



*Austroads*

Research Report  
AP-R596-19



# Passing Lanes Safety and Performance

## Passing Lanes: Safety and Performance

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### Abstract

This report examines the impacts of passing lanes on safety, journey time and user experience and provides guidance to assist in the development of passing lane installation projects.

The research found that passing lanes result in safety benefits, including perceived safety by motorists, safer operational conditions, and historical crash reductions. Passing lanes were also found to improve journey times through a small increase in travel speed and a significant reduction in percentage of time spent following a slower vehicle.

This project included a

- literature review
- safety analysis, before-and-after analysis of crash records, speed and headway analysis, and overtaking behaviour analysis
- journey time analysis, including development of modelling guidance and numerical experiments on the impact of passing lanes on travel speed and per cent time spent following
- road user experience survey analysis, including an analysis of perceptions and valuation of level-of-service
- a review and re-calibration of the TRAFFIC on Rural Roads (TRARR) model.

### Keywords

Passing lane, overtaking lane, safety, journey time, road user experience, level-of-service, traffic operation, capacity, passing lane density, passing lane length, willingness-to-pay, per cent time spent following, travel speed, survey, crash reduction, TRARR, modelling

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- Transport Canberra and City Services Directorate, Australian Capital Territory
- The Department of Infrastructure, Regional Development and Cities
- Australian Local Government Association
- New Zealand Transport Agency.

## Summary

This project examined passing lane impacts on safety, journey time and user experience. This was achieved through the following:

- literature review
- safety analysis, including before-and-after analysis of crash records, speed and headway analysis, and overtaking behaviour analysis
- journey time analysis, including development of modelling guidance and numerical experiments on the impact of passing lanes on travel speed and per cent time spent following
- road user experience survey, including an analysis of perceptions and valuation of level-of-service.

Passing lanes result in safety benefits, including perceived safety by motorists, safer operational conditions, and historical crash reductions. A review of past research also indicated that passing lane installation could lead to a reduction in crashes. Before-and-after crash analysis of routes where passing lanes were installed showed an average reduction of injury crashes by 16%. There was significant variation in the impacts across analysed routes with 66% of the routes showing a reduction in crashes while 34% showed an increase in crashes. The variation of before-and-after crash impacts was even larger when the analysis was focussed on specific segments, such as the passing lane segment, a 2 km upstream segment, and a 5 km downstream segment, wherein half of the segments showed a decrease in crashes and half showed an increase in crashes. The assumption of average crash reduction therefore applies to an analysis of several passing lanes and would not necessarily apply to a specific passing lane, unless it is supported by site-specific evidence.

Passing lanes improve journey times through a small increase in travel speed and a significant reduction in per cent time spent following a slower vehicle. Platooning behind a slow vehicle is a cause of frustration amongst motorists according to a review of literature. To assess journey time impacts of passing lanes, numerical experiments were conducted using the traffic simulation model, TRARR (or TRAffic on Rural Roads). The TRARR model was reviewed and its parameters were re-calibrated to match current vehicle fleet and recent field data. The numerical experiments showed incremental improvements in journey time with higher passing lane density and longer passing lane length. However, when traffic volumes reach very high levels (e.g. 1900 veh/h in one direction), it was found that passing lanes resulted in lower travel speeds, which may be attributed to the bottleneck at the merge section of the passing lane. Temporarily closing a passing lane during high traffic volume periods could potentially result in better traffic operation. It was also determined that travel speed on two-lane two-way highways degrades when traffic volume reaches 1600 veh/h in one direction. When peak traffic demand is expected to frequently exceed 1600 veh/h, the duplication of the highway may be considered.

Literature demonstrated that motorists consider passing lanes effective and beneficial. A survey of motorists indicated that for the journey experience to be generally acceptable, the per cent time spent following a slow vehicle should be limited to 30% to 40%. Motorists were also found to attach a value to per cent time spent following of approximately \$4 per 100 vehicle-km travelled for every 10% improvement in time spent following.

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# 1. Introduction

## 1.1 Objectives

The objective of this project was to develop and apply methods to facilitate the identification of potential passing lane locations and establish the benefits associated with passing lanes to provide guidance to practitioners. The analysis covered the following aspects:

- safety
- journey time
- user experience.

## 1.2 Scope

The project included the following tasks:

1. literature review (Section 2)
2. safety analysis, including before-and-after analysis of crash records, speed and headway analysis, and overtaking behaviour analysis (Section 3)
3. journey time analysis, including development of modelling guidance and numerical experiments on the impact of passing lanes on travel speed and per cent time spent following (PTSF) (Section 4)
4. user experience analysis, including an analysis of perceptions and valuation of level-of-service (LOS) (Section 5).

## 2. Literature Review

This section includes a review of the following:

- Section 2.1 covers key design features, warrants and LOS and capacity of passing lanes.
- Section 2.2 examines the effect of passing lanes on journey experience.
- Section 2.3 reviews impacts on crash risks.
- Section 2.4 examines road user expectations.

### 2.1 Passing Lanes

#### 2.1.1 Key Design Features

Passing lanes (or overtaking) lanes are a type of auxiliary lane and are provided to break up traffic platoons and improve traffic flow over a section of road (Austroads 2016). They provide overtaking opportunity and are sometimes the only practical chance for overtaking to occur. Passing lanes or overtaking lanes are distinguished from the following related types of auxiliary lanes:

- Climbing lanes are a special form of passing lane and are provided on inclines.
- Slow vehicle turnouts are a very short section of paved shoulder or added lane that are provided to allow slow vehicles to pull aside and be overtaken.
- Descending lanes are provided on steep downgrades to accommodate the lower speed of trucks.

Passing lanes are best arranged in pairs at regular intervals along two-lane two-way roads. Examples of passing lanes are shown in Figure 2.1 and Figure 2.2. Design guidelines for passing lanes are available in the *Guide to Road Design Part 3: Geometric Design* (Austroads 2016).

Austroads (2016) generally suggests the following lengths of passing lanes (excluding merge and diverge tapers):

- 80 km/h operating speed: 400 m and 650 m (as minimum and desirable, respectively)
- 100 km/h operating speed: 550 m and 950 m
- 110 km/h operating speed: 620 m and 1070 m.

For road trains, lengths are 1.5 times the desirable lengths above.

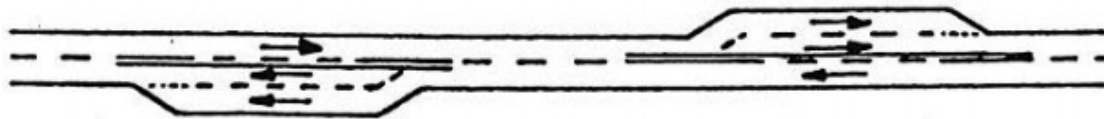
Passing lanes may be distributed along a route at a spacing of up to 20 km. A more desirable spacing would be from 10 km to 15 km, up to every 5 km (Austroads 2016).

Signage is installed indicating passing lane ahead 300 m in advance of the diverge taper and long-distance advance information (i.e. passing lane X km ahead) can be optionally provided. Keep left unless overtaking signs are erected at the start of the passing lane section. Signs indicating lane reduction are also erected at the end section of the passing lane.

Figure 2.1: Example 1 of layouts of passing lanes

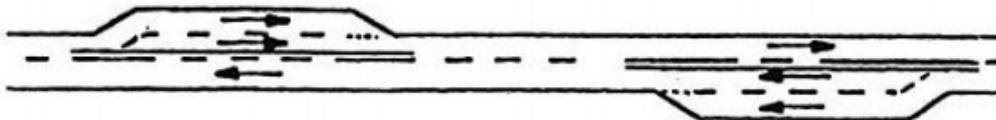


**ISOLATED OVERTAKING LANE**

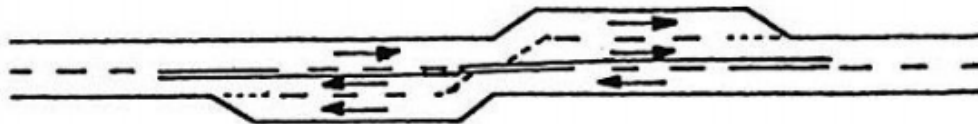


**SEPARATED OVERTAKING LANES - After location**

*Preferred Treatment*



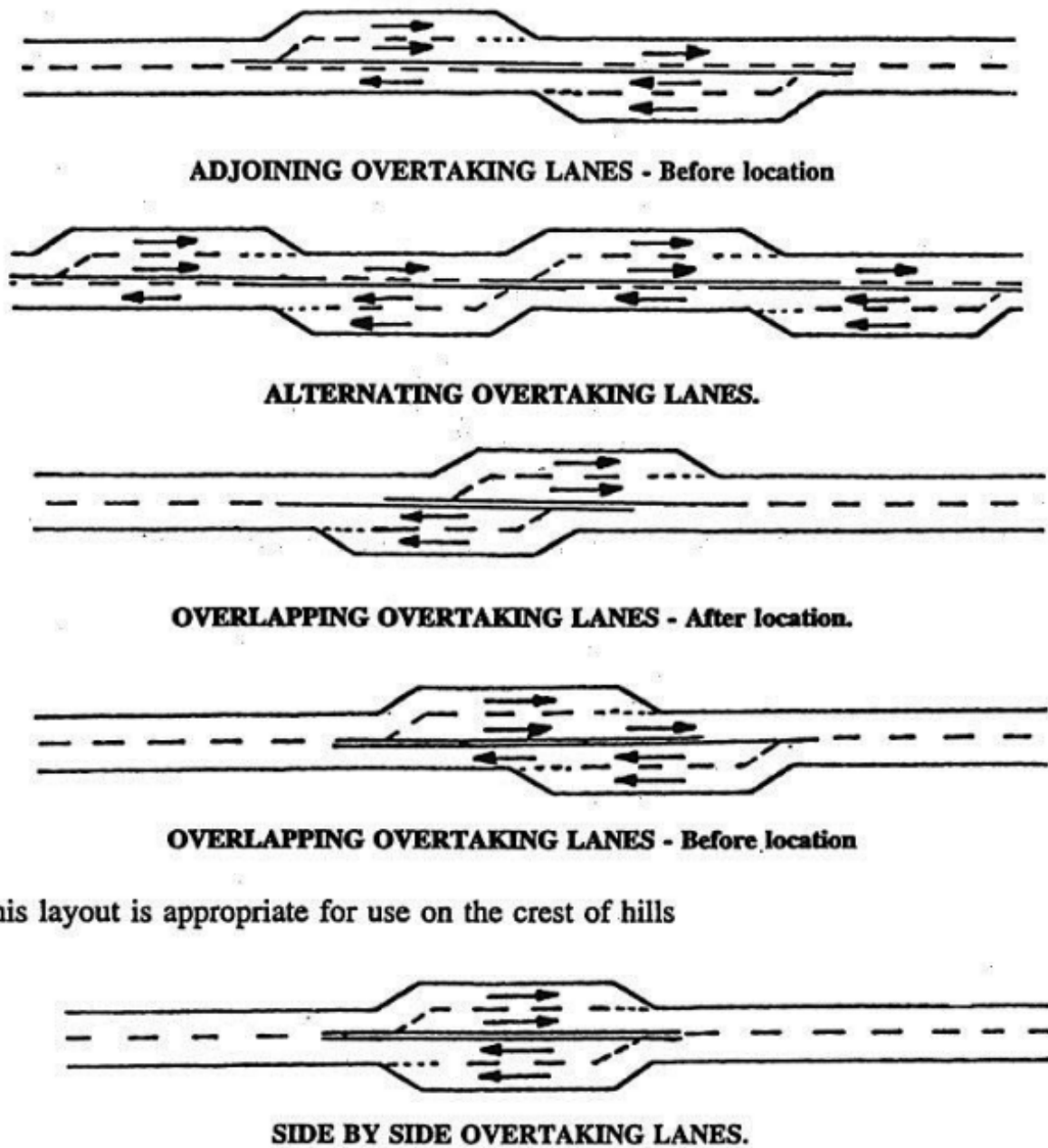
**SEPARATED OVERTAKING LANES - Before location**



