZs have been active for differing periods of time. Crash rates for all crash severities have decreased following installation of the ISZs at all sites except Newbury, at which the monthly crash rate has increased slightly from 0.300 to 0.309 crashes per month (Table 7), although the fatal and serious crash rate has reduced to zero. Fatal and serious crash rates were lower post-ISZ installation at all sites except at Burnham, at which fatal and serious crashes occurred at a rate of 0.017 per month prior to ISZ installation, going up to 0.036 fatal and serious injury crashes per month post-installation. There have been two serious injury crashes since the installation of the ISZ at this site, compared with the one prior.

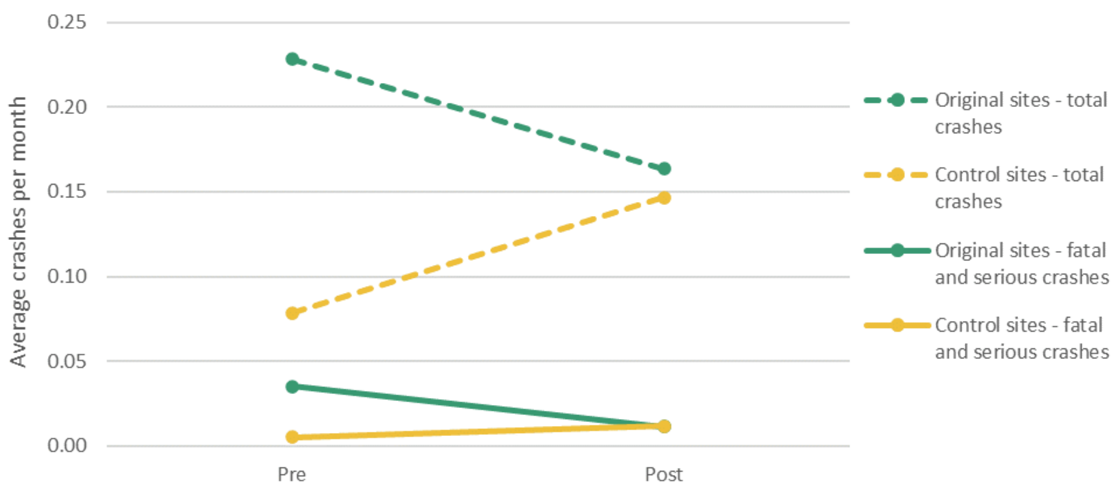
Table 7: Crashes per month pre- and post-ISZ across ten original sites

#	Site name	Fatal and serious crashes per month		Total crashes per month	
		Pre	Post	Pre	Post
1	**Himatangi**	0.050	0.013	0.233	0.154
2	**Yaldhurst**	0.050	0.000	0.133	0.068
3	**Kennington**	0.033	0.015	0.100	0.059
4	**Newbury**	0.033	0.000	0.300	0.309
5	**Pakaraka**	0.050	0.015	0.200	0.176
6	**Puketona**	0.017	0.000	0.133	0.044

7	**Burnham**	0.017	0.036	0.217	0.161
8	**Longlands**	0.033	0.000	0.200	0.143
9	**Kaiapoi**	0.033	0.018	0.283	0.182
10	**Puketaha**	0.033	0.019	0.483	0.340
	Average	0.035	0.011	0.228	0.164

The monthly crash rates show that both for total crashes and for fatal and serious crashes, the average crash rate went down at the original trial sites post-ISZ installation (Figure 2). Though the control sites have lower crash rates overall, the rate of both total crashes and of fatal and serious crashes at these sites increased over the same period.

Figure 2: Average monthly crash rates at original compared to control sites



Based on the average monthly rate of fatal and serious injury crashes occurring pre-ISZ installation at original sites, i.e. if that rate had continued, we would expect to have seen 23 such crashes at these sites in the post-ISZ installation period. Since only 7 fatal and serious injury crashes did occur, this suggests that ISZ installation at the original sites has contributed to the avoidance of around 16 fatal and serious crashes.

The average crash rates also show that there was a greater proportional reduction in fatal and serious injury crashes compared to that in total crashes at the original ISZ sites (Table 8). Post-ISZ installation, the average rate of fatal and serious injury crashes dropped to a third (31%) of the pre-installation rate, going from 0.035 to 0.011 per month, or 0.420 to 0.138 fatal and serious injury crashes per year. In comparison, for total crashes, the post-installation rate reduced to 72% of the pre-installation rate, going from an average of 0.228 to 0.164 crashes per month. This indicates the ISZs are having more impact on high-severity crashes compared to crashes resulting in no or minor injury. However, the reduction in the overall number of crashes is also noteworthy as it suggests that the ISZ is effective at reducing the likelihood of crashes in addition to their severity.

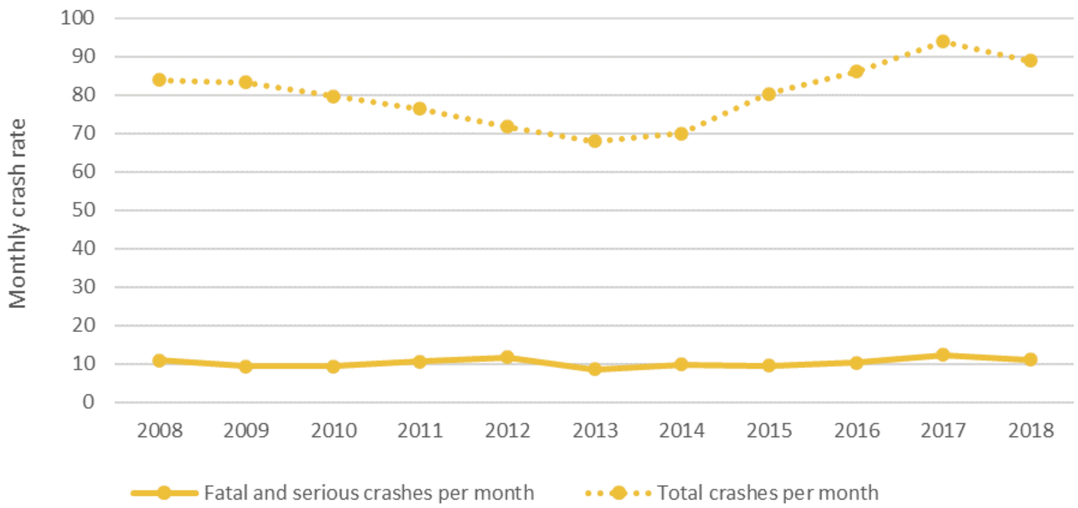
Table 8 also shows that crash rates for both fatal and serious as well as crashes overall have increased significantly over the same period. This suggests that the net benefit of ISZs is likely to be larger than the improvements described above, although regression to the mean effects (the extent to which any safety improvement over-estimates safety benefits at unusually high-risk intersections) are likely to negate this to some extent. A further, more in-depth statistical analysis would be needed accurately determine the overall net safety benefit of ISZs.

Table 8: Average monthly crash rates at original compared to control sites pre- and post-ISZ

	Average fatal and serious crashes per month			Average total crashes per month		
	Pre	Post	% change	Pre	Post	% change
Original sites	0.035	0.011	-69%	0.228	0.164	-28%
Control sites	0.005	0.012	+140%	0.078	0.147	+88%

Finally, a brief analysis of crashes across all rural intersections in the country was conducted to understand overall trends in these types of crashes. This analysis, which ignores any level of intersection treatment, so will include treated and untreated intersections, shows that there was a general downwards trend in total crashes between 2009 and 2013, from a rate of 83.9 to 67.9 crashes per month, followed by an increase in total crashes from 2014 to 2017, with a rate of 89.0 crashes per month in 2018 (the most recent year for which a full dataset is available; Figure 3). Fatal and serious crash rates were more stable overall, but also reached their lowest point in 2013, at an average rate of 8.6 crashes per month, and peaking in 2017 at 12.3 per month. They reduced slightly again in 2018 to an average rate of 11.0 fatal and serious injury crashes per month. This shows that the decrease in crashes at intersections with ISZs observed in this study does not reflect overall crash trends for these types of intersections, and hints at the remaining nationwide rural intersection problem.

Figure 3: Average monthly crash rate across all rural intersections 2008-2018



Includes crashes at all crossroads, T-junction, and Y-junction intersections on all major, medium, and arterial rural roads.

Casualty rates

The rate of casualties, i.e. the number of people injured in crashes, also decreased at original sites following ISZ installation, in line with the reduction in injury crashes. Overall, fatally and seriously injured casualties reduced by 68% post-ISZ installation at these sites, while the rate of all casualties (people who sustained any level of injury) reduced by 73% (Table 9) compared to before the ISZs were installed. This indicates ISZs are contributing to a reduction in injuries of any severity, with a slightly greater reduction in minor injuries than in DSIs.

ISZ sites have also seen a greater relative reduction in DSI casualty rates compared to control sites, where DSI casualties have increased more than have DSI crashes. DSI crashes that do occur at original sites have thus been less likely to result in harm to multiple people than those at control sites.

Table 9: Average monthly casualty rates at original and control sites pre- and post-ISZ

	Average fatal and serious casualties per month			Average total injuries per month		
	Pre	Post	% change	Pre	Post	% change
Original sites	0.042	0.013	-68%	0.215	0.057	-73%
Control sites	0.007	0.018	+175%	0.047	0.088	+89%

Based on the average monthly rate of DSI casualties occurring pre-ISZ installation at original sites, i.e. if that rate had continued, we would have expected to see 28 casualties in the follow-up period. Instead, we saw 8, suggesting 20 fewer people were fatally or seriously injured over the follow-up period at the original sites than would otherwise have been the case.

DSI equivalents, determined by taking all injury crashes occurring at a site and calculating the likely number of DSIs based on national ratios, show a similar trend of fewer expected DSI casualties post-ISZ compared to pre-ISZ (

Table 10). However, the actual DSI casualty reduction of 68% is greater than that predicted using DSI equivalent ratios (54%), suggesting ISZs contribute to a more considerable reduction in the harm sustained by the casualties of crashes that do occur than in crashes overall.

Table 10: Average monthly DSI equivalent and actual DSI casualty rates for original sites pre- and post-ISZ

	Average DSI equivalents per month			Average actual DSIs per month		
	Pre	Post	% change	Pre	Post	% change
Original sites	0.045	0.021	-54%	0.042	0.013	-68%

3.1.2. New sites

Absolute crash numbers

Since ISZs have been installed at the new sites, a total of 13 crashes have been recorded in CAS, including 1 serious crash (Table 11).

