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Preliminary evaluation of Rural Junction Activated Warning System (RJAWS) in rural South Australia

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TITLE

Preliminary evaluation of Rural Junction Activated Warning System (RJAWS) in rural South Australia

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ABSTRACT

This report describes a preliminary evaluation of the potential for the Rural Junction Activated Warning System (RJAWS) to reduce the travel speed of approaching vehicles on the major legs of a three-leg junction when another vehicle is detected on the minor road or turning right from the far-side major leg into the minor leg. When the RJAWS detects any of those two conditions, an electronic sign placed on each approach direction along the major road temporarily indicate a speed limit lower than the default limit. The system has been installed at four rural junctions in South Australia characterised by poor sight distances. At three of the four trial locations, the default and reduced speed limits are 80 km/h and 50 km/h, respectively; whereas at one of the trial locations a default speed of 100 km/h and a reduced speed of 70 km/h applies. Pre and post RJAWS installation speed profiles of vehicles travelling along the major road have been compared. When the temporary speed limit signs are activated, the average travel speed along the major road is reduced by 11.3 km/h to 22.1 km/h. Consequently, the expected average relative risk of a casualty crash at the trialled junctions is reduced by 42% to 65% compared to before the RJAWS installation. Despite a limited compliance with the reduced speed limit, the proportion of drivers travelling through the junction at speeds 20 km/h or higher than the reduced speed limit was considerably low when RJAWS is activated, indicating the system effectiveness in reducing risky behaviour when another vehicle is at the junction. An extension of the RJAWS program to additional junctions is strongly suggested. Also, further investigation should be carried out to confirm the findings of this study through a control-case before/after analysis with a larger and more accurate speed data sample.

KEYWORDS

Rural Junction Activated Warning System (RJAWS), Junction-activated variable speed limit signs, Rural junctions, Speed limits

Summary

The Department of Planning Transport and Infrastructure (DPTI) trialled a Rural Junction Activated Warning System (RJAWS) at four rural three-leg rural junctions between two-lane roads in South Australia. The RJAWS aims to reduce the travel speed of approaching vehicles on the major legs of a three-leg junction when another vehicle is detected on the minor road or turning right from the far-side major leg into the minor leg. When the RJAWS detects any of those two conditions, an electronic sign placed on each approach direction along the major road temporarily indicate a speed limit lower than the default limit. At three of the four trial locations, the default and reduced speed limits are 80 km/h and 50 km/h, respectively; whereas at one of the trial locations a default speed of 100 km/h and a reduced speed of 70 km/h applies.

The objective of this research was to assess whether the RJAWS can potentially reduce the risk of fatal and serious injuries at the trialled junctions by effectively decreasing the travel speed along the major approaches under conditions that may present the opportunity for an adjacent direction collision with another vehicle. An analysis of the speed data indicates that RJAWS appears to be capable of effectively reducing the risk of casualty injuries by reducing the speed of vehicles travelling along the major junction approaches when there is a risk of a potential for an adjacent collision with another vehicle. Thus, the use of RJAWS can be considered aligned to the principles of a Safe System approach of reducing the potential for harm by decreasing the severity of crashes when they occur.

The proportion of vehicles travelling at or below the reduced speed limit in proximity to the junction when the variable speed limit sign was activated varied between and 22.6% and 65.3% across the four trial junctions. Despite the relatively low compliance to the reduced speed limit, the proportion of drivers travelling through the junction at a speed 20 km/h or higher than the reduced speed limit was considerably low. This indicates that the RJAWS can effectively induce drivers to reduce their speed when travelling through the junctions to values that are still below the default speed limit in case the junction is occupied by another vehicle.

Depending on the specific trialled junction, the average travel speed in close proximity to the junction when the RJAWS sign is activated is reduced by 11.3 km/h to 22.1 km/h compared to the average speed when the sign is not active. As a consequence of the reduction in travel speed, the expected average relative risk of a casualty crash occurring at the trialled junctions could be potentially reduced by a value between 42% to 65% compared to before the RJAWS installation.

The analysis conducted in this study is characterised by the following limitations due to a series of issues related to the data collection, which were beyond our control:

- Short time span considered for both the before and after periods
- Lack of a control in the before/after analysis (However, confidence could be obtained that no uncontrolled events may have affected the before/after analysis)

Given the positive results obtained from the analysis of the data collected at the four trial junctions, it is suggested that the installation of RJAWS could be expanded to a larger number of junctions. Expanding the installations of the RJAWS system would also provide the opportunity to collect speed data at any of the new installation sites in a more precise and detailed manner. Future data should be collected so that they can allow to carry over a control-case study in the future.

Note that this report was substantially completed in September 2020 and does not consider developments after that date.

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1 Introduction

1.1 Background

Rural junctions continue to pose a substantial problem for road safety. High travel speeds, often equal or even in excess of 100 km/h, typically combined with a right-angle impact configuration mean that crashes at rural junctions likely involve impact energy far greater than what can be tolerated by the human body (Corben et al., 2010). Such crashes have an inherently high risk of fatal of serious injury (FSI) outcomes (Jurewicz et al., 2015).

Treatments that can reduce the risk of FSI outcomes, such as rural roundabouts or grade separation, are usually very expensive ($1 million plus). South Australia has an extensive network of high-speed rural roads making the wholesale adoption of such treatments unfeasible except at high traffic volume locations in urban areas and along rural arterial roads. Therefore, low-cost treatments that can be quickly implemented on a widespread basis are required to minimise harm on low and moderate volume rural roads in South Australia. Given the clear link between speed and crash severity (Jurewicz et al., 2015), one of the most cost-effective ways to reduce harm at rural junctions is likely to come from treatments that reduce vehicle speeds through the junction.

In 2012 and 2013, the New Zealand Transport Agency (NZTA) trialled the use of rural intersection activated warning system (RIAWS) at ten rural junctions in 100km/h zones (Mackie et al., 2017). In the New Zealand context, RIAWS is used to reduce the speed limit along the major road through an junction when the possibility of an adjacent direction collision is detected; this could be from a vehicle entering the junction from the minor road (right angle conflict) or turning right from the major road (right turn conflict). The RIAWS system was used to reduce the speed limit along the major road to 70 km/h when the possibility of either a right angle or right turn collision was detected. Long-term results from the trial (2-3 years following implementation) suggested a reduction in modal speed for adjacent-direction collisions from 88 km/h pre-trial to 73 km/h. Also, a recent study purely based on highly realistic driving simulations (Meuleners at al., 2018) indicated that, when a RIAWS sign indicates a speed limit of 80 km/h on a road with a default speed limit of 100 km/h, the average travel speed along the major road is expected to be reduced by around 20 km/h (from 98.6 km/h to 77.9 km/h).

Beside the potential to substantially reduce vehicle speeds through a rural junction and the consequent associated risk of FSI outcomes, another benefit of RIAWS-like systems is their relatively low cost. Additionally, these junction-activated variable speed signs may also improve speed limit compliance and community support, which are often cited as major concerns when investigating the possibility of reducing speed limits on rural roads. Using these systems, the speed limit is reduced only at the times and locations when vehicles are detected from adjacent directions. This context-sensitive imposition of lower speed limits that can be achieved using junction-activated variable speed signs is thought to possibly improve compliance and community support by making more perceivable to the general public the link between speed limit reduction and safety.

1.2 Objective

Following the success of the New Zealand trial, the Department of Planning, Transport and Infrastructure (DPTI) is undertaking the trial of Rural Junction Activated Warning System (RJAWS) at four rural junctions near Adelaide. The trial locations were selected because of geometric features that were deemed to increase the risk of adjacent direction crashes. This trial is being used to evaluate the potential safety benefits of RJAWS and assess whether expansion of the treatment across South Australia's rural road network is worthwhile. The objective of this study is to conduct a preliminary

evaluation of the potential speed reduction and associated safety benefits that could be achieved using the RJAWS at the trial locations.

2 Methodology

2.1 RJAWS system

The RJAWS trialled by DPTI consisted of two vehicle-activated variable speed limit signs, which are located at a distance between 130 m and 170 m from the relevant junction. One sign was placed along each approach along the major road and was used to impose a temporarily lower speed limit when a vehicle was detected as approaching the junction from the minor road or turning right from the far-side approach into the minor road. The RJAWS has been trialled at four rural junctions between two-lane roads in SA. At three of the four trial locations, the default and reduced speed limits along the major road are 80 km/h and 50 km/h, respectively; whereas at one of the trial locations a default speed of 100 km/h and a reduced speed of 70 km/h apply. Larger speed limit reductions were initially considered but it was decided to not progress due to concerns about compliance and the need for buffer speed zones.

The RJAWS is designed to activate under two scenarios: (i) when a vehicle is entering the junction from the minor road and (ii) when a vehicle is turning right from the far-side approach along the major road. For vehicles entering the junction from the minor road, induction loops sensors were used to detect a vehicle as it approached the junction (RJAWS activation) as well as when it cleared through the junction (RJAWS deactivation). Instead, a radar speed sensor in combination with a threshold speed equal to 50 km/h was used to identify vehicles that would likely perform a right turn from the far-side major approach. Using those sensors, the RJAWS speed limit signs were therefore only displayed under conditions where the potential for an adjacent direction crash was possible. At other times when the RJAWS speed limit was deactivated, the speed limit through the junction remained at the default limit (80 km/h or 100 km/h) for both major approaches. An example of an installed RJWAS sign indicating a reduced speed limit is shown in Figure 2.1.

Figure 2.1
RJAWS installed nearby McLaren Flat Rd/ Bakers Gully Rd (along the near-side direction of travel)

2.2 Trial locations

Four trial junctions where selected by DPTI. All the selected junctions were between two-lane roads. Details for each location are shown in Table 2.1 and aerial views are shown in Figure 2.2. The reasons for the selection of each of the four trial sites are listed below:

- **Cudlee Creek Rd/Fox Creek Rd:** History of crashes (three adjacent direction serious injury crashes, 2007-16); restricted sight distance to east for minor road vehicles; previous trial of transverse line markings to reduce major road vehicle speeds on the westbound approach.
- **Bull Creek Rd/Paris Creek Rd:** Irregular junction geometry and restricted sight distance to south for minor road vehicles.
- **McLaren Flat Rd/Bakers Gully Rd:** Recent fatal crash (right angle, 2015); irregular junction geometry.
- **Horrocks Hwy/Stradbrooke Rd:** Restricted sight distance to north for minor road vehicles.

Table 2.1
Details for each trial location

Trial junction	Default speed limit (km/h) [Major/Minor road]	RJAWS speed limit (km/h)	Major road Average Daily Traffic (*) (weekly based)	Minor road Average Daily Traffic (weekly based)
Cudlee Creek Rd/Fox Creek Rd	80/80	50	1,066	1,605
Bull Creek Rd/Paris Creek Rd	80/80	50	1,621	140
McLaren Flat Rd/Bakers Gully Rd	80/80	50	2,299	893
Horrocks Hwy/Stradbrooke Rd	100/100	70	1,310	915

(*) Through traffic ONLY (i.e., No traffic entering/leaving major road at junction)

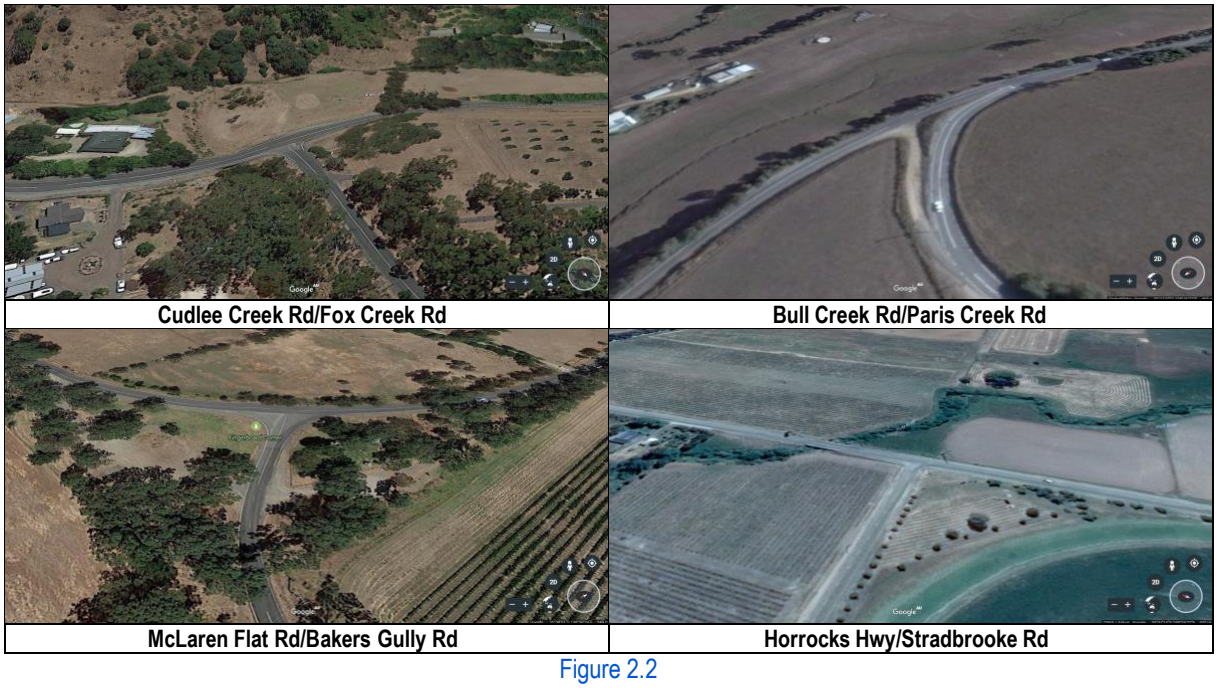

Figure 2.2
Aerial views of each trial junction (Google Earth, 2017; accessed 12 July 2017)

2.3 Evaluation method

Speed was used as a proxy for safety. A link between speed and the risk of FSI outcomes has been well documented in road safety research (Jurewicz et al. 2015). For adjacent direction crashes, the impact speed associated with a risk of FSI outcomes of 10% (the "Safe System speed") is suggested to be 30 km/h (Jurewicz et al. 2015). For fatal only outcomes, this speed is suggested to be 50 km/h (Wramborg 2005). Above these speeds, the associated risk of FSI or fatal outcomes substantially increases. Since the RJAWS reduced speed limit sign is activated when at least another vehicle is occupying the junction, a post-treatment reduction of the travel speed can therefore be projected to result in a reduced risk of FSI outcomes for road users traversing the junctions.