**ADJOINING OVERTAKING LANES - After location**

Source: Austroads (2016).

Figure 2.2: Example 2 of layouts of passing lanes



This layout is appropriate for use on the crest of hills

Source: Austroads (2016).

### 2.1.2 Warrants

Austroads (2016) warrants for providing short and low-cost passing lanes at 10 to 15 km spacing (or more) are shown in Table 2.1. The table was based on a cost-benefit analysis by Hoban and Morrall (1986). Roads and Maritime Services (Roads and Maritime) have developed a similar table to Table 2.1 which is available as Commentary 22 of Austroads (2016). A review of passing lane warrants (Austroads 2005) showed that the Austroads warrants were comparable to international practice.

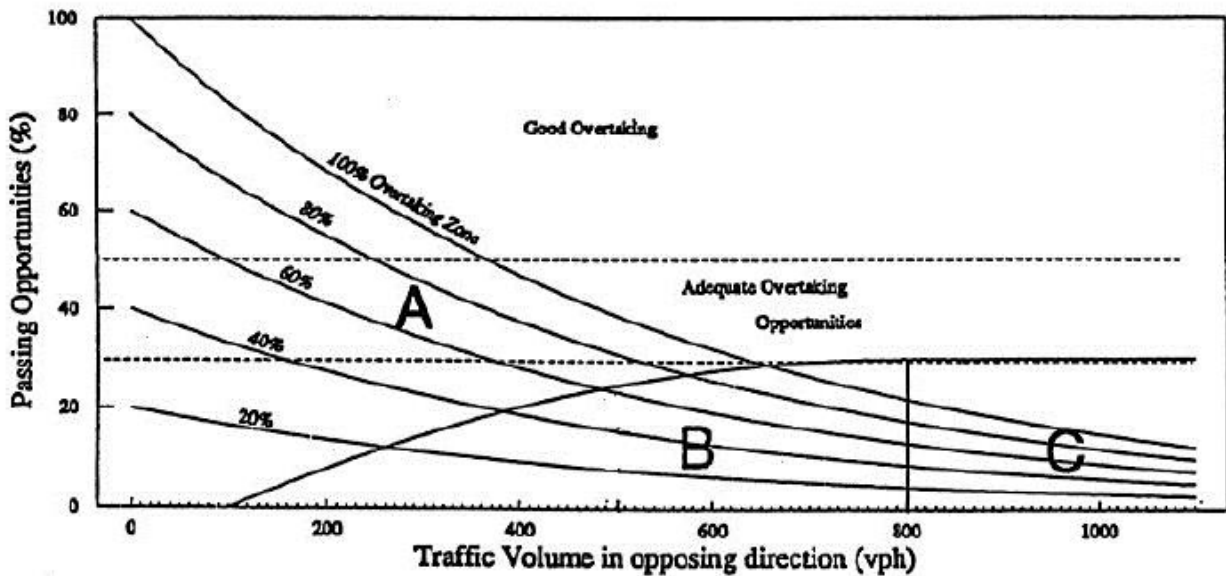
Table 2.1: Traffic volume guidelines for providing passing lanes (at 10 to 15 km or more spacing)

Overtaking opportunities over the preceding 5 km		Current year design volume (AADT, two-way)		
Description	Per cent length providing overtaking	Percentage of slow vehicles		
		5	10	20
Excellent	70–100	5670	5000	4330
Good	30–70	4330	3670	3330
Moderate	10–30	3130	2800	2470
Occasional	5–10	2270	2000	1730
Restricted	0–5	1530	1330	1130
Very restricted	0	930	800	670

Source: Austroads (2016).

Austroads (2016) further noted that passing lanes should be provided to maintain a desired level-of-service (LOS), e.g. see Figure 2.3. The upper limit for a passing lane could be about 500 to 800 veh/h in the opposing direction. At traffic volumes higher than these upper limits, full duplication will likely occur within the economic life of the passing lane pavement. The New Zealand Transport Agency (NZTA) passing lane development policy (reproduced by Kirby, Wilmshurst & Koorey 2014) are similar to the Austroads guideline.

Figure 2.3: Overtaking lane warrants



Notes:

A = no passing lane required

B = passing lanes warranted

C = lane warranted, duplication should be considered.

Source: Austroads (2016).

### 2.1.3 Level-of-service and Capacity

The *Guide to Traffic Management Part 3: Traffic Studies and Analysis* (Austroads 2017a) which was based on the Highway Capacity Manual (HCM) (Transportation Research Board (TRB) 2016) described the LOS of two-lane two-way roads according to average travel speed (ATS) and PTSF. LOS is set based on highway class, wherein the highway classes are defined as follows:

- Class I highways are expected to operate at relatively high speed, typically serving long-distance trips.
- Class II highways are not necessarily expected to operate at high speeds, such as highways serving as access to Class I highways.
- Class III highways serve moderately developed areas.

The LOS of the three classes of highways are defined in Table 2.2. Austroads (2016) suggested maintaining the LOS of highways to at least LOS C.

**Table 2.2: Automobile LOS for two-lane highways**

LOS	Class I highway		Class II highway	Class III highway
	Average travel speed (km/h)	Per cent time spent following (%)	Per cent time spent following (%)	Per cent of free-flow speed (%)
A	> 90	≤ 35	≤ 40	> 91.7
B	> 80–90	> 35–50	> 40–55	> 83.3–91.7
C	> 70–80	> 50–65	> 55–70	> 75.0–83.3
D	> 60–70	> 65–80	> 70–85	> 66.7–75
E	< 60	> 80	> 85	≤ 66.7

*Note: LOS F applies when the arrival flow exceeds capacity.*

*Source: TRB (2016).*

HCM (TRB 2016) suggests that the capacity of a two-lane highway under base conditions is 1700 passenger cars (pc)/h in one direction, with a limit of 3200 pc/h for the total of both directions. Rozic (1992) estimated capacity to be 2700 veh/h in both directions. Rozic suggested that under ideal conditions, the capacity can exceed 3000 veh/h in both directions, perhaps reaching 4000 pc/h. Kim and Elefteriadou (2010) estimated the following directional capacity estimates under base conditions:

- 1800 pc/h at 64 km/h average free flow speed
- 2000 pc/h at 80 km/h
- 2100 at 96 to 112 km/h.

Kim and Elefteriadou (2010) also noted that the presence of passing zones did not have an effect on capacity. However, the presence of horizontal curves, grades and trucks could reduce capacity by up to 40%.

## 2.2 Journey Experience

### 2.2.1 Impact of Passing Lanes

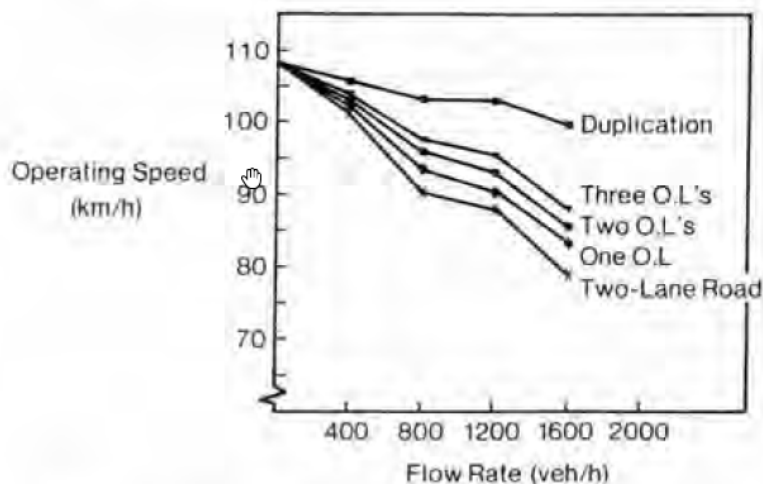
The journey experience on highways is based on the ATS and PTSF (Austroads 2016). PTSF is the average per cent of total travel time that vehicles must travel in platoons behind slower vehicles due to inability to pass on a two-lane highway (TRB 2016).

Table 2.3 lists estimated and measured impacts of passing lanes on ATS and PTSF from various sources. The impact on travel speed is positive but tends to be small (approximately +2 to +3 km/h). On the other hand, the primary impact of passing lanes on PTSF is significant (i.e. could be greater than 10%).