Table 11: Post-ISZ crash history across 11 new sites

#	Site name	Analysis period	Months	Fatal	Serious	Minor	Total injury	Non-injury	Total
11	**Brynderwyn**	01/01/2016-31/12/2019	36	0	0	0	0	2	**2**
12	**Oakleigh**	01/05/2019-31/12/2019	8	0	0	0	0	0	**0**
13	**Waipu**	01/05/2019-31/12/2019	8	0	0	1	1	0	**1**
14	**Kopu**	01/08/2019-31/12/2019	5	0	0	1	1	2	**3**
15	**Gordonton**	01/05/2019-31/12/2019	8	0	0	1	1	1	**2**
16	**Te Puninga**	01/08/2019-31/12/2019	5	0	0	0	0	0	**0**
17	**Hinuera**	01/05/2019-31/12/2019	8	0	0	0	0	2	**2**
18	**Hopkins**	01/08/2019-31/12/2019	5	0	0	0	0	1	**1**

19	**Piarere**	01/09/2019-31/12/2019	4	0	0	0	0	0	**0**
20	**Luggate**	01/05/2019-31/12/2019	8	0	0	0	0	0	**0**
21	**Moeraki**	01/07/2017-31/12/2019	30	0	1	0	1	1	**2**
	Total			**0**	**1**	**3**	**4**	**9**	**13**

Crash rates

Given the much more recent installation of ISZs at the majority of the new sites (9 out of 11 installed in April 2019 or later), a full pre-post crash rate comparison with original and control sites is not appropriate. However, monthly crash rates have nonetheless been calculated (Table 12) to provide a preliminary indication of the crash trends at these sites. These show a slightly lower overall rate of total crashes compared to the original sites, but with no reduction apparent since pre-ISZ installation. For DSI crashes, the post-ISZ rate has decreased more at new sites than at original sites, however, given the relative newness of the ISZs at these sites, and the lack of follow-up data, this is unlikely to represent a long-term trend. Note also that pre-ISZ crash rates were lower at the new sites than at the original sites.

Table 12: Crashes per month pre- and post-ISZ across 11 new sites

#	Site name	Fatal and serious crashes per month		Total crashes per month	
		Pre	Post	Pre	Post
11	**Brynderwyn**	0.033	0.000	0.100	0.056
12	**Oakleigh**	0.050	*0.000*	0.117	*0.000*
13	**Waipu**	0.033	*0.000*	0.067	*0.125*
14	**Kopu**	0.017	*0.000*	0.167	*0.600*
15	**Gordonton**	0.000	*0.000*	0.117	*0.250*
16	**Te Puninga**	0.033	*0.000*	0.100	*0.000*
17	**Hinuera**	0.050	*0.000*	0.533	*0.250*
18	**Hopkins**	0.000	*0.000*	0.000	*0.200*
19	**Piarere**	0.017	*0.000*	0.283	*0.000*
20	**Luggate**	0.000	*0.000*	0.000	*0.000*
21	**Moeraki**	0.017	0.033	0.067	0.067
	Average	**0.023**	***0.003***	**0.141**	***0.141***

Note post-ISZ monthly crash rates at new sites (in grey) are based on data from a short period of time following ISZ installation (fewer than 9 months) and are therefore likely to underestimate the crash rate as compared to a 5-year post-ISZ period.

Casualty rates

Casualty rates at the new sites show a greater initial reduction in DSI casualties compared to original sites, and a lesser reduction in total injuries (Table 13). However, as with the crash rates, these preliminary rates do not provide a reliable estimate of longer-term trends.

Table 13: Average monthly casualty rates at new sites pre- and post-ISZ

	Average fatal and serious casualties per month		Average total injuries per month	
	Pre	Post	Pre	Post
New sites	0.041	*0.003*	0.140	*0.106*

Note post-ISZ monthly crash rates at new sites (in grey) are based on data from a short period of time following ISZ installation (often fewer than 9 months) and are therefore likely to underestimate the crash rate as compared to a 5-year post-ISZ period. Averages are not weighted by length of observation period.

Crash severity and characteristics

Crash data from the original sites indicates that the ISZs help to reduce crash severity (in addition to reducing overall crashes). Given the lack of long-term follow-up data for the new sites, minor and non-injury severity crashes occurring post-ISZ installation have been examined at the new sites to assess whether the ISZs are likely to have influenced crash severity.

Of the 12 minor and non-injury crash cases recorded at new sites, the ISZs are likely to have played a role in reducing the severity of 4 crashes in which vehicles exiting a side road were hit by vehicles passing straight through the intersection along the priority road. The ISZs may also have contributed to less severe outcomes in a further 5 crashes. Of the remaining 3 crashes, two involved a vehicle rear-ending another vehicle on the side road approach to the intersection, and one involved a single vehicle on a side road; all were unrelated to the ISZ.

For the serious injury crash that happened at Moeraki, the ISZ either should have prevented a serious injury crash, or conversely may have prevented a more serious or fatal crash. The TCR suggests the priority driver noticed the sign and also braked but was unable to prevent the collision.

It is also interesting to note that vehicle speeds along the priority road were only recorded in 6 of these TCRs and were rarely mentioned as a factor in the crash, even when drivers were recorded as driving above the VSL in a situation where the ISZ sign should have been activated (3 cases). In one of these cases, where the driver said they were travelling at around 65km/h, the crash was described "slow impact" in the TCR. The 60km/h VSL is only noted in one crash, however, the posted speed limit was recorded as 100km/h. All three cases where the ISZ sign should have been active and drivers were reportedly exceeding the 60km/h VSL were at the Kopu site.

3.2. Fatal and serious injury crashes

Since the ISZs were installed, there have been 1 fatal and 7 serious injury crashes across the original sites, as well as 1 serious crash at a new site (Table 14). In 6 of the 8 crashes resulting in serious injury, vehicles exiting side roads with stop or give way signs were hit by (or hit) vehicles travelling straight along the right of way road where the ISZ signs are located. In all 6 cases, the ISZ signs should have been activated, however, this information is not recorded specifically in any of the traffic crash reports. In one case, the driver mentions slowing down as a precaution as they approached the intersection, which is likely a result of their observing the active variable speed limit sign. In another case the priority road driver mentions seeing the flashing speed sign and slows accordingly. In all of these cases there are estimates of the priority road vehicle's speed and some have a recorded speed in the TCR which is the same as the ISZ speed, hinting that the driver may have responded to it. There are also hints of ISZ non-compliance in these cases, with estimated priority vehicle speeds of 80 km/h in one case and 90 km/h in another. One of these two non-compliant cases involved the vehicle exiting the side road failing to stop at a stop sign, while in the other, the driver of the vehicle exiting the side road stated that a vehicle turning left off into the side road obscured their view of the vehicle travelling straight along the priority road behind them.

In one further serious injury case, the crash involved a vehicle turning right from the priority road into the side road in front of a vehicle travelling straight along the priority road in the opposite direction (right turn against). Given the presence of a relatively long right-turning lane on the priority road, the ISZ signs should have been activated, and the estimated speed of 70km/h of the straight-through driver suggests this was the case.

The remaining serious injury case and the fatal crash case were unrelated to the presence of the ISZ. The serious injury case has been outlined previously[9]. The fatal case involved loss of control of a single vehicle travelling straight along the priority road. No vehicles were present in the side roads, therefore the ISZ signs would not have been activated.

Table 14: Fatal and serious injury crash movements at original and new ISZ sites

Site #	Site name	Crash severity	Mvmt code	Movement	Speed (km/h)	Factors
1	Himatangi	Serious	FB	Side road rear end crash	-	Unrelated
3	Kennington	Fatal	DJ	Bend-Lost control	100	Unrelated
5	Pakaraka	Serious	JA	Right turn right side	60	ISZ compliant
7	Burnham	Serious	JO	Crossing One Turning	80	Some slowing
7	Burnham	Serious	HA	Crossing Not Turning (right angle)	90	Little slowing
9	Kaiapoi	Serious	JA	Right turn right side	70	Truck slowed
10	Puketaha	Serious	HA	Crossing Not Turning (right angle)	70	ISZ compliant
10	Puketaha	Serious	HA	Crossing Not Turning (right angle)	70	ISZ compliant
21	Moeraki	Serious	LB	Making turn (right turn against)	70	ISZ compliant

Note: Speed refers to estimated speed of vehicle travelling along priority road (i.e. that travelled past the ISZ signage).

A further ISZ fatality case occurred at the now transformed site of Gordonton and Thomas Rds, in Hamilton, involving a right turn against movement (Table 14). While the estimated speed of 60km/h suggests the priority vehicle driver was ISZ-compliant, if they did not brake before they hit the turning vehicle, the side impact speeds would still not be survivable. Another contributing factor may have been the older age of the vehicle that was hit, as it is unlikely to have had side curtain airbags, which may have helped reduce the severity of injuries for this crash type.

Table 15: Fatal crash movement at Thomas/Gordonton Rds, Hamilton

Site name	Crash severity	Mvmt code	Movement	Speed (km/h)	Factors
Thomas Rd	Fatal	LB	Making turn (right turn against)	60	ISZ compliant

3.3. Implications for ISZ performance

The reduction in total crashes, and especially high severity crashes, suggests that ISZs continue to be an effective road safety countermeasure. This runs counter to national trends, which show crash rates for both a comparison group of untreated intersections and across all rural

[9] Mackie, H., & Scott, R. (2016) Long-term update of RIAWS performance. A report prepared for the NZ Transport Agency.

intersections have increased since 2013. The incidence of some minor and non-injury outcomes from right turn against and right turn right side crashes at new ISZ sites also suggests the ISZs may be mitigating crash severity at these intersections.

However, the TCR data available suggests there are crash examples where drivers may have complied with the ISZ and a fatal or serious injury has still occurred. This highlights a limitation of the ISZ in that where braking does not happen, possibly due to inadequate warning time, or where there is non-compliance with the speed limit, then side impact speeds may still cause serious injury or death, depending on other crash contributing factors. Even with these examples, it is possible that the ISZ has still mitigated trauma and there may have been a greater number of fatal or more serious casualties in these examples, had the ISZ not been operational.

4. SPEED PERFORMANCE

The speed performance of each of the original and new ISZs are presented below. More detail is given to the original sites, so that comparisons can be made with earlier data along with judgements about long-term compliance.

Note that the speed distributions do not fully reflect driver understandings of the speed limit due to speeds being measured at the intersection, not the VSL sign. This means that in some cases drivers will have driven past the sign when it was inactive, following which the sign was activated, so their speed was recorded as occurring while the sign was on. Similarly, sometimes the sign will be inactive by the time a driver reaches the intersection, so they are driving as if the VSL were in place when this is no longer the case. This means there will be some data in the 'sign off' speed distribution that actually reflects 'sign on' speeds, and vice versa.