Thus, to assess the potential safety benefits of implementing a RJAWS at the trial locations, the speed profile of vehicles travelling along the major approaches of each junction when the system displayed a reduced speed limit was compared against the case when the RJAWS sign was not displaying a speed limit (i.e., the default speed limit applied). A comparison of the speed profile during the before and after period with an inactivated sign was also carried out to confirm whether other factors except the activation of the reduced speed could have likely contributed to change the speed between the before and after periods.

2.3.1 Speed measurement

Pneumatic tube traffic counters, or simply 'counters', were used to measure vehicle speed while traveling through the junction. The counters were set at specific locations relative to the junction on the major road. A counter was also set along the minor road to collect information that could be used to verify that the RJAWS system was being activated when a vehicle approached from the minor road. The locations of each counter are detailed in Table 2.2 and a diagram of the general counter layout is shown in Figure 2.3. The counters along the major road were placed both in proximity to the junction (distance A and B) and at distance similar to the required stopping sight distance (distance C and D). Note that the actual location of each counter was dependent on factors such as ability to safely access the road to place the counter and presence of other facilities upon which to secure the counters (e.g., poles, trees).

Table 2.2
Counter measurement/RJAWS locations with respect to adjacent direction crash impact locations

	Distance in metres (refer to Figure 2.3)						
Trial junction	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Cudlee Creek Rd/Fox Creek Rd	30	25	70	50	120	160	150
Bull Creek Rd/Paris Creek Rd	17	13	99	86	140	170	130
McLaren Flat Rd/Bakers Gully Rd	20	15	88	80	110	a150	140
Horrocks Hwy/Stradbrooke Rd	14	18	95	110	120	140	160

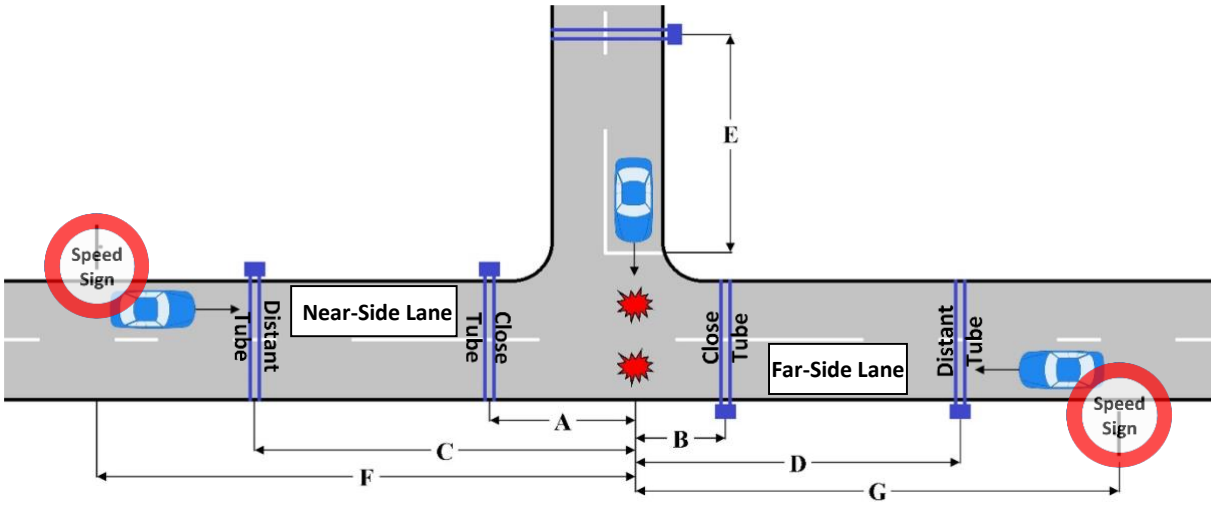

Figure 2.3
General layout of trial junctions and counter measurement/RJAWS locations
with respect to adjacent direction crash impact locations

In order to identify those instances recorded by the pneumatic tubes where the vehicles traversed the junction with the RJAWS activated, the clocks of the various tube dataloggers and the RJAWS system need to be synchronised with respect of each other as well as the clock of the RJAWS datalogger. Unfortunately, after the tube data had been collected, it was found that offsets larger than a minute were not uncommon between the clocks of the various tube dataloggers. Such offsets were identified through a sampled comparison of matching events recorded by the various tubes located along the main road. Additionally, large offsets between most of the tube dataloggers and the RJAWS dataloggers were identified through a sampled comparison of matching events of the RJAWS triggers and corresponding events recorded by tubes located nearby those triggers.

Thus, it was necessary to initially re-synchronise the timestamps of the events recorded by the tube dataloggers with respect to the clock of the RJAWS datalogger. This synchronisation process was performed in two phases. Initially, events that triggered the RJAWS were matched with corresponding events recorded by the tube located nearby the system trigger along the major road. Then, the remaining tubes located along the major road were synchronised by matching the same events recorded by those tubes with the corresponding events recorded by the initially synchronised tube. Practically, the overall synchronisation process was performed through an iterative process. Initially, time offset between three matching events were identified manually. Those offsets were then used as a starting point by an iterative algorithm that ran through all the tube events and RJAWS logs and identified the optimal offset that could guarantee the highest number of matching events in each of the two steps described above.

2.3.2 Speed analysis

The analysis of speed data for the after period covered a temporal period that started at least one month after the activation of the RJAWS. This temporal gap from the initial system activation was deemed to be sufficient to allow motorists to familiarise with the RJAWS reduced speed limit sign and thus assess the speed behaviour expected on the medium to long term. A summary of the activation date as well as the temporal period considered for the analysis of each trial site is provided in Table 2.3.

The focus of the project is to assess the potential risk of injury during a crash between a vehicle travelling along the major road and another vehicle leaving or entering the junction. Thus, the analysis was limited to events where the vehicle was deemed to travel in a fee-flow stream along the major road (i.e., not reducing speed to leave the major road at the junction). Also, speed was analysed only during the

vehicle approach to the junction (i.e., upstream of the junction only). Note that both the near-side and far-side directions of travel were considered in the analysis. The two directions of travel were then aggregated when performing the speed analysis.

A travel speed threshold equal to 40 km/h was used to identify those vehicles that were deemed to turn out of the major road. The definition of this threshold speed was based on an analysis of the vehicle speed distribution in proximity of the junction, as described in more detail in Appendix A.

Speed measurements were separated in two groups based on the status of the RJAWS sign (i.e., activated or non-activated). The speed measurements for each of those two groups were then analysed and compared considering the following characteristics:

- Distribution
- Average and percentiles
- Percentage of events within given various speed ranges (from 50 km/h to 80 km/h)

A paired t-test was carried out to confirm whether there was a statistically significant difference in the mean and 85th-percentile vehicle speed between the cases with the sign activated and non-activated. Additionally a t-test was also conducted considering the before period and the after period with an inactivated sign. This further analysis served to confirm whether other factors except the activation of the reduced speed sign have likely contributed to change the speed between the before and after periods.

Note that the following limitations apply to this study:

- Given the extensive amount of time required to synchronise the events recorded by the asynchronous pneumatic tube dataloggers, the analysis of the speed data has been limited to a period between 12 and 14 days for each of the four locations
- Weather conditions were not taken into consideration in the analysis of speed data during the relevant period
- Given the limited information that can be obtained from tube counts, it was not possible to completely exclude from the analysis specific cases when vehicles travelling along the major road had to slow down due to the presence of another slow-moving vehicle ahead of them (e.g., a vehicle ahead leaving or entering the junction)
- The analysis was limited to an aggregation of all vehicle types (i.e., light and medium-heavy vehicles considered all together)

Table 2.3
Temporal period covered by the speed analysis and system activation date for each of the trialled junctions

Trial junction	Activation Date	BEFORE ACTIVATION			AFTER ACTIVATION		
		Data Analysis Start Date	Data Analysis End Date	Analysis Period (days)	Data Analysis Start Date	Data Analysis End Date	Analysis Period (days)
Cudlee Creek Rd/Fox Creek Rd	Sep. 14, 2018	Aug. 7, 2018	Aug. 14, 2018	7	Nov. 9, 2018	Nov. 21, 2018	12
Bull Creek Rd/Paris Creek Rd	Oct. 8, 2018	Aug. 14, 2018	Aug. 21, 2018	7	Nov. 9, 2018	Nov. 21, 2018	12
McLaren Flat Rd/Bakers Gully Rd	Oct. 12, 2018	Aug. 14, 2018	Aug. 21, 2018	7	Oct. 29, 2018	Nov. 9, 2018	12
Horrocks Hwy/Stradbrooke Rd	Jan 12, 2019	Dec. 1, 2018	Dec. 8, 2018	7	May 17, 2019	May 31, 2019	14

2.3.3 Injury risk

The final goal of this research is to assess the potential safety benefits of travelling through the junction at a reduced speed when another vehicle is entering or leaving the major road. In order to achieve this objective, the relative risk of being involved in a vehicle crash that could result in one or multiple casualties was compared between the period before and after the installation of the RJAWS.

The risk of being involved in a casualty crash was calculated using a previously developed relationship between free-travelling speed and the risk of involvement in a casualty crash in rural South Australia (Kloeden et al., 2001). Given a vehicle's travel speed, the Kloeden relationship allows to calculate the risk of injury relative to a baseline risk associated to travelling at the default speed limit. Note that the Kloeden model generally applies to 80 km/h or greater speed limit zones. Since the default speed limit on the major road was equal or greater to 80 km/h at any of the four trialled junctions, the use of the Kloeden curve is still deemed to be valid also for those recorded events occurring when the speed limit was temporary reduced to 50 km/h by the RJAWS.

The relative risk was assessed for each event detected during the before period, after period with sign activated, and after period with a non-active sign. Note that the relative risk was calculated based on the speed collected measured in proximity to the junction. The average relative risk was then calculated for each of those three relevant periods. Also, the ratio of the average relative risk for the before period and after periods with a non-activated sign was calculated to assess any potential change in the injury risk when the sign is inactive compared to the period before the installation.

3 Results and discussion

This chapter provides an evaluation of the speed measurements that were collected at each site. Recommendations are also provided regarding the expected usefulness of the implemented treatment for the purpose of reducing crash severity and its alignment to the principles of a Safe System approach.

3.1 Activation time intervals

The hourly frequency of activation of the RJAWS over the assessed post-installation period is summarised in Figure 3.1. The plots indicate the average number of times the variable signs were activated each hour of the day during the post-installation period considered in this analysis. In general, the average hourly frequency of activation of the RJAWS was fairly constant for most of the day and then it significantly decreased during night time.