**Table 2.3: Impact of passing lanes**

Source	Location and demand	Impact
Al-Kaisy and Freedman (2010), based on field measurements	US-287 (USA) 155 veh/h	<ul style="list-style-type: none"> <li>Per cent of vehicles impeded decreased from 28.5% upstream to 14.1% downstream of the passing lane.</li> <li>Per cent of vehicles as followers decreased from 40.8% to 27.1%.</li> <li>Average travel speed as a ratio to free flow speed (ATS/FFS) decreased from 0.98 to 0.96</li> </ul>
	US-191 (USA) 330 veh/h	<ul style="list-style-type: none"> <li>Per cent of vehicles impeded decreased from to 33.5% to 18.8%.</li> <li>Per cent of vehicles as followers decreased from 48.4% to 42.4%.</li> <li>ATS/FFS decreased from 0.99 to 0.96.</li> </ul>
Bennett (2017a), based on microsimulation analysis	South Gippsland Highway, Foster to Welshpool 975 AADT	<ul style="list-style-type: none"> <li>PTSF decreased from 43% to 26%.</li> <li>ATS increased from 78 km/h to 81.7 km/h.</li> </ul>
Bennett (2017b), based on microsimulation analysis	Princes Highway, Stratford to Bairnsdale 308 veh/h	<ul style="list-style-type: none"> <li>PTSF decreased from 34.7% to 27.4%.</li> <li>ATS increased from 89.7 km/h to 91.4 km/h.</li> <li>Analysis assumed highway with median wire rope barrier.</li> </ul>
HCM (TRB 2016), based on sensitivity testing of models	Hypothetical (Various traffic demand, 100 veh/h to 1500 veh/h directional volume)	<ul style="list-style-type: none"> <li>PTSF decreases by around 10%.</li> <li>Tiny increase in ATS (even at higher demands, the change in average travel speed was tiny).</li> </ul>
Hoban and Morrall (1986), based on field data and microsimulation analysis	Various	<ul style="list-style-type: none"> <li>Percentage of platooned vehicles decreased an average of 5.1% (upstream and downstream field data from 15 sites with demand from 35 to 560 veh/h).</li> <li>Travel speeds increased by approximately 2 km/h (see Figure 2.4)</li> </ul>

**Figure 2.4: Simulated operating speed vs traffic volume and road type**



Note: OL refers to overtaking lane.

Source: Hoban and Morrall (1986).

## 2.2.2 Design Impacts on Performance

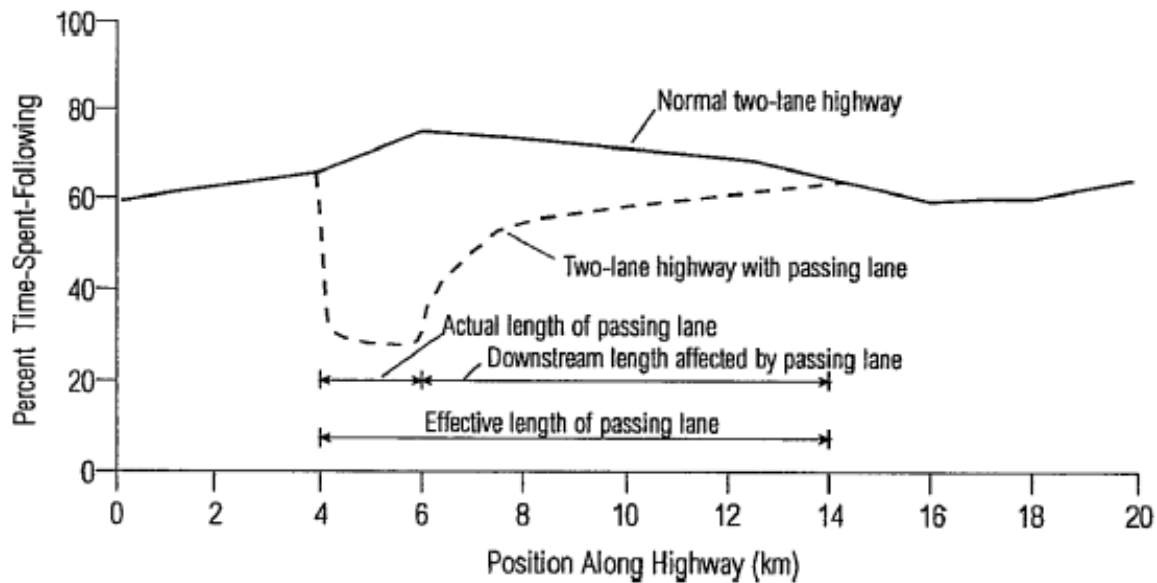
This section examines the impact of passing lane design on the (journey) performance of passing lanes. The design elements examined include length and spacing. Table 2.4 lists findings on the optimal or ideal passing lane spacing and length. The optimal spacing and length of passing lanes varies but is generally about 5 km spacing at high demand (e.g. 10 000 AADT) and 10 or 20 km spacing at low demand. The optimal length of the passing lane is around 1 km. Hoban and Morrall (1986) also suggested the following:

- On a given section of road, the first short length of passing lane in each direction provides the highest benefit-cost ratio (BCR), and this reduces as more passing lanes, or increased length, are provided.
- As a general rule, several short passing lanes, say less than 1 km in length, provide considerably higher benefits and are more cost-effective than a single passing lane of the same total length.

**Table 2.4: Spacing and length of passing lanes and impact on performance**

Source	Findings
Kirby, Wilmshurst and Koorey (2014)	<p>Sensitivity analysis was conducted to determine the optimal spacing and length of passing lanes based on various combinations of terrain, demand and heavy vehicle percentage. The calculations were based on benefit-to-cost (BCR) ratio under an assumed implementation cost of NZD 1 000/m (2011 value). The following are example results:</p> <ul style="list-style-type: none"> <li>• Flat/rolling terrain and low heavy vehicle percentage                             <ul style="list-style-type: none"> <li>- 5 000 AADT: 11 000 m to 18 000 m spacing and 750 m to 950 m length</li> <li>- 10 000 AADT: 5 500 m to 12 000 m spacing and 800 m to 1 100 m length</li> <li>- 20 000 AADT: 3 500 m to 4 500 m spacing and 900 m to 1 100 m length.</li> </ul> </li> <li>• Flat/rolling terrain and medium heavy vehicle percentage                             <ul style="list-style-type: none"> <li>- 5 000 AADT: 11 000 m to 18 000 m spacing and 800 m to 950 m length</li> <li>- 10 000 AADT: 6 750 m to 12 000 m spacing and 850 m to 1 000 m length</li> <li>- 20 000 AADT: 3 500 m to 6 000 m spacing and 850 m to 1 350 m length.</li> </ul> </li> </ul>
May (1991)	<p>Microsimulation analysis identified passing lanes with spacing of 3 200 m to 8 000 m and length of 400 m to 1 200 m to be most effective.</p>
Genek and Lester (2008)	<p>The ideal spacing of passing lanes is equal to its effective length (see Figure 2.5). The effective length varies from site to site but was generalised as follows:</p> <ul style="list-style-type: none"> <li>• 1 000 to 3 000 AADT: 8.4 km average (range of 3.5 km to 14.5 km)</li> <li>• 3 001 to 5 000 AADT: 10 km average (range of 6.4 km to 13.7 km)</li> <li>• 5 001 to 7 000 AADT: 6.8 km average (range of 4.1 km to 11 km)</li> <li>• 7 001 to 9 000 AADT: 6.9 km average (range from 3.4 km to 12.8 km)</li> <li>• &gt; 9 000 AADT: 3.9 km average (range from 1.3 km to 5.4 km).</li> </ul>
Austrroads (2016), based on Hoban and Morrall (1986)	<p>See Table 2.1.</p>
HCM (TRB 2016)	<p>Optimal passing lane length is:</p> <ul style="list-style-type: none"> <li>• 800 m when the directional demand is <math>\leq 100</math> veh/h</li> <li>• 800 m to 1 200 m when directional demand is 100 veh/h to 400 veh/h</li> <li>• 1 200 to 1 600 when the directional demand is 400 veh/h to 700 veh/h</li> <li>• 1 600 m to 3 200 m when the directional demand is &gt; 700 veh/h.</li> </ul>

Figure 2.5: Operational effect of a passing lane and its effective length



Source: Al-Kaisy and Freedman (2010).

### 2.2.3 Modelling of Journey Experience

There are established methods to model journey experience performance of passing lanes, and they include analytical modelling and simulation.

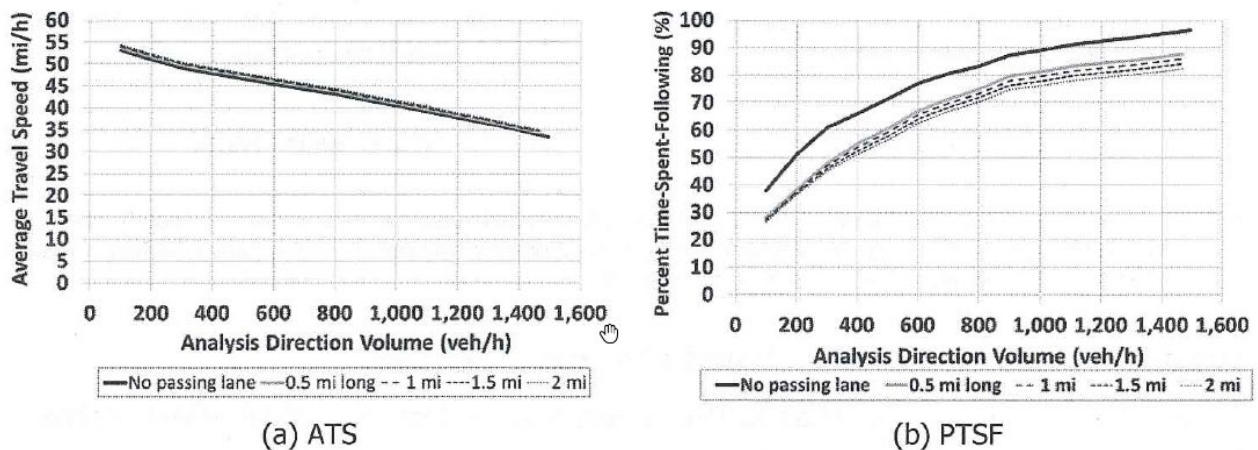
#### Analytical modelling

The Highway Capacity Manual (HCM) (TRB 2016) method is an analytical method for two-lane two-way highways. The HCM method involves a series of equations to estimate ATS, PTSF and capacity given the following inputs:

- free-flow speed
- demand flow rate
- heavy vehicle mix
- terrain
- per cent of no passing zones.