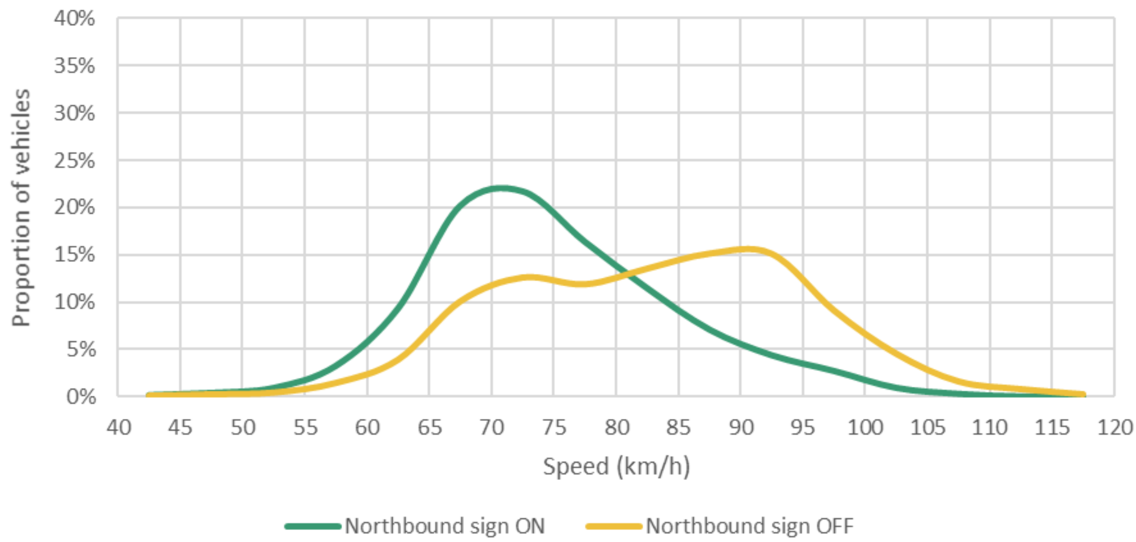
Note also that the speed data analysed in this study (from October 2019) is 7-day data, while previous analyses used 14-day data; the most recent vehicle counts are thus not comparable to those from previous years.

4.1. Original ISZ sites

4.1.1. Himatangi (70km/h)

Figure 4 shows that the ISZs continue to influence motorist speeds through the intersection, with substantially lower speeds when the signs are on compared to off. This is more marked in the northbound direction. Table 16 shows that compliance has remained reasonably consistent since the previous evaluation in February 2016. On average vehicles travel 8km/h slower when the signs are on (mean speeds), and at more consistent speeds (lower standard deviations then when signs are off). Speed variance overall has changed little since the signs went in. There was a small reduction in compliance initially but this has now settled down.

Figure 4: Himatangi speed distributions for sign on compared to sign off, northbound and southbound



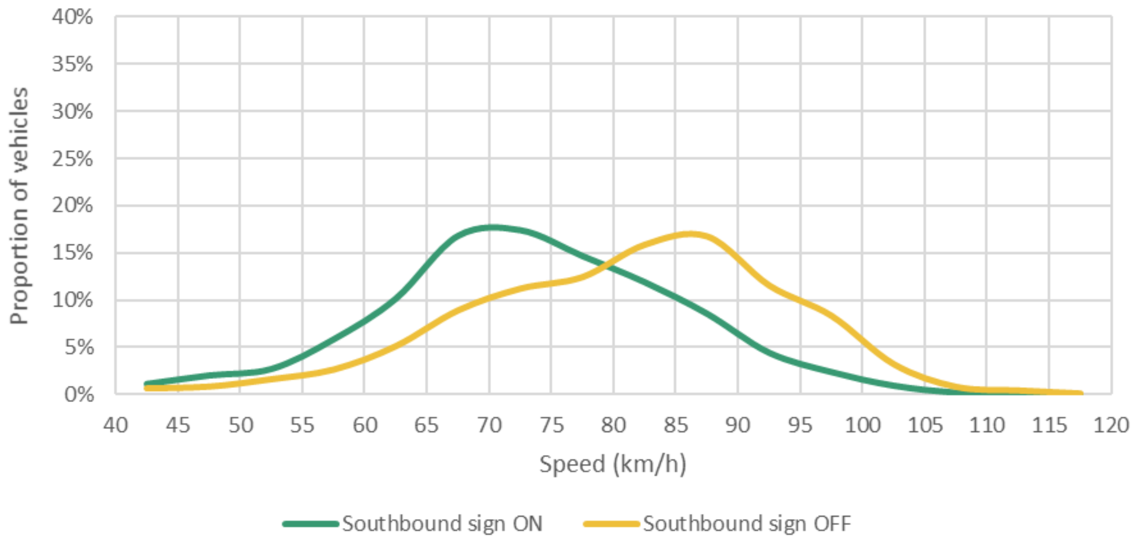


Table 16: Himatangi speed summaries pre and post ISZ-installation, northbound and southbound

Himatangi northbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Dec-12**	All	12,117	90	10	99
POST	**Jan-13**	Sign OFF	8,071	83	13	96
		Sign ON	13,774	73	10	83
	Feb-16	Sign OFF	5,230	84	13	96
		Sign ON	10,331	75	11	87
	Oct-19	Sign OFF	5,125	84	12	96
		Sign ON	12,419	75	10	86
Himatangi southbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Dec-12**	All	11,390	95	11	105
POST	**Jan-13**	Sign OFF	7,884	82	13	96
		Sign ON	18,803	71	10	81
	Feb-16	Sign OFF	5,954	82	13	96
		Sign ON	11,274	73	11	85
	Oct-19	Sign OFF	3814	81	13	94
		Sign ON	8476	74	12	86

Note 'sign on' and 'sign off' cannot be compared pre-ISZ at Himatangi due to a lack of intersecting vehicle indicators, therefore the 'pre' data represent both sign on and sign off.

4.1.2. Yaldhurst (70km/h)

Speeds continue to be lower when the signs are on at the Yaldhurst site (Figure 5) and have remained consistent since the first evaluation period immediately post ISZ-installation (Table 17). Vehicles travel an average of 7km/h slower when the signs are active.

Figure 5: Yaldhurst speed distributions for sign on compared to sign off, northbound and southbound

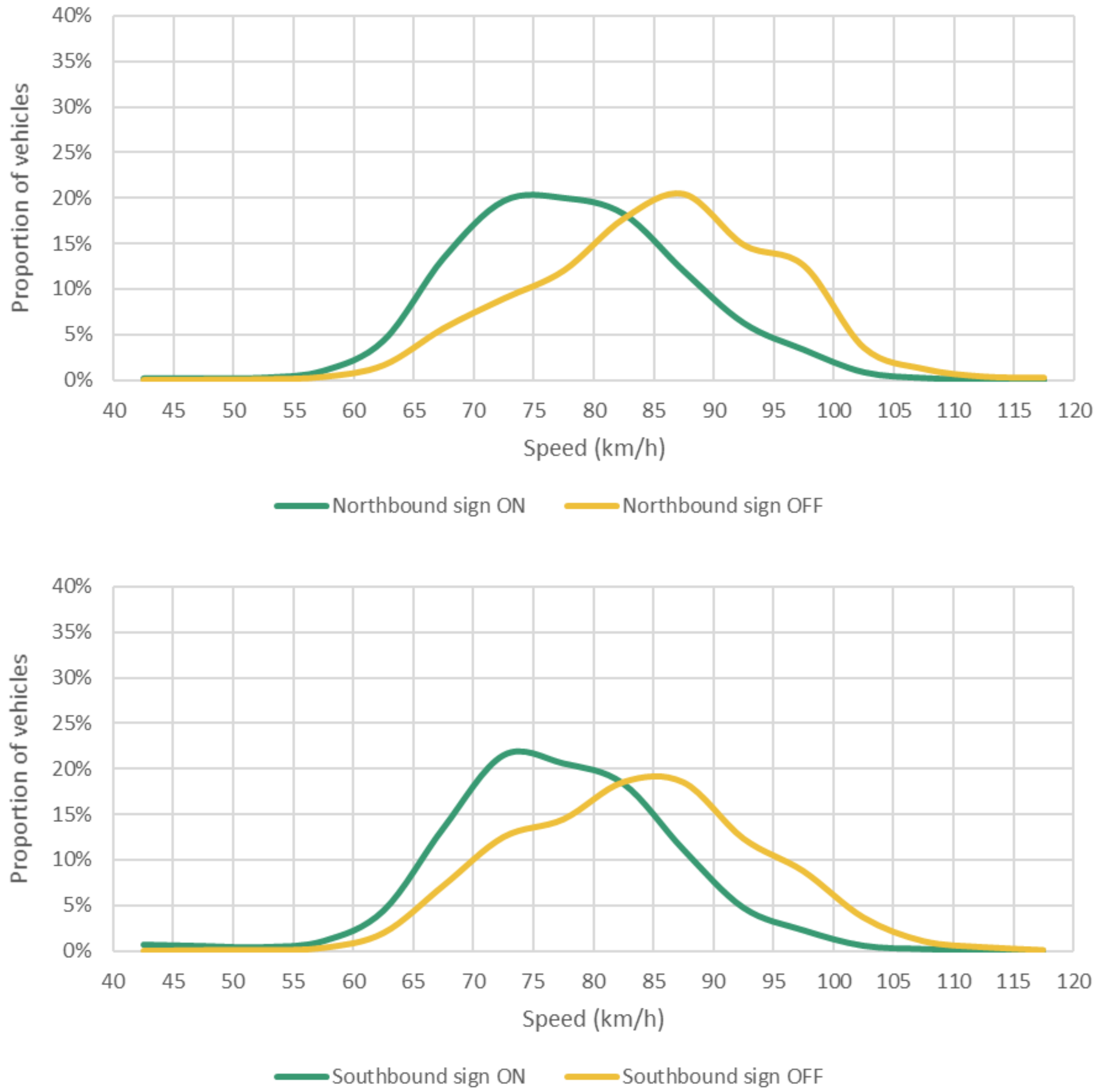


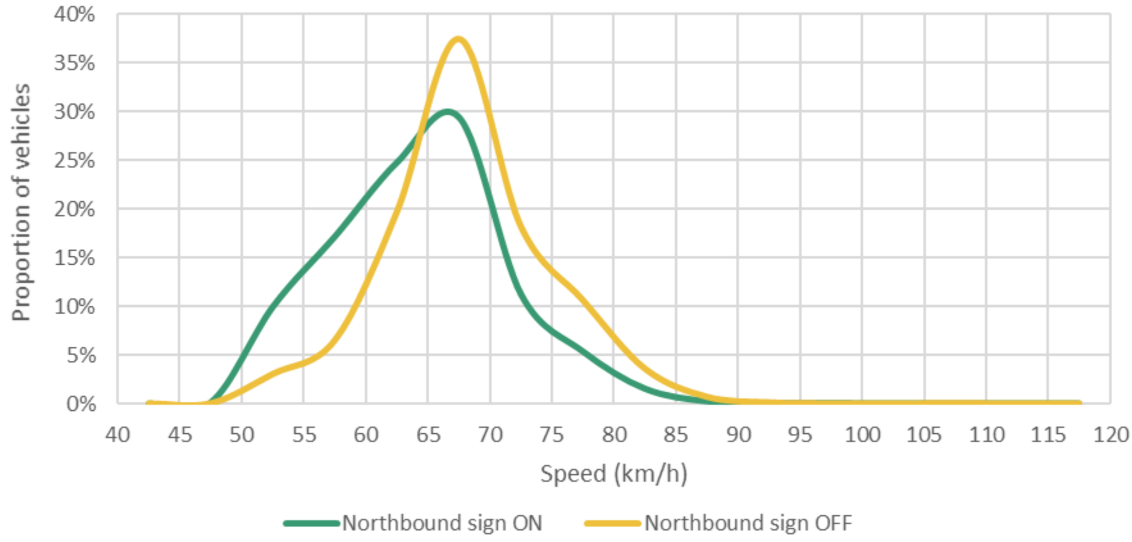
Table 17: Yaldhurst speed summaries pre and post ISZ-installation, northbound and southbound

