Redland Smart Signs and Smart Messages: A Driver Change Behaviour Project – Year 1 Report 2018-2019

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Executive summary

Redland City supports an important and well-known population of koalas. This formerly large and widespread population has been steadily declining for a range of reasons, with vehicle-strikes being of particular significance. Recent innovations in traffic signage offer a valuable new method that could potentially reduce the risk of wildlife-vehicle strikes. Currently, wildlife warning signage is the only wildlife-vehicle collision mitigation measure that can be implemented quickly, for relatively low cost, and at the landscape scale, particularly in the urban matrix. Although static wildlife warning signs are the most commonly used and widespread form of road mitigation throughout the world, evidence of their effectiveness is inconsistent. This 15-week pilot project aimed to evaluate the effectiveness of various dynamic sign designs to reduce vehicle speeds in areas known to support koalas. The sign trial is intended to be one part in a much larger, long-term project with the objective of enhancing the persistence of koalas in Redlands by heightening community awareness of the presence of this iconic species and influencing the behaviour of drivers living within the area.

Six sites were selected along three roads in Redland's Ormiston koala conservation safe neighbourhood: Sturgeon Street, Starkey Street, and Wellington Street. Six variable-message wildlife warning signs were to be installed and rotated at the sites, however technical issues with two of the signs at the beginning of the project resulted in only four signs being used in the trial. Despite this, all six sites remained in the trial, with the four signs being rotated between the six sites between each treatment period.

The signage used included two Sierzega Speedpacer 4568 C signs with standard fluorescent yellow panels with the wording 'DRIVE SAFELY' (referred to as the 'smiley signs') and two Sierzega Speedpacer 2368 FC signs with custom panels displaying a photo of a koala walking along on a road with the wording 'KOALA CROSSING' (referred to as the 'koala signs'). Sign messages were developed in discussion with Redland City Council and were restricted by the LED panel dimensions of each sign design. The smiley signs displayed a green smiling face image at low speeds (up to 11 km/h under the speed limit), a small yellow smiling face image with 'BE ALERT' below it at medium speeds (between 10 km/hr under the speed limit and the speed limit), and a small red sad face image with 'SLOW!' below it at high speeds (over the speed limit). The koala signs displayed 'THANK YOU!' in green at low speeds, 'STAY ALERT' in yellow at medium speeds, and 'SLOW DOWN' in red at high speeds. Both sign types were also programmed to alternate the relevant message with the speed of the vehicle, with the colour of the speed number matching that of the respective messages.

Each sign recorded the date, time, and two speeds: one when the vehicle was first detected and one when the vehicle passed the sign. The signs were covered to record control data at the beginning of the project, but due to technical issues and only four signs being deployed, some control data was obtained through different methods. Each sign type remained at each site for two weeks, with both sites on each road displaying the same sign type during the same period. After an eight week period, wildlife zone painted thresholds were installed and the signs were rotated between the sites, again remaining at each site for two weeks.

Numerous variables that were determined to be of potential interest were added to the data. Several summary statistics were calculated for each study site. Where possible, the speed difference was calculated between the initial speed (speed 1) and the final speed (speed 2). A generalised least squares (GLS) model was generated to examine the influence of different variables on the speed difference.

At all sites, both the smiley signs and the koala signs reduced average vehicle speeds and the proportion of vehicles speeding (which equated to thousands of vehicles). Differences between the two sign designs were marginal, however, the koala signs performed slightly better across the sites. The painted thresholds had little impact on vehicle speeds, and any effect was inconsistent across the sites and sign designs. However, the primary purpose of the wildlife zone painted thresholds was to demarcate the area through which drivers need to be cautious of wildlife near the road and do not instruct drivers to adjust their speeds.

The final model included sign treatment, painted threshold, site, speeding category (non-speeders, moderate speeders, and excessive speeders), and was weighted by three-hourly time blocks. Both sign designs had greater reductions in vehicle speeds than the control, with the painted thresholds generally slightly lessening these speed reductions. Vehicle speeds tended to be reduced more at night, with excessive speeders reducing their speeds more than both non-speeders and moderate speeders.

Overall, the koala signs were slightly more effective in reducing vehicle speeds compared to the smiley signs. It is possible that this was due to these signs providing additional information to drivers as to why they should alter their behaviour and/or the additional impact of the koala conservation community awareness campaign conducted during the study.

It is recommended that this sign trial be continued in 2019 in order to further investigate the influence of wildlife warning sign designs and messages on vehicle speeds and driver behaviour. Should the sign trial be continued, the several recommendations should be employed to gain a more comprehensive understanding of driver behaviour and reduce the risk of technical and data issues during the project.

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1. Introduction

Redland City supports an important and well-known population of koalas. The on-going persistence of these iconic animals is strongly supported by the Redlands community. This formerly large and widespread population has been steadily declining for a range of reasons, with vehicle-strikes being of particular significance (Rhodes *et al.* 2015; Gonzalez-Astudillo *et al.* 2017). The more recent Queensland Koala Expert Panel report (Rhodes *et al.* 2017) and the Queensland Government's response (Queensland Government 2018) both highlight the importance of reducing the impacts of vehicles and roads on koala populations. The involvement and collaboration with local governments is essential to achieving the recommended actions (Rhodes *et al.* 2017; Queensland Government 2018). Redland City Council has been active in providing koala conservation initiatives and has supported the Department of Transport and Main Roads in implementing wildlife-exclusion fencing and fauna underpasses along state-owned roads within the city, which have been successful in facilitating safe movements of koalas in certain locations. It is important, however, that new approaches be tried and evaluated that can be implemented on a broader scale and in suburban settings. The recent emergence of the field of road ecology has been accompanied by many novel technologies and perspectives of direct relevance to the precarious status of koalas in this region. Recent innovations in traffic signage, for example, offer an important new method that could potentially reduce the risk of wildlife-vehicle strikes.

The continued development and investigations into the elements of road signage that elicit desired responses from drivers is critical (Bond and Jones 2013). Although other effective wildlife-vehicle collision mitigation measures exist (i.e. wildlife underpasses and overpasses with wildlife-exclusion fencing), these measures are greatly restricted in terms of where they can be installed in roaded landscapes. Such mitigation measures are also highly costly, require significant ongoing maintenance, can only be installed during major construction activities, and must be located where the topography is appropriate for these engineering solutions (van der Ree *et al.* 2015; van der Ree and Tonjes 2015). Currently, wildlife warning signage is the only wildlife-vehicle collision mitigation measure that can be implemented quickly, for relatively low cost, and at the landscape scale – particularly in the urban matrix.

Wildlife warning signs are the most commonly used and widespread form of road mitigation (Forman *et al.* 2003; Huijser and McGowen 2010; Huijser *et al.* 2015). Despite their popular use, most often, sign effectiveness has been poorly evaluated (Romin and Bissonette 1996; Al-Kaisy *et al.* 2008). Where an evaluation of signs has occurred, evidence of their effectiveness is inconsistent (Huijser *et al.* 2015). Even where speed reductions are evident, it is not always discernible that these reductions will persist and lead to decreases in wildlife-vehicle collisions. Driver habituation to wildlife warning signs is an issue that has the potential to be tackled through the implementation of dynamic signage during the most high-risk periods in certain situations.

An early example of an animated deer crossing sign, depicting a lighted outline of a deer progressively leaping and the words 'DEER XING NEXT MILE', was installed on State Highway 82 in Colorado, USA in the mid-1970s. The sign was reported to reduce vehicle speeds, but the effect was too small (3 mi/h or 4.8 km/h on a highway with a posted speed limit of 60 mi/h or ~97 km/h) to reduce the deer-vehicle collision rate (Pojar *et al.* 1975).

Temporary deer warning signs with flags and flashing lights were placed along road sections with high numbers of deer-vehicle collisions during the deer migration season (Sullivan *et al.* 2004). Lights were controlled by a light sensor to flash between dusk and dawn. Across the sites, numbers of deer-vehicle

collisions were estimated to have been reduced by 51% (CI 3.2-75.1%) from periods before the signs were erected (Sullivan *et al.* 2004). The likelihood of a vehicle exceeding the speed limit by at least 8 km/h reduced significantly for treatment sites, from 19% to 8% of vehicles (Sullivan *et al.* 2004).

Standard static deer warning signs installed along 13 roads in Edmonton, Alberta, Canada (Found and Boyce 2011). Compared to 13 unsigned roads with historically similar numbers of deer-vehicle collisions, fewer collisions occurred along the signed roads after installation of the signs (Found and Boyce 2011). Although the total number of deer-vehicle collisions reduced substantially throughout the city, including along unsigned control roads, the signed roads experienced significantly greater reductions.

Al-Ghamdi and AlGadhi (2004) compared camel warning signs of different designs: the standard black camel silhouette on a white triangle with a red boarder, both with and with reflective material, and a yellow camel silhouette on black square background, with the wording 'camel-crossing' and an advisory speed. These three sign types were also compared at different sizes: the standard camel signs with and without reflective material were both tested at the normal size (110 x 110 x 110 cm) and double the normal size; with the alternate design tested at 75 x 75 cm, 150 x 150 cm, and 300 x 300 cm (Al-Ghamdi and AlGadhi 2004). Using the reduction in vehicle speed at night as the measure of effectiveness, the standard sign did not elicit a reduction in vehicle speed, with the other two sign designs significantly reducing speed by between 1.93 km/h and 6.51 km/h. The size of the signs did not have a significant influence on speed reductions. Both the standard sign with reflective material and the square sign designs were deemed effective at producing a relatively small reduction in vehicle speed (Al-Ghamdi and AlGadhi 2004). Furthermore, when a series of similar large signs for moose-vehicle collisions were installed in conjunction with an aggressive public awareness campaign, records indicated collisions with urban moose dropped by 41% in Prince George, British Colombia, Canada (Rea 2012).

Animal advisory dynamic message signs (displayed from 5pm to 9am only) were installed in 2005 on the Interstate-90 over Bozeman Pass, Montana (Hardy *et al.* 2006). Two animal advisory messages were displayed, one advising to watch for animals crossing and the other showing an updated tally of the number of animals hit that year. The average speed of passenger vehicles reduced by 0.1-4.7 mi/h when compared to either a blank sign or a general information message (Hardy *et al.* 2006). Average speeds increased by 0.4-1.7 mi/h for one of the animal advisory messages at one location. The average speed of trucks reduced by 0.5-5.3 mi/h when compared to either a blank sign or a general information message Montana (Hardy *et al.* 2006).

A small study conducted using a driving simulator investigated driver responses to four warning sign treatments: 1) a standard deer warning sign, 2) a standard deer warning sign with a flashing beacon, 3) a variable message sign (VMS) with the wording 'ANIMAL CROSSING NEXT 20 MILES BE ALERT', and 4) the VMS with a standard deer warning sign with a flashing beacon 6 mi further down the road (Stanley *et al.* 2006). The VMS elicited the largest reduction in average speed compared to the standard sign (4.6 mi/h or 7.4 km/h) (Stanley *et al.* 2006). The standard sign with a flashing beacon and the combined treatment also elicited slower average speeds compared to the standard sign (3.3 mi/h or 5.3 km/h, and 2.0 mi/h or 3.2 km/h slower, respectively).

In another driver simulation study, Jägerbrand and Antonson (2016) examined people's responses to either a speed camera, a moose warning sign, a radio message warning about moose on roads, a moose beside the road, and combinations of these while driving along a 9 km stretch of road. They also tested each of these factors in both an open and a forested landscape, and with and without a fence. The sign by itself reduced driving speeds for a short distance when a fence was present, but for

an extended distance when there was no fence present (Jägerbrand and Antonson 2016). Although, both the radio message and the sign together resulted in much slower speeds across all landscape and fence testing environments, this interaction was not significant in the linear-mixed effects model.

Recently, an experimental trial looked at the likelihood of vehicles colliding with a rubber snake when driving through Pilanesberg National Park in South Africa (Collinson *et al.* 2019). Drivers were more likely to change their behaviour upon encountering the snake when wildlife warning signs were present, which resulted in a lower likelihood of the snake being hit. Additionally, this likelihood was also reduced when the sign present depicted a snake, as opposed to a cheetah, but only if the rubber snake was 100 m after the sign compared with 1 km after the sign (Collinson *et al.* 2019). This clearly suggests that informing drivers of the type of animal likely to be near the road can improve driver responsiveness to an encounter. Interestingly, vehicles that were estimated to be speeding and were driven by visitors to the park were more likely to hit the snake than park staff who were not speeding; however, speed had the greater influence than the familiarity of the driver with the area (Collinson *et al.* 2019).

In South East Queensland, Dique *et al.* (2003) trialled differential-speed wildlife warning signs that aimed to reduce koala-vehicle collisions during the breeding season. These signs had the wording 'KOALA ZONE', with two speed limits posted below: a reduced speed limit between 7pm – 5am August to December, and the usual speed limit at all other times. Although the number of koala strikes detected on trial roads was fewer than on control roads, there was no reduction in strikes during the trial periods when compared to the control periods (Dique *et al.* 2003). Mean vehicle speeds were reduced by 1.8-4.7 km/h on the trial roads. However, vehicles speeds on two control roads were also reduced by 3.3 km/h and 5 km/h, with vehicle speeds on the last control road increasing by 1.1 km/h.

A trial of 16 vehicle-activated koala warning signs with flashing lights was conducted in South East Queensland in 2012-2013 (Sullivan *et al.* 2013). These signs displayed a standard yellow koala warning sign with the words 'SLOW DOWN' beneath on a large white background and two amber lights above the sign. The amber lights were programed to flash upon detecting a vehicle travelling at or over the set speed threshold. The set speed threshold varied at some sites throughout the study, with the highest being the speed limit (either 60, 70, or 80 km/h, depending on the site) and the lowest being 19 km/h (Sullivan *et al.* 2013). Across all sites and treatments, average vehicle speed was reduced by 1.672 km/h compared to the control period, although one site with a speed limit of 80 km/h recorded an average speed reduction of 8.331 km/h (Sullivan *et al.* 2013). Although most sites recorded small reductions in speed, this study provides evidence that dynamic wildlife warning signs can incur substantial reductions in vehicle speeds.

Little research has been conducted in Australia on developing alternative sign designs and studying their potential to reduce vehicle speed and increase driver vigilance. A couple of exceptions involved developing alternative signs based on the opinions of ecologists and various Government personnel. One study developed and installed an alternative sign design in Coles Bay and Bruny Island in Tasmania (Magnus *et al.* 2004). This design included an image of a car hitting a kangaroo, an advisory speed limit, and the words 'DUSK TO DAWN'. The design process involved the input of a comprehensive suite of perspectives; however, the opinions of drivers were not sought. Unfortunately, vehicle speeds recorded before and after installation of the signs were not directly comparable due to drastically different traffic volumes and flow during different months. Another study took a very different approach to this and developed a comprehensive questionnaire that asked drivers to rate their responses to several standard and alternative wildlife warning sign designs (Bond and Jones 2013).

The above literature suggests that most of the time, static wildlife warning signs have virtually no discernible impact on driver behaviour or rates of wildlife-vehicle collision (Huijser *et al.* 2015). This has been attributed, at least in part, to the static nature of these pictorial signs, resulting in rapid habituation (the reduction in response to a repeated stimulus) by passing motorists. The advent of dynamic signage that responds to the speed of individual vehicles has, however, lead to significant and positive influences on vehicle speed. A current example from South East Queensland are the now familiar dynamic 'Slow for SAM' signs and similar 'smiling' signs which detect vehicle speed and display an appropriate signal (Atfield 2015; Brisbane City Council 2018). When combined with unpredictable enforcement regimes, these signs have markedly affected driver behaviour in problem locations.

Although deployed on a much more limited basis, other forms of electronically illuminated signage has been shown to significantly reduce vehicle speeds in areas supporting koala populations. A recent trial of a specifically designed sign with conspicuous LED lighting was undertaken on roads running through the Brisbane Koala Bushland, adjacent to Redland City, and demonstrated that this type of signage can also be used where the focus is on wildlife (Jones *et al.* 2016).

The aim of the current pilot study was to evaluate the effectiveness of two dynamic sign designs and messages to reduce vehicle speeds in areas known to support koalas. The 15-week pilot sign trial was intended as one part in a much larger, long-term project with the objective of enhancing the persistence of koalas in Redlands by heightening community awareness of the presence of this iconic species and influencing the behaviour of drivers living within the area.

2. Methodology

2.1. Study sites

Six sites were selected along three roads in Redland's Ormiston koala conservation safe neighbourhood.

- Site 1: Sturgeon Street west
  - West of Hilliards Creek crossing
  - Displaying to eastbound traffic
  - 60 km/h speed limit
- Site 2: Sturgeon Street east
  - Near house #60
  - Displaying to westbound traffic
  - 60 km/h speed limit
- Site 3: Starkey Street north
  - Near corner of Anhs Place
  - Displaying to southbound traffic
  - 60 km/h speed limit
- Site 4: Starkey Street south
  - Near corner of Gilchrist Street
  - Displaying to northbound traffic
  - 60 km/h speed limit
- Site 5: Wellington Street north
  - Near houses #134 and #136
  - Displaying to northbound traffic
  - 50 km/h speed limit
- Site 6: Wellington Street south
  - Near entrance to Ormiston Springs Estate
  - Displaying to southbound traffic
  - 50 km/h speed limit

It should be noted that site 2 was originally located near #92 Sturgeon Street. The location of this site was moved early in the project due to insufficient sunlight for the solar panels to charge the sign batteries. Figure 1 shows the location of the signs in Ormiston.