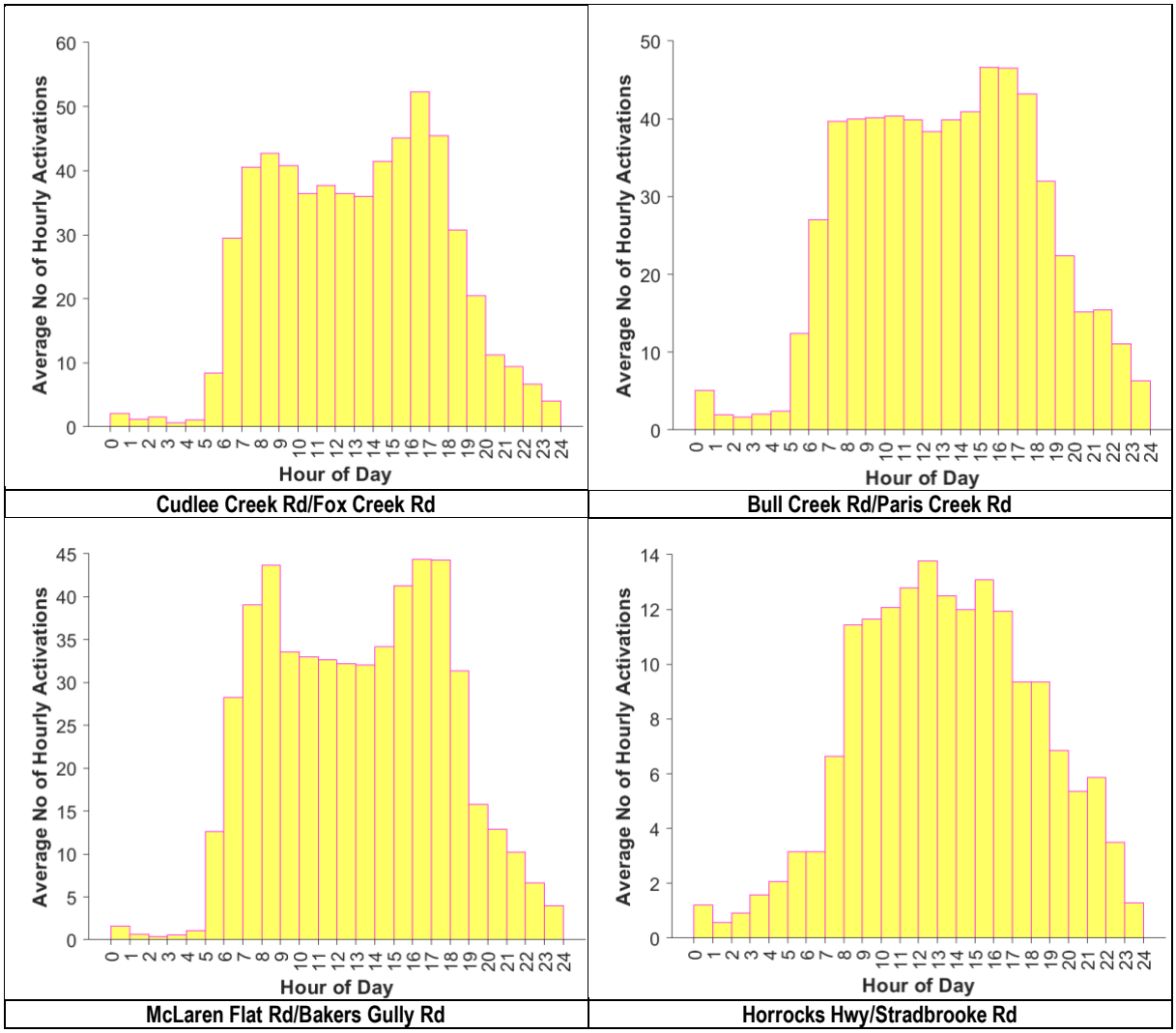

Figure 3.1
Average frequency of RJAWS activations by the hours of the day at each of the four trialled junctions

A summary of the most common descriptive statistics for the duration of the active periods (i.e., the time intervals when the variable speed limit sign was activated) is also provided in Table 3.1. The average duration of the active periods varied between 17.6 sec and 28.6 sec, depending on the considered trial site. Overall, the total amount of time the variable speed limit sign was activated accounted between 3.5% and 18.7% of the assessed post-installation period.

The extreme values for the interval duration (i.e., minimum and maximum) are likely caused by a temporary malfunctioning of the trigger system of the RJAWS. Given that the mean values are a within reasonable range, those extreme values are to be considered as outliers. Still, events occurring during those rare long activation intervals have been considered in the analysis.

Table 3.1
Summary statistics of the RJAWS activated time intervals

Trial junction	Interval Duration (sec)				Proportion of active time (%)
	Mean	Min	Max	Std	
Cudlee Creek Rd/Fox Creek Rd	18.6	1	1,811	24.4	13.7
Bull Creek Rd/Paris Creek Rd	28.6	1	737	18.2	18.7
McLaren Flat Rd/Bakers Gully Rd	17.6	1	100	9.4	10
Horrocks Hwy/Stradbrooke Rd	18.7	1	1,174	26.4	3.5

3.2 Detected vehicle events

The bar plots of Figures 3.2 and 3.3 provide a summary of the number of vehicles that were detected to travel in a free-flow fashion during the assessed before and after-installation periods, respectively. For each of the four trial locations, the bar plots indicate the number of vehicles detected along each of the two travel directions as well as the total number. As expected, the highest number of vehicles was detected at the trial site along Horrocks Hwy. The number of vehicles detected during the after period was generally lower than during the before period, except for the site along Horrocks Hwy.

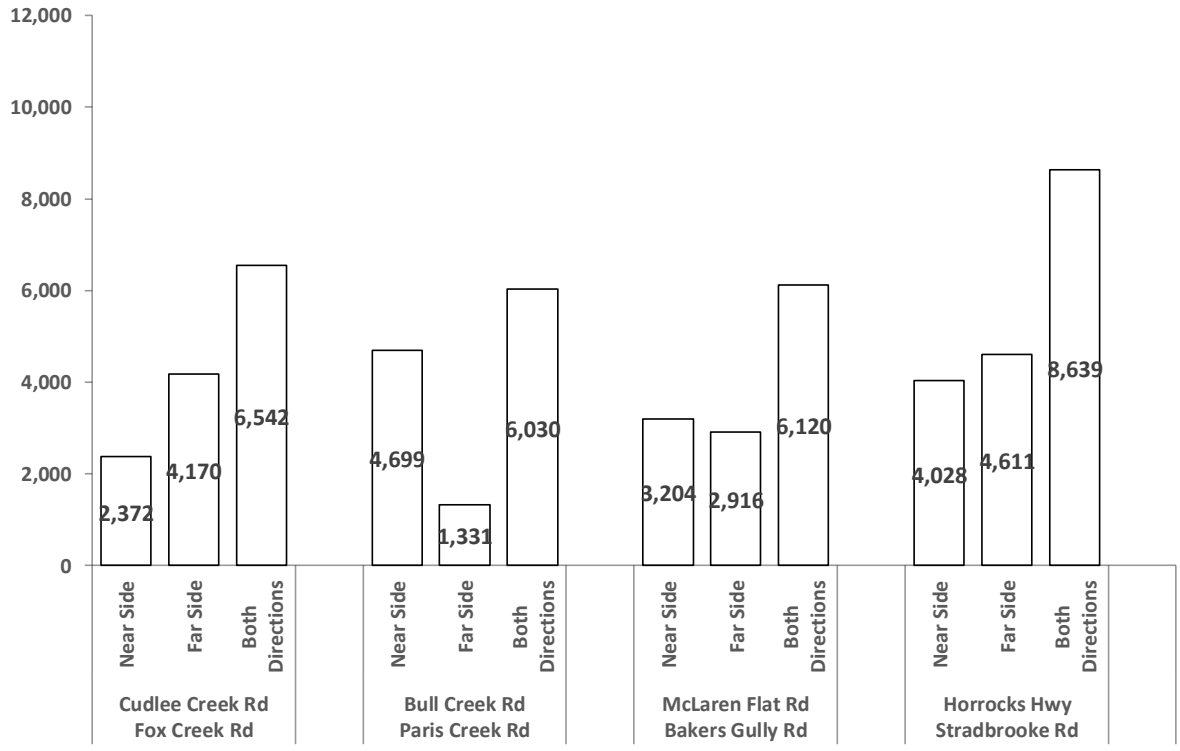

Figure 3.2
Number of vehicles detected at each of the four trialled junctions for near-side, far-side and both travel directions
Before period

Figure 3.3
Number of vehicles detected at each of the four trialled junctions for near-side, far-side and both travel directions
After period

3.3 Speed distribution

Plots of the speed distributions for each of the four trial installation sites are shown in Figures 3.4 through 3.7. Four speed distributions are presented for each site. Each distribution summarises the speed measured at each of the two different tube locations (i.e., distant and close to the junction) along the approach segment of each direction of travel (i.e., near side and far-side).

Each plot reports speed distributions for both the before and after periods. A single distribution is reported for the before period, whereas two separate distributions are used to describe the speed behaviour when the reduced speed limit sign is activated or inactive, respectively.

These plots allow to visually compare the distribution of the vehicle travel speeds between the before and after periods as well as and between the periods with an activated and a not activated speed sign.

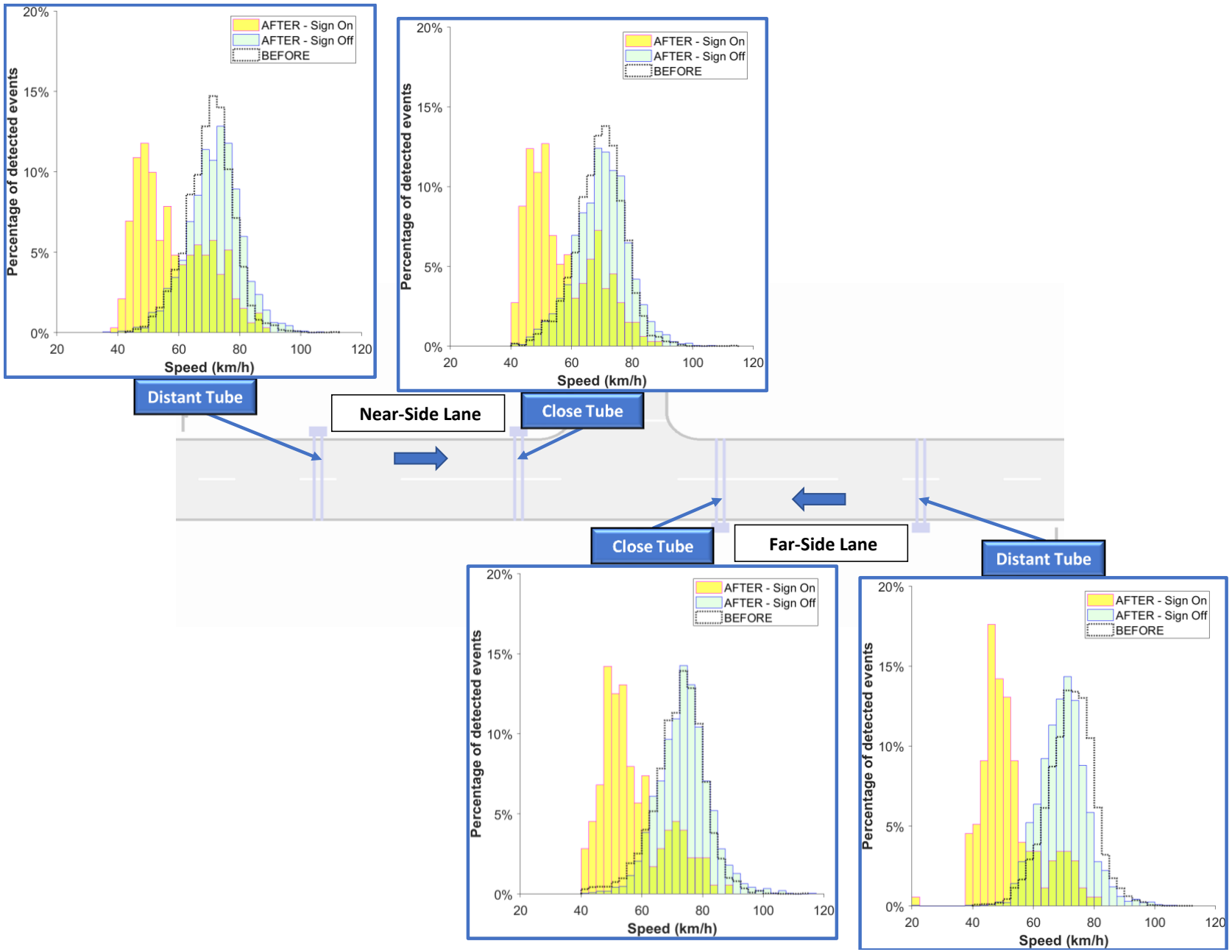

Figure 3.4
Speed distributions at distant and close locations along the approach segment of each direction of travel – Cudlee Creek

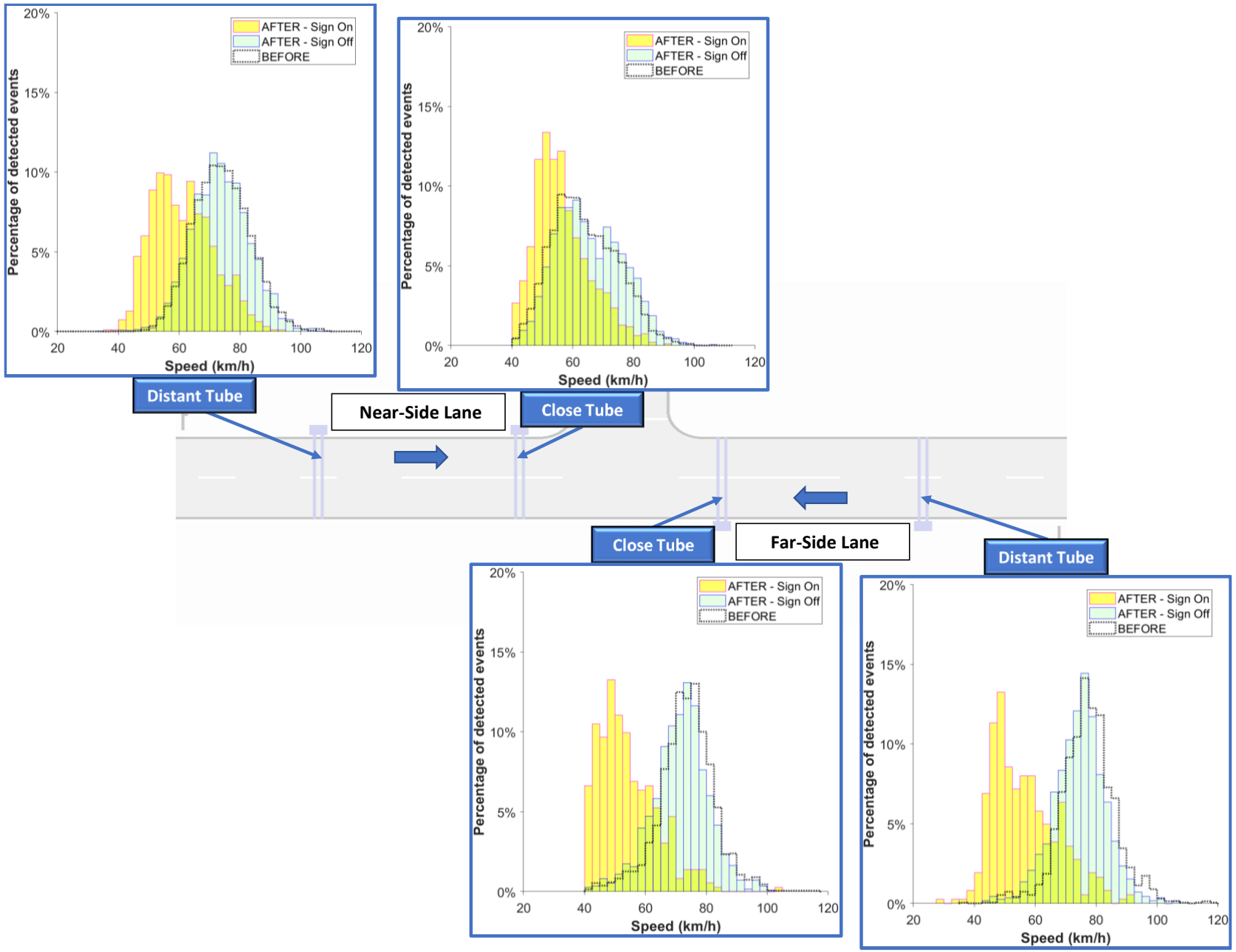

Figure 3.5
Speed distributions at distant and close locations along the approach segment of each direction of travel – Bull Creek