Yaldhurst northbound intersection speeds (70km/h VSL)						
	Date	Sign status	Vehicle count	Mean (km/h)	Std dev (km/h)	85th %ile (km/h)
PRE	**Apr-13**	Sign would be OFF	10,971	88	9	98
		Sign would be ON	16,410	84	12	94
POST	**May-13**	Sign OFF	12,448	83	13	95
		Sign ON	16,394	76	11	86
	Feb-14	Sign OFF	13,098	83	11	95
		Sign ON	24,946	76	11	86
	Jun-14	Sign OFF	29,392	84	11	95
		Sign ON	50,275	76	12	87
	Feb-16	Sign OFF	7388	86	11	98
		Sign ON	10,056	76	13	88
	Oct-19	Sign OFF	7962	86	10	97
		Sign ON	17208	78	10	88
Yaldhurst southbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Apr-13**	Sign would be OFF	11,227	90	9	99
		Sign would be ON	14,858	88	10	98
POST	**May-13**	Sign OFF	11,469	85	12	98
		Sign ON	16,435	77	10	88
	Feb-14	Sign OFF	14,611	86	12	98
		Sign ON	22,955	78	11	90
	Jun-14	Sign OFF	32,218	86	11	98
		Sign ON	43,640	78	11	89
	Feb-16	Sign OFF	8475	88	11	99
		Sign ON	10641	80	11	93
	Oct-19	Sign OFF	6817	84	10	95
		Sign ON	19086	77	10	87

4.1.3. Kennington (70km/h)

Figure 6 shows a greater number of vehicles driving at slower speeds through the intersection when the ISZ signs are active, though in the northbound direction, the mode is similar between sign on and sign off. There is some evidence of a reduction in compliance, though it's possible this is within measurement error given the nature of the data (Table 18). The difference in mean speeds between sign on and sign off is less marked than at other sites, at 4-5km/h lower when signs are on, and there is no difference between 85th percentile speeds in the northbound direction in the most recent data. Sign off speeds are already quite low though, so further large reductions are unlikely.

Figure 6: Kennington speed distributions for sign on compared to sign off, northbound and southbound



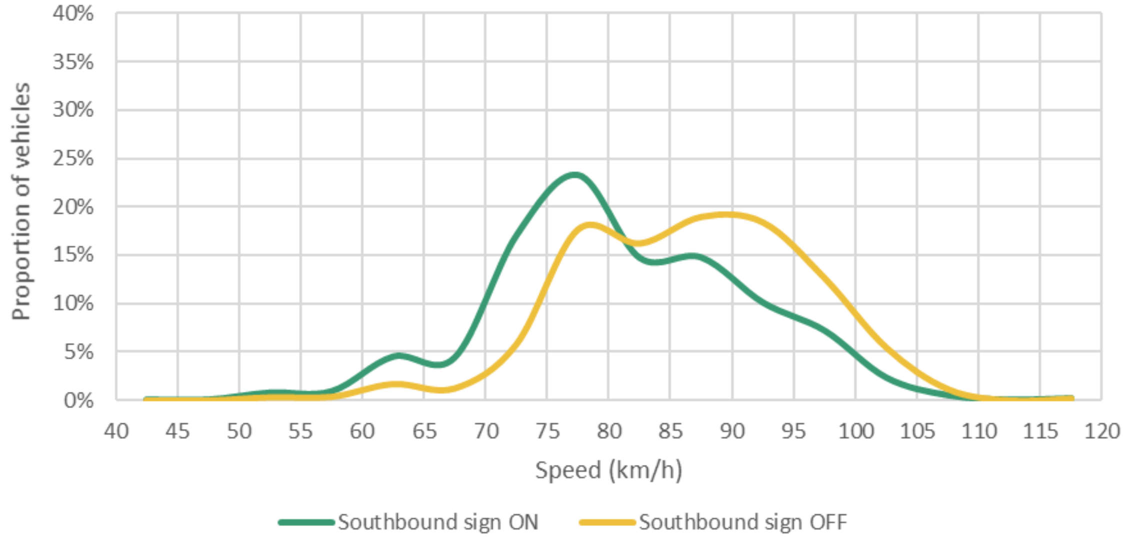


Table 18: Kennington speed summaries pre and post ISZ-installation, northbound and southbound

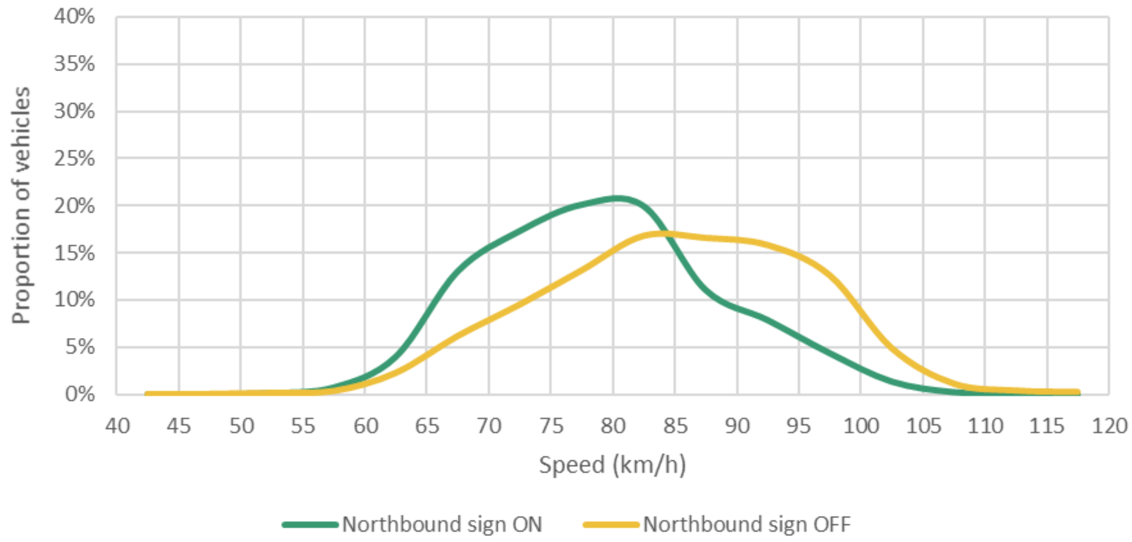
Kennington northbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Sep-13**	Sign would be OFF	7,424	72	7	79
		Sign would be ON	1,993	72	7	79
POST	**Nov-13**	Sign OFF	16,361	69	8	78
		Sign ON	4,868	62	8	71
	Feb-16	Sign OFF	35,890	69	7	78
		Sign ON	13,813	63	8	70
	Oct-19	Sign OFF	7,865	69	7	74
		Sign ON	2,093	65	7	74
Kennington southbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Sep-13**	Sign would be OFF	5,890	90	9	99
		Sign would be ON	1,621	89	9	98
POST	**Nov-13**	Sign OFF	16,117	84	10	92
		Sign ON	5,387	76	10	84
	Feb-16	Sign OFF	37,778	86	10	97
		Sign ON	14,971	80	10	92
	Oct-19	Sign OFF	7,955	87	9	97
		Sign ON	2,203	82	10	92

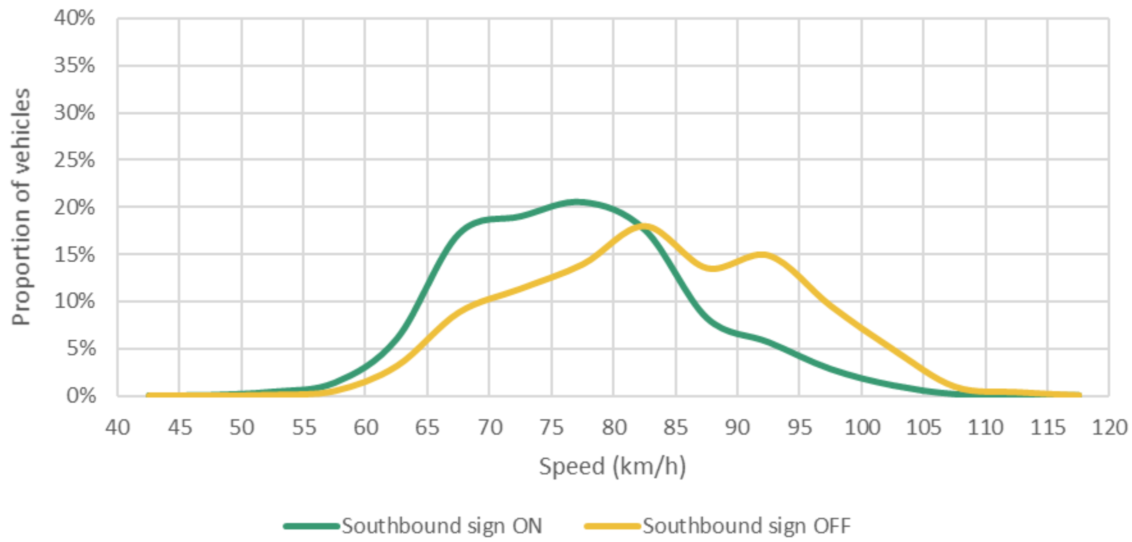
Earlier data (Sep-13, Nov-13, and Feb-16) have been truncated at 50km/h to attempt to remove turning traffic from the dataset. This has not been repeated with the Oct-19 data as there are few vehicles travelling below this speed.