Figure 1. The locations of the sites where signs were erected during the study in Ormiston. GPS Visualizer was used to create this map in Google Earth.

Signs were installed on the left-side verge at all sites. Selection of locations was dependent upon several factors, including signs required to be:

- clear of obstructions, so as to present drivers with a clear view of the signs and the radar with a clear view of the oncoming traffic;
- clear of interference from power lines and other utility services in the verge;
- an appropriate distance from traffic lights, roundabouts, school zones, bus stops, and other traffic signage; and
- in sufficient sunlight throughout the day to charge the batteries enough for the sign to operate uninterrupted 24 hours a day.

It should be noted that some sites were in close proximity to roundabouts and/or school zones that may have affected vehicle speeds approaching the signs. Site 2 Sturgeon Street east was near two roundabouts, which was unavoidable at this end of the street, with four roundabouts within approximately 870 m. The signs at this site were positioned closer to the roundabout that vehicles were approaching than the roundabout that vehicles were exiting. Additionally there was a school zone along Sturgeon Street, in between sites 1 and 2. The school zone did not directly affect the posted speed limit at these sites, only for a section in between them. Site 6 was in close proximity to a school zone and a train station car park. Along all road sections monitored by the signs, except for Site 1, vehicles could pull into or out of driveways and pull into or out of a roadside parking space.

2.2. Wildlife warning signs

Initially, six variable-message wildlife warning signs of two different designs were to be installed and rotated between the sites. Two of these signs were newly-acquired standard variable-message LED signs, and the remaining four signs were variable-message LED signs with custom-made koala panels purchased in 2009 that had not been used for several years before this sign trial. However, technical issues with two of the four older koala signs (purchased in 2009) at the beginning of the project resulted in only four signs being used in the trial. Despite this, all six sites remained in the trial, with two sites having no signs displayed for each treatment period. All signs were fitted with solar panels to charge the batteries and support continuous display and recording of data.

- Two Sierzega Speedpacer 4568 C signs with standard fluorescent yellow panels with the wording 'DRIVE SAFELY' (Figure 2b). These signs will be referred to as the smiley signs.
    - Connectivity to these signs was via remote connectivity and/or Bluetooth and all data was stored on the signs, as well as on a server.
    - These signs came with solar panels to be mounted and connected upon installation.
    - Sign IDs 14361 and 14370.
- Two Sierzega Speedpacer 2368 FC signs with custom panels displaying a photo of a koala walking along on a road with the wording 'KOALA CROSSING' (Figure 2a). These signs will be referred to as the koala signs.
    - Connectivity to these signs was via Bluetooth only and all data was stored on the signs.
    - Solar panels were custom fitted and connected to these signs for this trial.
    - Sign IDs 4244 and 4245.

All signs were supplied and supported by JENOPTIK Australia Pty Ltd, based in Sydney, and manufactured by Sierzega Elektronik, based in Austria.

Figure 2. The signs used in the sign trial. a) a smiley sign, Sierzega Speedpacer 4568 C, and b) a koala sign, Sierzega Speedpacer 2368 FC.

2.3. Sign messages

Redland City Council chose the messages used on the signs in discussion with Griffith University and were restricted by the LED panel dimensions of each sign design. The messages displayed on each of the sign types were intended to be similar and provide consistent instructions to drivers. The signs were programmed to display different messages in response to vehicles speeds. Table 1 shows the messages displayed on the smiley signs and koala signs at low, medium, and high speeds. Table 2 shows the speed ranges defined as low, medium, and high speeds for each road, as determined by the speed limit. The signs were programmed to display the speed of the vehicle and the associated message alternately and were set to blinking mode. The colour of the vehicle speed displayed matched that of the associated message. The way in which the two sign types alternated the message and vehicle speed differed slightly: the koala sign would display the message several times and then switch to displaying the vehicle speed, whereas the smiley signs would display the message once, then the speed once, and then back to the message. This meant that vehicles passing the koala signs would have seen the message(s) only, the vehicle speed(s) only, or both. All vehicles passing the smiley signs would have seen both the message(s) and the vehicle speed(s).

Table 1. Images and wording displayed on the smiley signs and koala signs. The message displayed changed in response to vehicle speed. See Table 2 for the speed ranges within which each message was displayed.

Sign name	Low speed	Medium speed	High speed
Smiley signs		 BE ALERT	 SLOW!
Koala signs	THANK YOU!	STAY ALERT	SLOW DOWN

Table 2. Speed ranges within which each message was displayed for the koala signs and smiley signs. Note that the speed ranges for each message were dependent on the speed limit of the road.

Speed limit	Streets	Speed ranges for sign messages	
60 km/h	Sturgeon St Starkey St	low speed	< 50 km/h
		medium speed	50-60 km/h
		high speed	> 60 km/h
50 km/h	Wellington St	low speed	< 40 km/h
		medium speed	40-50 km/h
		high speed	> 50 km/h

2.4. Sign rotation schedule

Table 3 shows the location of each sign type during each period of the sign trial. Signs were displayed at each site for approximately two weeks.

Table 3. Sign locations during each period of the trial.

Dates	Week	Road		
		Starkey St	**Sturgeon St**	**Wellington St**
21/08/2018 to 03/09/2018	1,2	No signs	Koala - signs covered*	Smiley - signs covered
03/09/2018 to 18/09/2018	3,4	No signs	Koala	Smiley
18/09/2018 to 05/10/2018	5,6	Smiley	No signs	Koala
05/10/2018 to 17/10/2018	7,8	Koala	Smiley	No signs
17/10/2018 to 23/10/2018	9	Koala – data not used	Smiley – signs covered to get proxy control data	No signs
23/10/2018 to 05/11/2018	10,11	Waiting for wildlife zone painted road thresholds to be installed		
06/11/2018 to 20/11/2018	12,13	No signs	Koala	Smiley
20/11/2018 to 04/12/2018	14,15	Smiley	No signs	Koala
04/12/2018 to 18/12/2018	16,17	Koala	Smiley	No signs

* Signs were installed on 24/08/2018 on Sturgeon Street.

2.5. Technical and data issues

The majority of the time all signs functioned correctly, displaying the correct messages and collecting viable data. However, at several points throughout the project one or more signs experienced technical problems that resulted in data loss, data anomalies, and/or message display errors. These issues are detailed in Appendix 2.

2.6. Control data

Due to the use of only four signs across six sites and technical issues with two koala signs at the beginning of the project (see Appendix 2), different sources of control data were required for different sites (see Table 4). For site 1, two historical pneumatic tube datasets varied in the pattern of traffic flow from that during the study and may not represent high quality control data for the purposes of this project. As this site also had proxy control data recorded in the middle of the study (during the week that the painted thresholds were initially planned to be installed), some data is presented in Appendix 6 on all three 'control' datasets to show the variability for this site. Each of these datasets will be referred to as control A, B, or C, as shown in Table 4. However, for the analyses only pneumatic tube data from 28/02/2018 to 08/03/2018 were included as the control data for this site, as this was the most recent historical data. According to Gates *et al.* (2004), assuming that the pneumatic tubes were set up correctly and accurately, vehicle speeds measured using the sign radars and the pneumatic tubes are equally accurate at speeds around 56 km/h. At higher speeds (88 km/h) the pneumatic tubes are less accurate (Gates *et al.* 2004), however, because the majority of speeds recorded during this study were closer to 56 km/h, it is reasonable to assume that the pneumatic tubes are equally accurate as the sign radars.

Table 4. Source of control data for each of the sites.

Road	Site	Position	Traffic direction	Control data	
Sturgeon St	1	west	eastbound	A	Pneumatic tube data 29/11/2017 to 06/12/2017
				B	Pneumatic tube data 28/02/2018 to 08/03/2018
				C	Covered sign 17/10/2018 to 23/10/2018
Sturgeon St	2	east	westbound	Covered sign 17/10/2018 to 23/10/2018	
Starkey St	3	north	southbound	Pneumatic tube data 05/09/2018 to 13/09/2018	
Starkey St	4	south	northbound	Pneumatic tube data 05/09/2018 to 13/09/2018	
Wellington St	5	north	northbound	Covered sign 21/08/2018 to 03/09/2018	
Wellington St	6	south	southbound	Covered sign 21/08/2018 to 03/09/2018	

All data that was obtained from pneumatic tubes included only a single vehicle speed. Therefore, speed 2 and any variables derived using speed 2 are missing for these control datasets.

2.7. Data processing and quality checks

Data files were usually downloaded fortnightly, at the end of each treatment period. Data files were occasionally downloaded more frequently if problems with the sign functionality were suspected. Data files were downloaded via Bluetooth from the koala signs and via online server access for the smiley signs. After each data download the data for each sign was processed, checked for errors, and data removed for any period outside which was specified as valid data dates and times. For example, some data was removed around the time of the sign rotations to remove any impact that the presence of the road crew and/or Griffith staff had on the speed of vehicles, or until the sign settings had been changed (if required). During data processing, additional data variables were added or calculated, which were of interest for analyses or assisted in finding data errors. The data for each site were then collated into a single file and progressively added to, after downloading and processing each new data file. Finally, a data quality control script was performed in R (R Core Team 2018) to identify any other issues that were not found manually.

It was assumed that each data observation was from a single vehicle, and thus speed 1 and speed 2 were measurements of the same vehicle. This allowed for the variable speed difference (speed 2 minus speed 1) to be calculated for each vehicle, as well as whether vehicles started speeding or stopping speeding on approach of the signs.

Vehicles travelling under half the speed limit (<25 km/h along Wellington Street and <30 km/h along Sturgeon and Starkey Streets) were excluded. There were several reasons for this, including to exclude bicycles, vehicles pulling into or out of driveways or parking, garbage collection trucks, buses pulling into or out of bus stops, and vehicles that were travelling too slow to trigger the dynamic sign message (< 15 km/h). These vehicles were also deemed not to be the target of the signs, as their kinetic energy was reduced by 75% when travelling half the speed limit compared to when travelling at the speed limit.

At site 4 (Starkey Street south) only 341 vehicles were recorded on 17th October, mostly in the early morning, and caused the percentage of vehicles speeding to increase dramatically (from 12% to 28% for speed 1 and 4% to 12% for speed 2). This day had a small amount of data because it was a sign rotation day, not because of a sign failure. This day of data was therefore removed as an outlier for this site only.

2.8. Data analyses

All statistics are reported by study site and study treatment. From here on, sites will generally be referred to by their site numbers for brevity. Study treatments will be referred to as the following: control, smiley sign NPT, koala sign NPT, smiley sign PT, and koala sign PT. NPT refers to no painted threshold and PT refers to painted threshold.

Any data for which the timestamps were potentially incorrect (see Appendix 2 for further details), yet the speed data appeared to be legitimate, were included for the data summary tables and graphs, but excluded for the modelling. This was done because a GLS model was initially performed with this data included; however, the interaction between the timestamp error flags and time block was significant.

2.8.1. Summary statistics

The following statistics were reported for each study treatment and site: total number of vehicles, average daily vehicles, number, and percentage of vehicles speeding at speed 1 and speed 2, percentage of vehicles that stopped speeding and started speeding between speed 1 and speed 2, and the median, mean, and standard deviation of speed 1, speed 2, and speed difference. Two graphs were generated showing the change in variables over time and between study treatment periods: 1) the average daily speed 1, speed 2, and speed difference, and 2) the daily percentage of vehicles speeding at speeds 1 and 2.

2.8.2. Modelling

Generalised least squares (GLS) modelling was used to take into account the potential influence of correlations over time. Speed difference (speed 2 minus speed 1) was used as the dependant response variable. The below protocol was followed, as demonstrated by Zuur *et al.* (2009) for the modelling the change in speed where a time component is involved:

1. A base model was derived using linear regression, including sign treatment, painted threshold, and the interaction between sign treatment and painted threshold.
2. Each time variable (hour of the day, time block, day of the week, study day, and study week) was added separately in turn to the base model to identify the most influential time variable by strength of contribution and autocorrelation plots.
3. The time variable with the greatest contribution was added to the base model, including any interactions.
4. Non-contributing variables and interactions were then removed to give a core model.
5. Additional explanatory variables were then added to the core model to assess their influence using linear regression. These additional explanatory variables included day versus night, site,

speed limit, school holidays, weekday versus weekend, rain, speeding category, and any interactions that were expected to be potentially influential.

- As mentioned above, this step was also initially conducted on the data including date and time errors, with the timestamp error flag included in the model. This, however, revealed the timestamp flag to be a significant contributing factor, indicating that these dates and/or times were highly likely to be incorrect. This data was then removed before re-conducting the protocol on the final dataset.

6. Non-contributing variables and interactions were then removed to give a final model.
7. The final model was rerun using generalised least squares, weighted using the most influential time variable, as identified in step 2.

As this dataset contained a very large number of observations (approximately 1.7 million in the dataset used for the modelling), all of the statistical test results were very highly significant ($p < 0.001$). Hence, the p-values could not be used as the standard arbiter. In very large samples, p-values are often highly significant, and solely relying on them can lead conclusions of no practical significance (Lin *et al.* 2013). An attempt was made to derive the associated variance components but this failed due to the size of the data. The decision to include a variable was based on whether the relative contribution to the model was meaningful, in terms of the F-value and the coefficient. Explanatory variables that contributed an effect of at least 0.5 km/h were retained in the final model. All modelling was conducted in R (R Core Team 2018).

3. Results

3.1. Summary statistics

3.1.1. Site 1 Sturgeon Street west

The speeds of 497,561 vehicles were analysed at Sturgeon Street west. On average, there were 7,897.8 vehicles per day in the analysed dataset.

The median, mean, and standard deviation for speed 1, speed 2, and speed difference for all study treatments at site 1, are shown in Table 5. Both the no painted threshold and the painted threshold treatments recorded a reduction in speed between speed 1 and speed 2 for both sign types. These treatments also recorded slightly higher speeds for speed 1 than the control. The koala NPT recorded the greatest speed decrease between speed 1 and speed 2 (8.6% decrease) and the smiley NPT recorded the smallest decrease (5.5%).

The no painted threshold treatment (smiley NPT and koala NPT combined) recorded the greatest speed difference (-3.9 km/h) compared to the painted threshold treatment (smiley PT and koala PT combined; -3.5 km/h). The no painted threshold treatment also recorded a slightly lower average speed 2 (50.55 km/h) than the painted threshold treatment (51.1 km/h).

Table 5. The median, mean, and standard deviation for speed 1, speed 2, and speed difference for each of the study treatments at site 1 Sturgeon Street west (60 km/h speed limit).

Treatment		Speed 1 (km/h)			Speed 2 (km/h)			Speed difference (km/h)		
		Median	Mean	Std. dev.	Median	Mean	Std. dev.	Median	Mean	Std. dev.
Control B		53	52.3	6.8	N/A	N/A	N/A	N/A	N/A	N/A
No painted threshold	Smiley sign	55	54.1	6.5	51	51.1	6.5	-2	-3.0	5.1
	Koala sign	55	54.7	6.2	50	50.0	7.0	-3	-4.7	6.1
Painted threshold	Smiley sign	55	54.6	6.3	52	51.6	6.3	-2	-3.1	5.1
	Koala sign	55	54.4	6.4	51	50.6	6.9	-3	-3.8	6.2
Overall		55	54.1	6.5	51	50.9	6.7	-3	-3.6	5.7

The average daily speeds of vehicles recorded at site 1 are shown in Figure 3. There was a small amount of variance in the daily recorded speeds during all treatments except the control which, recorded a peak in average daily speeds towards the middle of the data collection period. The smiley NPT recorded a small decline in average daily speeds towards the middle of the treatment period. The koala NPT recorded two small peaks in average daily speeds towards the middle and end of the treatment period.

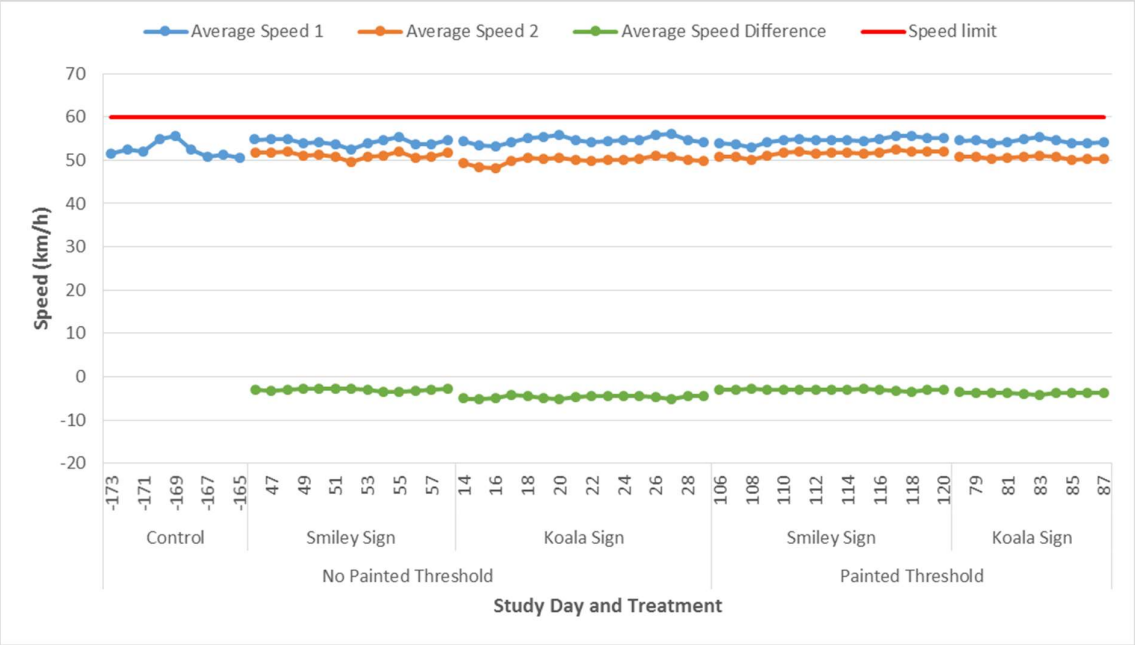

Figure 3. Average daily speeds of vehicles recorded at site 1 Sturgeon Street west. Speed 1 is the initial recorded speed of the vehicle and speed 2 is the speed of the vehicle as it passes the sign. Speed difference is speed 2 minus speed 1 (where applicable). Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability. Negative study days are where data were historical and not collected during the study period.