The impact of passing lanes is incorporated in the analysis using the concept of the effective length of the passing lane, wherein the ATS and PTSF are improved within the effective length as shown in Figure 2.5. The effective length of passing lanes with respect to ATS is equal to the length of the passing lane plus 2.7 km (i.e. constant). The effective length with respect to PTSF is considerably longer (i.e. 5.7 km to 21 km) and is dependent on demand. Higher demand shortens the effective length. Figure 2.6 illustrates the effect of demand and the availability of passing lanes (of different lengths) on ATS and PTSF using the HCM method.

Figure 2.6: Illustrative effect of volume and passing lane length on ATS and PTSF



Source: TRB (2016).

## Simulation

Simulation models trace the movement of vehicles at every time step, including lane change manoeuvres. Koorey (2003) identified three simulation models for passing lane analysis:

- TRARR (Traffic on Rural Roads)
- TWOPAS (Two-lane Passing)
- PARAMICS (Parallel Microsimulations).

TRARR is designed for analysis of two-lane rural highways with occasional passing lane or four-lane sections. Slow vehicle bays can also be modelled (Hoban et al. 1991; Koorey 2003). Figure 2.4 illustrates an example of TRARR output. TRARR is maintained by the Australian Road Research Board (originally developed in the late 1970s) and continues to be used in Australia and New Zealand. For example, TRARR was recently applied to analyse South Gippsland Highway (Victoria) (Bennett 2017a).

TWOPAS was developed in 1985 through the support of Federal Highway Administration (FHWA). Austroads (2005) reported that in 2004, FHWA abandoned plans to release and support TWOPAS as a commercially available stand-alone model. FHWA has used TWOPAS as the basis of the Traffic Analysis Module in its Interactive Highway Safety Design Model.

PARAMICS was developed by SIAS Ltd (Scotland) (Austroads 2005). The authors are not aware of the status of the application of PARAMICS for rural highway analysis in Australia or New Zealand.

In 2013, Aimsun announced an alpha version of a microsimulator of two-way overtaking (Aimsun 2013). The authors are not aware of an application in Australia or New Zealand.

## 2.3 Safety

### 2.3.1 Passing Lane Design and Safety

This section examines various passing lane design aspects and how they may impact crashes.

#### Length of passing lanes

Oxley et al. (2004) suggested that the length of passing lanes can affect crash risk. Referring to a number of studies from the United States, it was suggested that usage rates for passing lanes with lengths of 274 m (900 ft) and below were often very low, as vehicles could not safely pass one another within this length. Koorey et al. (1999) found that passing lanes of 800 m length or less had reduced crash rates, while the findings for longer passing lanes on crash rates were inconclusive.

#### Merge sections

It has been recommended that merge sections should not be implemented along or near either horizontal or vertical curves that limit sight distance to drivers along the passing lane (Luther et al. 2004; Potts & Harwood 2004; Wooldridge et al. 2001). It was also recommended that the merge sections should not occur near intersections (Jaehrig 2014; Wooldridge et al. 2001). A study from Kansas recommended that intersections should be avoided along passing lanes altogether (Russell, Mutabazi & Stokes 1997).

In a study from New Zealand, simulations were performed and the results from these suggested that correct design of the merge, particularly the length of the taper, encourages correct merging behaviour (Charlton 2007). Additionally, different forms of signage at the merge were shown to affect the behaviour of drivers when the design of the merge section was sub-standard. Refer to the *Guide to Road Design Part 3* (Austroads 2016) for recommended design guidelines of passing lanes.

#### Overtaking in the opposing direction

There does not seem to be a consensus on whether traffic in the opposing direction to the passing lane should be allowed to overtake. Some literature recommends that overtaking in the opposing direction be prohibited along the length of a three-lane section of road, but other literature recommends that it may sometimes be permitted (Hoban & Morrall 1985; Jaehrig 2014; Kilburn 1994; Mutabazi, Russell & Stokes 1999).

#### Median barriers

A study from New Zealand suggested that median barriers should be used along high volume three-lane roads (Luther et al. 2004). However, a lack of escape routes is a possible crash risk should a driver make an error of judgement (Luther et al. 2004).

#### Effects of speed

Passing lanes are intended to speed up traffic and reduce journey times. It is natural to consider that an increase in traffic speed is likely to have a negative outcome regarding road safety (e.g. refer to Jurewicz et al. (2015)). While safety aspects associated with speed are an important consideration, there is considerable room for debate as to whether negative safety effects associated with greater speeds along or downstream of passing lanes should be considered or not as part of the overall safety effect of passing lanes. The reviewed literature has mainly considered crash numbers as a measure of safety effect. Speed, along with many other factors, are intrinsically considered in such an approach.

#### Sealed shoulders

Luther et al. (2004) identified that sealed shoulder widths on three-lane sections of roads were not wide enough to allow a driver to move out of the way should it be necessary to avoid another vehicle. In many cases, the sealed shoulder width had been reduced as part of the passing lane construction design.

### 2.3.2 Safety Effects of Passing Lanes

Rinde (1977), in quantifying the safety benefit of passing lanes installed along 23 sections of Californian highways, concluded that an overall crash reduction of about 25% could be expected from their installation. Following on from that study, Harwood and St John (1985) concluded that, while not proven conclusively, there is a strong suggestion that passing lanes may reduce crash rates. Though not statistically significant at a p-value of 0.05, they suggested a decrease in crash rates of 24.3%. Referring to this previous study, Harwood and Hoban (1987) concluded that the installation of passing lanes on two-lane rural highways decreased crashes by approximately 25%.

A New Zealand study (Koorey et al. 1999) found a 54% reduction in the number of injury crashes after the construction of passing lanes that also included major road realignment. However, little reduction in crash rates was seen when passing lanes were constructed with no change to the road alignment (i.e. an additional lane was 'tacked-on' to the existing lanes).

In Victoria, Bui (2001) found a 12% reduction in crashes along passing lanes.

In Missouri, Potts and Harwood (2004) observed that the per kilometre crash rate along three-lane (passing lane) sections of road was 12 to 24% lower than the adjoining two-lane sections.

In Germany, Jaehrig (2014) showed that when shorter passing lanes between 600 and 1200 m in length were implemented, overtaking-related crashes were reduced by more than 60%.

'Super 2' is the name used in Texas to refer to two-lane highway corridors having low to moderate traffic volumes where periodic passing lanes have been constructed. A report by Brewer et al. (2011) indicated that installation of passing lanes led to statistically significant crash reductions of 35% (segment only, KABC) and 42% (segment plus intersection crashes, KABC). KABC refers to crashes in which someone was killed or injured.

In 2005 and 2006, nine passing lanes were constructed on a 26-mile section of WY59, a rural two-lane highway in Wyoming. Schumaker, Ahmed and Ksaibati (2017) reported an evaluation of the safety effects of this intervention, based on eight years of data before and seven years of data after the construction, as follows:

- The estimated reduction in FI (fatal or injury) crashes was 20% based on the Empirical Bayes method, that uses traffic flows and estimates of the effects of traffic flow.
- Schumaker et al. also reported that an unadjusted before-after comparison showed a 23% increase in FI crashes.

It is noted that the estimate of a 20% reduction, as contrasted with a 23% increase, presumably rests on the validity of the Empirical Bayes model used.

In 2009, sixteen sections (13 km) of 2+1 roads in rural areas were constructed in Poland. Cafiso, D'Agostino and Kiec (2017) report an evaluation of the safety effects of this intervention, based on four years of (fatal and injury crash) data before and four years of data after construction. The findings were as follows:

- Crashes were reduced from 37 to 20 at the treated sites, and from 129 to 101 at a reference group of road sections. The ratio of ratios (20/37 divided by 101/129) is 0.69.
- The opinion of Cafiso, D'Agostino and Kierc was that a better estimate of the ratio was 0.53 which accounted for traffic flow (year-to-year) and other factors.
- However, Cafiso, D'Agostino and Kiec also estimated a ratio of 0.96, i.e. very little reduction, if crashes in the upstream and downstream road sections were included in the comparison.

Kirby, Wilmshurst and Koorey (2014) reviewed passing lane operation and safety. Much of the discussion in Kirby, Wilmshurst and Koorey refers to '2+1 roadways'. It included continuous three-lane roads and two-lane roads with passing lanes. The summary reduction figures given are 33% for fatal crashes and 21% for fatal plus injury crashes. The figures were higher if a wire rope barrier was installed, but there was evidence of an increase in non-injury crashes with the installation of a wire rope barrier.

Elvik et al. (2009) noted that passing lanes seem to reduce crashes, especially severe crashes and mostly on highways with large traffic volumes. Passing lanes could reduce crashes by 30% within the passing lane and by 20% on road sections before and after the passing lane.

### 2.3.3 Summary

Section 2.3.2 showed that there appears to be a degree of consensus in the literature that passing lanes contribute to safety, and injury crashes after a passing lane has been constructed are likely to be (20% to 40%) less than if it had not been constructed. It is, however, unclear to what extent the reduction in crashes apply. In many of the studies, it is difficult to understand whether the results are specific to the passing lane itself, the passing lane and immediately surrounding road or an entire route. It is understandable that crashes would be reduced where the passing lane is built given the increased number of lanes on the passing lane section. Whether the impacts also manifest in crashes for the route is not clear. In one particular case, Cafiso, D'Agostino and Kiec (2017) found that while crash reduction was apparent on the treated sites, when upstream and downstream sections were included, the impacts appeared negligible. Elvik et al. (2009) on the other hand noted a 20% reduction in upstream and downstream sections.