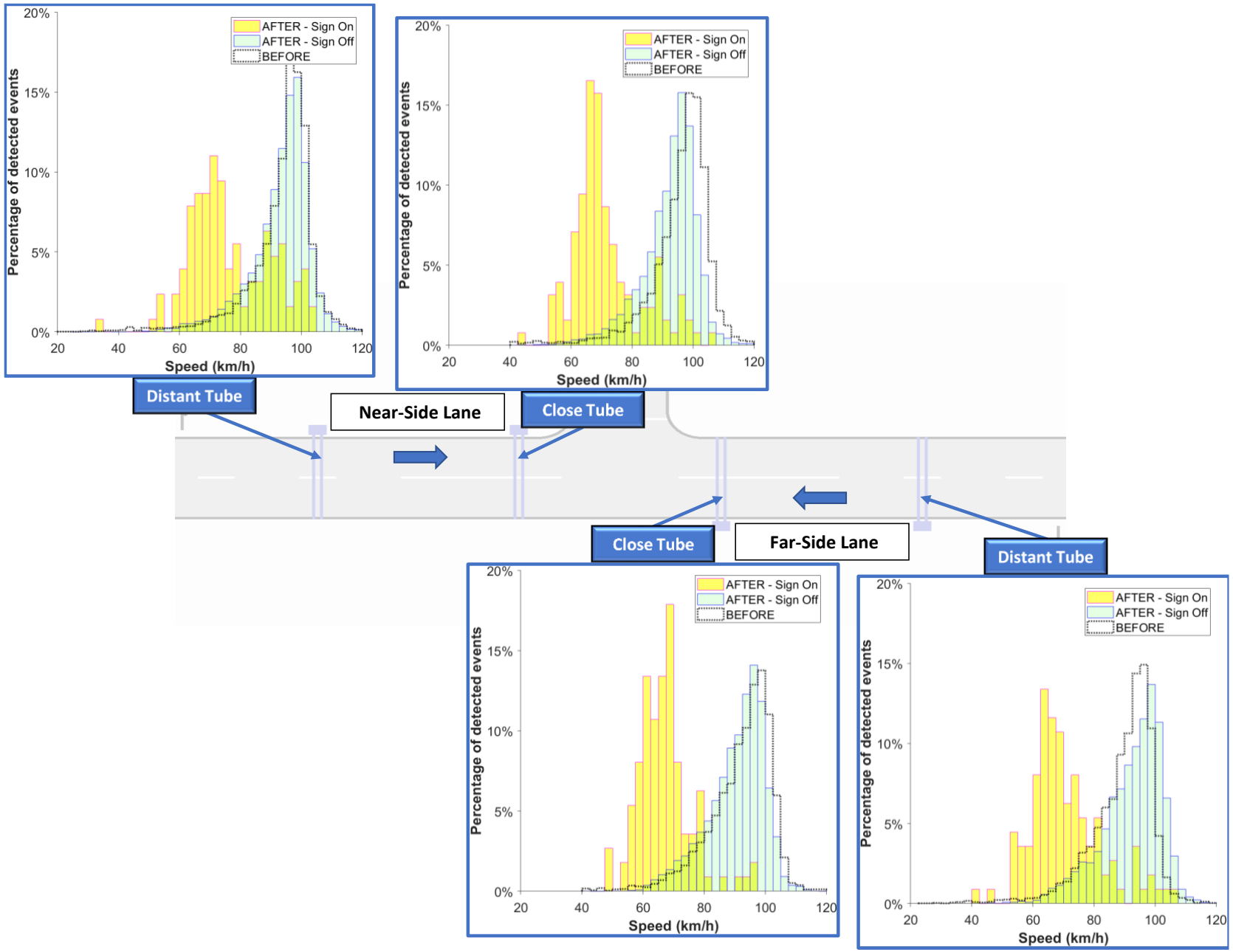

Figure 3.6
Speed distributions at distant and close locations along the approach segment of each direction of travel – McLaren Flat

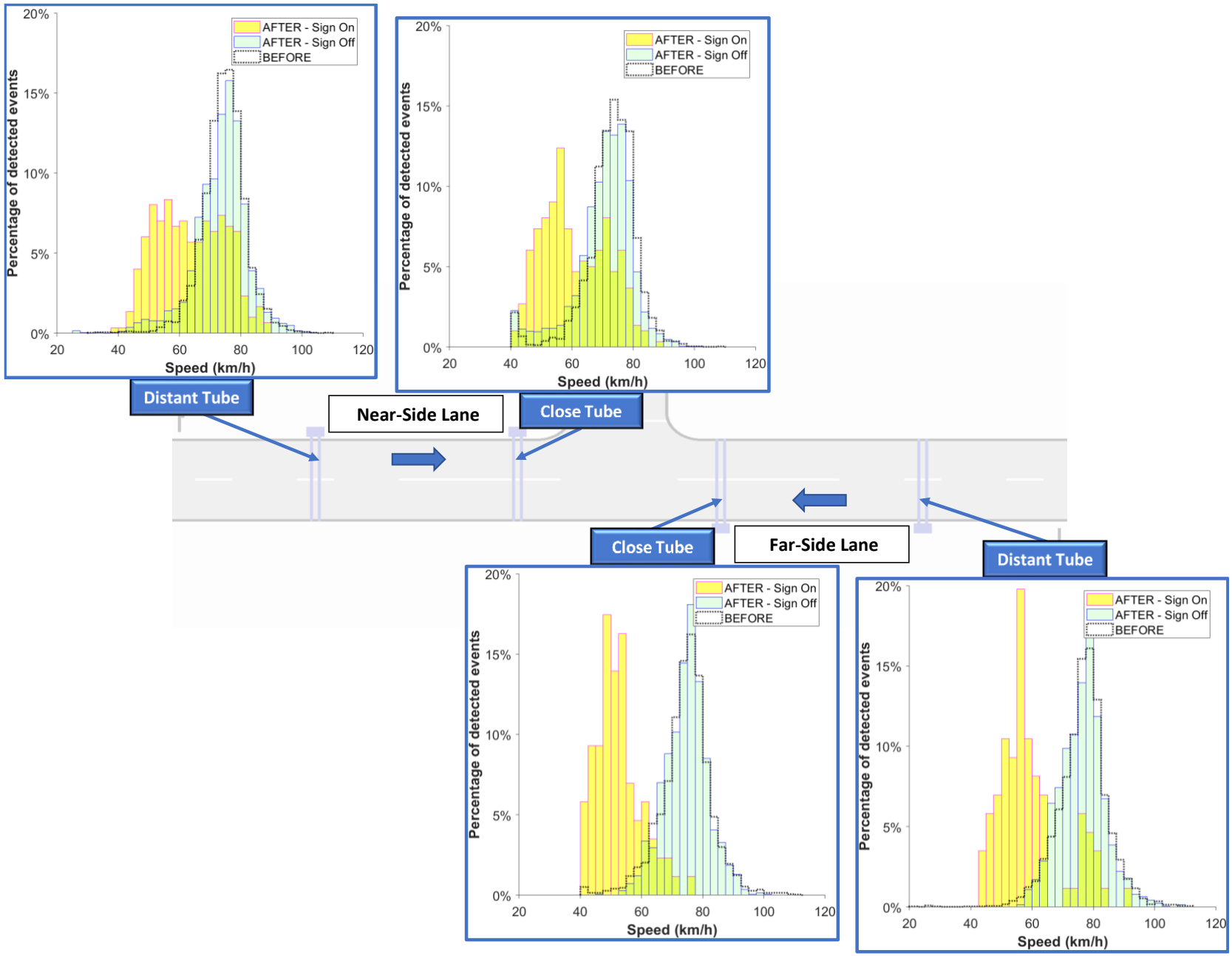

Figure 3.7
Speed distributions at distant and close locations along the approach segment of each direction of travel – Horrocks Hwy

3.4 Average, Median and 85th percentile speeds

The plots in Figures 3.8 to 3.11 provide a visual and concise summary of some of the most common statistical metrics for the distributions of the various speeds collected at each of the four trial installation sites. A combination of box plots and lines was used to summarise the information for the speed distribution at each of the four locations where speed was measured along the major road.

Box plots provide a visual indication of the quartiles (25th, 50th and 75th-percentiles) as well as the value of the minimum, maximum and the outliers for each distribution. The box horizontal edges indicate the quartiles, the extremes of the whiskers indicate the minimum and maximum values, and the 'plus' symbols indicate the outliers. Two additional line plots that are overlayed on the box plots provides a visual representation of the average and the 85th percentile of the speed distribution, respectively.

For each of the four locations three box plots were drawn: one boxplot for the speed distribution during the before period and two additional boxplots for the distributions when the reduced speed limit sign was activated or inactive, respectively. This graphical representation allows to compare in a concise manner the variation of the vehicle travel speed between the before and after period as well as between the periods with sign activate vs sign inactive.

The values of the mean and the 85th-percentile speeds that were measured at tubes located either close or distant from the junction is reported in Table 3.2. The table reports the values for either the near-side and far-side direction of travel as well aggregating together both directions. When considering both directions of travel, the difference between those values for periods with an activated sign and a not activated sign ranges between 11.3 km/h and 22.1 km/h for the mean and 5.4 km/h and 20.7 km/h for the 85th percentile.

Results of the paired t-test conducted on both the mean an 85th-percentile values are provided in Table 3.3. To increase this relatively small sample size, the mean and 85th percentile speeds measured along each of the two directions of travel were considered separately when computing the t-test.

The results of the t-test confirmed the following two points:

- No statistically significant difference in vehicle speeds between the before period and the after period if the sign was not activated. .
  (This confirmation provides confidence that no other factors except the activation of the reduced speed sign have likely contributed to change the speed between the before and after periods)
- Statistically significant difference in vehicle speeds between the activated and a non-activated sign at any of the locations of each of the four trial locations