The number and percentage of vehicles speeding for speed 1 and speed 2 during each study treatment at site 1 are shown in Table 6. There was a clear reduction in the proportion of vehicles speeding between speed 1 and speed 2 for the no painted threshold and painted threshold treatments. However, there was a higher proportion of speeding vehicles for these treatments at speed 1 than the control treatment. Despite this, the proportion of speeding vehicles for speed 2 was lower for every treatment than that of speed 1 for the control, meaning that ultimately fewer vehicles were travelling above the speed limit. Overall, the koala NPT recorded a 9.3% reduction in the proportion of speeding vehicles, the greatest reduction of all the treatments. This was followed by the koala PT with 8.1%. The smiley NPT recorded a 6.7% reduction in the proportion of speeding vehicles, the smallest reduction of all the treatments.

The no painted threshold treatment (smiley NPT and koala NPT combined) recorded 6.2% of speeding vehicles at speed 2 and the painted threshold treatment (smiley PT and koala PT combined) recorded 6.55% of vehicles speeding at speed 2.

Table 6. The number and percentage of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 1 Sturgeon Street west.

Treatment		No. of vehicles	Speed 1		Speed 2	
			No. of vehicles speeding	% of vehicles speeding	No. of vehicles speeding	% of vehicles speeding
Control B		77,944	7,850	10.1%	N/A	N/A
No painted threshold	Smiley sign	95,082	12,630	13.3%	6,273	6.6%
	Koala sign	106,819	16,176	15.1%	6,185	5.8%
Painted threshold	Smiley sign	128,783	18,539	14.4%	8,979	7.0%
	Koala sign	88,933	12,644	14.2%	5,452	6.1%
Grand total		497,561				

The daily percentages of speeding vehicles for speed 1 and speed 2 recorded for each study treatment at site 1 are shown in Figure 4. All treatments show a large daily variance in the percentage of speeding vehicles for speed 1. The koala NPT recorded smaller variance for speed 2 than all other treatments, however, the variance in speed 2 was lower overall than for speed 1.

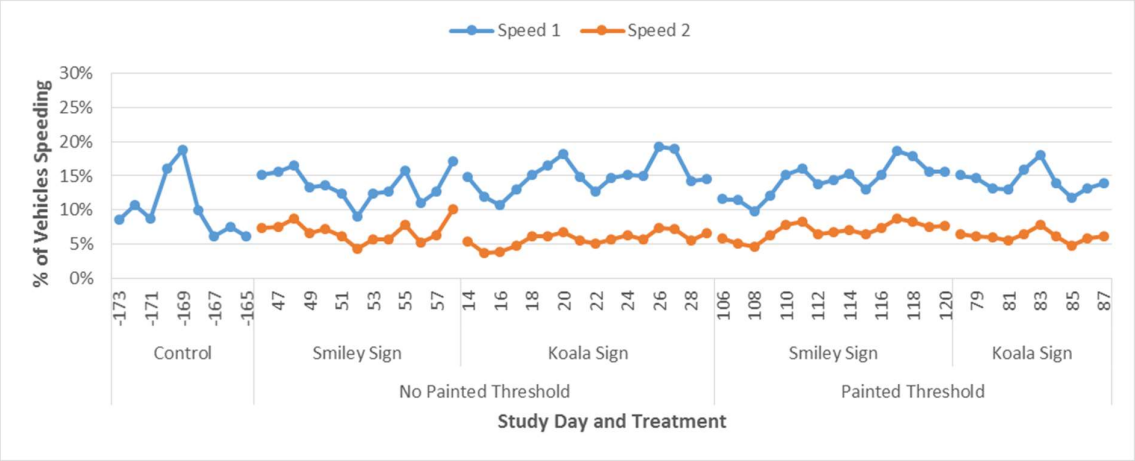

Figure 4. The daily percentages of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 1 Sturgeon Street west. Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability. Negative study days are where data were historical and not collected during the study period.

The percentages of vehicles that showed no change in speeding, stopped speeding, and started speeding across all treatments are shown in Table 7. Overall, the majority of vehicles showed no change in whether or not they were speeding, with a range of 2% between all the treatments. The koala NPT recorded the largest percentage of vehicles that stopped speeding as well as the smallest percentage of vehicles that started speeding. The smiley NPT recorded the smallest percentage of

vehicles that stopped speeding. The smiley PT recorded the highest percentage of vehicles that started speeding.

The no painted threshold treatment (smiley NPT and koala NPT combined) and painted threshold treatment (smiley PT and koala PT combined) recorded similar percentages for all three variables, with both treatments resulting in 9.2% of vehicles ceasing to speed. However, the painted threshold treatment resulted in 1.5% of vehicles starting to speed, compared to 1.2% of vehicles starting to speed with the no painted threshold.

Table 7. The percentage of vehicles that showed no change in speeding, stopped speeding, and started speeding for each of the study treatments at site 1 Sturgeon Street west.

Treatment		No change in speeding	Stopped speeding	Started speeding
Control B		N/A	N/A	N/A
No painted threshold	Smiley sign	90.6%	8.0%	1.3%
	Koala sign	88.6%	10.4%	1.0%
Painted threshold	Smiley sign	89.6%	8.9%	1.5%
	Koala sign	89.1%	9.5%	1.4%
Overall		89.5%	9.2%	1.3%

Overall, at Sturgeon Street west (site 1) the koala sign, both with and without the painted thresholds, performed the best, with the painted thresholds very slightly reducing its influence on vehicle speeds (see pages 35-36 in section 4. Discussion for further assessment of the painted thresholds).

3.1.2. Site 2 Sturgeon Street east

The speeds of 423,938 vehicles were analysed at Sturgeon Street east. On average, there were 6,949.8 vehicles per day in the analysed dataset.

The median, mean, and standard deviation for speed 1, speed 2, and speed difference for all study treatment periods at site 2 are shown in Table 8. Overall, all treatments recorded a reduction in speed between speed 1 and speed 2, with a range of -3.2 km/h. When comparing the control treatment and the no painted threshold treatment, there was a clear difference between speed 1, speed 2, and the speed difference of the control and the koala NPT. The koala NPT resulted in a 13% decrease in speed between speed 1 and speed 2, compared to the control, showing a 10% decrease. The smiley NPT recorded smaller reductions in speed than the koala NPT, but larger than the control.

The no painted threshold treatment (smiley NPT and koala NPT combined) recorded the greatest speed difference (-6.4 km/h) compared to the painted threshold treatment (smiley PT and koala PT combined; -5.3 km/h). The no painted threshold treatment also recorded a lower average speed 2 (46.65 km/h) than the painted threshold treatment (47.4 km/h).

Table 8. The median, mean, and standard deviation for speed 1, speed 2, and speed difference for each of the study treatments at site 2 Sturgeon Street east (60 km/h speed limit).

Treatment		Speed 1 (km/h)			Speed 2 (km/h)			Speed difference (km/h)		
		Median	Mean	Std. dev.	Median	Mean	Std. dev.	Median	Mean	Std. dev.
Control		54	54.1	6.2	48	48.5	7.3	-5	-5.6	6.4
No painted threshold	Smiley sign	53	52.9	6.2	47	47.1	7.2	-5	-5.8	6.4
	Koala sign	53	53.1	6.2	46	46.2	7.3	-6	-6.9	7.1
Painted threshold	Smiley sign	53	53.2	5.9	50	49.5	6.4	-3	-3.7	5.3
	Koala sign	52	52.1	6.2	45	45.3	7.0	-6	-6.8	6.7
Overall		53	53.0	6.1	47	47.4	7.1	-4	-5.6	6.4

The average daily speeds of vehicles recorded at site 2 are shown in Figure 5. All treatments show daily variance in average speeds, with smiley PT showing the least variance in speed 1 and speed 2, as well as the smallest reduction in speed. The koala NPT and koala PT treatments recorded similar patterns in daily variance of average speeds which, experienced peaks towards the middle and the end of the treatment period.

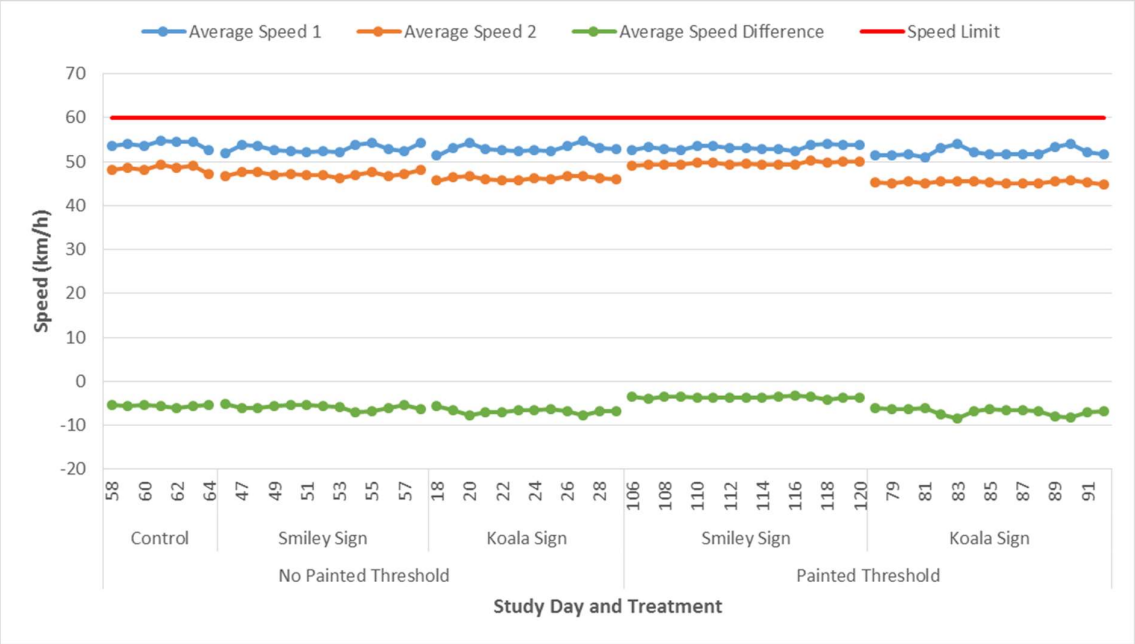

Figure 5. Average daily speeds of vehicles recorded at site 2 Sturgeon Street east. Speed 1 is the initial recorded speed of the vehicle and speed 2 is the speed of the vehicle as it passes the sign. Speed difference is speed 2 minus speed 1 (where applicable). Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability.

The number and percentage of vehicles speeding for speed 1 and speed 2 during each treatment are shown in Table 9. There was a clear reduction in the number of vehicles speeding between speed 1

and speed 2 for all treatments. The control treatment recorded the highest proportion of vehicles speeding at speed 1, however, there was an 8.2% reduction in vehicles speeding between speed 1 and speed 2. This was a greater reduction than any other treatment. This pattern was also reflected in the koala NPT treatment which, resulted in a 7.4% reduction in speeding vehicles. The smiley PT treatment recorded the smallest reduction in speeding vehicles (5.2%) between speed 1 and speed 2, of all the treatments and the highest proportion of vehicles speeding at speed 2. All sign treatments recorded lower proportions of vehicles speeding at both speed 1 and speed 2 than the control period, with the koala NPT and koala PT treatments being the lowest.

The no painted threshold treatment (smiley NPT and koala NPT combined) recorded 2.95% of speeding vehicles at speed 2 and the painted threshold treatment (smiley PT and koala PT combined) recorded 2.85% of vehicles speeding at speed 2.

Table 9. The number and percentage of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 2 Sturgeon Street east.

Treatment		No. of vehicles	Speed 1		Speed 2	
			No. of vehicles speeding	% of vehicles speeding	No. of vehicles speeding	% of vehicles speeding
Control		50,059	6,601	13.2%	2,483	5.0%
No painted threshold	Smiley sign	88,682	8,379	9.4%	2,930	3.3%
	Koala sign	75,921	7,609	10.0%	2,008	2.6%
Painted threshold	Smiley sign	121,458	11,307	9.3%	4,973	4.1%
	Koala sign	87,818	6,515	7.4%	1,366	1.6%
Grand total		423,938				

The daily percentages of speeding vehicles for speed 1 and speed 2 recorded for each treatment at site 2 are shown in Figure 6. All treatments show a daily variance in the percentage of speeding vehicles, however, there was a clear difference in variation between speed 1 and speed 2, with speed 1 being more variable. The koala PT experienced the smallest percentage of speeding vehicles for speed 2. The koala NPT experienced the highest daily variance of all the treatments.

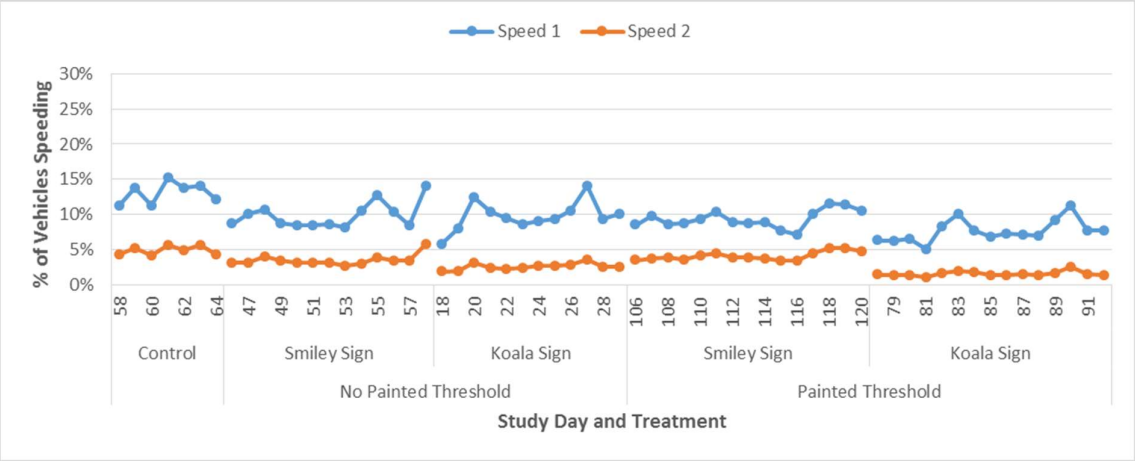

Figure 6. The daily percentages of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 2 Sturgeon Street east. Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability.

The percentages of vehicles that showed no change in speeding, stopped speeding, and started speeding across all treatments are shown in Table 10. Overall, the majority of vehicles showed no change in whether or not they were speeding. The control treatment resulted in the greatest percentage of vehicles that stopped speeding, however, it also resulted in the greatest percentage of vehicles that started speeding. This also does not take in account the overall proportion of vehicles speeding (see Table 9 above). The smiley PT treatment recorded only a 0.1% difference in vehicles that started speeding compared to the control treatment. Furthermore, it recorded the smallest percentage of vehicles – along with koala PT – that stopped speeding.

The no painted threshold treatment (smiley NPT and koala NPT combined) and painted threshold treatment (smiley PT and koala PT combined) recorded similar percentages for all three variables. Both combined treatments resulted in 0.6% of vehicles starting to speed, however, the no painted threshold treatment resulted in 7.3% of vehicles ceasing to speed compared to the painted threshold treatment that resulted in 6.1% of vehicles ceasing to speed.

Table 10. The percentage of vehicles that showed no change in speeding, stopped speeding, and started speeding for each of the study treatments at site 2 Sturgeon Street east.

Treatment		No change in speeding	Stopped speeding	Started speeding
Control		89.7%	9.3%	1.0%
No painted threshold	Smiley sign	92.5%	6.8%	0.7%
	Koala sign	91.9%	7.8%	0.4%
Painted threshold	Smiley sign	93.0%	6.1%	0.9%
	Koala sign	93.7%	6.1%	0.2%
Overall		92.4%	6.9%	0.6%

Overall, at Sturgeon Street east (site 2) the koala sign, both with and without the painted thresholds, performed the best, with the painted thresholds slightly improving its influence on vehicle speeds (see pages 35-36 in section 4. Discussion for further assessment of the painted thresholds).

3.1.3. Site 3 Starkey Street north

The speeds of 278,213 vehicles were analysed at Starkey Street north. On average, there were 4,091.4 vehicles per day in the analysed dataset.