4.1.4. Newbury (70km/h)

Figure 7 shows similar speed distributions to previous evaluations[10], though the first peak of vehicles travelling at between 65 and 70km/h southbound when the sign is on is less marked than previously. Table 19 shows that the ISZ has remained consistently effective since installation with no evidence of a reduction in compliance. There was a small increase in speed variance after the signs were installed, which has decreased again over time. Mean vehicle speeds at Newbury are 6-7km/h lower when the signs are on.

Figure 7: Newbury speed distributions for sign on compared to sign off, northbound and southbound





[10] Mackie, H., & Scott, R. (2016) Long-term update of RIAWS performance. A report prepared for the NZ Transport Agency.

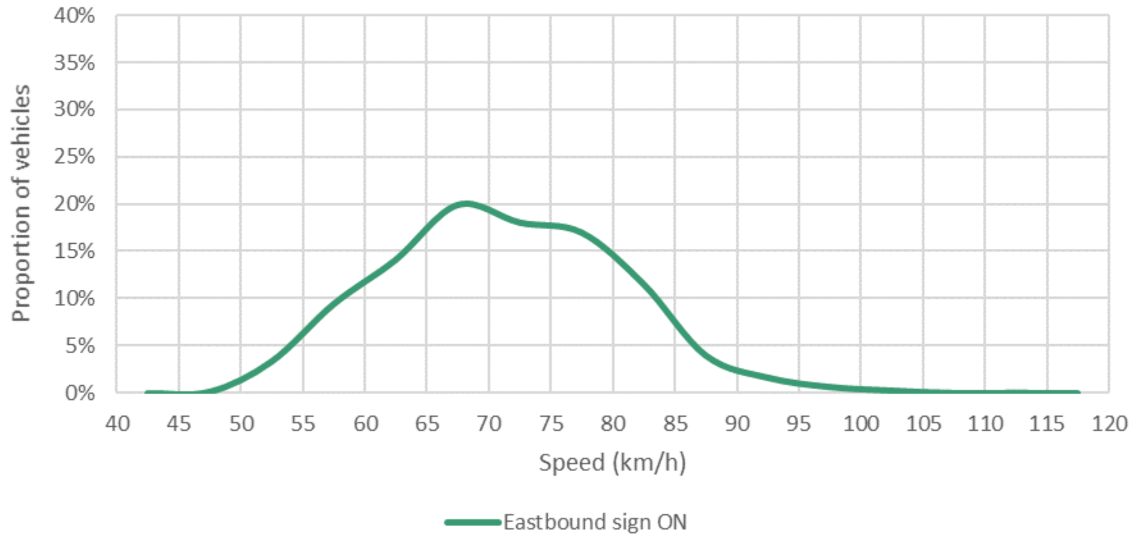
Table 19: Newbury speed summaries pre and post ISZ-installation, northbound and southbound

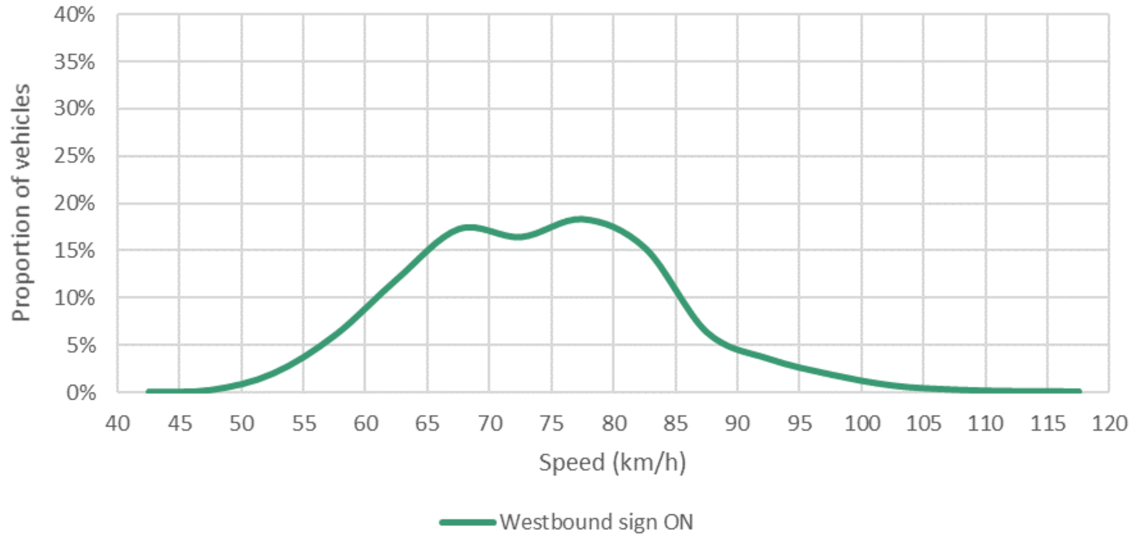
Newbury northbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Sep-13**	Sign would be OFF	9,671	87	8	95
		Sign would be ON	25,875	85	8	92
POST	**Nov-13**	Sign OFF	11,426	87	11	98
		Sign ON	33,016	79	10	91
	Feb-14	Sign OFF	9,221	86	11	96
		Sign ON	24,595	78	10	89
	Jun-14	Sign OFF	21,266	86	11	96
		Sign ON	60,201	78	10	89
	Feb-16	Sign OFF	25545	85	12	96
		Sign ON	93,689	78	9	89
	Oct-19	Sign OFF	4361	85	10	96
		Sign ON	20418	79	9	89
Newbury southbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Sep-13**	Sign would be OFF	10,518	87	8	95
		Sign would be ON	28,914	85	8	92
POST	**Nov-13**	Sign OFF	14,586	83	12	96
		Sign ON	33,468	76	10	87
	Feb-14	Sign OFF	11,398	83	11	96
		Sign ON	23,915	76	10	87
	Jun-14	Sign OFF	27,678	82	11	96
		Sign ON	60,867	75	9	85
	Feb-16	Sign OFF	9995	83	11	96
		Sign ON	35802	76	9	87
	Oct-19	Sign OFF	5033	84	11	96
		Sign ON	21642	77	9	87

4.1.5. Pakaraka (60km/h)

The Pakaraka ISZ signs were continuously activated during the data collection period at Pakaraka, therefore it is not possible to compare sign on to sign off speeds. The speed distributions in Figure 8 look similar to previous 'sign on' data, though westbound, vehicle speeds are slightly higher than in previous years, while eastbound, they are slightly lower. These lower speeds eastbound are also reflected in the mean and 85th percentile speed calculations (Table 20). However, vehicle counts are especially low at Pakaraka compared to previous years, suggesting there may also be less traffic going through the intersection due, for example, to roadworks or other network disruptions.

Figure 8: Pakaraka speed distributions for sign on, eastbound and westbound





Note: The ISZ signs were continuously activated at the Pakaraka site during the period of analysis.

Table 20: Pakaraka speed summaries pre and post ISZ-installation, eastbound and westbound

Pakaraka eastbound intersection speeds (60km/h VSL)						
	Date	Sign status	Vehicle count	Mean (km/h)	Std dev (km/h)	85th %ile (km/h)
PRE	**Sep-13**	Sign would be OFF	6,748	83	10	94
		Sign would be ON	7,008	81	10	91
POST	**Jan-15**	Sign OFF	11,932	78	12	91
		Sign ON	15,096	73	11	85
	Feb-16	Sign OFF	17,461	81	11	93
		Sign ON	20,166	76	10	87
	Oct-19	Sign OFF	-	-	-	-
		Sign ON	8169	72	9	81
Pakaraka westbound intersection speeds (60km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Sep-13**	Sign would be OFF	5,015	83	10	93
		Sign would be ON	7,899	79	11	89
POST	**Jan-15**	Sign OFF	9,997	77	11	89
		Sign ON	16,054	71	10	81
	Feb-16	Sign OFF	15,114	79	12	89
		Sign ON	21,363	74	10	85
	Oct-19	Sign OFF	-	-	-	-
		Sign ON	8300	74	10	85

4.1.6. Puketona (70km/h)

Speed data is only available for the northbound direction at Puketona. The speed distribution looks similar to previous years, with a mode of around 68km/h when the sign is on and 82km/h when the sign is off (Figure 9). ISZ effectiveness has been consistent since installation, with sign on speeds on average 7km/h lower than sign off.

Figure 9: Puketona speed distributions for sign on compared to sign off, northbound

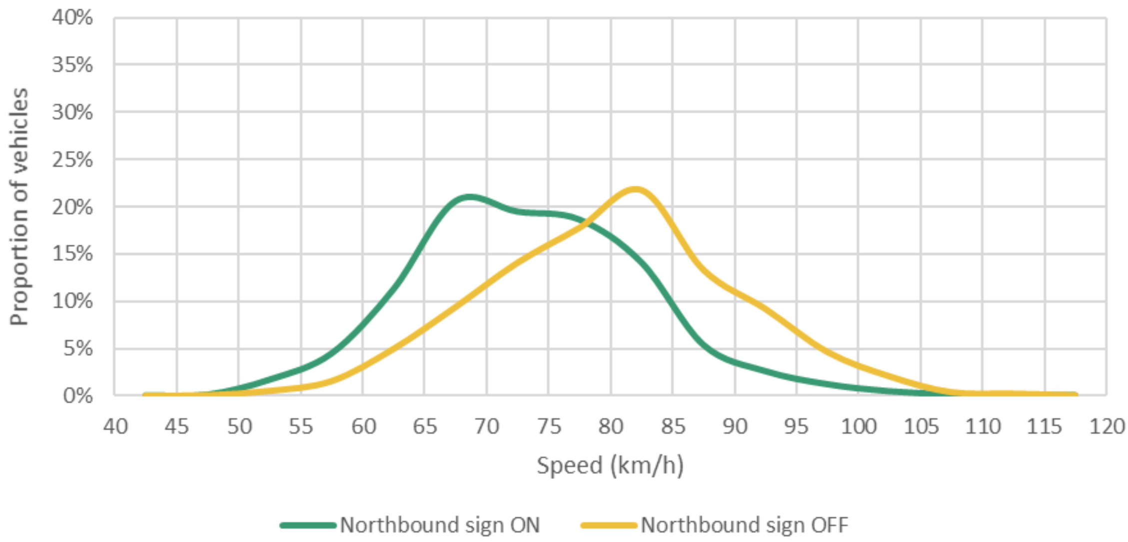


Table 21: Puketona speed summaries pre and post ISZ-installation, northbound

Puketona northbound intersection speeds (70kmh)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Oct-13**	Sign would be OFF	7,297	82	10	92
		Sign would be ON	8,121	79	10	88
POST	**Apr-14**	Sign OFF	9,889	81	11	91
		Sign ON	15,197	74	10	85
	Oct-14	Sign OFF	16,262	80	11	91
		Sign ON	23,917	74	11	85
	Feb-16	Sign OFF	9,683	79	17	91
		Sign ON	16,195	74	10	83
	Oct-19	Sign OFF	3749	80	10	91
		Sign ON	8332	74	9	83

Note low speeds during the pre-installation data collection may have been caused by traffic management.