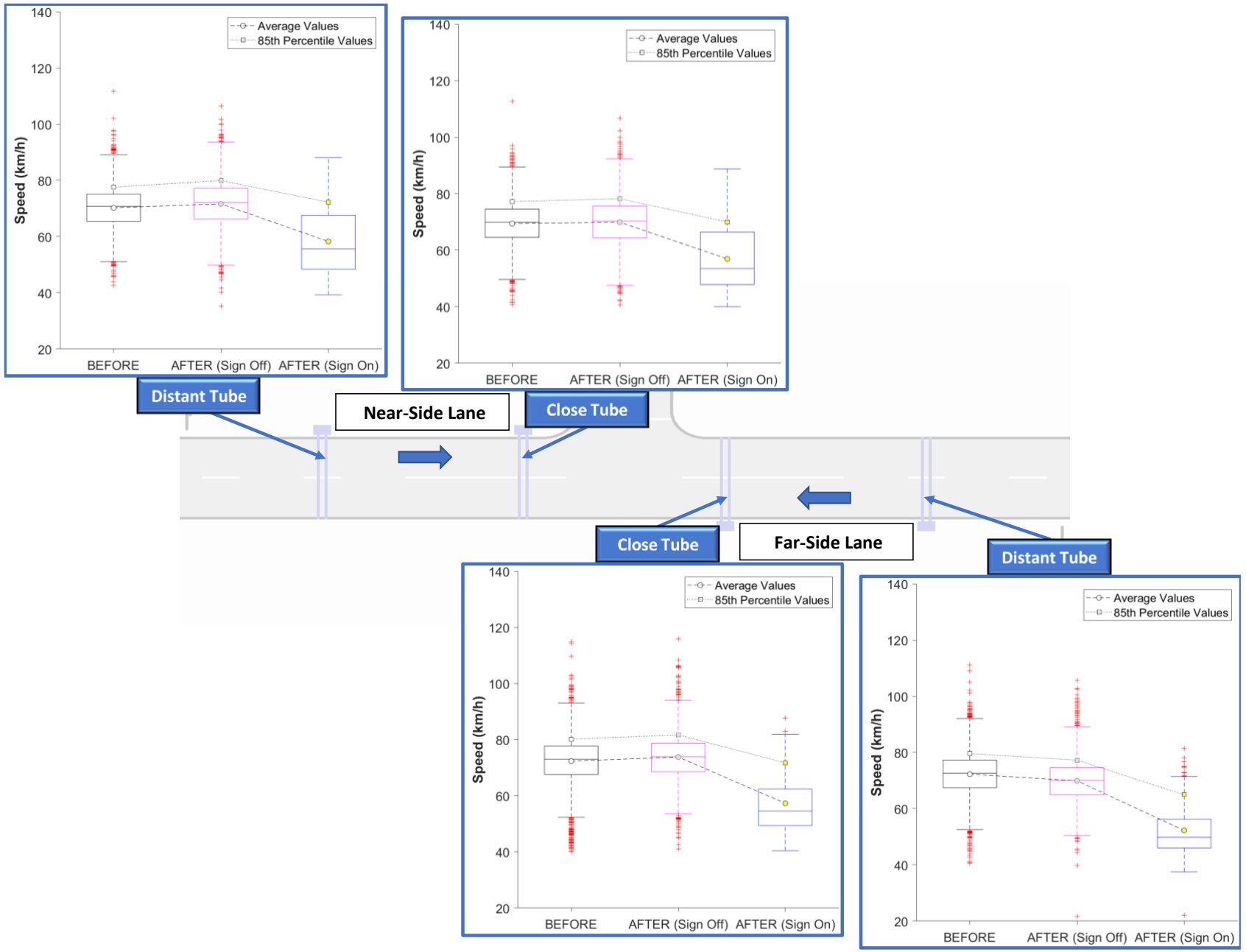

Figure 3.8
Boxplots and trendlines of mean and 85th-percentile speeds measured at distant and close locations along the approach segment of each direction of travel – Cudlee Creek

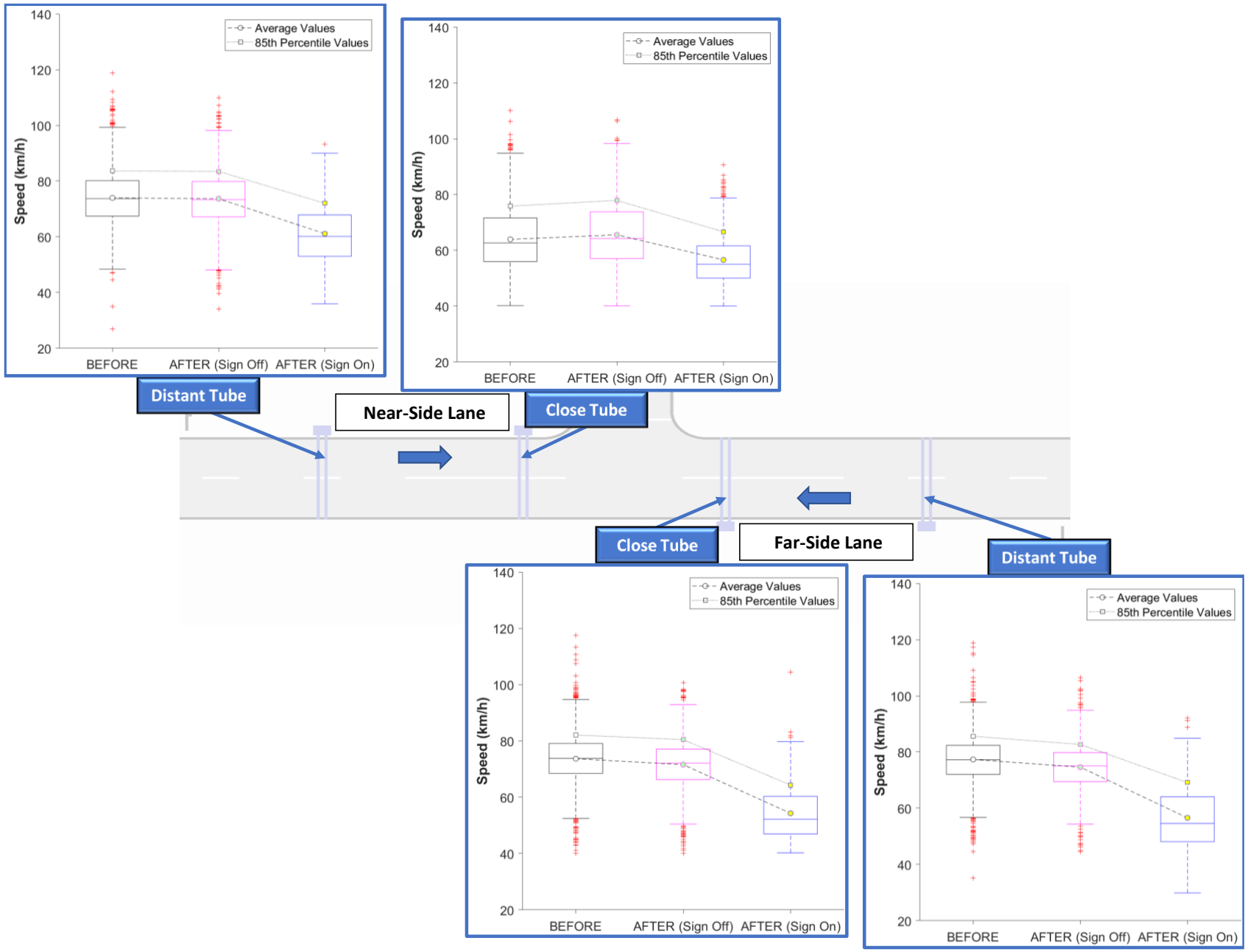

Figure 3.9
Boxplots and trendlines of mean and 85th-percentile speeds measured at distant and close locations along the approach segment of each direction of travel – Bull Creek

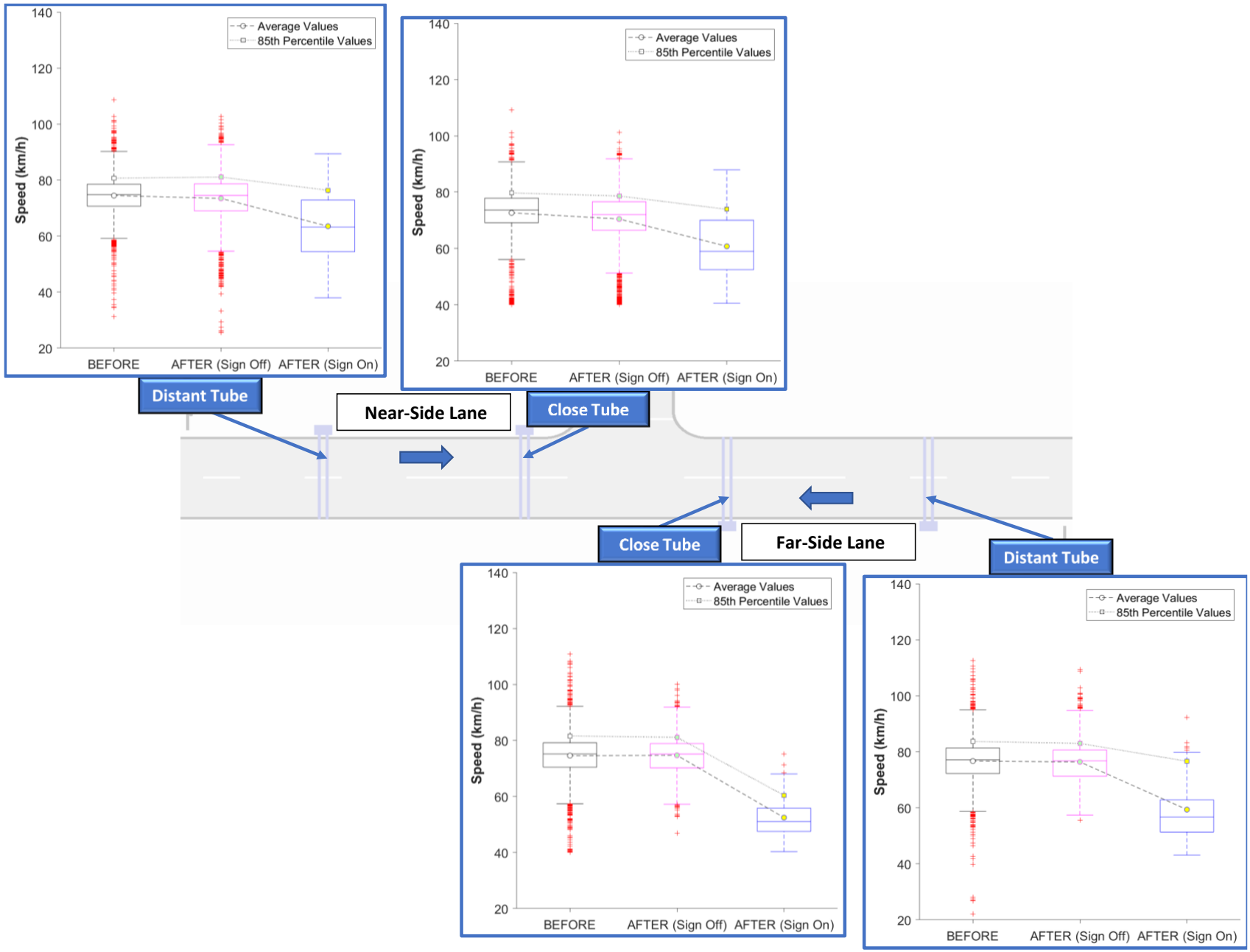

Figure 3.10
Boxplots and trendlines of mean and 85th-percentile speeds measured at distant and close locations along the approach segment of each direction of travel – McLaren Flat

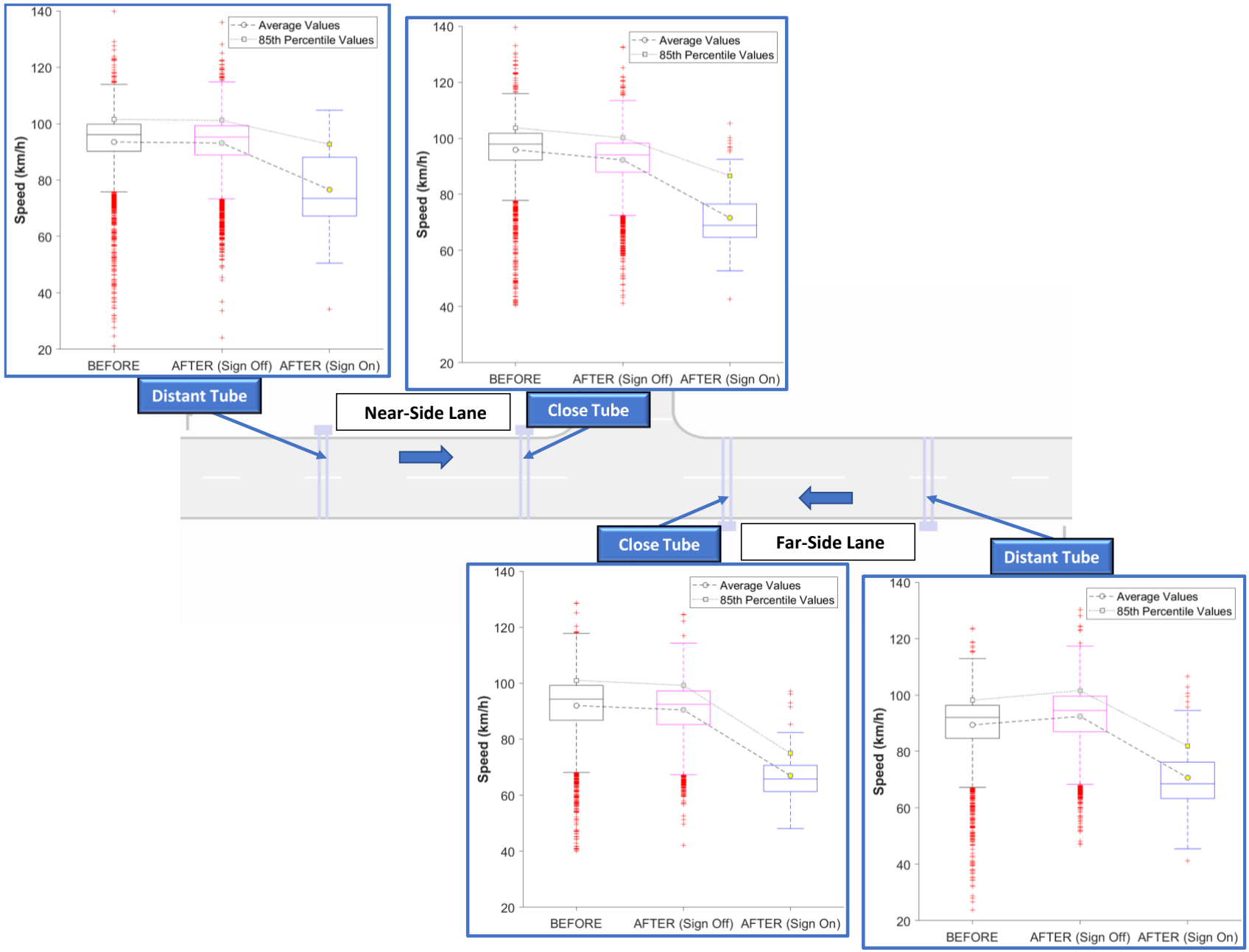

Figure 3.11
Boxplots and trendlines of mean and 85th-percentile speeds measured at distant and close locations along the approach segment of each direction of travel – Horrocks Hwy