The median, mean, and standard deviation for speed 1, speed 2, and speed difference for all study treatment periods at site 3, are shown in Table 11. Overall, all treatments recorded a reduction in speed between speed 1 and speed 2. All of the treatments recorded similar values for speed 1, with a range of 0.6 km/h. The koala NPT recorded the smallest speed 1 and speed 2 averages, and a 10% decrease in speed between speed 1 and speed 2. On the other hand, the smiley NPT recorded that greatest speed 1 however, there was a similar decrease in speed to the koala NPT. The smiley PT treatment recorded the smallest decrease in speed (6% decrease) and the highest speed 2.

The no painted threshold treatment (smiley NPT and koala NPT combined) recorded the greatest speed difference (-5.5 km/h) compared to the painted threshold treatment (smiley PT and koala PT combined; -4.2 km/h). The no painted threshold treatment also recorded a lower average speed 2 (49.7 km/h) than the painted threshold treatment (51.15 km/h).

Table 11. The median, mean, and standard deviation for speed 1, speed 2, and speed difference for each of the study treatments at site 3 Starkey Street north (60km/h speed limit).

Treatment		Speed 1 (km/h)			Speed 2 (km/h)			Speed difference (km/h)		
		Median	Mean	Std. dev.	Median	Mean	Std. dev.	Median	Mean	Std. dev.
Control		55	55.2	5.4	N/A	N/A	N/A	N/A	N/A	N/A
No painted threshold	Smiley sign	56	55.5	6.2	50	50.1	7.9	-3	-5.4	7.1
	Koala sign	55	54.9	6.0	49	49.3	6.7	-5	-5.5	6.0
Painted threshold	Smiley sign	56	55.3	5.9	52	52.0	6.6	-1	-3.4	5.5
	Koala sign	56	55.3	6.0	50	50.3	6.8	-4	-5.0	6.0
Overall		56	55.3	6.0	51	50.6	7.2	-3	-4.7	6.3

The average daily speeds of vehicles recorded at site 3, are shown in Figure 7. There was little variance in the daily average speeds for all treatments.

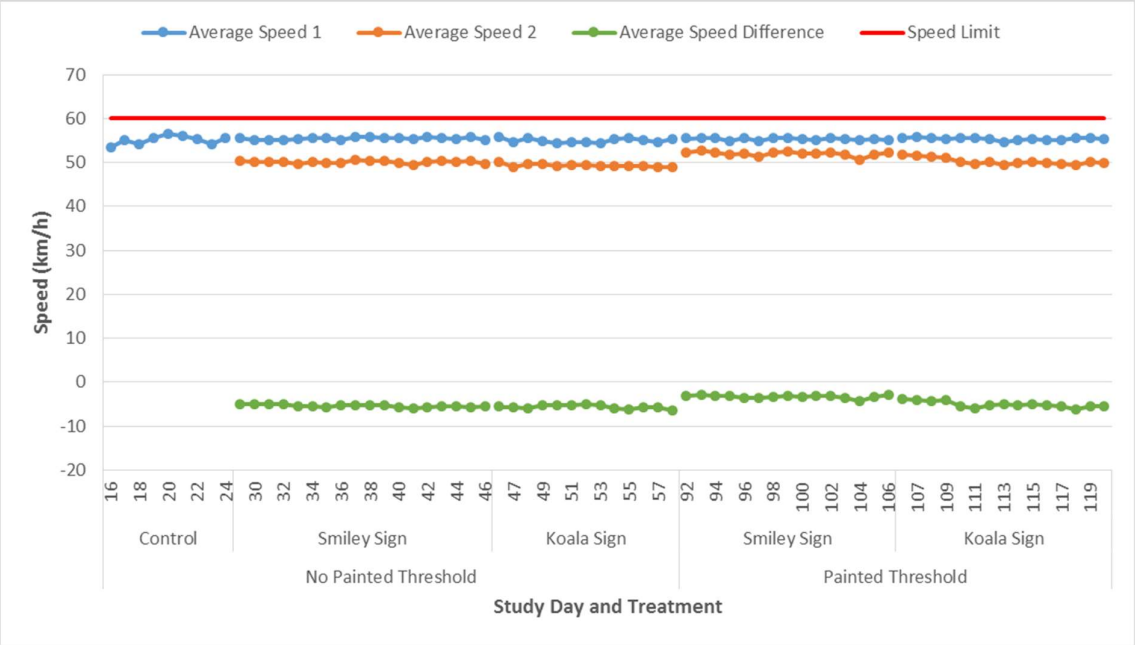

Figure 7. Average daily speeds of vehicles recorded at site 3 Starkey Street north. Speed 1 is the initial recorded speed of the vehicle and speed 2 is the speed of the vehicle as it passes the sign. Speed difference is speed 2 minus speed 1 (where applicable). Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability.

The number and percentage of vehicles speeding for speed 1 and speed 2 during each study treatment for site 3, are shown in Table 12. The two treatments that recorded the largest decrease in speed were the koala PT (9.4% decrease) and the koala NPT (9% decrease). These treatments also recorded smallest proportions of vehicles speeding at speed 2. The smiley PT recorded the smallest decrease in speeding vehicles at 6.9% and the highest proportion of vehicles speeding at speed 2. All treatments, except the koala NPT, recorded higher proportions of speeding vehicles for speed 1, than during the control period, but much lower proportions of vehicles speeding at speed 2.

The no painted threshold treatment (smiley NPT and koala NPT combined) recorded 6.2% of speeding vehicles at speed 2 and the painted threshold treatment (smiley PT and koala PT combined) recorded 7.05% of vehicles speeding at speed 2.

Table 12. The number and percentage of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 3 Starkey Street north.

Treatment		No. of vehicles	Speed 1		Speed 2	
			No. of vehicles speeding	% of vehicles speeding	No. of vehicles speeding	% of vehicles speeding
Control		26,710	3,987	14.9%	N/A	N/A
No painted threshold	Smiley sign	77,622	12,400	16.0%	6,064	7.8%
	Koala sign	43,087	5,864	13.6%	1,977	4.6%
Painted threshold	Smiley sign	73,581	11,030	15.0%	5,953	8.1%
	Koala sign	57,213	8,818	15.4%	3,418	6.0%
Grand total		278,213				

The daily percentages of speeding vehicles recorded for each treatment and both signs for site 3, are shown in Figure 8. All treatments show a daily variance in the percentage of speeding vehicles however, there was a clear difference in variation between speed 1 and speed 2, with speed 1 being more variable. The control treatment recorded the highest variation in the percentage of speeding vehicles for speed 1.

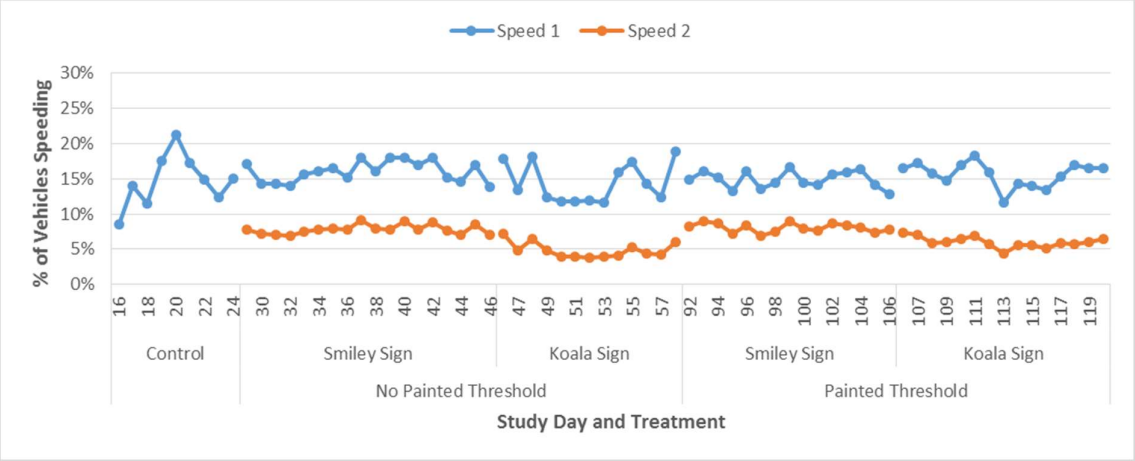

Figure 8. The daily percentages of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 3 Starkey Street north. Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability.

The percentages of vehicles that recorded no change in speeding, stopped speeding, and started speeding across all study treatments at site 3 are shown in Table 13. Overall, the majority of vehicles showed no change in whether or not they were speeding. The koala PT recorded the largest percentage of vehicles that stopped speeding, whereas koala NPT recorded the smallest percentage of vehicles that started speeding. Both the smiley NPT and the smiley PT recorded the highest percentage of vehicles that started speeding. The smiley PT recorded the lowest percentage of vehicles that stopped speeding.

The no painted threshold treatment (smiley NPT and koala NPT combined) recorded the highest percentage of vehicles that stopped speeding (9.4%) compared to the painted threshold treatment (smiley PT and koala PT combined) (9.2%). The no painted threshold treatment also recorded the lowest percentage of vehicles that started to speed (0.8%).

Table 13. The percentage of vehicles that showed no change in speeding, stopped speeding, and started speeding for each of the study treatments at site 3 Starkey Street north.

Treatment		No change in speeding	Stopped speeding	Started speeding
Control		N/A	N/A	N/A
No painted threshold	Smiley sign	89.7%	9.2%	1.1%
	Koala sign	90.0%	9.5%	0.5%
Painted threshold	Smiley sign	90.7%	8.1%	1.2%
	Koala sign	89.1%	10.2%	0.7%
Overall		89.9%	9.2%	0.9%

Overall, at Starkey Street north (site 3) the koala sign, both with and without the painted thresholds, performed the best, with the painted thresholds slightly reducing its influence on vehicle speeds (see pages 35-36 in section 4. Discussion for further assessment of the painted thresholds).

3.1.4. Site 4 Starkey Street south

The speeds of 214,101 vehicles were analysed at Starkey Street south. On average, there were 3,509.9 vehicles per day in the analysed dataset.

The median, mean, and standard deviation for speed 1, speed 2, and speed difference for all study treatments at site 4 are shown in Table 14. All of the treatments recorded similar values for speed 1, with a range of 1.4 km/h. The control recorded the highest average speed 1. The koala NPT recorded a 12.4% decrease in speed from speed 1 to speed 2, the largest speed difference. It also recorded the slowest speed 1 and speed 2. On the other hand, the smiley PT recorded a 9.2% decrease in speed from speed 1 to speed 2, the smallest speed difference.

Of the two threshold treatments, no painted threshold (smiley NPT and koala NPT combined) recorded a speed difference of -6.2 km/h, compared to the painted threshold (smiley PT and koala PT combined) which recorded a speed difference of -5.8 km/h. The no painted threshold treatment also recorded a slightly lower average speed 2 (48.9 km/h) than the painted threshold treatment (49.35 km/h).

Table 14. The median, mean, and standard deviation for speed 1, speed 2, and speed difference for each of the study treatments at site 4 Starkey Street south (60 km/h speed limit).

Treatment		Speed 1 (km/h)			Speed 2 (km/h)			Speed difference (km/h)		
		Median	Mean	Std. dev.	Median	Mean	Std. dev.	Median	Mean	Std. dev.
Control		56	56.1	6.1	N/A	N/A	N/A	N/A	N/A	N/A
No painted threshold	Smiley sign	56	55.6	6.2	50	49.9	7.9	-3	-5.6	6.6
	Koala sign	55	54.7	5.9	48	47.9	7.8	-5	-6.8	7.3
Painted threshold	Smiley sign	55	55.2	6.0	50	50.1	7.4	-3	-5.1	6.2
	Koala sign	55	55.0	5.8	49	48.6	7.7	-5	-6.4	7.0
Overall		55	55.3	6.1	49	49.3	7.8	-4	-5.8	6.7

The average daily speeds of vehicles recorded for all study treatments at site 4 are shown in Figure 9. There was very little variance in the average daily speeds for all treatments.

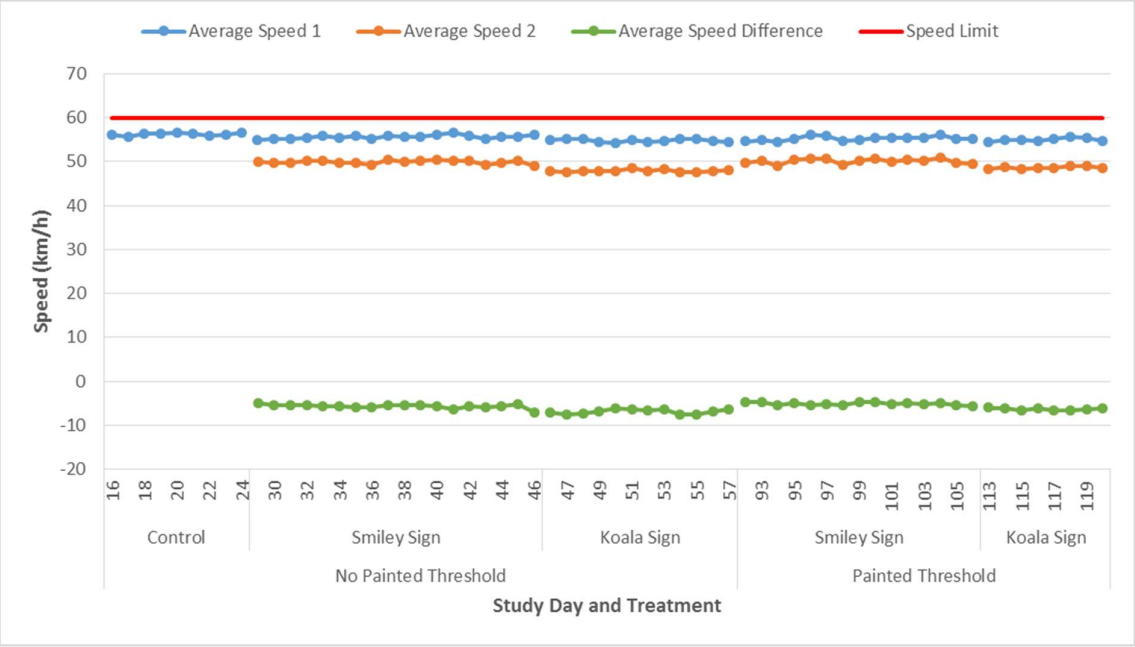

Figure 9. Average daily speeds of vehicles recorded at site 4 Starkey Street south. Speed 1 is the initial recorded speed of the vehicle and speed 2 is the speed of the vehicle as it passes the sign. Speed difference is speed 2 minus speed 1 (where applicable). Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability.

The number and percentage of vehicles speeding for speed 1 and speed 2 for each study treatment at site 4 are shown in Table 15. The koala NPT and koala PT treatments recorded the smallest proportions of vehicles speeding at both speed 1 and speed 2. The two treatments that recorded the largest reduction in speeding vehicles where the smiley NPT (8.9% reduction) as well as the koala NPT (8.6%

reduction). However, the smiley NPT recorded a highest percentage of vehicles speeding at speed 2 compared to all other treatments.

The no painted threshold treatment (smiley NPT and koala NPT combined) recorded 6.1% of speeding vehicles at speed 2 and the painted threshold treatment (smiley PT and koala PT combined) recorded 5.9% of vehicles speeding at speed 2.

Table 15. The number and percentage of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 4 Starkey Street south.

Treatment		No. of vehicles	Speed 1		Speed 2	
			No. of vehicles speeding	% of vehicles speeding	No. of vehicles speeding	% of vehicles speeding
Control		25,146	5,328	21.2%	N/A	N/A
No painted threshold	Smiley sign	63,168	10,568	16.7%	4,908	7.8%
	Koala sign	42,557	5,518	13.0%	1,880	4.4%
Painted threshold	Smiley sign	57,579	8,424	14.6%	3,914	6.8%
	Koala sign	25,651	3,444	13.4%	1,287	5.0%
Grand total		214,101				

The daily percentages of speeding vehicles recorded for each study treatment at site 4 are shown in Figure 10. All treatments show a daily variance in the percentage of speeding vehicles and both speed 1 and speed 2 show similar patterns of variance.

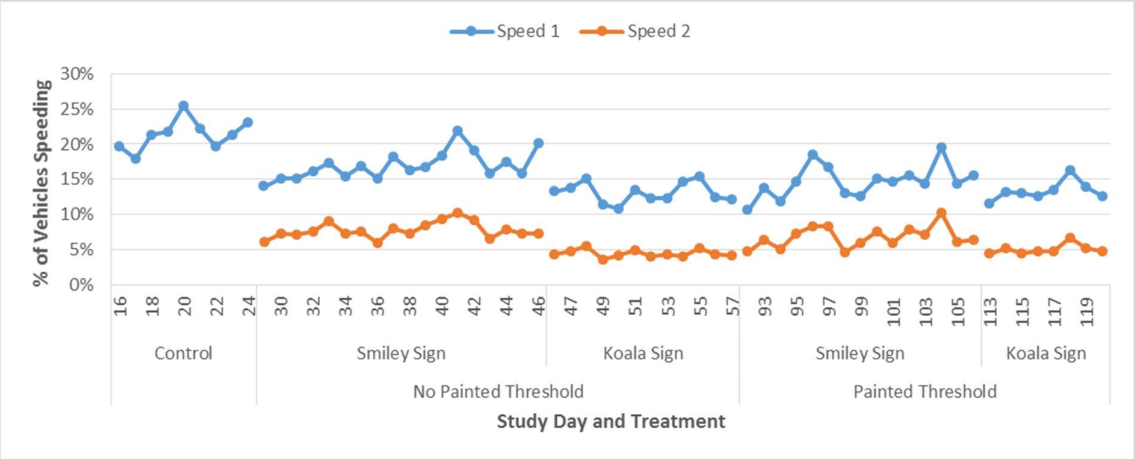

Figure 10. The daily percentages of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 4 Starkey Street south. Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability.