4.1.7. Burnham (70km/h)

At Burnham, speed data was only available for the westbound direction. While the range of speeds is similar to previous years, the distribution is quite different in the most recent data, with two clear peaks in each dataset (sign on and sign off; Figure 10). It's unclear as to why this may be; it may be due to changes in traffic patterns over time, or it could be an issue with the data. Further investigation is needed to determine the cause. Mean speeds are slightly lower in the most recent data, reflecting the presence of the first, lower-speed peak, and speed variance has been slightly higher in the sign off condition since sign installation (Table 22). The difference in mean speeds between sign on and off in this most recent data is 7km/h.

Figure 10: Burnham speed distributions for sign on compared to sign off, westbound

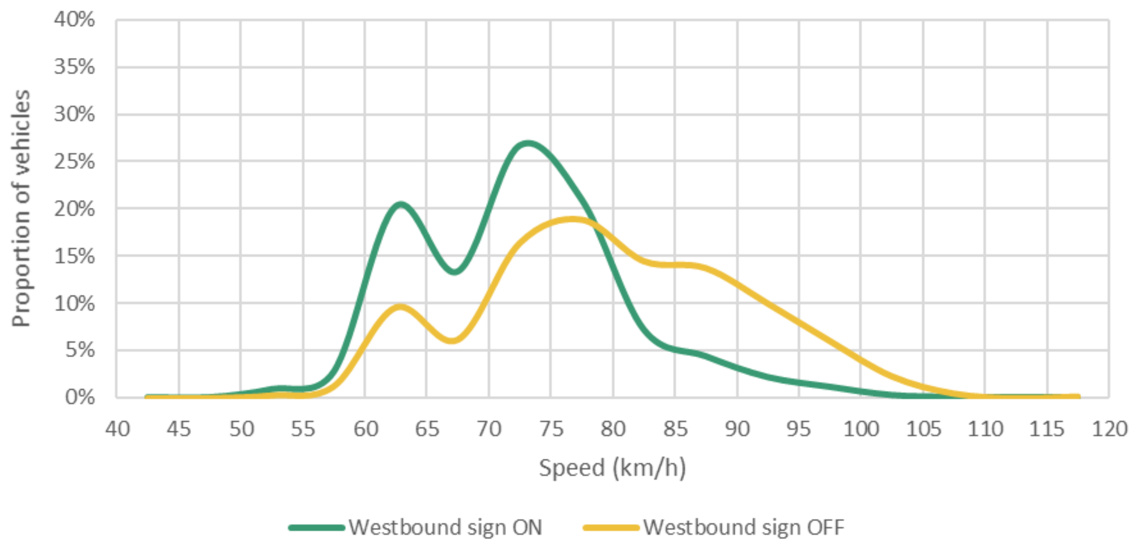


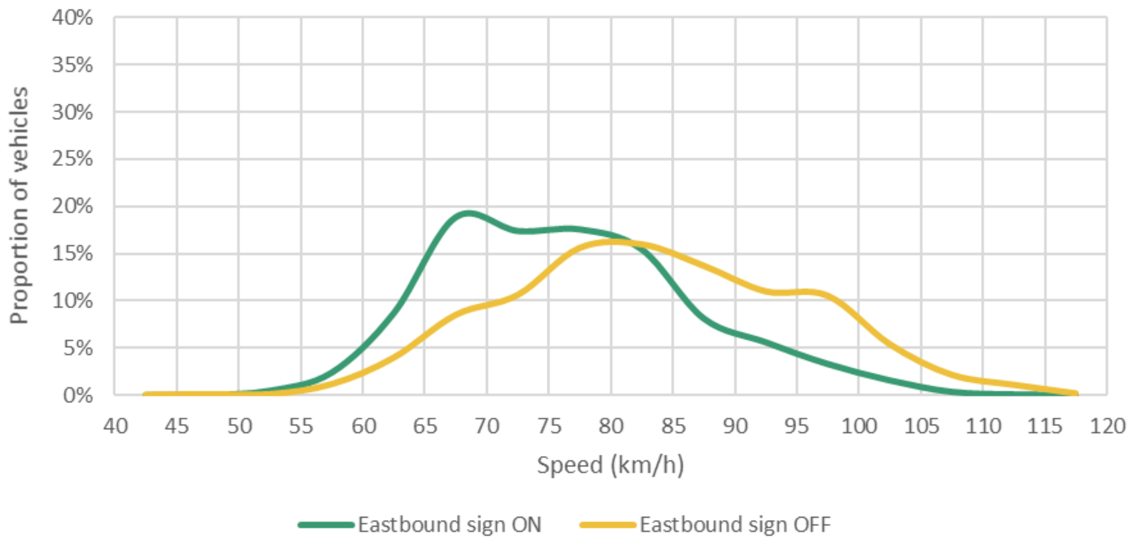
Table 22: Burnham speed summaries pre and post ISZ-installation, westbound

Burnham westbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Sep-14**	Sign would be OFF	19,436	94	8	102
		Sign would be ON	47,386	92	8	101
POST	**Oct-14**	Sign OFF	15,655	85	12	99
		Sign ON	44,514	76	9	87
	Feb-16	Sign OFF	35,783	84	12	96
		Sign ON	101,101	77	9	87
	Oct-19	Sign OFF	7246	80	11	92
		Sign ON	26001	73	9	84

4.1.8. Longlands (70km/h)

Figure 11 shows very similar speed distributions to the previous set of post-installation data from February 2016, with several peaks, rather than one clear one for each sign condition. Mean and 85th percentile speeds have also remained reasonably consistent since ISZ installation, with a difference in mean speeds of 5-7km/h between sign on and sign off in the most recent data (Table 23). Speed variance during sign off has also increased somewhat since sign installation. There may have been a small deterioration in speed compliance over time.

Figure 11: Longlands speed distributions for sign on compared to sign off, eastbound and westbound



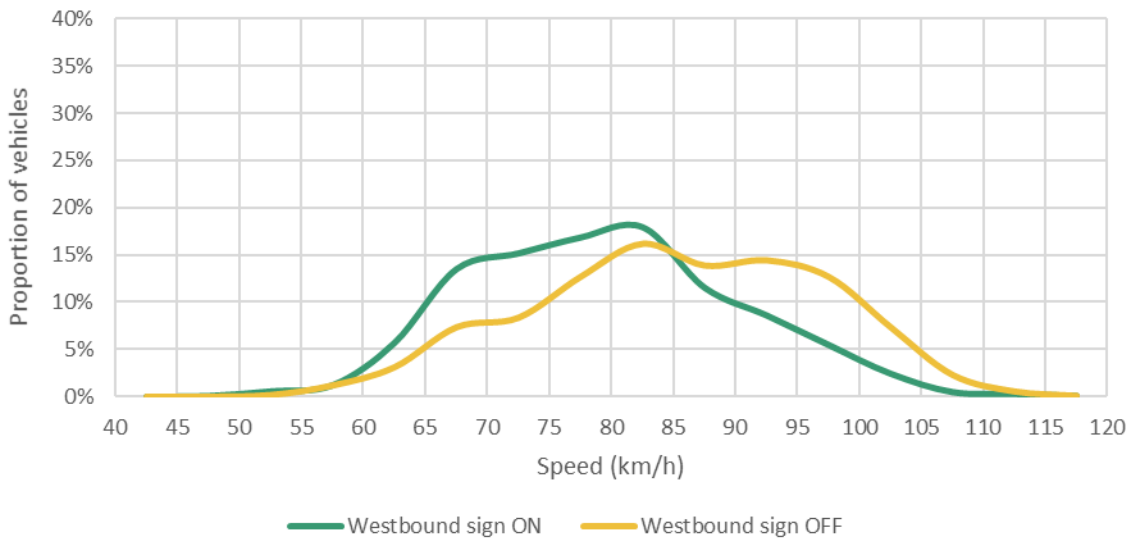


Table 23: Longlands speed summaries pre and post ISZ-installation, eastbound and westbound

Longlands eastbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Sep-14**	Sign would be OFF	2,634	91	8	99
		Sign would be ON	6,096	88	9	98
POST	**Oct-14**	Sign OFF	2,431	82	12	96
		Sign ON	5,593	75	10	87
	Jan-15	Sign OFF	3,791	81	12	94
		Sign ON	11,875	73	9	83
	Feb-16	Sign OFF	7,708	84	12	96
		Sign ON	21,658	76	10	87
	Oct-19	Sign OFF	1318	84	12	96
		Sign ON	7018	77	10	87
Longlands westbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Sep-14**	Sign would be OFF	4,452	92	10	99
		Sign would be ON	8,266	89	10	99
POST	**Oct-14**	Sign OFF	4,411	84	12	96
		Sign ON	7,562	77	10	89
	Jan-15	Sign OFF	3,637	83	12	96
		Sign ON	11,032	76	10	87
	Feb-16	Sign OFF	7,383	84	15	98
		Sign ON	21,252	79	11	91
	Oct-19	Sign OFF	1092	85	12	98
		Sign ON	6610	80	11	91

4.1.9. Kaiapoi (70km/h)

Only northbound speed data is available for the Kaiapoi site, as was the case in the previous evaluation. The speed distributions look similar to previous post-installation distributions, though the sign on peak has shifted slightly from around 70km/h in previous years to around 77km/h in the most recent data (Figure 12). Mean and 85th percentile speeds, however, have remained consistent, with a 5-6km/h difference between the sign on and sign off conditions (Table 24).