Table 3.2
Mean and 85th percentile speed measured at tubes located either close or distant from the junction

Junction	Sign Status	Mean Speed (km/h)						85th Percentile Speed (km/h)					
		Distant			*Close*			*Distant*			*Close*		
		Near Side	*Far Side*	*Both Sides*	*Near Side*	*Far Side*	*Both Sides*	*Near Side*	*Far Side*	*Both Sides*	*Near Side*	*Far Side*	*Both Sides*
Cudlee Creek Rd Fox Creek Rd	ON	58.2	52.2	56.2	56.9	57.3	57.0	72.2	64.9	70.8	70.0	71.7	70.2
	OFF	71.6	69.9	70.7	69.9	73.8	72.0	79.9	77.2	78.6	78.2	81.7	80.3
	SPEED REDUCTION	13.4	17.7	14.5	13.0	16.5	15.0	7.7	12.3	7.8	8.2	10.0	10.1
Bull Creek Rd Paris Creek Rd	ON	61.1	56.6	59.9	56.6	54.3	55.9	72.0	69.1	71.4	66.6	64.3	66.1
	OFF	73.7	74.6	73.9	65.5	71.6	67.2	83.5	82.7	83.2	77.9	80.5	78.7
	SPEED REDUCTION	12.6	18.0	14.0	8.9	17.3	11.3	11.5	13.6	11.8	11.3	16.2	12.6
McLaren Flat Rd Bakers Gully Rd	ON	63.5	59.3	62.6	60.8	52.4	58.9	76.3	76.6	76.3	73.9	60.4	72.1
	OFF	73.4	76.4	74.5	70.5	74.7	72.0	81.1	83.0	81.7	78.6	81.1	79.6
	SPEED REDUCTION	9.9	17.1	11.9	9.7	22.3	13.1	4.8	6.4	5.4	4.7	20.7	7.5
Horrocks Hwy Stradbrooke Rd	ON	76.6	70.7	73.8	71.6	67.0	69.4	92.7	81.9	90.8	86.6	74.9	79.0
	OFF	93.1	92.4	92.8	92.3	90.5	91.5	101.2	101.6	101.3	100.2	99.2	99.7
	SPEED REDUCTION	16.5	21.7	19.0	20.7	23.5	22.1	8.5	19.7	10.5	13.6	24.3	20.7

Table 3.3
Results of the t-test for the mean and 85th-percentile speeds at the distant and close locations along the approach segment of each direction of travel: activated vs non-activated sign and before vs after (sign off)

			p-Value	t-Stat	95% CI (Lower) (km/h)	95% CI (Upper) (km/h)
Sign ON vs Sign OFF	**Mean Speed**	**Distant**	6.00E-06	-18.962	-12.763	-12.1014
		Close	6.81E-05	-21.1441	-11.8309	-8.3724
	85th %tile Speed	**Distant**	4.21E-04	-14.5544	-6.5706	-6.2567
		Close	5.97E-04	-19.0823	-8.1677	-5.9037
Before vs After (Sign OFF)	**Mean Speed**	**Distant**	0.6311	0.5019	-1.2165	1.87210
		Close	0.3279	1.0517	-0.8846	2.3017
	85th %tile Speed	**Distant**	0.9695	0.0396	-1.7624	1.8224
		Close	0.5056	0.7015	-1.1261	2.0761

3.5 Distribution of events by speed ranges and thresholds

A distribution of the reported events within selected speed ranges is visually represented in the plots in Figures 3.12 to 3.15 for each of the four trial sites. Also, a summary of the percentages of the vehicles that were detected for the corresponding speed thresholds is provided in Tables 3.4 and 3.5. For simplicity and conciseness, speeds measured along the two directions of travel (i.e., near side and far side) have been aggregated together for both the close and distant locations. Two distributions are presented for each aggregated location, one for the case when the speed sign was activated and one for the case when the sign was not activated.

The presented plots allow the intuitive and easy identification of the proportion of events where the vehicles travelled at speeds within each of the selected ranges as well as the proportion of vehicles whose speed was below or above any of the range thresholds. Also, the plots allow for an intuitive side-by-side visual comparison of the distributions between different status of the sign as well as close vs distant locations.

The following two major points can be derived from the analysis of the provided speed plots:

- **Speed limit compliance:**
  The percentage of drivers complying with the reduced speed limit when the RJAWS sign is activated is lower than the compliance of the default speed limit for the case with an inactive sign. Note that speed compliance when the RJAWS sign is activated is generally higher in proximity to the junction compared to further from the centre of the junction, with the exception of Cudlee Creek.
- **Extreme speeding:**
  The percentage of drivers travelling 20 km/h or higher in excess of the reduced speed limit when the RJAWS sign is activated is considerably smaller compared to the proportion of drivers travelling at lower and safer speeds.

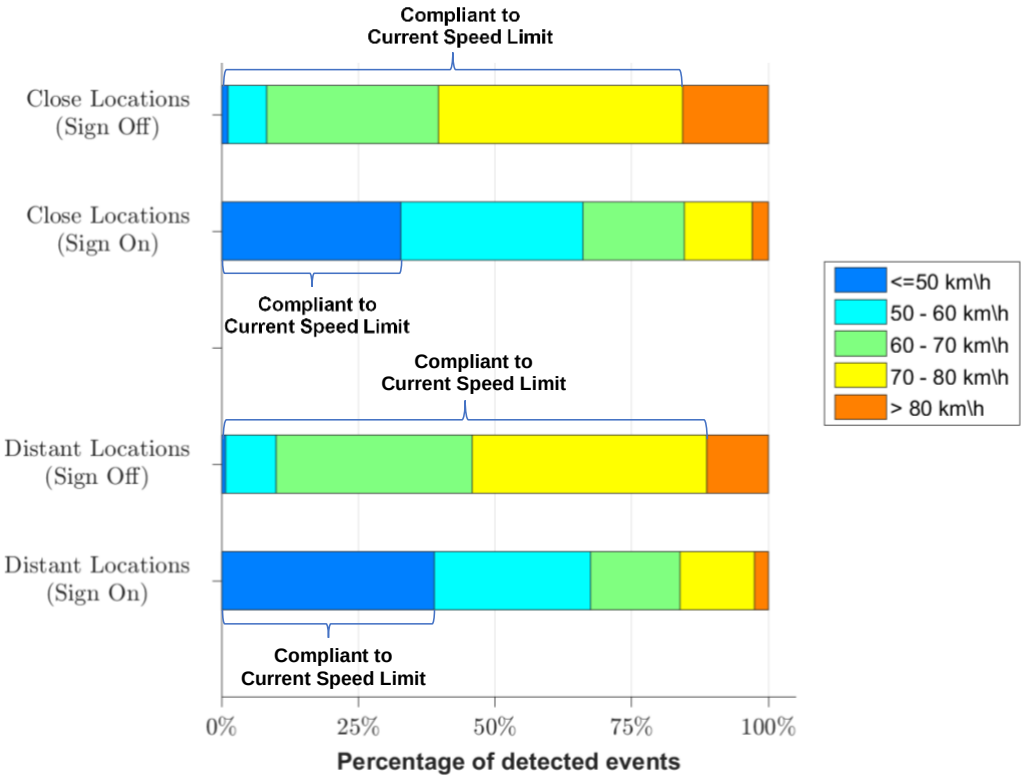

Figure 3.12
Visual representation of the distribution of recorded events by speed ranges – Cudlee Creek

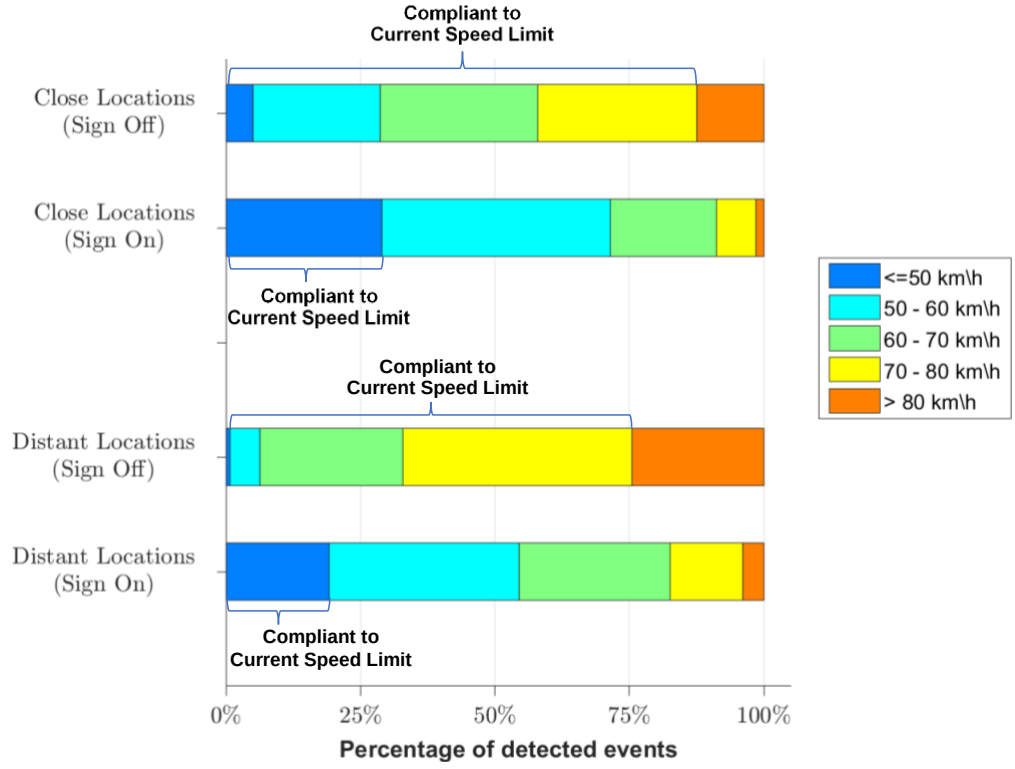

Figure 3.13
Visual representation of the distribution of recorded events by speed ranges – Bull Creek.

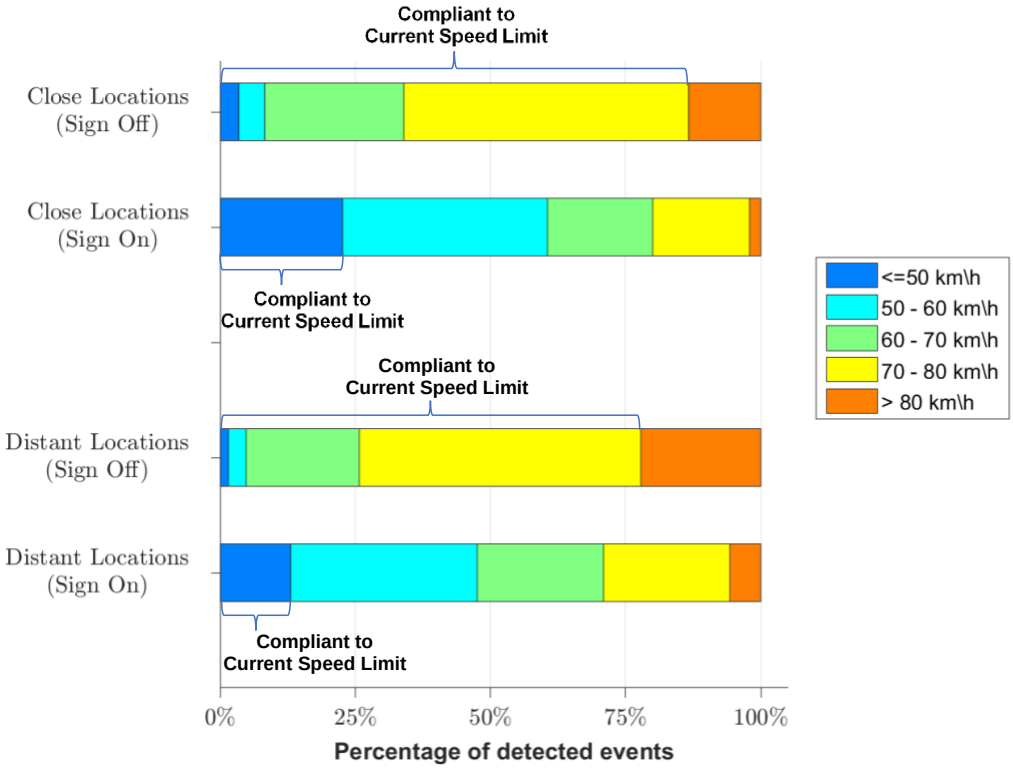

Figure 3.14
Visual representation of the distribution of recorded events by speed ranges – McLaren Flat