The percentages of vehicles that showed no change in speeding, stopped speeding, and started speeding across all study treatments at site 4 are shown in Table 16. Overall, the majority of vehicles showed no change in whether or not they were speeding, with a range of 1.2% between all treatments.

The smiley NPT saw the greatest percentage of vehicles stop speeding, however, along with the smiley PT, it also recorded the greatest percentage of vehicles that started to speed. The koala NPT and koala PT had similar percentages across all three variables and recorded the lowest percentages of vehicles to start speeding.

The no painted threshold treatment (smiley NPT and koala NPT combined) resulted in highest percentage of vehicles that stopped speeding (9.3%) compared to the painted threshold treatment (smiley PT and koala PT combined) which recorded 8.7% of vehicles that stopped speeding. The no painted threshold also recorded a slightly lower percentage of vehicles that started speeding (0.5%) compared to the painted threshold (0.6%).

Table 16. The percentage of vehicles that showed no change in speeding, stopped speeding, and started speeding for each of the study treatments at site 4 Starkey Street south.

Treatment		No change in speeding	Stopped speeding	Started speeding
Control		N/A	N/A	N/A
No painted threshold	Smiley sign	89.8%	9.6%	0.6%
	Koala sign	90.6%	9.0%	0.4%
Painted threshold	Smiley sign	91.0%	8.4%	0.6%
	Koala sign	90.6%	8.9%	0.5%
Overall		90.5%	9.0%	0.5%

Overall, at Starkey Street south (site 4) the koala sign, both with and without the painted thresholds, performed the best, with the painted thresholds very slightly reducing its influence on vehicle speeds (see pages 35-36 in section 4. Discussion for further assessment of the painted thresholds).

3.1.5. Site 5 Wellington Street north

The speeds of 327,503 vehicles were analysed at Wellington Street north. On average, there were 4,612.7 vehicles per day in the analysed dataset.

The median, mean, and standard deviation for speed 1, speed 2, and speed difference for all study treatments at site 5 are shown in

Table 17. Overall, all treatments recorded a reduction in speed between speed 1 and speed 2. The koala NPT recorded a 9.3% speed decrease between speed 1 and speed 2, shortly followed by the koala PT (8.7% decrease). The koala NPT and PT also recorded the lowest speed 2 averages. The smiley NPT and smiley PT recorded similar, lower speed differences between speed 1 and speed 2. They were also lower than the speed difference recorded during the control treatment however, the control treatment recorded the highest speed 1 average.

The two threshold treatments were recorded very similar speed 2 and speed difference averages at site 5. The no painted threshold treatment (smiley NPT and koala NPT combined) recorded a speed difference of -3.7 km/h and the painted threshold treatment (smiley PT and koala PT combined) recorded a speed difference of -3.6 km/h. The no painted threshold treatment recorded an average speed 2 of 44.4 km/h compared to 44.8 km/h for the painted threshold treatment.

Table 17. The median, mean, and standard deviation for speed 1, speed 2, and speed difference for each of the study treatments at site 5 Wellington Street north (50 km/h speed limit).

Treatment		Speed 1 (km/h)			Speed 2 (km/h)			Speed difference (km/h)		
		Median	Mean	Std. dev.	Median	Mean	Std. dev.	Median	Mean	Std. dev.
Control		52	52.3	7.1	49	48.7	7.2	-3	-3.7	5.5
No painted threshold	Smiley sign	48	47.7	6.8	45	44.9	7.1	-1	-2.8	5.9
	Koala sign	48	48.4	6.9	44	43.9	7.6	-3	-4.5	7.0
Painted threshold	Smiley sign	48	48.4	6.6	46	45.4	7.0	-1	-2.9	5.8
	Koala sign	48	48.5	6.6	44	44.2	7.2	-3	-4.3	6.3
Overall		49	48.6	6.9	45	45.1	7.4	-2	-3.6	6.2

The average daily speeds of vehicles recorded at site 5 are shown in Figure 11. There was little variance in the daily recorded speeds during all the treatments. The control was the only treatment that consistently recorded daily average speeds above the speed limit.

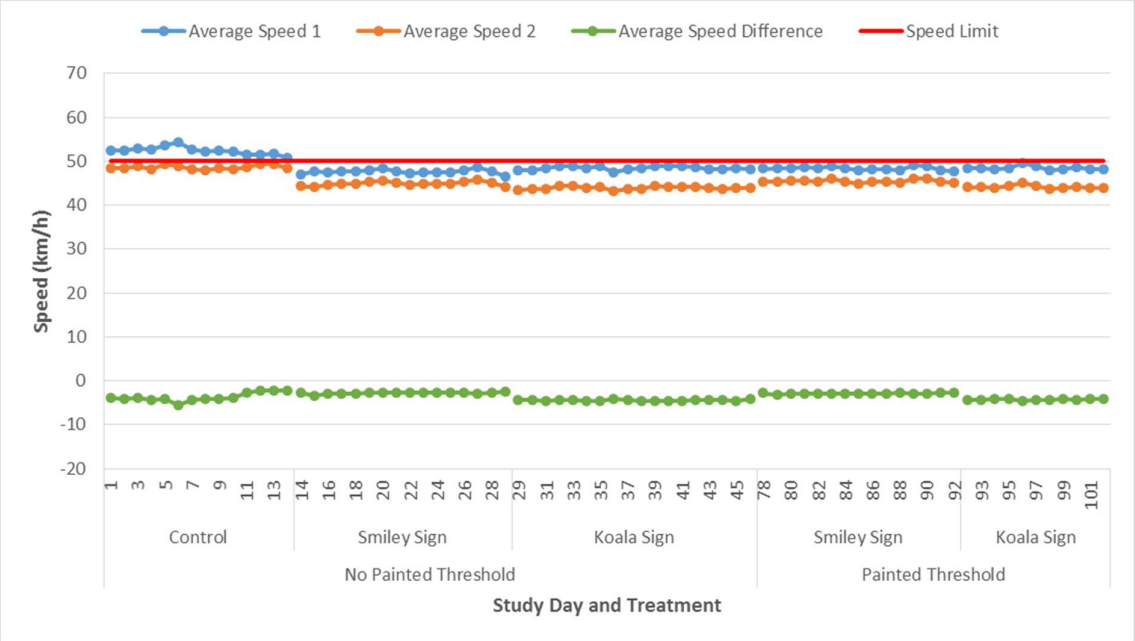

Figure 11. Average daily speeds of vehicles recorded at site 5 Wellington Street north. Speed 1 is the initial recorded speed of the vehicle and speed 2 is the speed of the vehicle as it passes the sign. Speed difference is speed 2 minus speed 1 (where applicable). Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability.

The number and percentage of vehicles speeding for speed 1 and speed 2 during each study treatment for site 5 are shown in Table 18. There was a clear reduction in the number of vehicles speeding

between speed 1 and speed 2 for all treatments. Both sign types for both threshold treatments recorded lower proportions of speeding vehicles at speed 1 and speed 2 than the control. Overall, the control treatment recorded the highest reduction in the percentage of speeding vehicles between speed 1 and speed 2 (22.7% reduction). However, it also recorded the highest percentage of vehicles speeding at both speed 1 and speed 2. This was followed by the koala PT (17.8% decrease in speeding vehicles) and the koala NPT (17.6% decrease in speeding vehicles), with koala PT recording the lowest proportion of speeding vehicles at speed 2. The smiley NPT recorded the lowest reduction in the percentage of speeding vehicles, with an 11.1% decrease.

The no painted threshold treatment (smiley NPT and koala NPT combined) recorded 19.3% of speeding vehicles at speed 2 and the painted threshold treatment (smiley PT and koala PT combined) recorded 20.35% of vehicles speeding at speed 2.

Table 18. The number and percentage of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 5 Wellington Street north.

Treatment		No. of vehicles	Speed 1		Speed 2	
			No. of vehicles speeding	% of vehicles speeding	No. of vehicles speeding	% of vehicles speeding
Control		33,697	20,867	61.9%	13,221	39.2%
No painted threshold	Smiley sign	82,595	25,725	31.1%	16,531	20.0%
	Koala sign	83,105	30,077	36.2%	15,446	18.6%
Painted threshold	Smiley sign	78,846	28,108	35.6%	17,813	22.6%
	Koala sign	49,260	17,692	35.9%	8,912	18.1%
Grand total		327,503				

The daily percentages of speeding vehicles recorded for each treatment and both signs at site 5 are shown in Figure 12. All treatments show a daily variance in the percentage of speeding vehicles and both speed 1 and speed 2 show similar patterns of variance. The control treatment recorded the greatest range in daily variance for both speed 1 and speed 2.

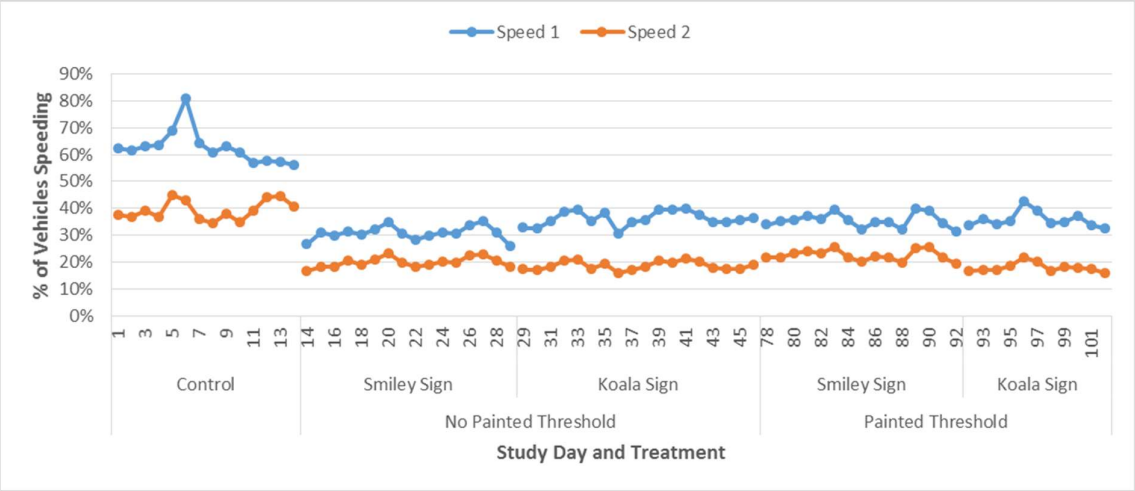

Figure 12. The daily percentages of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 5 Wellington Street north. Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability.

The percentages of vehicles that showed no change in speeding, stopped speeding, and started speeding across all study treatments at site 5 are shown in Table 19. Overall, the majority of vehicles showed no change in whether or not they were speeding, with a range of 12% across all treatments. The control treatment recorded the highest percentage of vehicles that stopped speeding, however, also recorded the highest percentage of vehicles that started speeding. However, this does not account for the overall proportions of vehicles speeding (see Table 18 above). The koala PT recorded the lowest percentage of vehicles that started speeding.

The painted threshold treatment (smiley PT and koala PT combined) recorded a higher percentage of vehicles that stopped speeding (18.05%) than the no painted threshold treatment (smiley NPT and koala NPT combined; 18.9%), as well as a slightly lower proportion of vehicles that started to speed.

Table 19. The percentage of vehicles that showed no change in speeding, stopped speeding, and started speeding for each of the study treatments at site 5 Wellington Street north.

Treatment		No change in speeding	Stopped speeding	Started speeding
Control		69.1%	26.8%	4.1%
No painted threshold	Smiley sign	81.1%	15.0%	3.9%
	Koala sign	75.5%	21.1%	3.5%
Painted threshold	Smiley sign	79.0%	17.0%	4.0%
	Koala sign	76.2%	20.8%	3.0%
Overall		77.2%	19.1%	3.7%

Overall, at Wellington Street north (site 5) the koala sign, both with and without the painted thresholds, performed the best. The painted thresholds made no discernible difference to the influence of the koala sign on vehicle speeds (see pages 35-36 in section 4. Discussion for further assessment of the painted thresholds).

3.1.6. Site 6 Wellington Street south

The speeds of 119,611 vehicles were analysed at Starkey Street south. On average, there were 1,594.8 vehicles per day in the analysed dataset.

The median, mean, and standard deviation for speed 1, speed 2, and speed difference for all study treatments at site 6 are shown in Table 20. Overall, all of the treatments recorded a reduction in speed between speed 1 and speed 2, with a range of -3.3 km/h. All treatments also recorded similar speeds for speed 1, with a range of 1.7 km/h. The koala PT recorded a 13.5% decrease between speed 1 and speed 2 compared to the 6.7% decrease recorded by the control. Overall, the koala PT recorded the lowest speed 2, followed by the smiley NPT. The smiley PT recorded a similar, yet slightly larger, speed decrease to the control.

The no painted threshold treatment (smiley NPT and koala NPT combined) saw a 5.3 km/hr decrease in speed and the painted threshold (smiley PT and koala PT combined) recorded a 5.05 km/h decrease in speed. However, the no painted threshold treatment recorded a slightly higher average speed 2 (43.75 km/h) than the painted threshold treatment (43.6 km/h).

Table 20. The median, mean, and standard deviation for speed 1, speed 2, and speed difference for each of the study treatments at site 6 Wellington Street south (50 km/h speed limit).

Treatment		Speed 1 (km/h)			Speed 2 (km/h)			Speed difference (km/h)		
		Median	Mean	Std. dev.	Median	Mean	Std. dev.	Median	Mean	Std. dev.
Control		49	49.2	8.1	46	45.9	8.4	-3	-3.3	5.8
No painted threshold	Smiley sign	48	48.0	7.1	43	43.4	8.5	-2	-4.7	6.8
	Koala sign	50	50.0	7.3	44	44.1	8.3	-5	-5.9	6.6
Painted threshold	Smiley sign	48	48.3	7.0	45	44.8	7.9	-1	-3.5	5.8
	Koala sign	49	49.0	7.2	42	42.4	8.6	-6	-6.6	7.4
Overall		49	48.8	7.3	44	44.1	8.4	-3	-4.7	6.6

The average daily speeds of vehicles recorded at site 6 are shown in Figure 13. Each treatment shows a similar pattern of variance, though the peaks on the weekends are less prominent for the koala NPT treatment. The peaks in speed 1 fall above the speed limit on some days for all treatments for this site.

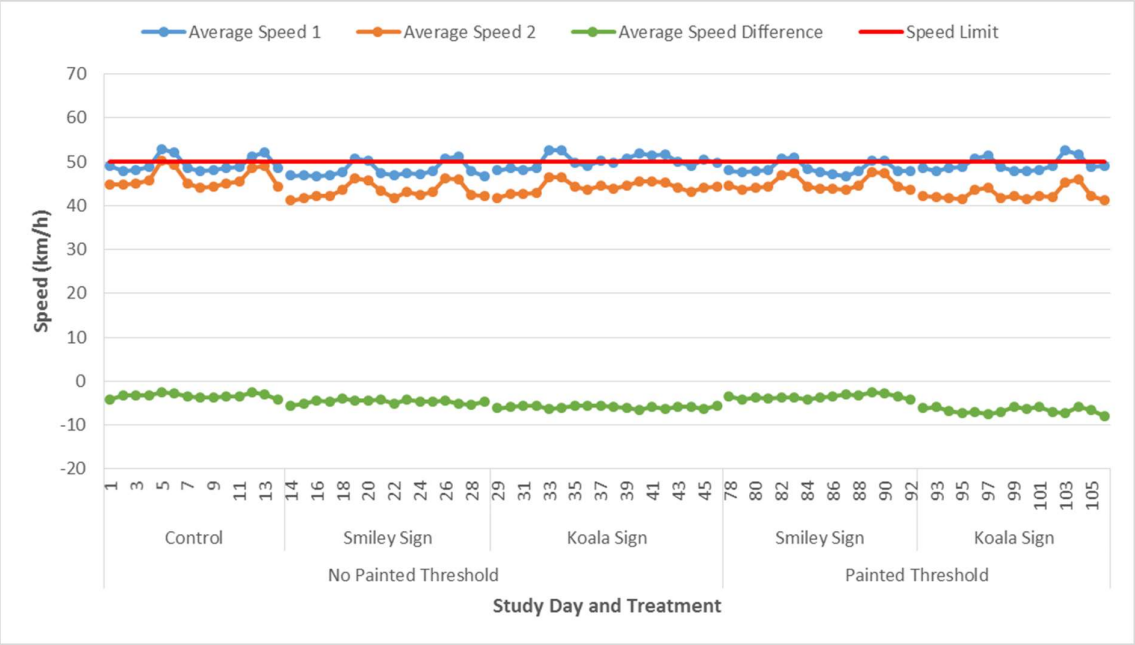

Figure 13. Average daily speeds of vehicles recorded at site 6 Wellington Street south. Speed 1 is the initial recorded speed of the vehicle and speed 2 is the speed of the vehicle as it passes the sign. Speed difference is speed 2 minus speed 1 (where applicable). Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability.