The transferability of the reviewed international results to Australia and New Zealand needs careful consideration. A New Zealand study (Koorey et al. 1999) indicated significant reduction in crashes, but the reduction in crashes could not be clearly attributed to passing lanes. Implementation of passing lanes (only) did not appear to have resulted in a notable reduction in crashes. In Victoria, Bui (2001) reported a reduction in crashes as a result of passing lanes, but it is at a relatively lower magnitude of 12%. It is possible that Australian and New Zealand conditions may not align with international conditions and the crash reduction impacts of passing lanes should be validated using Australian and New Zealand data.

Section 2.3.1 showed that the design of specific passing lanes could have a significant effect on crashes. It is informative to determine how various design elements impact crashes; however, it is acknowledged that data to conduct a detailed study is not available and is a limitation of this study.

## 2.4 User Expectations

All years of the International Traffic Safety Data and Analysis Group (IRTAD) database were searched using the key words 'overtaking lane'. The search resulted in only three reports that were relevant to road user opinion in relation to overtaking lanes. One other relevant paper was identified in one of these three papers and included in the review.

The most relevant study for the purposes of this review is a comprehensive attempt to document drivers' attitudes, understanding and acceptance of passing lanes (Mutabazi, Russell & Stokes 1990) carried out for the Kansas Department of Transportation (KDOT). Drivers were stopped downstream of passing lanes by KDOT personnel and handed self-addressed postage-paid survey cards which they were requested to fill in and mail later. The surveys were distributed at nine sites distributed across two routes; the overall response rate was approximately 41%, which did not differ across routes.

Respondents were asked how often they travelled the highway, what sort of vehicle they drove and which state they lived in. Two questions were asked about passing lanes. The first asked respondents to indicate which of a series of statements about passing lanes they thought were true, and the second asked whether they thought KDOT should build more passing lanes. The responses to the first question were as follows:

- almost 54% of respondents thought the passing lanes were too short and 46% thought they were just the right length

- 93% thought they would improve safety
- 8% thought they would increase speeding
- 53% thought they would save time.

Eighty-six per cent of respondents believed more passing lanes should be built, indicating a high level of acceptance of passing lanes and a recognition of their benefits. Four per cent thought there was no need for extra passing lanes, and 10% were undecided.

Respondents were invited to add their own comments. The most frequent comments related to improvements at specific locations or over the network. Very few of these comments were negative and most were positive towards the passing lane system, although almost half suggested building more four lane highways. Some drivers complained about the behaviour of others, particularly their inappropriate use of passing lane sections. The other major issue commented upon was signing, with complaints that the signs were too small, that drivers did not obey the signs and that 'keep right unless overtaking' signs be posted.

Other work of direct relevance to the present study has been carried out in New Zealand. A literature review identified platooning behind slow vehicles as a major source of delays and frustration, pointing out that the frequent speed changes and time spent following other vehicles can give rise to the perception of a low level of service, even if delays are small (Thrush 1996). Consequently, the perceived level-of-service is likely to be determined by the frequency of passing opportunities. Thrush went on to consider a wide range of material relating to passing lanes and their provision. The main conclusions relevant to user perceptions of overtaking lanes were that there was a need for easily-calculated measures that reflected users' perceptions of level-of-service relating to passing opportunities. It was suggested that aborted passing manoeuvres could be used as a measure of driver frustration, and that the length of road where overtaking was feasible, traffic flow, length of passing lanes, gradient and percentage of heavy vehicles should all be considered when developing guidelines. Interviews and focus groups confirmed the ability to pass slower vehicles as a major concern for nearly all road user groups.

Koorey et al. (1998) attempted to relate journey experience to Willingness-to-Pay (WTP) for additional passing opportunities. Journey experience and WTP were established using a self-completed questionnaire which was distributed in three ways:

- at petrol stations located at the endpoints of routes of interest
- to drivers waiting to load onto inter-island ferries
- to non-transportation staff in a consultant's office just before holiday time.

The section dealing with the respondent's demographics, the route to be taken and the expectations about the journey was completed prior to travel; and, the section dealing with the experience of the trip was completed after the trip and the completed questionnaire returned by post. The questionnaire included:

- a question on the number of times the driver would have liked to pass but was not able to do so immediately
- how much time was lost because of the above
- how satisfactory were the passing opportunities and how frustrating was this route compared to others taken in the past.

A return rate of 35% was achieved, resulting in just over 300 responses.

WTP was assessed by asking respondents to consider two hypothetical situations involving routes similar to the one just driven but with passing lanes available for the whole way. In the first case, respondents were asked to say how much extra time they would be willing to accept to have passing lanes all the way; in the second case, they were asked to say how much further they would be prepared to travel to having passing lanes all the way. The results were converted to a monetary value by applying values for travel time and vehicle operating costs respectively.

A novel feature of the survey was the development of a surrogate measure of frustration by estimating Unsatisfied Passing Demand (UPD), which is related to PTSF. This is achieved by considering passing demand (D) in relation to passing supply (S). D was estimated by a formula which takes into account traffic flow, speed and the standard deviation of the speed distribution. S was estimated from the proportion of gaps in the opposing traffic stream and the proportion of the road with adequate overtaking sight distance. UPD is calculated according to the formula:  $UPD = D \times (1 - S)$ , in overtaking/km per hour.

When UPD was compared with WTP, a statistically significant but weak relation was found. The WTP model that was developed had poor correlations with UPD (i.e. 0.14), although UPD was a significant explanatory variable of WTP (i.e. at the 99% level). The authors estimated a WTP of 3 to 4 cents/vehicle-km of passing opportunity provided. The poor correlation could be due to some significant factors not incorporated in the model or that UPD may not be an appropriate measure of driver frustration.

## 3. Safety Benefit Assessment

It is commonly considered that the installation of passing lanes has a net benefit to road user safety (as discussed in Section 2.3). The assumption is that overtaking is safer when performed in these areas as the risk of conflict between the overtaking and overtaken vehicles, and with oncoming vehicles, is lessened. It is assumed that any increased risk of crash or injury concentrated at the location of passing lanes is less than the reduced risk of crash or injury along all other sections of the road. In other words, the net risk of crash or injury along the entire road is reduced. The purpose of this safety performance study was to test this assumption using crash data provided by jurisdictions. The results are in Section 3.1.

This section also examines motorist behaviour related to overtaking and passing lanes to better understand the safety consequences of passing lanes, as follows:

- Section 3.1.3 examines lane use, speed and headway along the passing lane.
- Section 3.3 examines percentage of overtaking using the passing lane and overtaking speed and space gap.

The field survey data collection used in the above two sections was undertaken by The Centre for Automotive Safety Research (CASR) for the Department of Transport, Planning and Infrastructure (DPTI) in South Australia. DPTI has provided permission to use the data obtained from these surveys as part of this project.

### 3.1 Crash Data Analysis

#### 3.1.1 Method

Crash data and passing lane location and attribute data were requested from jurisdictions. Analyses were performed using crash data provided by three jurisdictions. The data request sent to the jurisdictions is provided in Appendix A.1.

Due to differences in the recording and provision of crash data between the jurisdictions, some analyses were restricted to data from specific jurisdictions. These restrictions are noted, where relevant, in the results section.

#### Data cleansing

Data cleansing was performed before analyses were conducted. This was undertaken to reduce the likelihood of bias due to errant data and included:

- the removal of duplicate crash reports
- the removal of crash reports with missing or obviously erroneous information
- the repair of erroneous information where the intent of the information was obvious (e.g. a date '20013' changed to '2013').

#### Excluded data

Some crash and infrastructure attribute data were excluded because of conflicting or missing information. Some jurisdictions provided information regarding infrastructure attributes as part of the crash data, instead of as separate data directly related to the infrastructure. As such, some information about infrastructure attributes were duplicated amongst multiple crash reports and could be conflicting.

Some information, particularly that regarding infrastructure attributes, was not available or was obviously erroneous. Such conflicting and erroneous data necessitated the exclusion of certain passing lanes or road sections from the analysis, and included:

- the exclusion of passing lanes where place-holding installation dates were used and could be identified as such (e.g. identified as many passing lanes being installed on the same day)
- the exclusion of passing lanes where the installation date was obtained from crash reports and was conflicting between crash reports.

### Statistical testing of cohorts

Statistical tests were undertaken on cohorts of passing lanes, road sections upstream and downstream of passing lanes, and along routes where passing lanes operated. Combined upstream and downstream sections (i.e. where one passing lane's downstream section overlapped the upstream section of the following passing lane) were excluded from the analyses. Interactions between the two mean that isolating the effect of one or the other is not possible and there was not enough data to warrant a separate evaluation for such situations. Descriptions of each cohort are as follows:

- **Passing lane:** a length of three-lane road where the third lane has been installed over a relatively short distance for the purposes of providing overtaking opportunity in one direction. Merge and diverge tapers were included in the analyses if identifiable, e.g. some data were provided without information pertaining to whether the taper was counted as part of the passing lane.
- **Upstream section:** a section of road of 2 km in length directly upstream of the passing lane or passing lane diverge taper (if identifiable).
- **Downstream section:** a section of road 5 km in length directly downstream of the passing lane or passing lane merge taper (if identifiable).
- **Route:** a length of road where one or more passing lanes had been installed. The start/end locations were specified as being 5 km after each passing lane located at the extreme ends of the route. Passing lanes were grouped with a maximum time separation of 10 years between the earliest and latest installation dates.

Passing lanes were excluded from analysis if no crashes were recorded for the period of analysis.

### Statistical methods

Before-and-after crash analyses were used to compare the relative effect on crash rate by the installation of passing lanes. Ideally, statistical analysis should be undertaken on the actual, measurable, responses to an event. For this study, this would mean directly comparing the number of crashes before installation of a passing lane with the number of crashes after installation of a passing lane. The issue is then to make sense of the difference between these numbers. This is sufficient for the comparison of data at an aggregate level, but not on a site-by-site basis where data is ranked. Ranking differences in the number of crashes would bias sites with more crashes, where larger variation is expected to occur. To account for this, analyses of ranked data were applied to differences between the square-root of the number of crashes. The reasons for this are as follows:

- Crashes at a specific location (events) can be approximated by a Poisson distribution.
- The coefficient of variation for a Poisson distribution is the square-root of the expected value (i.e. the number of events).
- Natural variation takes the form of the square-root of the expected value and thus provides a consistent measure for ranking differences between each site.