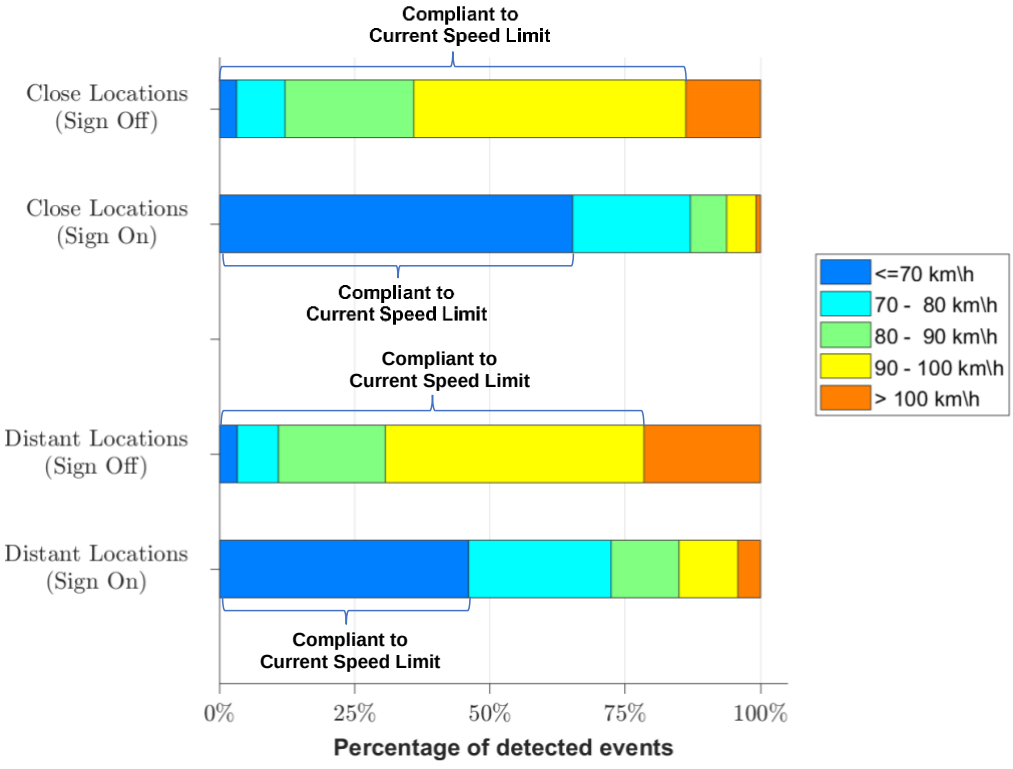

Figure 3.15
Visual representation of the distribution of recorded events by speed ranges – Horrocks Hwy

Table 3.4
Distribution of recorded events by speed thresholds in proximity of the junction
(Close Locations) for each of the four trial sites

		Below speed thresholds (%)				Above speed threshold (%)
Site	**Period**	**<= 50 km/h [1]**	**<= 60 km/h**	**<= 70 km/h**	**<= 80 km/h [2]**	**> 80 km/h**
Cudlee Creek Rd Fox Creek Rd	BEFORE	1.5	9.2	41.1	87.5	12.5
	AFTER (Sign OFF)	1.1	8.2	39.6	84.3	15.7
	AFTER (Sign ON)	32.7	66.1	84.6	97.0	3.0
Bull Creek Rd Paris Creek Rd	BEFORE	6.6	32.8	62.3	89.3	10.7
	AFTER (Sign OFF)	5.0	28.6	57.9	87.5	12.5
	AFTER (Sign ON)	28.9	71.5	91.2	98.5	1.5
McLaren Flat Rd Bakers Gully Rd	BEFORE	2.1	5.6	26.7	82.7	17.3
	AFTER (Sign OFF)	3.4	8.2	33.9	86.6	13.4
	AFTER (Sign ON)	22.6	60.5	80.0	97.9	2.1
Site	**Period**	**<= 70 km/h [1]**	**<= 80 km/h**	**<= 90 km/h**	**<= 100 km/h [2]**	**> 100 km/h**
Horrocks Hwy Stradbrooke Rd	BEFORE	3.4	9.6	27.0	72.0	28.0
	AFTER (Sign OFF)	3.1	12.1	35.9	86.2	13.8
	AFTER (Sign ON)	65.3	87.0	93.7	99.2	0.8

[1] Reduced speed limit (RJAWS sign ON)
[2] Default speed limit (Before Period / RJAWS sign OFF)

Table 3.5
Distribution of recorded events by speed thresholds on the approach to the junction
(Distant Locations) for each of the four trial sites

		Below speed thresholds (%)				Above speed threshold (%)
Site	**Period**	**<= 50 km/h [1]**	**<= 60 km/h**	**<= 70 km/h**	**<= 80 km/h [2]**	**> 80 km/h**
Cudlee Creek Rd Fox Creek Rd	BEFORE	0.6	7.8	39.6	88.4	11.6
	AFTER (Sign OFF)	0.7	9.9	45.8	88.7	11.3
	AFTER (Sign ON)	38.9	67.5	83.8	97.4	2.6
Bull Creek Rd Paris Creek Rd	BEFORE	0.4	5.3	30.9	72.1	27.9
	AFTER (Sign OFF)	0.7	6.3	32.9	75.5	24.5
	AFTER (Sign ON)	19.1	54.5	82.6	96.1	3.9
McLaren Flat Rd Bakers Gully Rd	BEFORE	0.5	2.7	20.2	75.4	24.6
	AFTER (Sign OFF)	1.5	4.8	25.7	77.8	22.2
	AFTER (Sign ON)	13.0	47.5	70.9	94.3	5.7
Site	**Period**	**<= 70 km/h [1]**	**<= 80 km/h**	**<= 90 km/h**	**<= 100 km/h [2]**	**> 100 km/h**
Horrocks Hwy Stradbrooke Rd	BEFORE	4.5	12.3	33.7	85.0	15.0
	AFTER (Sign OFF)	3.3	10.9	30.6	78.5	21.5
	AFTER (Sign ON)	46.0	72.4	84.9	95.8	4.2

[1] Reduced speed limit (RJAWS sign ON)
[2] Default speed limit (Before Period / RJAWS sign OFF)

3.6 Predicted safety benefits

This section presents the results of the risk analysis to assess the potential safety benefits of the speed reductions that were measured in proximity to each of the four trialled junctions.

The average relative risk of being involved in a vehicle crash that could result in one or multiple casualties for both the periods before and after the installation of the RJAWS is provided in Table 3.6. The values provided indicate the average risk of being involved in a casualty crash relative to a baseline risk that is associated to travelling through the junction at the default speed limited.

For the period after the installation of the RJAWS, the relative risk of a casualty crash was calculated separately for those events where the speed sign was activated or inactive, respectively. Note that the baseline risk for the relative risk was based on the default speed limit independently of the sign status.

The ratios of the average relative risks between the period with activated signs and the period before the RJAWS installation range between 0.35 and 0.58, indicating that the average risk of casualty during a crash at the trialled junctions is potentially reduced by 42% to 65%, depending of the specific site. On average, this corresponds to a 50% reduction of the risk of casualty crashes after the RJAWS installation across all the four trial sites. Ratios of the average relative risks between the after periods with an inactive speed sign and the before period are also reported. For those ratios, values ranging between 0.82 and 1.09 indicate that the average risk of casualty at the trialled junctions when the sign was inactive is similar to the existing risk before the RJAWS was installed.
This seems to indicate that the simple presence of an inactive RJAWS signal (i.e., electronic signal not showing any reduced speed limit) has minimal effect on the risk, while the risk can be reduced considerably when the speed signal is activated.

Table 3.6
Average relative risks of being involved in a casualty crash for before and after period and corresponding ratios

Trial junction	Baseline Speed[1] (km/h)	Average Relative Risk[2] (%)			Ratios of Average Relative Risks		
		Before	After (Sign Off)	After (Sign On)	$\frac{\text{Rel. Risk}_{\text{After}(On)}}{\text{Rel. Risk}_{\text{Before}}}$	$\frac{\text{Rel. Risk}_{\text{After}(Off)}}{\text{Rel. Risk}_{\text{Before}}}$	$\frac{\text{Rel. Risk}_{\text{After}(On)}}{\text{Rel. Risk}_{\text{After}(Off)}}$
Cudlee Creek Rd Fox Creek Rd	80	70.4	76.6	38.5	0.55	1.09	0.50
Bull Creek Rd Paris Creek Rd	80	61.3	62.3	35.6	0.58	1.02	0.57
McLaren Flat Rd Bakers Gully Rd	80	80.7	72.2	40.3	0.50	0.89	0.56
Horrocks Hwy Stradbrooke Rd	100	88.1	72	30.6	0.35	0.82	0.43
Average ratios for all trial sites					**0.49**	**0.95**	**0.51**

[1] Default speed limit at each site used as baseline speed
[2] Relative to the risk at the baseline speed

4 Conclusions

The Department of Planning Transport and Infrastructure (DPTI) trialled Rural Junction Advanced Warning Signs (RJAWS) at four three-leg rural junctions between a major and a minor road. The objective of this research was to assess whether the RJAWS can potentially reduce the risk of fatal and serious injuries at the trialled junctions by effectively decreasing the travel speed along the major road when another vehicle is occupying the junction. Based on the analysis of the data collected at the four trialled junctions, the RJAWS appears to be capable of effectively reducing the risk of casualty injuries by reducing the speed of vehicles travelling along the major road during conditions when there is a risk of a potential collision with another vehicle at the junction. Thus, the use of RJAWS can be considered well-aligned to the principles of a Safe System approach to reduce the potential for harm.

4.1 Speed and casualty risks

Extensive pre-processing was required to synchronise the timestamps of the raw speed data collected during the evaluation period for three of the four trial sites. Due to the considerable additional burden associated with implementing a synchronisation methodology, the analysis of the collected speed data had to be limited to a period of about two weeks for both the before and after period.

The analysis of the refined and postprocessed vehicle speeds for each of the four trialled junctions indicates that the RJAWS can effectively induce drivers to reduce their speed when travelling through junctions with the sign is activated.

The proportion of vehicles travelling at or below the reduced posted speed limit in proximity to the junction when the variable speed limit sign was activated varied between and 22.6% and 65.3%, depending on the trial junctions. Despite the relatively low compliance to the reduced speed limit at most trial sites, the proportion of drivers travelling through the junction at a speed 20 km/h or higher than the reduced speed limit was considerably low. This indicates that the RJAWS can effectively induce drivers to reduce their speed when travelling through the junctions to values that are still below the default speed limit in case the junction is occupied by another vehicle.

Depending on the specific trial junction, the average travel speed in close proximity to the junction is reduced by 11.3 km/h to 22.1 km/h when the RJAWS sign is activated compared to the average speed when the sign is not active. As a consequence of the reduction in travel speed, when the RJAWS sign is activated the average relative risk of a casualty crash occurring at the trialled junctions could be potentially reduced between 42% to 65% compared to before the RJAWS installation, with an average reduction of 50% across the four trialled sites.

The analysis conducted in this study is characterised by the following limitations:

- Short time span for both the before and after periods, due to the lengthy synchronisation process necessary to fix the issue with asynchronous speed data
- Lack of a control in the before/after analysis (However, a good match of the speed distribution between the before period and the after period with an inactive sign indicates that likely no uncontrolled events may have affected the before after analysis.)
- Despite the considerable effort in synchronising the timestamps of the tube data, the quality of the postprocessed data may have been partially affected by the relatively large time gaps between some data loggers as well as fluctuating changes in those differences during the collection periods.

4.2 Recommendations

Given the positive results obtained from the analysis of the data collected at the four trial junctions, it is suggested the installation of the RJAWS be expanded to a larger number of junctions in South Australia.

If further expansion occurred, the additional installations of the RJAWS system would also provide the opportunity to collect speed data at any of the new installation sites in a more precise and detailed manner.

Future data should be collected so that they can allow to carry over a control-case study in the future. In particular, future collection of speed data at new installation sites should be conducted considering at a minimum the following requirements:

- Accurate clock synchronisation of all the speed dataloggers with the RJAWS system
- Initial collection of speed data with RJAWS in 'silent mode' (to allow for collection of a control travel speed dataset when another vehicle is occupying the junction, but no speed reduction is imposed)

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The views expressed in this report are those of the authors and do not necessarily represent those of the University of Adelaide or the funding organisations.

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Appendix A – Threshold speed for identifying turning vehicles

A minimum travel speed threshold was used to identify those vehicles that were deemed to turn out of the major approaches, either on near-side or far-side directions of travel. The definition of this threshold value was based on the analysis of the distributions of the measured vehicle speeds in proximity of each of the four trialled junctions considered in this study, which are shown in Figure A.1.

For almost all the trialled junctions, with the exception of Bull Creek, the distribution of the speed measured at locations close to the junction along each direction of travel showed a clear bimodal shape, with a major peak for speeds above 40 km/h and a second smaller peak for speeds below that value. The second smaller distribution represents the group of vehicles turning out of the main road at the junctions, which are a smaller group compared to the overall vehicles travelling through the major road. Thus, a value of 40 km/h was deemed to be a representative threshold to identify vehicles turning out of the major road.