The number and percentage of vehicles speeding for speed 1 and speed 2 for each study treatment at site 6 are shown in Table 21. There was a clear reduction in the proportions of vehicles speeding between speed 1 and speed 2 for all treatments. Overall, the koala NPT saw the greatest reduction in the percentage of speeding vehicles at 23.6%, however, it recorded a higher proportion of speeding vehicles at speed 1 than the control. The koala PT recorded the smallest proportion of vehicles speeding at speed 2, followed by smiley NPT. The smiley PT recorded the smallest reduction in the percentage of speeding vehicles at 12.8%.

The no painted threshold treatment (smiley NPT and koala NPT combined) recorded 21.1% of speeding vehicles at speed 2 and the painted threshold treatment (smiley PT and koala PT combined) recorded 20.8% of vehicles speeding at speed 2.

Table 21. The number and percentage of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 6 Wellington Street south.

Treatment		No. of vehicles	Speed 1		Speed 2	
			No. of vehicles speeding	% of vehicles speeding	No. of vehicles speeding	% of vehicles speeding
Control		18,437	8,080	43.8%	5,127	27.8%
No painted threshold	Smiley sign	30,069	10,170	33.8%	6,229	20.7%
	Koala sign	23,006	10,367	45.1%	4,946	21.5%
Painted threshold	Smiley sign	30,512	11,000	36.1%	7,104	23.3%
	Koala sign	17,587	6,935	39.4%	3,210	18.3%
Grand total		119,611				

The daily percentages of speeding vehicles recorded for each study treatment at site 6 are shown in Figure 14. All treatments show a large daily variance in the percentage of speeding vehicles and both speed 1 and speed 2 show similar patterns of variance. The koala NPT saw a slight reduction in variance for speed 2.

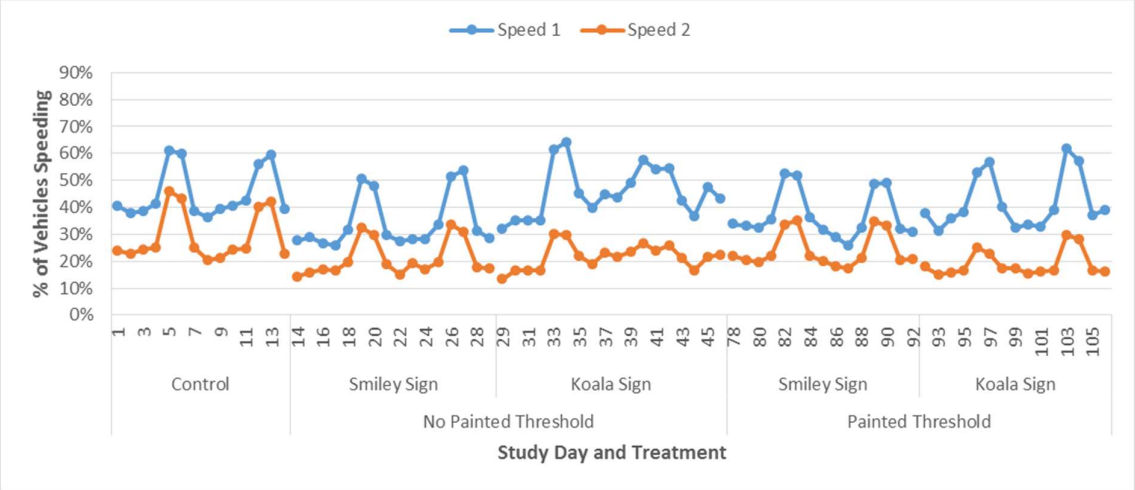

Figure 14. The daily percentages of vehicles speeding for speed 1 and speed 2 during each of the study treatment periods at site 6 Wellington Street south. Study days are consecutive within each treatment period, however, the x-axis is ordered by treatment period for consistency and readability.

The percentages of vehicles that showed no change in speeding, stopped speeding, and started speeding across all treatments and for both signs at site 6, are shown in Table 22. Overall, the majority of vehicles showed no change in whether or not they were speeding, with a range of 8.7% between all treatments. The koala NPT recorded the highest percentage of vehicles that stopped speeding, with both koala NPT and koala PT recording the lowest percentage of vehicles that started speeding. The control treatment recorded the highest number of vehicles that started speeding. The smiley PT recorded the lowest percentage of vehicles that stopped speeding.

The no painted threshold treatment (smiley NPT and koala NPT combined) recorded the higher percentage of vehicles that stopped speeding (20.7%) compared to the painted threshold treatment (smiley PT and koala PT combined; 19.2%).

Table 22. The percentage of vehicles that showed no change in speeding, stopped speeding, and started speeding for each of the study treatments at site 6 Wellington Street south.

Treatment		No change in speeding	Stopped speeding	Started speeding
Control		76.0%	20.0%	4.0%
No painted threshold	Smiley sign	81.2%	16.0%	2.9%
	Koala sign	73.0%	25.3%	1.7%
Painted threshold	Smiley sign	81.7%	15.6%	2.8%
	Koala sign	75.7%	22.8%	1.6%
Overall		78.1%	19.3%	2.6%

Overall, at Wellington Street south (site 6) the koala sign, both with and without the painted thresholds, performed the best, with the painted thresholds very slightly improving its influence on vehicle speeds (see pages 35-36 in section 4. Discussion for further assessment of the painted thresholds).

3.2. Model of speed difference

Of the time variables reviewed, time block was the greatest contributor to variation, and was therefore added to the final model as a weighting factor. The interaction between sign treatment and painted threshold caused errors in the GLS model, as no the control treatment included painted thresholds, so this interaction was removed. The final model included sign treatment, painted threshold, site, speeding category, and was weighted by time block (Table 23).

Table 23. The final GLS model results, showing variable category effects on the model (relative to the first category for each variable), standard errors, t-values, and p-values.

Variable: Category	Value	Std. error	t-value	p-value
Intercept	-3.203	0.062	-51.893	<0.001
Sign treatment: Control	0.000			
Sign treatment: Smiley	-0.477	0.021	-22.851	<0.001
Sign treatment: Koala	-1.893	0.021	-89.368	<0.001
Paint threshold: No	0.000			
Paint threshold: Yes	0.732	0.009	77.638	<0.001
Time block: 0000-0259	0.000			
Time block: 0300-0559	0.127	0.066	1.927	0.054
Time block: 0600-0859	0.941	0.059	15.975	<0.001
Time block: 0900-1159	0.921	0.059	15.669	<0.001
Time block: 1200-1459	0.870	0.059	14.810	<0.001
Time block: 1500-1759	1.144	0.059	19.553	<0.001
Time block: 1800-2059	0.527	0.059	8.893	<0.001
Time block: 2100-2359	0.051	0.062	0.828	0.408
Site: 1 Sturgeon St west	0.000			
Site: 2 Sturgeon St east	-2.179	0.013	-165.309	<0.001
Site: 3 Starkey St north	-1.203	0.015	-80.328	<0.001
Site: 4 Starkey St south	-2.250	0.017	-135.765	<0.001
Site: 5 Wellington St north	0.833	0.014	58.056	<0.001
Site: 6 Wellington St south	-0.458	0.022	-21.021	<0.001
Speed category: Non-speeders	0.000			
Speed category: Moderate speeders	-2.957	0.015	-203.594	<0.001
Speed category: Excessive speeders	-4.488	0.019	-241.776	<0.001

It should be noted that because speed difference was the response variable used in the model, negative values are associated with greater reductions in speed, and positive values are associated with smaller reductions in speed. There was an overall average 3.2 km/h reduction in speed regardless of other conditions. The koala sign had the largest impact on vehicle speed, with an additional average reduction of 1.9 km/h compared to the control. The painted thresholds had little effect and may even be associated with a 0.7 km/h lesser reduction in speeds compared to without the painted thresholds. Vehicles were least likely to reduce their speeds during peak hours, with the worst time being 15:00-17:59, followed by 06:00-08:59 and 09:00-11:59. Sites 4 and 2 had the best additional reductions of 2.3 km/h and 2.2 km/h, relative to site 1 respectively. Site 5 the worst with a 0.8 km/h smaller reduction in speed, relative to site 1. Excessive speeders (those exceeding the speed limit by at least 5 km/h) showed the greatest the reduction in speed upon encountering a sign. Moderate speeders (those exceeding the speed limit by 1-4 km/h) reduced their speed on average an additional 3 km/h and excessive speeders reduced their speed by an additional 4.5 km/h, compared to non-speeders.

4. Discussion

In general, the presence of both signs was associated with a reduction in vehicle speeds and a decrease by thousands in the number of vehicles speeding, with the painted thresholds having little and variable impact. Across all sites, the koala signs performed the best, either with or without the painted thresholds. This is very encouraging from a koala conservation perspective, suggesting that drivers do alter their driving behaviour, presumably because this will reduce the risk of collision with a koala. As the smiley signs and messages gave no information about the reason for the sign or for drivers to stay alert when travelling under the speed limit, this design and message may have been too general to elicit the same level of response as the koala sign. Additionally, the koala signs aid in informing drivers to look out for koalas on or near the road. This has the potential to increase the likelihood of drivers seeing a koala near the road sooner, as they were previously prompted with a similar image (Bond and Jones 2013; Collinson *et al.* 2019). It is also possible that the citywide koala conservation awareness campaign (commenced on 17th September; C. Dexter personal communication), enhanced the effectiveness of the koala signs. Although this campaign was not specifically focussed on the risk of koalas on roads, it was part of the message and the public were made aware that it was koala breeding season and that koala movements increase during this time.

In terms of speed difference, site 4 (Starkey St south) saw the greatest reductions in speeds due to the signs overall, closely followed by site 2 (Sturgeon St east), while site 5 (Wellington St north) saw the smallest reductions in speed. Although, it should be noted that vehicles driving at site 5 had the greatest reductions in speed 1 during the treatment periods (see Appendix 4). This earlier reduction in speed at site 5 may be due to numerous reasons, possibly including the lower speed limit (50 km/h) and drivers having just passed a speed limit sign as they exited a roundabout (approximately 200 m before the sign). The smallest proportions of vehicles speeding were at site 2 (Sturgeon St east), with the greatest proportions vehicles speeding at sites 5 and 6 (Wellington St north and south respectively). Site 2 likely had fewer vehicles speeding due to its proximity to two roundabouts, also likely influencing the relatively large speed difference at this site. Across all sites and study treatments (excluding controls), vehicle speeds were reduced between 2.8 km/h and 6.9 km/h, on average. Speed 1 and speed 2 averages for all sites and study treatments were at or below the speed limit, except for speed 1 during the control period at site 5. Some speed 1 daily averages at sites 5 and 6 were, however, above the speed limit, with some speed 2 daily averages only exceeding the speed limit during the control periods. Sites 5 and 6 also had by far the highest proportions of vehicles speeding at both speed 1 and speed 2, likely due to the speed limit along Wellington Road being 50 km/h, as opposed to 60 km/h along both Sturgeon and Starkey Streets.

Overall, the painted thresholds had very little impact on vehicle speeds and it is difficult to know whether any small apparent influence at each of the sites was in fact due to the painted thresholds or other factors, given the inconsistent patterns across the sites and signs. Generally, it appeared as if the painted thresholds were not effective in enhancing the benefits of signs, but more data are required to test this comprehensively. In the cases where the sign performance appeared to be slightly lessened by the presence of the painted thresholds, it is possible that this was due to the beginning indications of habituation to the signs and not in fact due to the painted thresholds, however this is purely speculative. In order to investigate the possibility of habituation further, the signs would need to be in place for longer periods between rotations. Even though the painted thresholds appeared to slightly improve the performance of the koala signs at some sites, they had a marginal additional impact at these sites. However, the primary purpose of the wildlife zone painted thresholds is to demarcate the sections of road along which drivers need to be cautious of wildlife near the road. The painted thresholds do not expressly instruct drivers to alter their behaviour in anyway, yet simply

indicate that they are entering a wildlife zone. With this in mind, it may be expecting too much of drivers to slow down even further when the painted thresholds are present without sufficient education as to how they should behave in wildlife zones. Additionally, it is possible that some drivers are changing their behaviour upon entering a wildlife zone, by increasing their vigilance instead of slowing down. Lastly, as the placement of the painted thresholds is offset from the dynamic signs, it is possible that drivers are slowing down for a short period when passing the painted threshold, but speeding up soon after.

With regard to the influence of the signs, painted thresholds, and sites on difference in speed, the model confirms the patterns shown by the summary statistics and reports the overall influence of each variable category. The model also identified peak traffic hours to be the times when reductions in speed were smallest, whereas reductions in speed were greatest in the hours around midnight. Greater speed reductions during these hours encourage the notion that the signs have the potential to reduce koala-vehicle collisions, as these times align with peak movement periods for koalas (Ryan *et al.* 2013). However, this could be misleading, as excessively high vehicle speeds were more prevalent at night, and excessive speeders were found to reduce their speeds more than both moderate speeders and non-speeders. This highlights the importance of not relying on a single variable (in this case, speed difference) in order to reveal the entire pattern of speed change.

The relative performance of the study treatments sometimes varied depending on the variable being considered, and no single variable provided a reliable overview of the impact of the signs and painted thresholds on vehicle speeds. It should also be noted that the variable reporting the proportions of vehicles that stopped speeding between speed 1 and speed 2 is perhaps too generalised to be of great value. At the sites where this information was available for the control periods, the proportion of vehicles that stopped speeding was often higher for the control period than the sign treatment periods. This, however, does not take into consideration the overall proportion of vehicles speeding at speed 1 and speed 2, and therefore, can be deceptive when drawing conclusions about the impact of the sign treatments. Alternately, the proportions of vehicles that started speeding did provide a better indication of the impact of the sign treatments, albeit simplistic.

Reductions in vehicle speeds in this study can be cautiously compared with those recorded for large koala warning signs with vehicle-activated flashing lights by Sullivan *et al.* (2013). However, as Sullivan *et al.* (2013) were unable to record two speeds per vehicle, the differences in speed 1 between the controls and treatments can only be considered. Considering only speed 1 (and excluding sites 1 and 2 as having potentially unrepresentative control data), speed changes vary considerably: the koala signs go from increasing speed by 0.8 km/h to decreasing speed by 3.9 km/h, and the smiley signs increasing speed by 0.3 km/h to decreasing speed by 4.6 km/h. This comparison is still not entirely accurate, as low speed records were excluded from the data in the current study and Sullivan *et al.* (2013) excluded all data records during public and school holidays. Comparing the data from the current study to the results of Sullivan *et al.* (2013), the signs used in Sullivan *et al.* (2013) appear to be more effective in reducing vehicle speeds than either the koala or smiley signs used in the current study. However, considering this alone, the conclusions of this report would have been very different and serves as a warning for all future projects looking at the impact of signs on vehicle speeds to record a minimum of two speeds for each vehicle.

It is difficult to determine whether the vehicle speed reductions observed in this study were sufficient to reduce the likelihood of wildlife-vehicle collisions. Although such associations have been able to be determined in some studies (e.g. Sullivan *et al.* 2004), the rate of deer-vehicle collisions were much higher than would ever be observed for koalas, simply due to larger populations of the focal species

or taxa being studied. To our knowledge, no koalas were struck by vehicles along these roads during the study. The last reported koala strikes within or adjacent to the Ormiston koala conservation safe neighbourhood were four in 2017, with one of these possibly occurring on Sturgeon Street. The other three strikes occurred on Delancey Street, Gordon Street, and Northern Arterial Road. However, Sturgeon Street has historically been a high koala strike location (C. Dexter personal communication). Given koala-vehicle collisions are generally infrequent events, long-term data on the signs, vehicle speeds, and wildlife-vehicle collisions would need to be collected in order to determine if any reductions in wildlife-vehicle collisions could be a consequence of the signs. Although such a study was conducted by Dique *et al.* (2003), speed measurements were not continuous and the automatic traffic counters used to measure speed were not always placed in the same locations (Queensland Department of Main Roads 2000). Relatively small reductions in vehicle speeds have been associated with substantial reductions in the likelihood of a vehicle being involved in a collision (Kloeden *et al.* 1997; Kloeden *et al.* 2002).

Determining safe driving speeds for wildlife depends on several factors, such as roadside visibility, location of the animal, time of day, weather, whether a vehicle has high-beam or low-beam headlights turned on, driver vigilance and reaction time, the presence of other distractions, and the species of concern. Making some assumptions about some of these factors, Hobday (2010) determined safe driving speeds for several species found in Tasmania, yet many were below what would be considered acceptable speed limits along most roads, unless high-beam headlights were used.

4.1. Conclusion

Overall, both sign designs reduced vehicle speeds, with the koala signs being slightly more effective in reducing vehicle speeds compared to the smiley signs. It is possible that this is due to these signs providing additional information to drivers as to why they should alter their behaviour and/or the additional impact of the koala conservation community awareness campaign conducted during the study. Any effect of the wildlife zone painted thresholds was very slight and inconsistent across the sites and sign designs. However, the primary purpose of these painted thresholds is simply as a demarcation of wildlife zones and do not instruct drivers to change their behaviour. This pilot study has shown that there is indeed potential for dynamic wildlife warning signs to change driver behaviour. With further investigation of driver responses to various sign designs and messages, along with continued community education, there is the potential to optimise driver responses to wildlife warning signs and provide opportunity for these adaptable mitigation measures to reduce wildlife-vehicle collisions.