Figure 12: Kaiapoi speed distributions for sign on compared to sign off, northbound

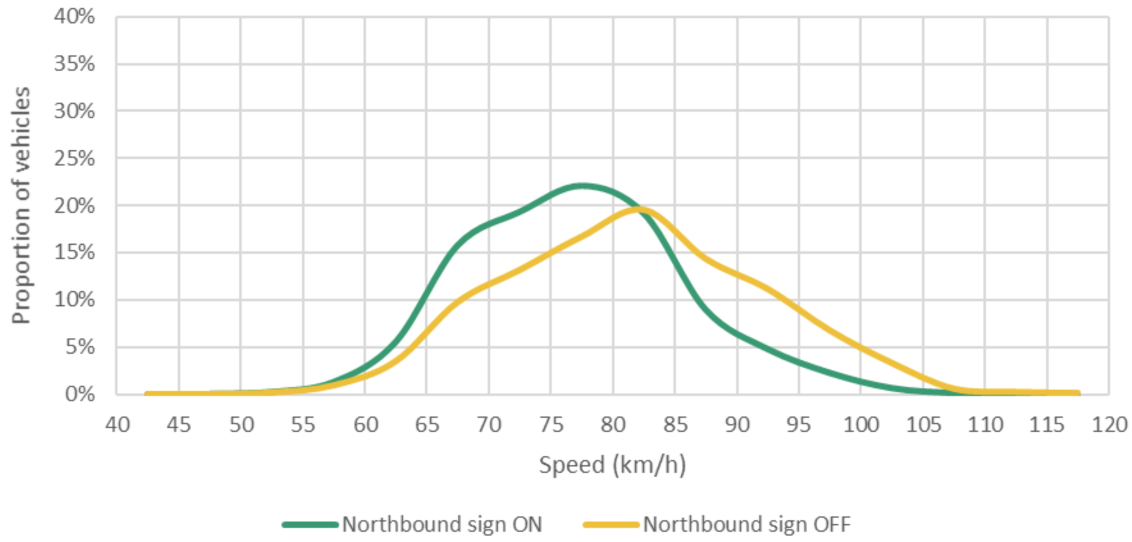


Table 24: Kaiapoi speed summaries pre and post ISZ-installation, northbound

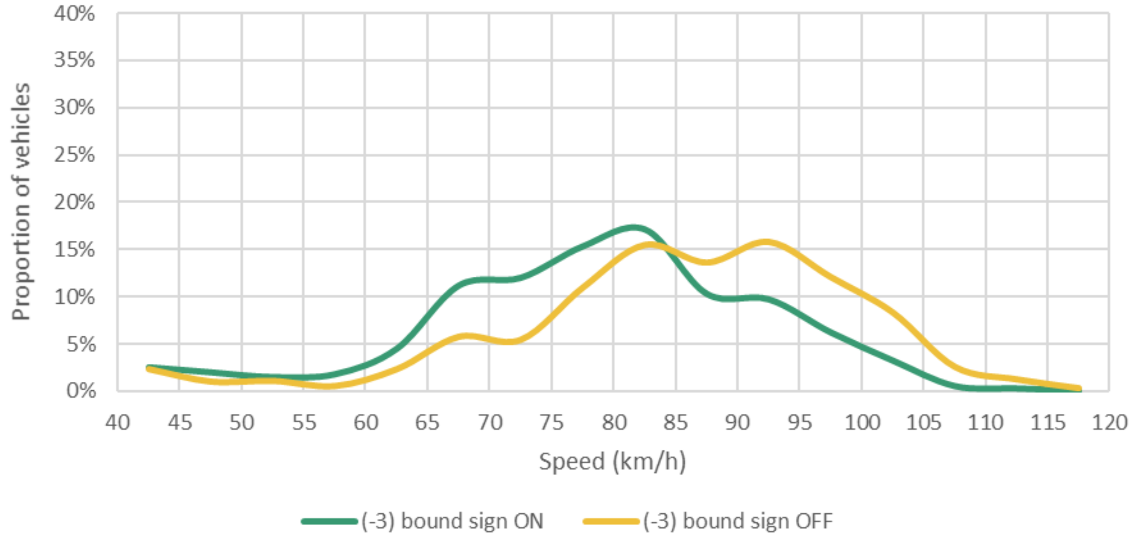
Kaiapoi northbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Sep-14**	Sign would be OFF	25,673	90	8	98
		Sign would be ON	38,686	88	8	96
POST	**Nov-14**	Sign OFF	32,268	84	11	96
		Sign ON	52,467	77	9	87
	Feb-16	Sign OFF	80,630	82	11	93
		Sign ON	108,948	76	9	85
	Oct-19	Sign OFF	14239	82	10	93
		Sign ON	31852	77	9	87

4.1.10. Puketaha (70km/h)

Due to recent device failure the direction of the speed data is unable to be determined.

The difference in mean speeds for sign on compared to sign off at Puketaha is between 5 and 7km/h.

Figure 13: Puketaha speed distributions for sign on compared to sign off, directions uncertain



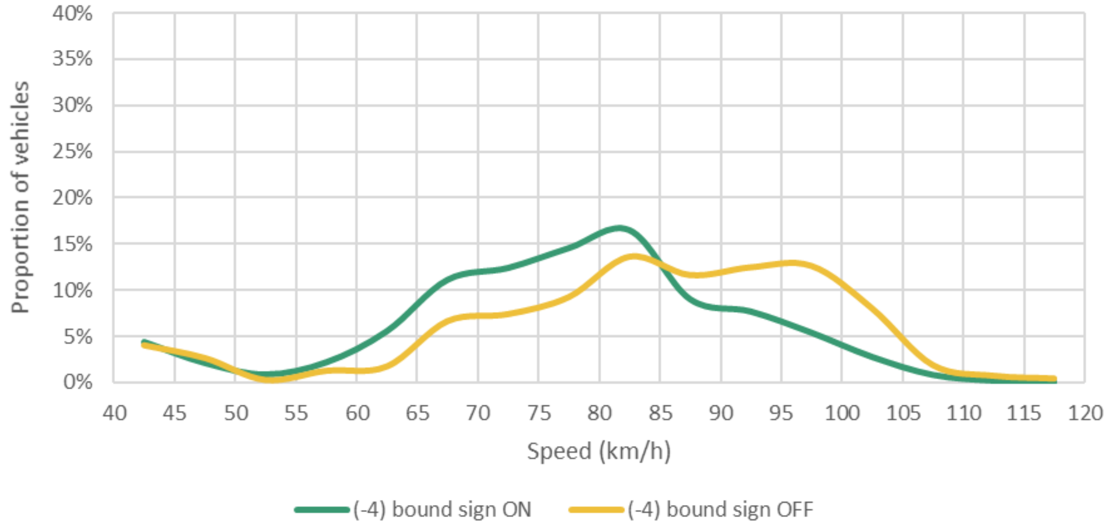


Table 25: Puketaha speed summaries pre and post ISZ-installation, eastbound and westbound

Puketaha eastbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Feb-15**	Slowdown sign OFF	3,542	83	17	98
		Slowdown sign ON	7,719	80	17	96
POST	**Feb-16**	70km/h sign OFF	4,002	83	17	98
		70km/h sign ON	8,442	77	15	93
Puketaha westbound intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
PRE	**Feb-15**	Slowdown sign OFF	3,431	82	19	98
		Slowdown sign ON	8,678	78	18	96
POST	**Feb-16**	70km/h sign OFF	3,981	82	19	99
		70km/h sign ON	8,726	76	18	94

Note electronic 'slow down' signage was present during 'pre' data collection at Puketaha.

Table 26: Puketaha speed summaries October 2019, directions uncertain

Puketaha intersection speeds (70km/h VSL)						
	Date	**Sign status**	**Vehicle count**	**Mean (km/h)**	**Std dev (km/h)**	**85th %ile (km/h)**
POST	**Oct-19** *(direction -3)*	70km/h sign OFF	1289	85	15	99
		70km/h sign ON	4369	78	14	94
	Oct-19 *(direction -4)*	70km/h sign OFF	1307	81	18	98
		70km/h sign ON	4565	76	16	96

4.2. New ISZ sites

Speed data from the new sites indicates that ISZs are equally effective in reducing speeds through the intersection when turning vehicles are present (Table 27). ISZ effectiveness varies across the sites, with mean speeds through the intersection between 3 and 10km/h lower when the signs are active compared to inactive. The greatest speed reductions are seen at the Waipu, Piarere, Hopkins, and Te Puninga sites, with less marked ISZ effects at the Luggate, Brynderwyn, Oakleigh, and Kopu sites.

Speeds do remain relatively high, however, with 85th percentile speeds at most sites falling between 85km/h and 95km/h when the signs are active. Speeds during sign activation are highest at Te Puninga, Luggate, and Waipu, the first two of which have 70km/h, rather than 60km/h VSLs. Together with the smaller ISZ effect at Luggate, this suggests a 60km/h VSL may be more appropriate at this site, depending on more site-specific knowledge of the area.

Table 27: Summary of speeds in each direction at new sites for sign on compared to sign off, October 2019

#	Site name	VSL (km/h)	Direction	Sign ON/OFF	Vehicle count	Mean speed (km/h)	Standard deviation (km/h)	85th percentile (km/h)
11	Brynderwyn	60	NB	OFF	10369	84	11	96
			NB	ON	11615	80	11	92
			SB	OFF	9258	84	10	95
			SB	ON	12637	78	10	88
12	Oakleigh	60	NB	OFF	30776	81	10	91
			NB	ON	20848	75	10	85
			SB	OFF	29671	81	10	91
			SB	ON	22223	76	10	87
13	Waipu	60	NB	OFF	18430	89	11	99
			NB	ON	13393	80	12	91
			SB	OFF	18474	90	10	99
			SB	ON	13103	83	11	96
14	Kopu	60	EB	OFF	5374	81	11	91
			EB	ON	12361	75	10	87
			WB	OFF	7070	85	10	94
			WB	ON	15093	80	9	89
15	Gordonton	60	NB	OFF	10517	74	12	87
			NB	ON	11138	67	10	77
			SB	OFF	11472	78	12	91
			SB	ON	12704	72	10	83
16	Te Puninga	70	NB	OFF	13561	93	10	104
			NB	ON	3682	86	11	99
			SB	OFF	14757	93	9	101
			SB	ON	3675	86	11	96
17	Hinuera	60	EB	OFF	2135	82	12	94
			EB	ON	18122	76	11	87
			WB	OFF	2188	82	11	94
			WB	ON	17698	75	10	87

18	**Hopkins**	60	EB	OFF	7092	87	12	97
			EB	ON	12008	79	12	92
			WB	OFF	6956	85	11	97
			WB	ON	12347	77	12	88
19	**Piarere**	60	EB	OFF	9030	86	10	96
			EB	ON	28510	78	10	89
			WB	OFF	8671	83	11	94
			WB	ON	28244	73	10	85
20	**Luggate**	70	NB	OFF	9209	88	10	99
			NB	ON	3110	83	10	94
			SB	OFF	9234	85	10	94
			SB	ON	3215	82	10	91

VSL = variable speed limit on ISZ signs; NB = northbound, SB = southbound, EB = eastbound, WB = westbound

4.3. Implications for ISZ performance

The effectiveness of the signs at the original sites has remained reasonably consistent since installation, with mean speeds between 4 and 8km/h lower when the signs are on compared to when the signs are off. At some sites, there appears to be a small reduction in compliance over time, or after an initial period of adjustment. The new sites appear to be equally effective, though there is a greater range of effect, with mean speeds between 3 and 10km/h lower when the signs are on. At some sites, speed variance while signs are off has increased since the signs went in. However, there is little difference in speed variance between the 'sign on' and 'sign off' conditions, with over half of sites showing slightly less speed variance when the signs are on, i.e. when intersecting vehicles are present, than when they are off. This is somewhat complicated by how the system records 'sign on' and 'sign off' drivers and is discussed later.