In other words, if the difference in the square-root of the number of crashes (before-and-after) is the same for two sites, there is an equal likelihood that the change in the number of crashes at these two sites was due to natural variation unattributed to the effect of external actions, such as installation of a passing lane.

Pearson's Chi-Squared test, Student's T-test and the Wilcoxon Signed-Rank test were used to validate the statistical significance of before-and-after comparisons. A statistical significance limit of  $p \leq \alpha$  ( $\alpha = 0.05$ ) was assumed. Pearson's Chi-Squared test and Student's T-test were conducted using Microsoft Excel (Version 14.0.7190.5000), while the Wilcoxon Signed-Rank test was conducted using IBM SPSS Statistics (Version 24).

Pearson's Chi-Squared test was applied to aggregated before-and-after crash numbers for each cohort. The application of this test can be used to determine confidence that a significant change in crash rate has occurred at the cohort level; in other words, if the installation of passing lanes has affected the crash rate at a global level.

The Wilcoxon Signed-Rank test and Student's T-test were applied to the ranked individuals in each cohort. The test was applied to the difference in the square-root (see above explanation of using this method) of the number of crashes before and after treatment. Student's T-test requires the assumption of normality; the Shapiro-Wilk test of normality was used to test the validity of this underlying assumption and was applied using IBM SPSS Statistics. Unlike Student's T-test, the assumption of normality is not required for the Wilcoxon Signed-Rank test statistic to be valid. The application of both tests can be used to determine confidence that the distribution of change between the cohort of individuals (i.e. sites being tested) is different to the expected distribution of change had no treatment been implemented; in other words, if a significantly large proportion of sites are skewed to either an increased or reduced crash rate.

A maximum of five years was used for the length of the before-and-after periods. This was reduced if there was insufficient data (e.g. a passing lane installed in 2014, where data for 2015–16 only was available in the after period) or for routes where the minimum/maximum passing lane installation dates for two groupings of passing lanes along the same length of road were less than five years apart. A minimum of two years was used for the length of the before-and-after periods. The before-and-after periods were always of equal length, thus negating the need for conversion to a rate.

### Crash severity

All analyses were conducted considering only crashes where at least one injury was recorded. Comparison of crash severity between fatal and non-fatal crashes was made at an aggregated level only. There were insufficient numbers of fatal crashes to make a worthwhile comparison on a site-by-site basis.

No other differentiation was made between injury severity as it was not known whether the definitions of non-fatal severity were consistent over the different jurisdictions or over the time used for the analysis.

Property damage only crashes were not considered due to the issue of under-reporting of these crashes that is common throughout Australia and New Zealand.

### Crash types

Six categories of crashes were considered for analysis. These categories were defined by either the primary crash code or if not provided, the crash type description. Sub-codes were not considered. Crash codes considered were RUM (road user movement), DCA (definitions for coding accidents) or vehicle movement codes. The definitions used for each category are provided in Appendix A.2. A brief description of each category is as follows:

- all types: crashes of any crash code or crash type description
- head-on crashes: crashes involving two or more vehicles which collided with one or more vehicles travelling in the opposing direction
- same-direction crashes: crashes involving two or more vehicles travelling in the same direction
- intersection crashes: crashes involving two or more vehicles travelling in adjacent directions or with one or more vehicles turning right or left from the opposing direction
- single vehicle crashes: crashes recorded as involving a single vehicle
- non-single vehicle crashes: crashes recorded as involving more than one vehicle.

While it would be beneficial to analyse crashes involving vehicles undertaking an overtaking manoeuvre, the crash codes and crash type descriptions provided by the jurisdictions were unable to identify such manoeuvres.

### Control data

Before-and-after crash data analyses were undertaken using control data to represent the expected change in injury crashes for each jurisdiction, should no passing lanes have been installed. A linear adjustment to the time-dependent trend in the background crash rate was applied to the expected number of crashes before-and-after installation of a passing lane (see Appendix A.3). This adjustment was assumed to be equal to the average change in crash rate (number of injury crashes per year) along rural undivided roads with a speed limit of 80 km/h or more. This adjustment was the most direct form of control adjustment and is thereby less likely to introduce unrealistic bias than other forms of adjustment. Control data was requested and applied separately for each jurisdiction.

Other forms of adjusting the time-dependent trend of either the observed or expected number of crashes were considered but excluded from the analysis. While some adjustments could be estimated with reasonable accuracy, others could not and including some adjustments while excluding others could introduce bias into the analysis. An example of this would be to include adjustment for the time-dependent changes in traffic volumes, which can be estimated with reasonable accuracy, while excluding consideration of the time-dependent changes to the level of safety of passenger vehicles, which is more difficult to quantify. Such an example could lead to an over-estimation of the benefits of installing passing lanes.

## 3.1.2 Results

### Passing lane sites

Crash data was provided by three jurisdictions for the analysis of injury crashes that occurred along sections of road where passing lanes were installed (i.e. excluding upstream and downstream sections). Not all passing lanes had reported crashes for the analysis period and where no crashes were recorded, the passing lanes were excluded from the analysis.

Figure 3.1 is a profile of the crash types on passing lane sites. Crashes involving overtaking are most likely to be reported as head-on or same direction crashes. These accounted for 38.1% of all injury crashes before installation and 35.4% after installation. The actual proportion of overtaking-related crashes would be less than these two values. There was an approximately even proportion of single vehicle and non-single vehicle crashes along the lengths of road where passing lanes were installed, both before and after their installation. Overall, the profile of injury crashes did not appear to have substantially changed since the installation of passing lanes.

The results in Table 3.1 show that injury crashes for most of the tested crash types were reduced by approximately 20% or more. Chi-Squared test results were statistically significant at a 5% confidence level for all crash types bar intersection crashes, providing confidence that most injury crash reductions were real.

On a site-by-site basis, 227 (52%) of the passing lane sites showed a reduction in crashes, with 208 (48%) showing an increase in crashes (Figure 3.2). Of these, 62 (14%) sites had no crashes after installation of the passing lane, while 77 (18%) had no crashes before installation. The Wilcoxon Signed-Rank test results were only significant for same direction crashes (Table 3.1). Student's T-test results were not valid for any of the comparisons as distributions did not fit the assumption of normality. These results suggest that, for a given site, there is an approximately equal likelihood that injury crashes will reduce or increase after installation of a passing lane. The median change in crashes before-after treatment was a reduction of 1.1%, and a wide variation was seen across the sites with a 25<sup>th</sup> percentile change of -71.8% (reduction) and a 75<sup>th</sup> percentile change of +217.1% (increase) (Table 3.2).

Figure 3.1: Types for injury crashes on passing lane sites before and after installation

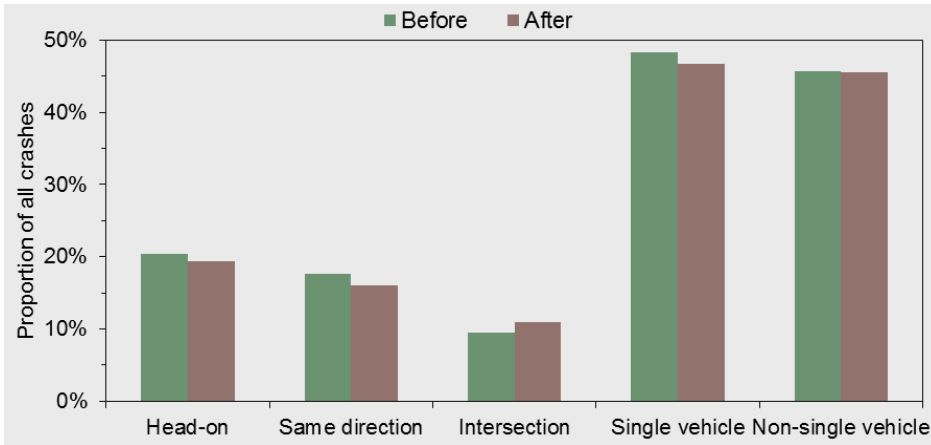
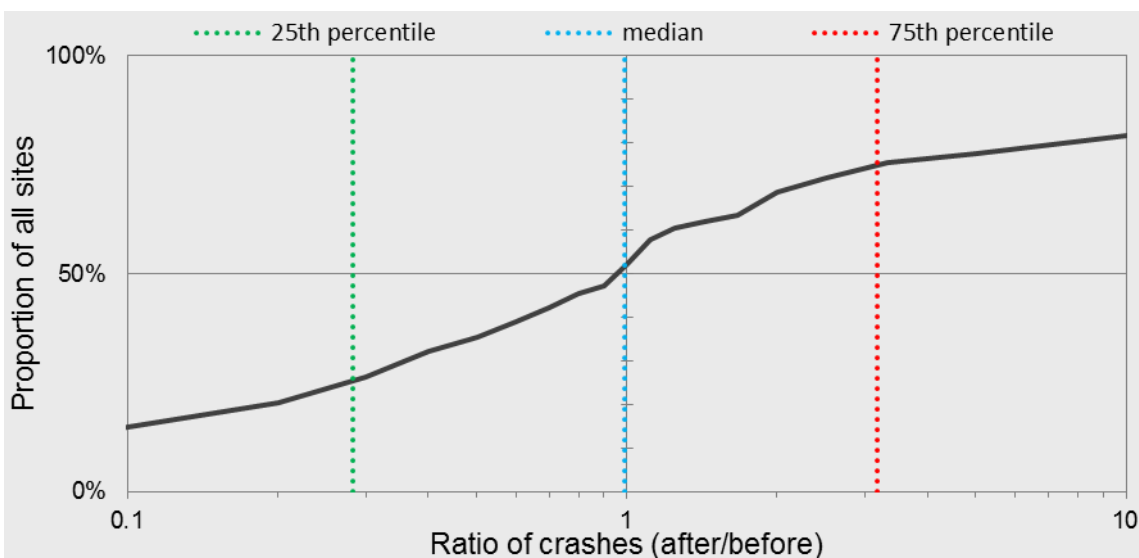


Table 3.1: Before-and-after analysis of injury crashes on passing lane sites

Crash type	Number of sites analysed	Number of injury crashes analysed	% change	Chi Squared p-value	Student's T-test p-value <sup>(2)</sup> (Shapiro-Wilk p-value)	Wilcoxon p-value
All types <sup>(1)</sup>	435	4019	-18.9%	0.000 (s <sup>(3)</sup> )	N/A (0.009)	0.192
Head-on crashes	274	802	-23.3%	0.000 (s)	N/A (0.000)	0.069
Same direction crashes	261	681	-27.9%	0.000 (s)	N/A (0.000)	0.004 (s)
Intersection crashes	169	408	-7.6%	0.428	N/A (0.000)	0.969
Single vehicle crashes	397	1913	-21.5%	0.000 (s)	N/A (0.000)	0.313
Non-single vehicle crashes	356	1835	-19.2%	0.000 (s)	N/A (0.000)	0.099

- <sup>1</sup> 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.
- <sup>2</sup> Student's T-test statistic given only if Shapiro-Wilk test-of-normality p-value > 0.05 (i.e. rejecting assumption of non-normality).
- <sup>3</sup> 's' means statistically significant.