Note that such bimodal shape in the speed distribution did not occur for the speed data collected at the Bull Creek junction because of the following two reasons:

- **Left turn into the minor road (from far side lane)** – vehicles could still perform the turning manoeuvre without the need to reduce their travel speed due to the fact that the minor road intersects the major road at a very shallow angle
- **Right turn into the minor road (from near side lane)** – the majority of vehicles entered the minor road through a right turn into an unpaved shortcut that is located upstream of the junction and eventually intersects the minor road

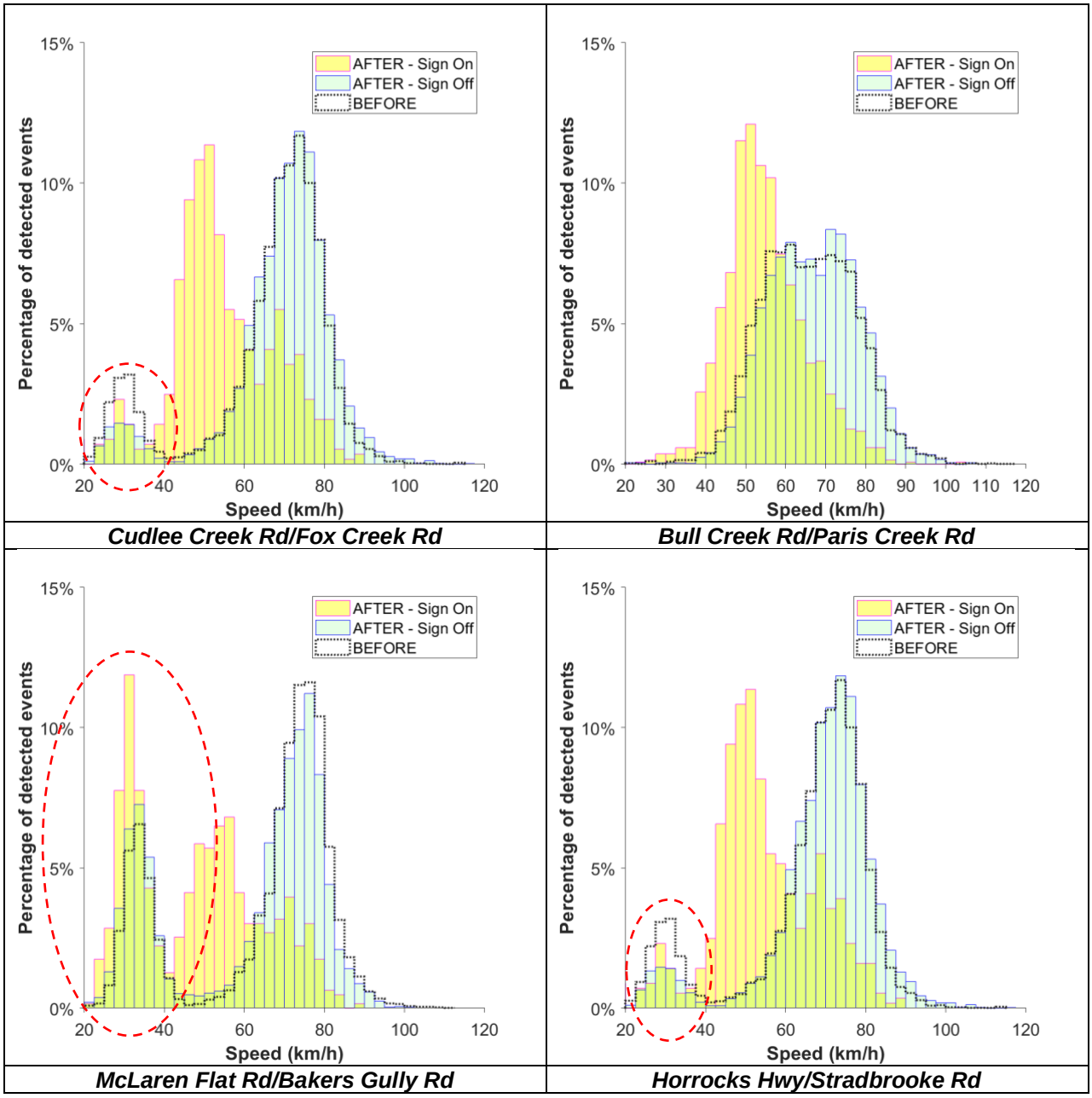

Figure A.1
Distributions of the measured vehicle speeds in proximity of each of the four trialled junctions
(close tubes aggregated by both direction of travel)

Appendix B – Verification of the synchronisation process

This section briefly describes the verification of the process used to synchronise the time stamps of the events detected by the tube dataloggers against the clock of the RJAWS datalogger.

What was verified is that the data pre-processed using the implemented algorithm can provide results consistent with the nature of the investigated phenomenon. Given that speeds were collected along a road with a variable speed limit, either a default or a reduced speed limit, it is reasonable to expect some difference when comparing speeds measured under those two scenarios.

The verification covered two major scenarios: (i) comparison of original data that were highly asynchronous and (ii) comparison of original data already well synchronised. The former scenario served to verify that the synchronisation algorithm can properly readjust the timestamp of asynchronous data, whereas the latter scenario served to confirm that the algorithm does not alter the timestamps of data if they are already well synchronised.

The comparisons of the speed distributions before and after applying the synchronisation algorithm to highly asynchronous speed data as well as to speed data that were already originally synchronised are shown in Figures B.1 and B.2, respectively. The asynchronous data were collected at the Bull Creek trial site while the synchronous data were collected at the trial site along Horrocks Hwy, where data were collected more precisely after the synchronisation issue was discovered.

If the timestamps of the original speed data are non-synchronised with the clock of the RJAWS logger, such as in the upper row shown in Figure B.1, the speed distributions measured by the tubes close to the centre of the junction overlap for either the case of the variable speed sign activated or non-activated. However, after the speed data are synchronised against the clock of the RJAWS the speed distribution clearly indicates a reduction in the travel speed in proximity to the junction when the speed sign was activated, as shown in the lower row of in Figure B.1.

Additionally, a confirmation that the synchronisation process does not introduce any artefact in the speed distribution is provided by the second comparison shown in Figure B.2. Since in this second case the original data were already well synchronised, the speed distributions for both original and synchronised speed data look almost identical.

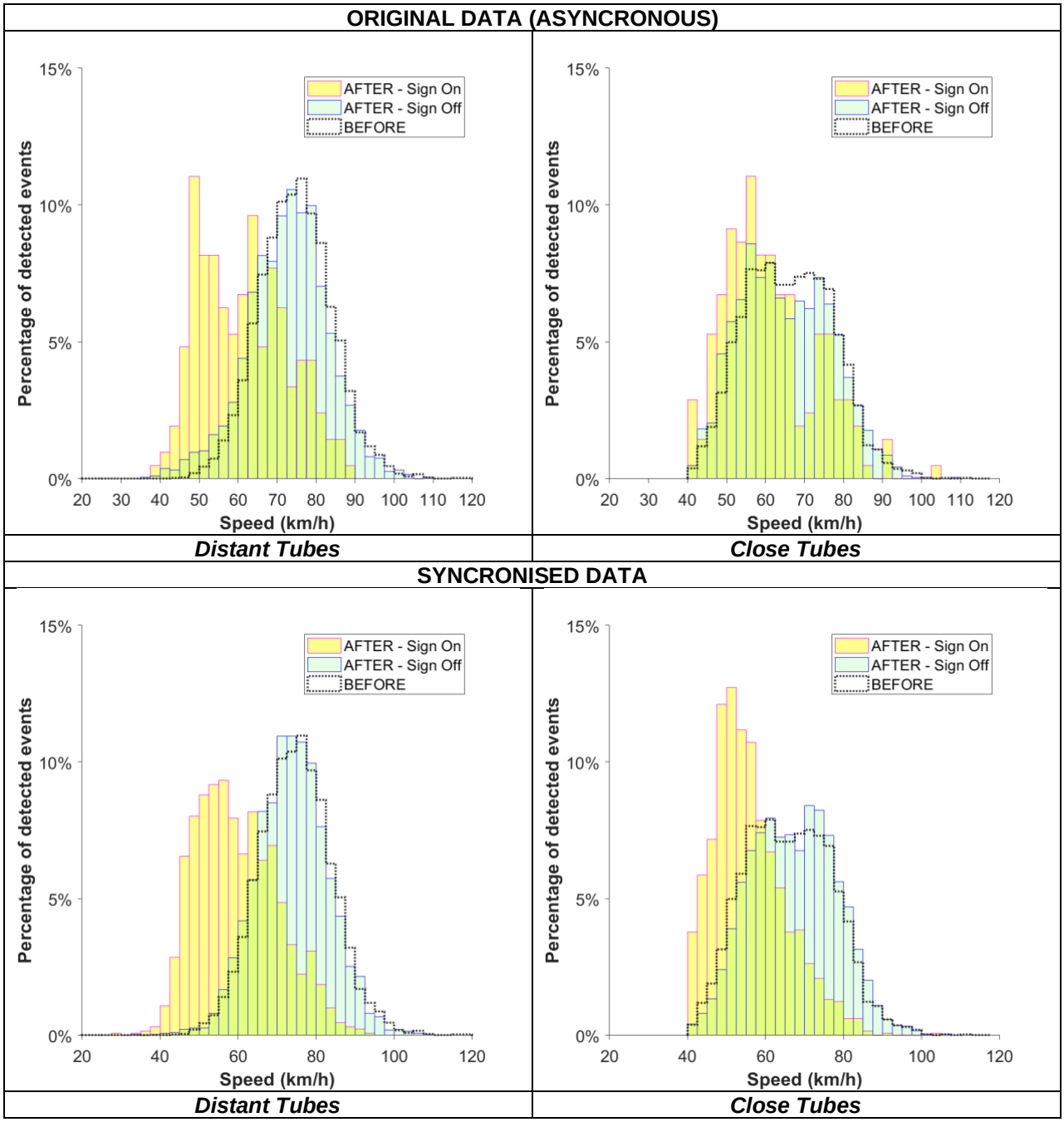

Figure B.1
Speed distribution of original and synchronised data
(distant and close tubes aggregated by both direction of travel)
Bull Creek

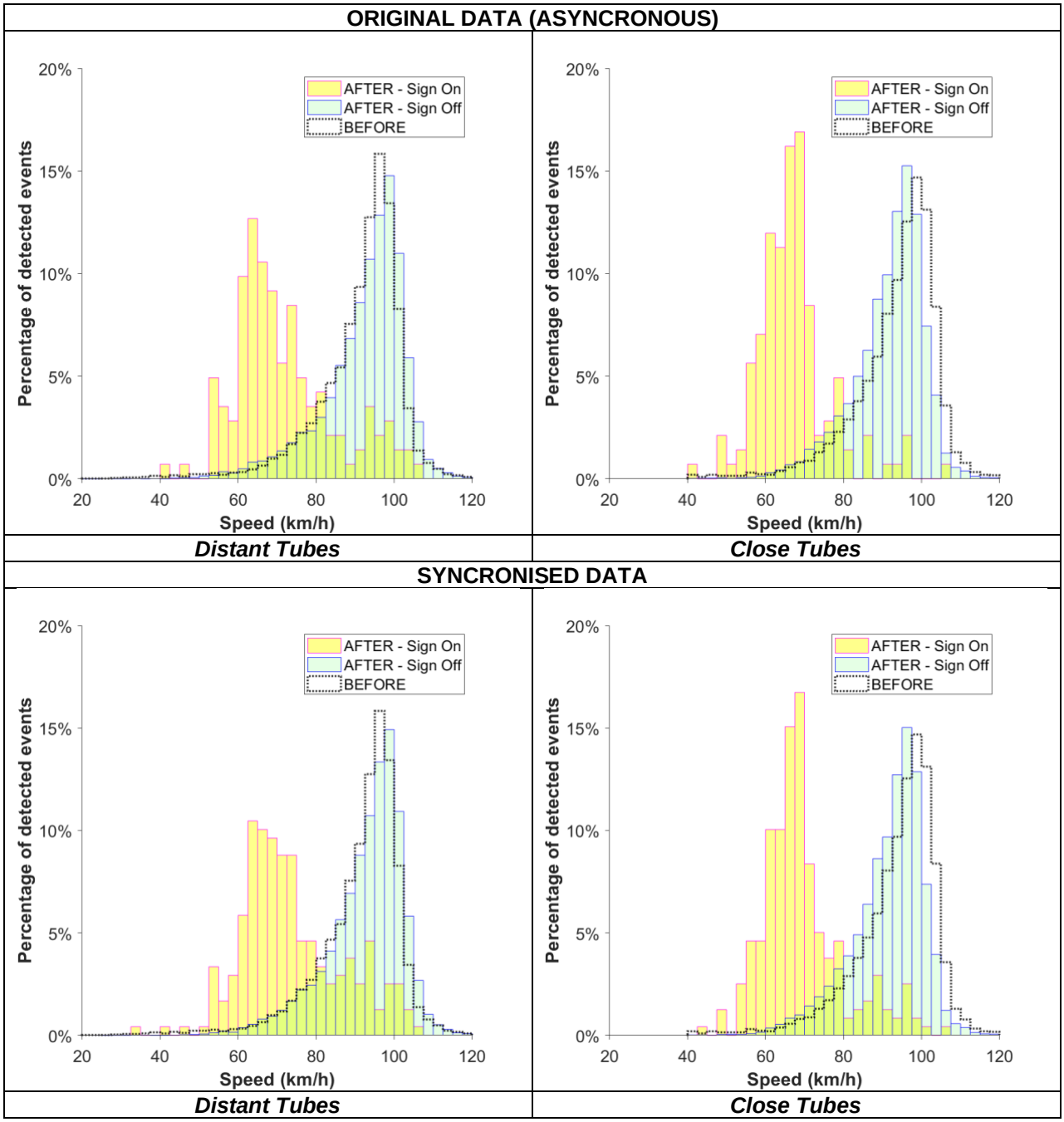

Figure B.2
Speed distribution of original and synchronised data
(distant and close tubes aggregated by both direction of travel)
Horrocks Hwy