There is no clear evidence to indicate that a 60km/h or 70km/h VSL is more effective, although it may be the case that at sites with 85th percentile speeds below 100km/h, a lower VSL encourages greater slowing. However, most of the 60km/h ISZs were installed fewer than six months before speed data collection, so the greater effect of the ISZs at some new sites may be attributable to an adjustment period.

Overall, the speed data indicate that the ISZs effectively reduce speeds when intersecting vehicles are present and continue to do so several years after installation. At Himatangi, the longest running site, the signs remain effective almost 7 years after they were installed. While the effectiveness varies across different sites, there is little overall evidence to indicate a reduction in compliance or loss of credibility over time, even when a fault causes the ISZ to be continuously activated, as at the Pakaraka site.

5. OPERATIONAL PERFORMANCE

Customer and internal stakeholder feedback on the operational performance of RIAWS was carried out. The SH29/1 (Piarere) and SH25/Hauraki (Kopu) sites in particular have received a lot of recent attention from both customer and internal stakeholders.

The following themes have emerged from the information that is available:

- Uncertainty about how the system works and why the speed limit switches (sometimes suddenly) between 100 km/h and 60 or 70 km/h
- The potential for rear-end crashes due to motorists responding suddenly to the speed limit change
- The need for advanced warning of the approaching ISZ
- The lower speed limit being activated all of the time
- Poor conspicuity of the approaching VSL sign, particularly at SH1/29 (Piarere) Northbound, where the sign is on a sweeping left-hand curve and also motorists are often looking for intersection traffic on SH29.

An interview with the ISZ supplier yielded the following key points related to both operational and technical considerations:

- Generally, the design and layout of the ISZ has been consistent based on the guidance that exists. This includes the size of the roundel and numbers. However, there may be other installations by City Councils that have different configurations
- A key difference in the newer installations is the use of a pulsing roundel instead of amber beacons for the dynamic component of the signs, in line with Australian practise for VSLs. This has also meant the overall box size is smaller and lighter/cheaper poles are able to be used
- Improved power usage technology has meant that some signs in lower use situations (e.g. SH 27/Horrell - Te Puninga) are able to utilise solar panels to power the signs, substantially decreasing cabling costs
- The remotely programmable newer signs mean that the speed limit can be changed for various purposes (e.g. permanent 60 if a fault, 30 km/h road works or crash, 70 km/h if behaviour is being adversely affected by 60 km/h)
- Costs have remained relatively consistent for ISZ installations, but traffic management costs and requirements have significantly increased
- It does seem that some sites operate differently to others, and advance warning or gating of VSL signs may be useful in some circumstances.
- Especially for 60 km/h installations, the target sign installation distance could be increased to 200m from the intersection (although this would increase the proportion of people who miss the reduced speed limit when intersecting traffic is present)
- Ongoing maintenance needs to be factored into the lifetime costs, as this is important for the efficient and effective operation and credibility of the system.

A conversation with key operational internal stakeholders resulted in the following key points:

- Agreed with the range of issues that are often reported
- The objective data being collected (e.g. speed and crashes) should be interrogated before decisions are made for system modifications
- There is no evidence from objective data and years of site experience of operational issues that cause unsafe behaviours or crashes
- The new format with the pulsing roundel appears not to be as conspicuous as the older format with the flashing alternating amber beacons.

6. DISCUSSION

6.1. Implications

The findings show a 28% reduction in total crashes following ISZ installation at the original ISZ sites and a 69% reduction in fatal and serious injury crashes, indicating that ISZs reduce the overall crashes, but particularly the severity of crashes that do occur. This runs counter to a cohort of similar intersections (albeit with lower crash rates) and national trends for rural intersections, providing good evidence for ISZ effectiveness. Crash casualty rates show a similar trend, with an estimated 20 fatalities and serious injuries having been avoided at original sites over the follow-up period.

This crash performance is less strong than reported in an earlier study, which reported a 71% reduction in total crashes and a 93% reduction in fatal and serious injury crashes (with lower net crash reduction). This is to be expected, as there has now been a longer period for crashes to emerge. Overall, however, the findings point to a continued and substantial ongoing reduction in crashes and crash severity at ISZ sites.

However, there have been some high severity crashes at ISZ sites and this is a reminder that the system isn't fail-safe and the whole Safe System needs to be considered in preventing high severity casualties including improved vehicle safety.

Speed performance of the ISZs were also found to remain strong over time, with mean speeds at each ISZ between 3km/h and 10km/h lower when ISZ signs are active compared to when they are inactive At most sites modal (most common) speeds are close to the VSL suggesting that the most common response is to approximately comply with the VSL. In addition, variability in vehicle speeds is mostly unchanged or lower while signs are active. This is slightly complicated by the fact that a minority of drivers will not be aware of the VSL status as it will have changed after they have passed the VSL sign, but before they register on the speed loops at the intersection. While there is some evidence of small reductions in speed compliance over time at some sites, the general trend is for ongoing compliance with ISZs.

Although there continue to be tangible speed reductions at intersections with ISZ active, as originally found, the large safety benefits suggest that speed reduction alone is not responsible for the safety outcomes. Many motorists don't comply with the ISZ and compliance is generally worse than for other speed limit applications. In addition, information reported in TCRs indicates police officers may not be familiar with how the ISZ VSLs function. However, it is likely that ISZs also play a vital role in increasing the situation awareness and alertness of motorists so that they are more ready to react to events as needed. With improved alertness and awareness of their surroundings, motorist's reaction times will be lower and hence both the likelihood of a collision, as well as the severity of collisions (because there is more time available for braking or swerving) are likely to be reduced.

Overall, ISZs remain a very effective and cost-effective road safety countermeasure. Their DSI reducing effects, compared with the cost of installation and maintenance is likely to be high compared with other intersection countermeasures. This raises an important point regarding the strategy that should be adopted to treat intersections for the whole country. The biggest challenge might not be reducing DSI crashes at single locations, but rather addressing the hundreds of intersections around the country that are all, in their own small way, contributing to road trauma. If this is the case, then using high effectiveness and relatively low-cost safety interventions perhaps should be prioritised over high cost transformational projects. In addition to ISZs, other interventions that may fall into the high effectiveness/lower cost category might include raised safety platforms, compact roundabouts, and continued lower speed limits in general. However, this is a conceptual approach based on the success of ISZs, and clearly there are other considerations that need to be balanced before strategic decisions like this are made.

There are some reported ongoing issues with the ISZ, but the issues raised by motorists or internal stakeholders don't seem to be supported by the safety and speed performance. For example, there are no examples of rear-end crashes on the priority approach at any ISZ, and yet there have been many complaints that this is a key risk from them. However, feedback should always be considered seriously, and it may be that the data available doesn't completely reflect the everyday events that road users experience, and hence further investigations may be needed in some instances.

The conspicuity of signs is something has been raised repeatedly for SH1/29 (Piarere) Northbound. However, the speed data from these sites indicate that drivers are responsive to the VSLs, and indeed this sign has one of the highest levels of compliance in the country.

There is also the possibility of surprise if the sign comes on when motorists are quite close to it, giving them less time to respond. These issues could potentially be mitigated by the addition of advance warning signs, gating, or painted thresholds, so that drivers are primed to expect a change in speed limit.

The shift from the use of alternating flashing beacons to pulsing roundels has also not been formally assessed, and yet a number of stakeholders suggest that the pulsing roundel is not as effective as the earlier used flashing beacons. It would be useful to understand whether the roundels are as effective as the beacons used previously, through controlled user-testing.

The risk with any suggestion of modifications is that the cost of the system increases for diminishing returns, if the system is already proving to be performing effectively.

Nevertheless, some sites such as Burnham, Puketaha, Kopu, and Piarere, deserve further inspection, either for ongoing serious injury crashes involving vehicles failing to give way as they exit side roads, ISZ compliance, or through repeated raised issues from stakeholders.

An interesting trend in the data is increasing sign activation over time (more turning traffic and probably more traffic overall). This may affect sign credibility, and gap availability in the longer-term and it suggests that the ongoing performance of intersections need to be monitored to ensure that the ISZ is still fit for purpose. However, it has been shown earlier that even at some of the busiest intersections (e.g. Newbury), the system continues to be effective with ongoing speed and safety benefits. Finally, better information in the TCRs, regarding driver's response to the ISZ or the activation of it, would be useful to determine the ongoing effectiveness of the ISZ over time.

6.2. Limitations

In this report a rather more conventional set of comparison intersections were used as a control group, compared to earlier analyses. This was unavoidable, as understandably, high risk intersections get improved over time. Nevertheless, this does indicate a difference from previous analyses. This does however mean that these newer comparison intersections are more representative of the average NZ intersection and the larger 'NZ Rural Intersection' cohort.

There were some issues with homogeneity of the data with some patterns that indicate minor system processing issues. This may lead to 'Swedish rounding' of speeds and timing limitations, plus possible loss of some data at peak times, meaning that mean speed data are not necessarily representative. However, this method hasn't changed since baseline and there is no difference between sign on versus off, so this doesn't affect any comparative analyses and conclusions drawn about the effectiveness of the ISZs.

Finally, the estimates do not account for regression to the mean effects. Intersections that are targeted for treatment due to their unusually high crash rates are unlikely to sustain these consistently high rates over time even without treatment, so analyses incorporating regression to the mean are useful for understanding the true impact of a treatment on crash rates. As this was not taken into account in this study, a crash modification factor is not able to be calculated from the data presented, and should be pursued in future work.

6.3. Recommendations

The following recommendations are based on the analysis and discussion:

- Continue the roll-out of ISZs based on proven success, and indeed consider scaling up their roll-out based on their high effectiveness to cost ratio. However, their application may still be most appropriately limited to high/medium high risk intersections where more enduring, primary Safe System solutions such as roundabouts or raised platforms are unlikely to be installed in the short to medium term, or are impractical and/or unaffordable. ISZs require a reasonable level of monitoring and maintenance to retain their functionality and credibility, and their association with higher risk locations is likely important for maintaining their credibility.
- Consider the various operational issues that have been identified, but prioritise any improvements based on their ability to *tangibly* improve performance.
- For existing sites with remaining safety, effectiveness, or operational issues, carry out site visits and/or further analyses to gain a deeper understanding of their day to day operation and the behaviours that are resulting from the system.
- Formally test the conspicuity of the older flashing beacons with the newer pulsing roundel to determine the most effective design for alerting motorists in advance of the intersection.

6.4. Conclusion

Overall, the Intersection Speed Zones are continuing to demonstrate effectiveness in reducing speed, high severity crashes, and to a lesser extent all crashes, at high-speed rural intersections. The ongoing use of ISZ is therefore suggested as an effective road safety countermeasure. On the basis of these findings and their relative cost-effectiveness, ISZs should be considered for further application, with minor operational issues being addressed as needed.