Figure 3.2: Cumulative distribution of after/before crash ratios for passing lane sites



**Table 3.2: Median, 25<sup>th</sup> percentile and 75<sup>th</sup> percentile change in number of crashes on passing lane sites**

Crash type	Number of sites analysed	% change		
		25 <sup>th</sup> percentile	Median	75 <sup>th</sup> percentile
All types <sup>(1)</sup>	435	-71.8%	-1.1%	+217.1%
Head-on crashes	275	-(2)	-1.1%	-(2)
Same direction crashes	261	-(2)	-1.1%	-(2)
Intersection crashes	169	-(2)	-0.7%	-(2)
Single vehicle crashes	397	-83.5%	-1.1%	-(2)
Non-single vehicle crashes	356	-85.9%	-10.1%	+295.5%

1 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

2 Zero crashes in either before or after period; percentile not calculated.

Correlation pairs between before-and-after analysis results and specific parameters were evaluated using the R<sup>2</sup> statistical measure for the following:

- passing lane length
- vertical alignment
- speed limit
- average annual daily traffic (AADT).

None of the pairs showed substantial correlations between any of the crash types and parameters (Table 3.3).

**Table 3.3: Correlations between before-and-after analysis results and specific parameters for injury crashes on passing lane sites**

Crash type	Correlation (R <sup>2</sup> )			
	Passing lane length	Vertical alignment <sup>(2)</sup>	Speed limit	AADT
All types <sup>(1)</sup>	0.1%	2.3%	0.1%	0.0%
Head-on crashes	0.2%	0.4%	0.4%	0.2%
Same direction crashes	0.9%	4.5%	0.2%	0.0%
Intersection crashes	1.2%	0.2%	0.0%	1.7%
Single vehicle crashes	1.0%	2.5%	0.1%	0.2%
Non-single vehicle crashes	0.2%	0.1%	0.1%	0.2%

1 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

2 Based on data from two jurisdictions only. Vertical alignment measured as the proportion of analysed crashes occurring on a non-flat gradient.

Comparison between the jurisdictions suggests that the results were biased in favour of Jurisdiction 3, with over 90% of crashes occurring along passing lanes. Analysed individually, the results for the jurisdictions were largely statistically non-significant (Table 3.4). While the results suggest some notable points of interest, it would be unwise to read too much into these, as the low crash numbers in Jurisdictions 1 and 2 mean that the results for these jurisdictions are unlikely to be representative of any real effects.

Table 3.4: Before-and-after analysis of injury crashes on passing lane sites by jurisdiction

Crash type	Jurisdiction 1		Jurisdiction 2		Jurisdiction 3	
	No. of crashes analysed	% change	No. of crashes analysed	% change	No. of crashes analysed	% change
All types <sup>(1)</sup>	200	-5.9%	48	-16.4%	3 771	-19.3%
Head-on crashes	27	+16.5%	7	+168.3%	768	-25.1%
Same direction crashes	28	-48.7%	10	-28.4%	643	-25.1%
Intersection crashes	5	+62.7%	3	-100.0%	400	-6.8%
Single vehicle crashes	113	+39.2%	23	-30.8%	1 778	-23.9% (s <sup>(2)</sup> )
Non-single vehicle crashes	63	-23.9%	20	-12.3%	1 752	-19.0%

1 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

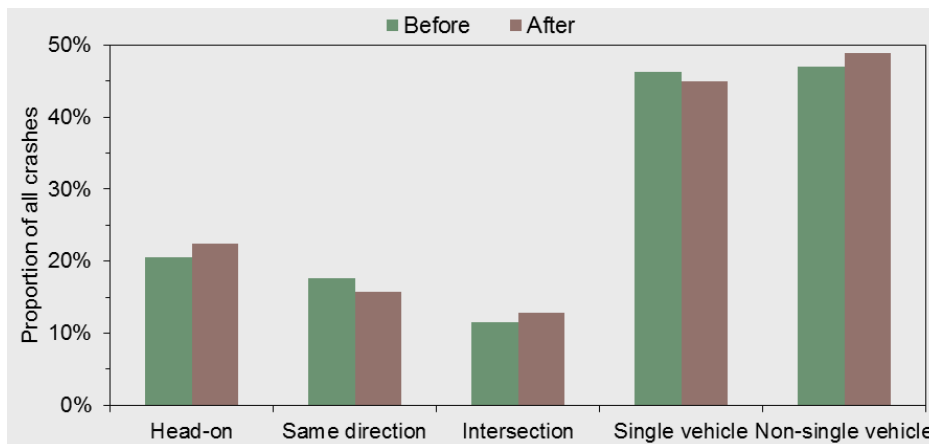
2 's' means statistically significant.

### Upstream sections

Crash data was provided by three jurisdictions for the analysis of injury crashes that occurred along the 2 km section upstream of where passing lanes were installed. Not all passing lanes had reported crashes for the analysis period and where no crashes were recorded, the upstream sections were excluded from the respective analysis.

Figure 3.3 illustrates the profile of crashes upstream of the passing lane. There appeared to be little change to the profile of crash type categories before-and-after the installation of passing lanes. Head-on and same direction crashes are crash types that overtaking crashes are most likely reported as. They represented 38.2% of injury crashes both before and after installation, combined.

Figure 3.3: Type of injury crashes upstream of passing lanes before and after installation



The before-and-after analysis of upstream sections showed an overall reduction in crashes after installation of passing lanes (Table 3.5). Of the 419 sites included in the analysis, 250 (60%) showed a reduction in crashes and 169 (40%) showed an increase in crashes. Some of the results were statistically significant according to both the Chi-Squared test and Wilcoxon Signed-Rank test. These results suggest that injury crashes had reduced after installation of passing lanes and that this reduction could be expected at more than half of all sites. The results suggest no change in the likelihood of head-on and intersection crashes upstream of passing lanes after their installation.

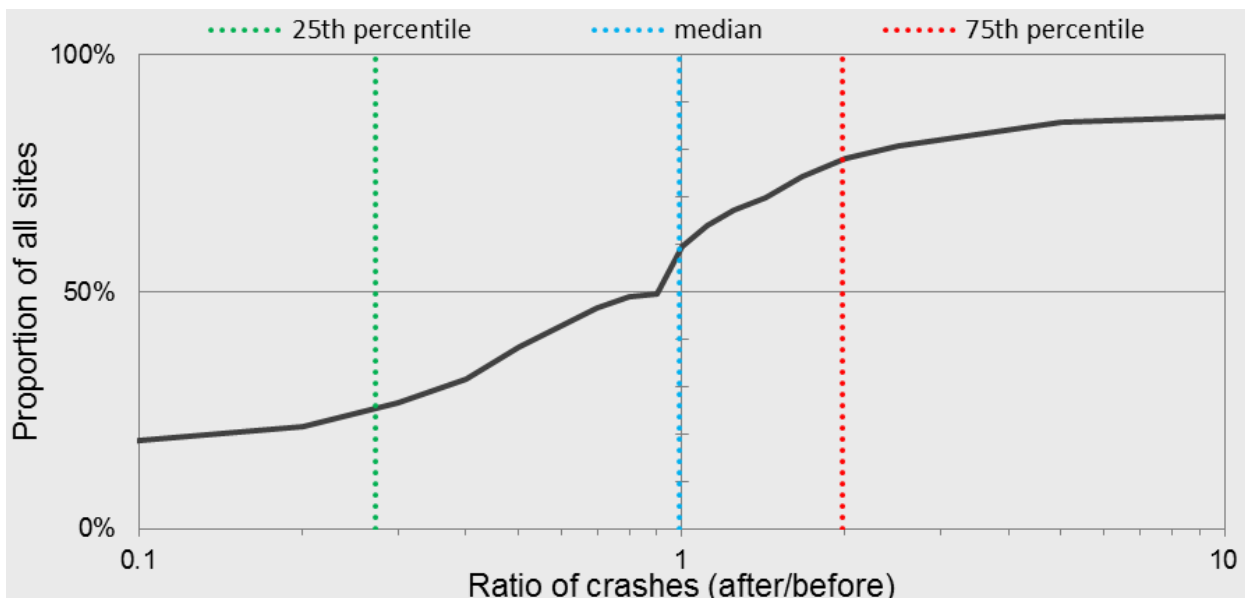
Table 3.5: Before-and-after analysis of injury crashes upstream of passing lanes

Crash type	Number of sites analysed	Number of injury crashes analysed	% change	Chi Squared p-value	Student's T-test p-value <sup>(2)</sup> (Shapiro-Wilk p-value)	Wilcoxon p-value
All types <sup>(1)</sup>	419	2712	-17.6%	0.000 (s <sup>(3)</sup> )	N/A (0.034)	0.000 (s)
Head-on crashes	248	581	-10.1%	0.200	N/A (0.000)	0.090
Same direction crashes	224	455	-26.1%	0.001 (s)	N/A (0.000)	0.000 (s)
Intersection crashes	146	329	-8.3%	0.431	N/A (0.000)	0.353
Single vehicle crashes	368	1239	-20.0%	0.000 (s)	N/A (0.000)	0.016 (s)
Non-single vehicle crashes	339	1298	-14.3%	0.005 (s)	N/A (0.000)	0.012 (s)

- 1 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.
- 2 Student's T-test statistic given only if Shapiro-Wilk test-of-normality p-value > 0.05 (i.e. rejecting assumption of non-normality).
- 3 's' means statistically significant.