5. Recommendations

It is recommended that this sign trial be continued in 2019 in order to further investigate the influence of wildlife warning sign designs and messages on driver behaviour. Further research is required in order to better understand how drivers respond to wildlife warning signs and what improvements can be made to optimise this behaviour change. The following recommendations are made for future research.

- Investigations into when and for how long drivers alter their behaviour can begin to address the longevity for driver responses to wildlife warning signs and inform the frequency at which drivers need to be reminded to be cautious for wildlife. This research would be particularly valuable where roads cut through large conservation areas or longer sections of habitat matrices.
- Investigations into driver behavioural responses to various wildlife warning signs other than speed reductions. Reduced vehicle speeds are only one aspect of driver behaviour that is targeted by the signs, and investigating how to increase driver vigilance is a major research gap and challenge.
- Investigations into whether different wildlife warning sign designs and messages have a greater impact on driver behaviour, both in relation to vehicle speeds and driver vigilance.
- Investigations into when drivers start to habituate to the signs are needed so that signs can be installed for the optimum amount of time, before either being removed or swapped with another sign design. Habituation is still one of the greatest challenges in changing driver behaviour.
- Although the wildlife zone painted thresholds appeared to have little impact of vehicle speeds, public education about how drivers are expected to behave when entering a wildlife zone may be needed.

Should this sign trial be continued, the following recommendations should be considered.

- The functionality of all signs should be tested and confirmed well in advance to the commencement of the study and installation of the signs.
- All signs should be installed (and covered) one week before the planned commencement of data collection. This week would allow time for any functionality issues with the signs to be realised and resolved without affecting the data. During this period, the signs and data should be checked every few days for issues.
- All sign messages and related bitmaps should be uploaded to all signs prior to installation of the signs to avoid connection issues when uploading the files. It should also be confirmed that all new signs have detected the correct time zone before installation to avoid having to adjust any incorrect time stamps in the data.
- The locations of signs need to be very carefully considered in order to reduce any direct influence of road features on the speeds of vehicles and the likelihood of speeds being reduced. Ideally, an alternative location for each sign should be planned in case any issues with the preferred initial location are realised during the preliminary week of sign testing.
- The koala signs or other signs without remote connectivity should have the data downloaded and cleared from these signs on a two to three weekly basis (depending on traffic volumes) to avoid data losses.

- Due to numerous display and data issues experienced by koala sign 4244, this unit should be replaced. Replacement of both koala signs should also be considered to minimise potential future data errors and technical issues due to the age and deterioration of these signs.
- Two additional signs should be acquired for the Ormiston koala conservation safe neighbourhood, so that signs can be placed at all sites throughout the data collection periods. This will also ensure that all future control data can be collected using the signs. Not only will this provide consistency in data collection methods, it will also provide two speed measurements for all control data. It should be noted, however, that any collection of control data at these sites in the future will not provide true baseline vehicle speeds, due to the installation of the painted thresholds during this study. Nonetheless, this will still provide control data when considering the influence of the signs only.
- Any new signs to be acquired for the purposed of the sign trial should include remote connectivity capabilities. The remote connectivity capabilities enable regular checks of sign functionality and data collection, remote uploading of bitmaps to signs via a stable internet connection, remote downloading of data, and remote changing of sign settings. Although any uploading of bitmaps and changing of settings should be checked by driving by the signs, this was generally easier to manage than uploading of bitmaps via Bluetooth, as was necessary for the koala signs. This was particularly more efficient when uploading the bitmaps of the speed numbers, as this involved uploading approximately 150 bitmaps, which was difficult to do on the consistently unstable Bluetooth connection to the koala signs.
- Future research would be enhanced by the addition of pneumatic tubes or other vehicle speed recording devices at various distances after each sign. This would reveal information on the distances over which any speed reductions are maintained or further reduced after the signs. Due to high demand and regular scheduling of pneumatic tubes devices on other roads throughout Redland City, there are often constraints on the length of time pneumatic tubes are placed at any one location. Therefore, it would be greatly beneficial to have a minimum of one pneumatic tube device per sign that can be dedicated to the sign trial.
- Continued pursuit of other contributing partners, such as the Queensland Department of Transport and Main Roads, the City of Gold Coast, Brisbane City Council, and Logan City Council.
- Continued pursuit of additional funding to supplement any future funding provided by Redland City Council.

It is proposed that a sign trial continue to be conducted in 2019 at the Ormiston koala conservation safe neighbourhood with four new signs to replace all four old koala signs. It is anticipated that the replacement of these signs would constrain expanding the sign trial to any additional roads in 2019. Despite this, the purchasing of new signs provides the opportunity to add additional sign designs and/or messages to the experimental design. It is recommended that the signs be displayed at each site for a minimum of four weeks to enable the investigation of the longevity of the effect of the signs on driver behaviour. This would have the potential to begin to investigate driver habituation to the signs. It is estimated that the costs associated with the delivery of the Ormiston smart sign trial in 2019 will range between $60,000 and $80,000 for the services of Griffith University's Applied Road Ecology Group.

6. Study limitations

It must be noted that there were several limitations to this study which need to be taken into consideration when interpreting the results.

6.1. Control data

As the control data for all sites did not come from the same source, there is potential for the pneumatic tube data (for sites 1, 3, and 4) and the data collected by the signs in the middle of the study (site 2) to not be truly comparative to the treatment data. This is particularly of concern for the historic pneumatic tube data (site 1) and the data collected by the signs in the middle of the study (site 2).

The two historic pneumatic tube data showed differences in the patterns of traffic flow and vehicle speeds to the data collected during the study period. Furthermore, different patterns of traffic flow and speeds are apparent between the two historic datasets sourced from the pneumatic tubes (see Appendix 6). Despite not knowing why the traffic patterns would be different across these periods, it raises concerns regarding the representativeness of the data as to what was occurring immediately before the signs were displayed to drivers for the first time.

The control data for site 2 (and control C for site 1) raise similar concerns as to the whether or not it is truly representative of vehicle speeds that immediately before the signs were displayed to drivers for the first time. At the time when this data was collected, the signs were covered and the painted thresholds were yet to be installed, but drivers had already been exposed to signs at this site for four weeks (collectively) and residual effects may have influenced their speed. Therefore, comparisons made between the study treatments and the control data for these two sites should be made with caution.

Although, it is possible that different vehicle speeds could be recorded by different equipment, assuming that the pneumatic tubes were set up accurately, a study that conducted a controlled comparison of these equipment types revealed no differences around the speeds at which the majority of the vehicles in this study were travelling (Gates *et al.* 2004). Therefore, control data acquired from the pneumatic tubes for sites 3 and 4 should be comparable to that collected by the signs during the treatment periods, as this control data was collected just prior to the signs being displayed to traffic and within the study period.

6.2. Results of the model using speed difference as the response variable

In the case of this study, the variable speed difference was not as informative as it was expected to be due to vehicles slowing down at speed 1 for some sites and during the control period at speed 2. Therefore, looking at this variable alone does not show the overall impact of the signs. The variables reported in the summary statistics together are more informative as to the effect of the signs than any one single variable. Speed difference would have been a useful single variable if, and only if, speed difference for the control periods been close to zero, and vehicles did not reduce their speeds before being first detected by the signs (speed 1) during the sign treatment periods. Additionally, the variable speed difference could not be calculated for data from the pneumatic tube data, as only a single speed was recorded for each vehicle. For these reasons, the results of the model do not represent the entire effect of the signs on vehicle speeds.

6.3. Length of treatment periods

Due to the short length of time that each study treatment was allocated to each site, no insights can be drawn as to the time it would take for drivers to start to habituate to the signs. The short treatment periods also meant that for some treatments at some sites, school holidays overlapped with up to half of the treatment period. Although school holidays were seen to have little influence on speed difference in our initial models, there is still the potential for this to have affected vehicle speeds.

6.4. Separating the effects of sign design from sign message

As only four signs were able to be used in the study, the design of the signs was not able to be separated from the messages displayed on the signs as a factor in the analyses. The two sign designs had different configurations of the LED displays and so the messages displayed were similar, but not able to be the same.

6.5. Replication of study sites

Due to this study being a brief pilot experiment with limited funding for signs, data processing, and analysis, the number of study sites was limited and generalisations about the potential influence of these signs on vehicle speeds along other roads should be made with caution. This is particularly relevant for roads that have different speed limits and are in less urbanised settings.

7. Lessons learnt

Sign management and functionality issues which occurred at the beginning of the study unexpectedly limited the number of signs that could be used in the study, and therefore affected the collection of control data. Ideally, the functionality of all signs should have been tested and confirmed well in advance to the commencement of the study and installation of the signs. Having only four signs in the trial meant that control data for two sites had to be collected via pneumatic tubes.

During the first fortnight of the current study, during which time the signs were covered to collect control data, one of the koala signs recorded only one day of data before losing power due to and incorrectly installed regulator. The other koala sign failed to record continuous data due to it receiving insufficient sunlight to completely charge the batteries. After realising that this was the case, it was decided to move the sign to a sunnier location, but meant that the control data collected could not be used. Future studies could avoid this by installing all signs one week before the planned commencement of data collection.

Connection issues when initially uploading the bitmap files to one of the smiley signs meant that the initial installation of the signs took much longer than expected. All sign messages and related bitmaps should be uploaded to all signs prior to installation of the signs.

As the koala signs did not have remote connections available, all data recorded by these signs was stored on the sign drives. One of the koala signs appeared to reach its data storage capacity when left to record data for four continuous weeks during the delay of the painted threshold installation and the following data collection period. The signs were left unattended during this period, as there was no foreseen need to check the signs or download the data, and Jenoptik had reassured Griffith University that there should be sufficient data storage space to enable the signs to record continuous data for over a month (assuming traffic volumes were not extremely high). This resulted in a loss of five days of data for one of the signs during this period that could have been avoided. It is recommended that any future use of these signs involves downloading and clearing the data from these signs on a two to three weekly basis (depending on traffic volumes) to avoid data losses. The lack of remote connectivity for the koala signs also affected the efficiency of uploading bitmaps. This was particularly inefficient when uploading the bitmaps of the speed numbers, as this initially involved uploading approximately 150 bitmaps, which was difficult to do on the consistently unstable Bluetooth connection to the koala signs and required many attempts to upload an acceptable number of bitmaps. The speed number bitmaps also had to be updated whenever the signs were move to or from Wellington Street in order to have to the colour of the speed numbers match the message when the speed limit was different.

Even if all of these precautions were implemented in this study, some technical and data issues could not have been avoided or realised before the commencement of data collection. One of the koala signs malfunctioned unpredictably, causing display issues and data errors. This sign, however would then reset itself and recommence displaying the correct messages and recording valid speed data with correct timestamps. It was also not known whether the sign display issues coincided with the data record errors. At some point throughout the study, some of the other signs also experienced some data errors and/or data loss due to unknown reasons (see Appendices 2 and 3 for further details). All known data errors and data losses will be reported back to Jenoptik, with the suggestion for them to forward these on to Sierzega, in an effort provide the opportunity to rectify these issues for any new signs.

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Appendices

Appendix 1 – Glossary of terms

Appendix Table 1. Definitions of terms used throughout the report.

Term	Definition
Control	Data collected and used as a baseline either before signs were installed or when signs were covered. See Table 4 for the type of control data used at each site.
Smiley sign	Sierzega Speedpacer 4568 C signs with standard fluorescent yellow panels with the wording 'DRIVE SAFELY' (Figure 2a).
Koala sign	Sierzega Speedpacer 2368 FC signs with custom panels displaying a photo of a koala walking along on a road with the wording 'KOALA CROSSING' (Figure 2b).
NPT	No painted thresholds.
PT	Painted thresholds.
Study treatments	Control, smiley NPT, koala NPT, smiley PT, and koala PT.
Sign treatments	Control, smiley sign, and koala sign (regardless of painted threshold treatment).
Speed 1 or vehicle speed 1	The initial detected speed of vehicles as they approached the sign, approximately 200 m before the sign. Where pneumatic tubes were used to collect control data, this was the only speed recorded.
Speed 2 or vehicle speed 2	The final detected speed of vehicles as they passed the sign. Where pneumatic tubes were used to collect control data, only one speed was recorded and so speed 2 was missing from this data.
Speed difference	Speed 2 – speed 1. A negative value means that the vehicle reduced its speed and a positive value means the vehicle increased its speed.
Timestamp error flags	Where data was flagged as having potentially incorrect dates and/or times recorded. See Appendix 2 – Technical and data issues for further details.
Time block	A variable that blocked data into eight three-hourly time periods: 00:00-02:59, 03:00-05:59, 06:00-08:59, 09:00-11:59, 12:00-14:59, 15:00-17:59, 18:00-20:59, and 21:00-23:59.
Speeding category	A variable that categorised all vehicles by their initial speed (speed 1): non-speeders, moderate speeders (exceeding the speed limit by 1-4 km/h), and excessive speeders (exceeding the speed limit by 5 km/h or more).
Day versus night	A variable that categorised each observation by whether it was day-time (06:00 to 18:00) or night-time (18:00 to 06:00).

Appendix 2 – Technical and data issues

- Smiley sign 14370 at site 5 (Wellington St north) did not detect the correct time zone upon installation and did not correct itself until approximately eight hours after being installed. This meant that the time stamp on the first day for this sign had to be adjusted to the correct time zone, and thus seven hours were added to these times.
- Smiley sign 14370 at site 5 (Wellington St north) lost almost exactly 24 hours of data on 26th August. The last data record on 26/08/18 was at 00:49 and the next data record occurred on 27/08/18 at 00:09. The reason for this data loss is unknown.
- Koala sign 4244 at site 1 (Sturgeon St west) was functioning for approximately 23 hours after installation on 24th August. The last data record on 25/08/18 was at 10:22. As the sign was covered to collect control data at this time, it was not realised until 3rd September that this sign had not been functioning. Due to the sign collecting insufficient data for the control period, this data was excluded from analyses. This data loss occurred because the regulator was incorrectly installed. The batteries were changed on 3rd September and the regulator was correctly installed on 4th September to rectify this issue.
- Where initially installed, Koala sign 4245 at site 2 (Sturgeon St east) was exposed to insufficient sunlight to completely charge the batteries in order for the sign to run continuously. This issue was realised after the first download of data on 3rd September, when no data was recorded for a period on several nights and into the following morning, and for a three-day period that had heavily overcast weather. This sign was moved to a sunnier location on 7th September, further east along the road. Due to the layout of the road and a roundabout being located between the initial sign position and the final sign position, no data can be used from before the sign was moved, including all control data. Nightly data gaps continued on 7th, 8th, and the morning of the 9th September, until the batteries were completely charged.
- Koala sign 4244 at site 1 (Sturgeon St west) was exposed to insufficient sunlight to completely charge the batteries in order for the sign to run continuously during some heavily overcast days. This resulted in some data loss and the sign not displaying at all times on 5th, 6th, and 7th September. The period over which data loss occurred varied each day.
- Koala sign 4244 at site 6 (Wellington St south) experienced some data anomalies during the period of 18th September to 5th October. These anomalies included incorrect dates recorded with obviously incorrect speed data. The data immediately before and after these anomalies have overlapping dates for the 1st and 2nd October. All data before and after the anomalies from this data file were kept for the data summary tables and graphs. However, these were separately flagged and excluded from the GLS model due to the dates and times possibly being unreliable. This also caused possible loss of data from 30th September to 5th October, though as some of these dates and times are likely to be unreliable, we were unable to ascertain the periods over which data was lost.
- Koala sign 4244 experienced occasional data losses of unknown cause throughout the study. The period over which data loss occurred varied each day, varying from 1 hour 2 minutes to 8 hours 37 minutes. This occurred on the dates and at the sites as specified below.
    - 7th-17th and 19th November at site 2 (Sturgeon St east), varying from 1 hour 2 minutes to 8 hours 37 minutes.
    - 20st-26th November and 28th November to 3rd December at site 6 (Wellington St south), varying from 1 hour 27 minutes to 5 hours 17 minutes.
- Some isolated date and time anomalies occurred for Koala sign 4244. The data immediately before and after these anomalies but with the correct date showed incorrect speed records and were also removed from the data. These anomalies were followed by a data gap.

  - 13/11/18 at 10:02 at site 2 (Sturgeon St east), followed by a data gap until 13:36.
  - 29/11/18 at 08:55 at site 6 (Wellington St south), followed by a data gap until 13:23.
- Smiley sign 14370 at site 4 (Starkey St south) recorded potentially incorrect dates and times on 22nd November. All speed data for these dates appeared to be legitimate. The data recorded as 21/11/2018 and 22/11/2018 was in the order below in the data file downloaded.
  1. 21/11/2018 00:00-23:59 – this data was assumed to be the correct date and time and was not flagged or excluded from any data analyses
  2. 21/11/2018 01:00-23:59 – this data was assumed to be for 22/11/2018 and the dates for this data block were changed to 22/11/2018 but the times were not altered. This data flagged as potentially incorrect and removed for the GLS models.
  3. 22/11/2018 00:00-00:59 – this data was assumed to be correct, but due to the order of the data, the times may be incorrect, but were left unaltered. Therefore, this data was also flagged as potentially incorrect and removed for the GLS model analyses.
- Koala sign 4245 at site 5 (Wellington St north) was vandalised on 30th November. The regulator was stolen and the sign lost power at 12:48. This resulted in a data gap until the end of that sign rotation on 4th December. This sign was then moved to be ready at site 4 (Starkey St south), but was not fixed until 10th December and the settings were corrected on 11th December. Therefore, this resulted in a data gap for site 4 from 4th December to 11th December at 14:30.
- Koala sign 4244 at site 3 (Starkey St north) experienced some data anomalies during the period of 4th to 18th December. These anomalies included incorrect dates recorded with no speed data or obviously incorrect speed data. These anomalies appear to have occurred over a very short period in this instance, with the data before and after the anomalies continuing with consistent dates and times. All data anomalies were removed from the dataset and data before and after the anomalies were used as legitimate dates and times. All data anomalies occurred between 09:08 and 09:32 on 11/12/18.
- During the installation of the painted road thresholds (and the weather delays that preceded the installation), all signs were left in place and turned on. This meant that the Koala signs accumulated data from 23rd October to 20th November (the end of the next rotation period). Despite being informed that the Koala signs had the capacity to record approximately three months of data, Koala sign 4245 at site 1 (Sturgeon St west) stopped recording data on 15th November at 22:57, presumably because it's data storage was filled.
- Koala sign 4244 occasionally experienced display issues, where the sign name would display, alternating with "LOW BATTERY". Each time this issue occurred when we were present, the sign settings were read, and the batteries were read as being within good working range. Sometimes the sign would still display the correct messages to passing vehicles. This sign continued to intermittently display this error and reset itself sometime later in the day. It is possible that this display error coincided with data anomalies and/or data gaps, however there was no way to be certain of this.

Appendix 3 – Data loss summary

Appendix Table 2 summarises the data removed for the summary statistics and the model. Data loss for the summary statistics was due to removal of data speed errors (where invalid speeds were recorded), outliers, signs being moved or sign settings being updated, and abnormally low speed vehicles (those travelling at less than half the speed limit at either speed 1 or speed 2). Additional data loss for the model was due to removal of timestamp errors (where dates and/or times were likely to be incorrect) and for all pneumatic tube data (as only one speed was recorded and so speed difference could not be calculated). See Appendix 2 for details of data errors.

Appendix Table 2. The number of observations that were in the raw data, removed, and used for the summary statistics and the model. Observations were removed for the summary statistics where speed data errors occurred, outliers, signs were being moved or sign settings being changed, and/or vehicles were travelling at abnormally low speeds (less than half the speed limit). Additional observations were removed for the model where timestamp errors occurred and for all pneumatic tube data (as speed difference could not be calculated).

Sign ID	No. of obs. in raw data	Summary statistics			Model		
		No. of obs. removed	No. of obs. used	% of raw data lost	No. of obs. removed	No. of obs. used	% of raw data lost
Pneumatic tubes	135,276	5,476	129,800	4.0%	135,276	0	100.0%
Smiley sign 14361	460,359	20,727	439,632	4.5%	20,727	439,632	4.5%
Smiley sign 14370	635,453	44,915	590,538	7.1%	48,805	586,648	7.7%
Koala sign 4244	348,954	13,424	335,530	3.8%	36,430	312,524	10.4%
Koala sign 4245	389,796	24,369	365,427	6.3%	24,369	365,427	6.3%
Total	1,969,838	108,911	1,860,927	5.5%	265,607	1,704,231	13.5%

Appendix 4 – Summary of speed differences between controls and treatments

Appendix Table 3. Summary of the differences in mean vehicle speeds between the controls and treatments for speed 1 and speed 2. A negative value represents a decrease in speed and a positive value represents an increase in speed relative to the control. N/A represents where only one speed was recorded for control periods.

Site	Treatment		Treatment speed 1 minus control speed 1 (km/hr)	Treatment speed 2 minus control speed 2 (km/hr)	Treatment speed 2 minus control speed 1 (km/hr)
Site 1*	No painted threshold	Smiley sign	1.8	N/A	-1.2
		Koala sign	2.4	N/A	-2.3
	Painted threshold	Smiley sign	2.3	N/A	-0.7
		Koala sign	2.1	N/A	-1.7
Site 2*	No painted threshold	Smiley sign	-1.2	-1.4	-7.0
		Koala sign	-1.0	-2.3	-7.9
	Painted threshold	Smiley sign	-0.9	1.0	-4.6
		Koala sign	-2.0	-3.2	-8.8
Site 3	No painted threshold	Smiley sign	0.3	N/A	-5.1
		Koala sign	-0.3	N/A	-5.9
	Painted threshold	Smiley sign	0.1	N/A	-3.2
		Koala sign	0.1	N/A	-4.9
Site 4	No painted threshold	Smiley sign	-0.5	N/A	-6.2
		Koala sign	-1.4	N/A	-8.2
	Painted threshold	Smiley sign	-0.9	N/A	-6.0
		Koala sign	-1.1	N/A	-7.5
Site 5	No painted threshold	Smiley sign	-4.6	-3.8	-7.4
		Koala sign	-3.9	-4.8	-8.4
	Painted threshold	Smiley sign	-3.9	-3.3	-6.9
		Koala sign	-3.8	-4.5	-8.1
Site 6	No painted threshold	Smiley sign	-1.2	-2.5	-5.8
		Koala sign	0.8	-1.8	-5.1
	Painted threshold	Smiley sign	-0.9	-1.1	-4.4
		Koala sign	-0.2	-3.5	-6.8

* Note that the speeds recorded for the control at sites 1 and 2 may not representative of speeds immediately before the signs were installed.

Appendix 5 – Summary of treatment change in vehicle kinetic energy relative to control

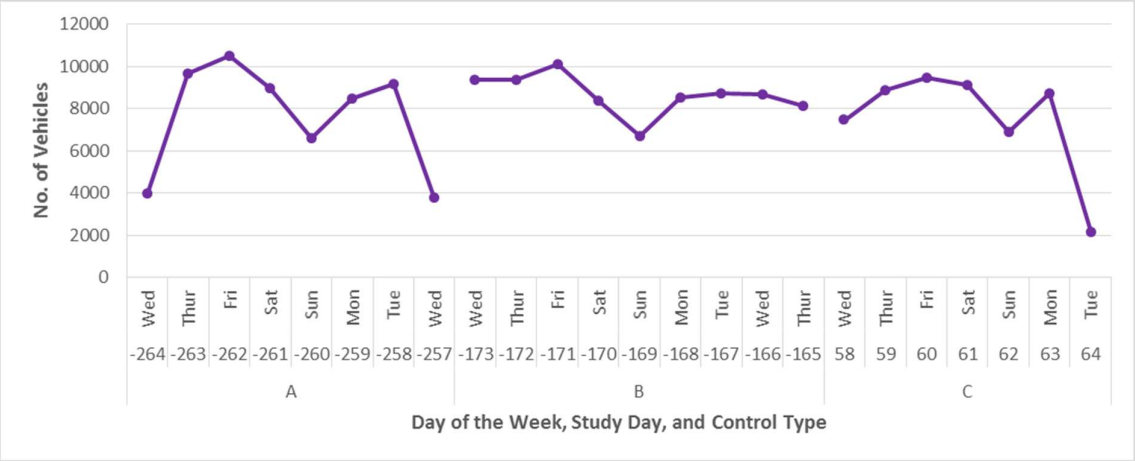
Appendix Table 4. Summary of the treatment change in vehicle kinetic energy relative to the control for speed 1 and speed 2. A negative value represents a decrease in kinetic energy and a positive value represents an increase in kinetic energy relative to the control. N/A represents where only one speed was recorded for control periods.

Site	Treatment		Treatment speed 1 change in kinetic energy relative to control speed 1	Treatment speed 2 change in kinetic energy relative to control speed 2	Treatment speed 2 change in kinetic energy relative to control speed 1
Site 1*	No painted threshold	Smiley sign	7.0%	N/A	-4.5%
		Koala sign	9.4%	N/A	-8.6%
	Painted threshold	Smiley sign	9.0%	N/A	-2.7%
		Koala sign	8.2%	N/A	-6.4%
Site 2*	No painted threshold	Smiley sign	-4.4%	-5.7%	-24.2%
		Koala sign	-3.7%	-9.3%	-27.1%
	Painted threshold	Smiley sign	-3.3%	4.2%	-16.3%
		Koala sign	-7.3%	-12.8%	-29.9%
Site 3	No painted threshold	Smiley sign	1.1%	N/A	-17.6%
		Koala sign	-1.1%	N/A	-20.2%
	Painted threshold	Smiley sign	0.4%	N/A	-11.3%
		Koala sign	0.4%	N/A	-17.0%
Site 4	No painted threshold	Smiley sign	-1.8%	N/A	-20.9%
		Koala sign	-4.9%	N/A	-27.1%
	Painted threshold	Smiley sign	-3.2%	N/A	-20.2%
		Koala sign	-3.9%	N/A	-25.0%
Site 5	No painted threshold	Smiley sign	-16.8%	-15.0%	-26.3%
		Koala sign	-14.4%	-18.7%	-29.5%
	Painted threshold	Smiley sign	-14.4%	-13.1%	-24.6%
		Koala sign	-14.0%	-17.6%	-28.6%
Site 6	No painted threshold	Smiley sign	-4.8%	-10.6%	-22.2%
		Koala sign	3.3%	-7.7%	-19.7%
	Painted threshold	Smiley sign	-3.6%	-4.7%	-17.1%
		Koala sign	-0.8%	-14.7%	-25.7%

* Note that the speeds recorded for the control at sites 1 and 2 may not representative of speeds immediately before the signs were installed.

Appendix 6 – Control comparisons for site 1 Sturgeon Street west

The number of vehicles for each study day and each control type at site 1 are shown in Appendix Figure 1. There was daily variance for all three control types, however, the all three peak on Fridays and have lowest traffic volumes on Sundays. The pattern of traffic volume in between these days does vary slightly. The lows at either end of each data collection period are due to collection of partial days.

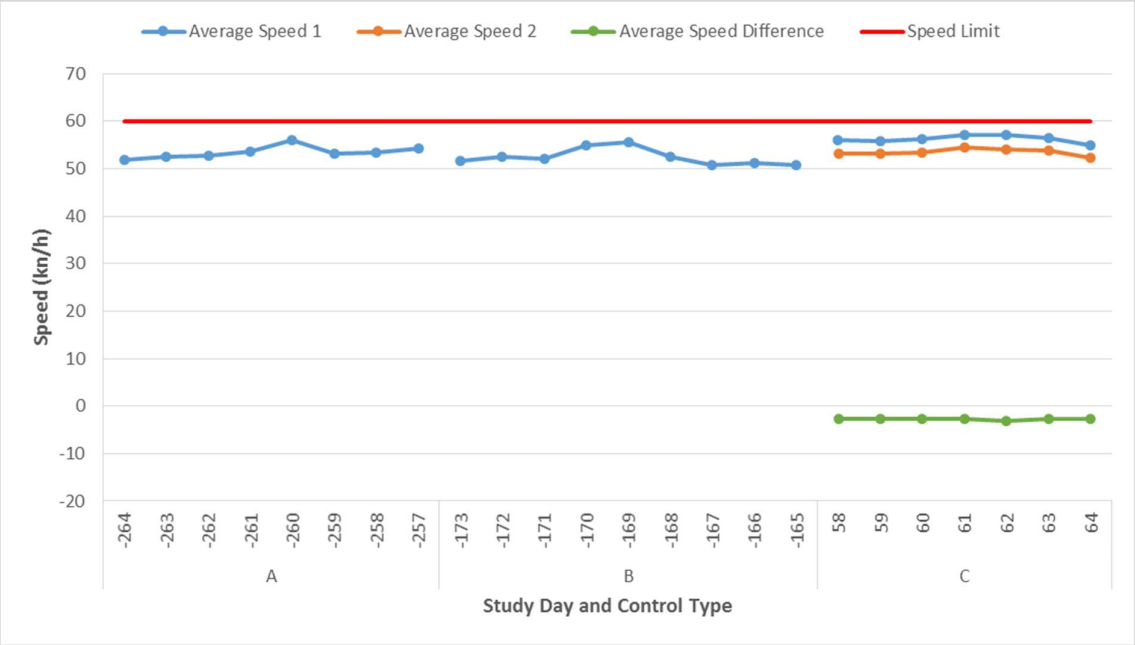


Appendix Figure 1. The number of vehicles recorded for each day of the week and for each control type at site 1. Negative study days are where data were historical and not collected during the study period.

The median, mean, and standard deviation for speed 1, speed 2, and speed difference for all three control types are shown in Appendix Table 5. Control C recorded a 5% decrease in speed between speed 1 and speed 2. Average speeds for speed 1 were 3-4 km/h lower for the two historical controls (controls A and B) than the control data collected by the covered sign during the study period (Appendix Table 5). The average daily speeds of vehicles recorded for all control types at site 1, are shown in Appendix Figure 2. There was little variance in the average daily speeds, however, there are small peaks in speed 1 towards the middle of the each of the data collection periods for controls A and B.

Appendix Table 5. The median, mean, and standard deviation for speed 1, speed 2, and speed difference for each control type.

Control type	Speed 1 (km/h)			Speed 2 (km/h)			Speed difference (km/h)		
	Median	Mean	Std. dev.	Median	Mean	Std. dev.	Median	Mean	Std. dev.
Control A	54	53.4	6.3	N/A	N/A	N/A	N/A	N/A	N/A
Control B	53	52.3	6.8	N/A	N/A	N/A	N/A	N/A	N/A
Control C	57	56.4	6.6	54	53.6	6.6	-2	-2.8	5.2

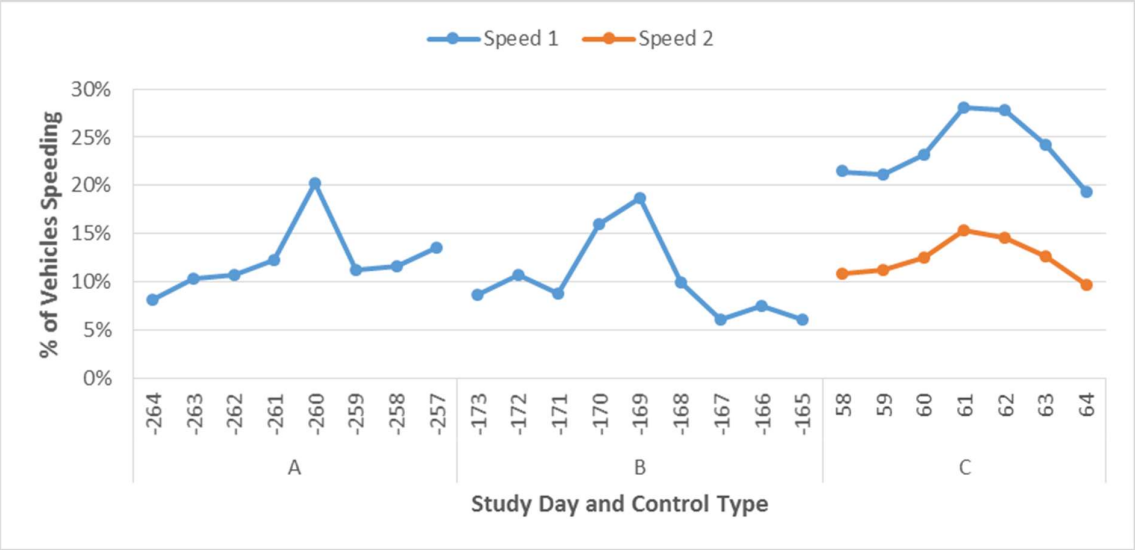


Appendix Figure 2. Average daily speeds of vehicles recorded for each control type. Speed 1 is the initial recorded speed of the vehicle and speed 2 is the speed of the vehicle as it passes the sign. Speed difference is speed 2 minus speed 1 (where applicable). Negative study days are where data were historical and not collected during the study period.

The percentage of vehicles exceeding the posted speed limit ('speeding') for all three control types at site 1 is shown in Appendix Table 6. Control C recorded the highest percentage of speeding vehicles at speed 1. However, it also recorded the largest number of vehicles overall, and an 11.3% decrease in the percentage of speeding vehicles between speed 1 and speed 2. The daily percentage of speeding vehicles for all three control treatments at site 1, are shown in Appendix Figure 3. All three control treatments recorded peaks in the percentage of speeding vehicles towards the middle of each data collection period before sharply declining towards the end.

Appendix Table 6. The number and percentage of vehicles speeding for speed 1 and speed 2 for each control type.

Control type	No. of vehicles	Speed 1		Speed 2	
		No. of vehicles speeding	% of vehicles speeding	No. of vehicles speeding	% of vehicles speeding
Control A	61,078	7,432	12.2%	N/A	N/A
Control B	77,944	7,850	10.1%	N/A	N/A
Control C	52,665	12,686	24.1%	6,715	12.8%



Appendix Figure 3. The daily percentages of vehicles speeding for speed 1 and speed 2 for each control type. Negative study days are where data were historical and not collected during the study period.

Overall, across the control datasets there was a lack of consistency. Additionally, speed 2 for control C was more closely comparable to speed 1 for both control A and B, with control C's speed 1 consistently being higher.