Two hundred and fifty (60%) of the analysed upstream sites showed a reduction in crashes, while 208 (40%) showed an increase in crashes as shown in Figure 3.4. Seventy-five (18%) sites had no crashes after installation of the passing lane, while 54 (13%) had no crashes before installation. The Wilcoxon Signed-Rank test results were significant for all but head-on and intersection type crashes (Table 3.5). Student's T-test results were not valid for any of the comparisons as distributions did not fit the assumption of normality. The median change in crashes before-and-after treatment was a reduction of 1.1%, though a wide variation was seen across the sites with a 25<sup>th</sup> percentile change of -72.7% (reduction) and a 75<sup>th</sup> percentile change of +97.7% (increase) (Table 3.6).

Figure 3.4: Cumulative distribution of after/before crash ratios upstream of passing lanes



**Table 3.6: Median, 25<sup>th</sup> percentile and 75<sup>th</sup> percentile change in number of crashes upstream of passing lanes**

Crash type	Number of sites analysed	% change		
		25 <sup>th</sup> percentile	Median	75 <sup>th</sup> percentile
All types <sup>(1)</sup>	419	-72.7%	-1.1%	+97.7%
Head-on crashes	248	-(2)	-1.1%	-(2)
Same direction crashes	224	-(2)	-50.6%	-(2)
Intersection crashes	146	-(2)	-1.1%	-(2)
Single vehicle crashes	368	-(2)	-18.1%	+199.5%
Non-single vehicle crashes	339	-(2)	-1.1%	+196.6%

1 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

2 Zero crashes in either before or after period; percentile not calculated.

Correlation pairs between before-after analysis results and specific parameters were evaluated using the R<sup>2</sup> statistical measure for speed limit and AADT. None of the pairs showed substantial correlations between any of the crash types and parameters (Table 3.7).

**Table 3.7: Correlations between before-and-after analysis results and specific parameters for injury crashes upstream of passing lanes**

Crash type	Correlation (R <sup>2</sup> )	
	Speed limit	AADT
All types (see note)	0.0%	0.1%
Head-on crashes	1.3%	0.0%
Same direction crashes	0.3%	0.2%
Intersection crashes	0.2%	1.7%
Single vehicle crashes	0.1%	0.5%
Non-single vehicle crashes	0.5%	0.1%

Note: 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

Results per jurisdiction is shown in Table 3.8. The results were biased towards Jurisdiction 3, owing to the nearly 90% of crashes occurring in this jurisdiction. Results were mostly statistically significant for Jurisdiction 3 but not for Jurisdictions 1 and 2. Any differences in results between the jurisdictions are unlikely to be representative of any real differences, owing to the low number of crashes in Jurisdictions 1 and 2.

**Table 3.8: Before-after analysis of injury crashes upstream of passing lanes by jurisdiction**

Crash type	Jurisdiction 1		Jurisdiction 2		Jurisdiction 3	
	No. of crashes analysed	% change	No. of crashes analysed	% change	No. of crashes analysed	% change
All types <sup>(1)</sup>	212	-22.8%	95	-11.8%	2405	-17.3% (s <sup>(2)</sup> )
Head-on crashes	29	+26.3%	18	+33.7%	534	-12.9%
Same direction crashes	34	-44.0%	17	+20.1%	404	-25.9% (s)
Intersection crashes	17	-8.8%	6	-78.8%	306	-6.1%
Single vehicle crashes	114	-10.8%	51	-19.0%	1074	-21.0% (s)
Non-single vehicle crashes	75	-23.6%	41	+1.6%	1182	-14.2% (s)

1 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

2 's' means statistically significant.

### Downstream sections

Crash data was provided by three jurisdictions for the analysis of injury crashes that occurred along the 5 km long sections of road downstream of where passing lanes were installed. Not all passing lanes had reported crashes for the analysis period and where no crashes were recorded, the downstream sections were excluded from the analysis.

Figure 3.5 profiles the crash types downstream of passing lanes before and after their installation. Crashes involving overtaking would be included in head-on and same direction crashes, which accounted for 36.4% of injury crashes before installation and 36.2% after installation.

Figure 3.5: Types of injury crashes downstream of passing lanes before and after installation

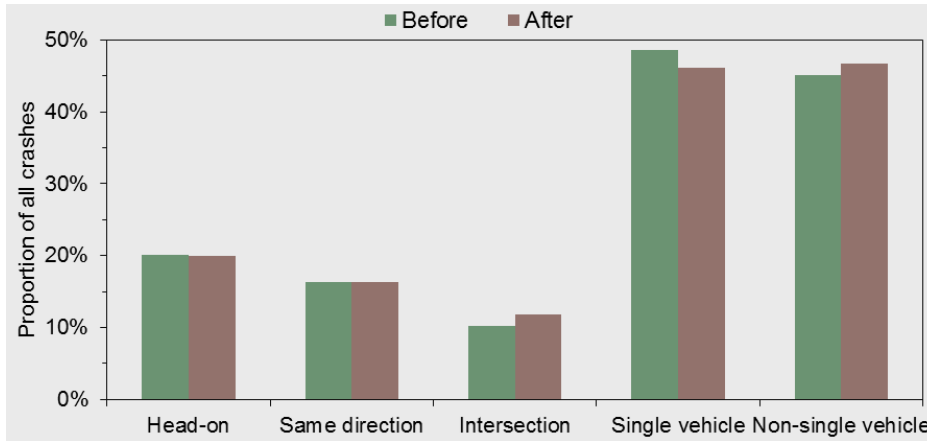


Table 3.9 summarises the results of before-and-after analysis. While injury crash reductions of around 10% were found, most of these results were not statistically significant. The Wilcoxon Signed-Rank test results were not significant for any of the crash types. Student's T-test results were not valid for any of the comparisons as distributions did not fit the assumption of normality. Given the large number of sites and injury crashes available for the before and after periods, the results seem to suggest that the installation of passing lanes has little effect on injury crashes downstream of the passing lanes.

Table 3.9: Before-and-after analysis of injury crashes downstream of passing lanes

Crash type	Number of sites analysed	Number of injury crashes analysed	% change	Chi Squared p-value	Student's T-test p-value <sup>(2)</sup> (Shapiro-Wilk p-value)	Wilcoxon p-value
All types <sup>(1)</sup>	425	3 624	-10.2%	0.002 (s <sup>(3)</sup> )	N/A (0.002)	0.460
Head-on crashes	248	647	-11.1%	0.135	N/A (0.000)	0.669
Same direction crashes	216	528	-10.5%	0.205	N/A (0.000)	0.917
Intersection crashes	153	355	+4.3%	0.693	N/A (0.000)	0.518
Single vehicle crashes	368	1534	-14.7%	0.002 (s)	N/A (0.000)	0.911
Non-single vehicle crashes	330	1484	-7.0%	0.164	N/A (0.000)	0.619

1 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.  
 2 Student's T-test statistic given only if Shapiro-Wilk test-of-normality p-value > 0.05 (i.e. rejecting assumption of non-normality).  
 3 's' means statistically significant.

Two hundred and eight (49%) of the analysed downstream sites showed a reduction in crashes, while 217 (51%) showed an increase in crashes (Figure 3.6). Of these, 78 (18%) sites had no crashes after installation of the passing lane, while 133 (31%) had no crashes before installation. The median change in crashes before-after treatment was an increase of 2.7%. The 25<sup>th</sup> percentile change was -78.3% (reduction) but the 75<sup>th</sup> percentile change could not be calculated due to many sites having no crashes before installation (Table 3.10).

Figure 3.6: Cumulative distribution of after/before crash ratio downstream of passing lanes

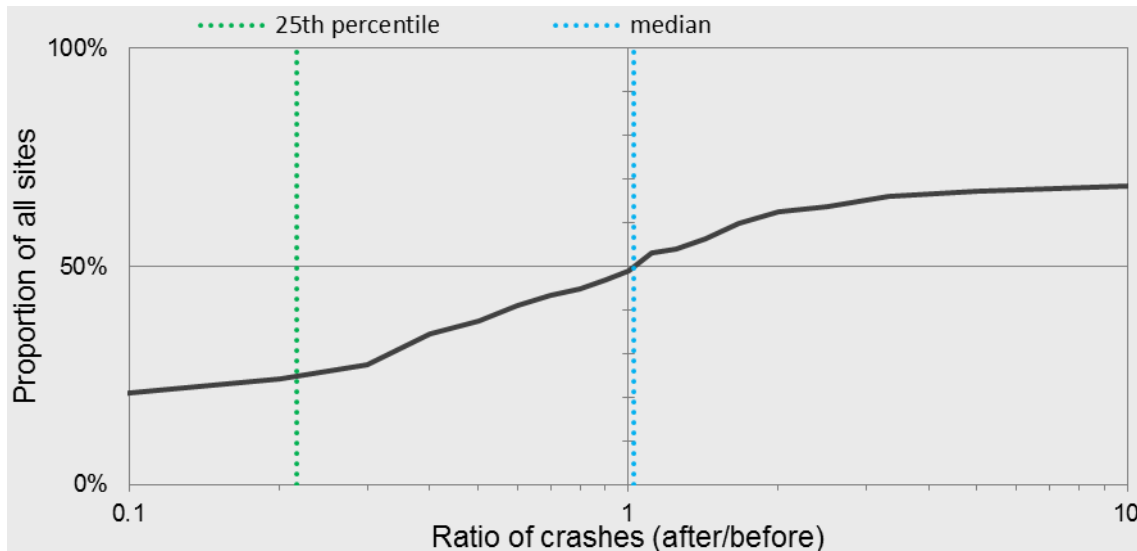


Table 3.10: Median, 25<sup>th</sup> percentile and 75<sup>th</sup> percentile change in crashes downstream of passing lanes

Crash type	Number of sites analysed	% change		
		25 <sup>th</sup> percentile	Median	75 <sup>th</sup> percentile
All types <sup>(1)</sup>	425	-78.3%	+2.7%	-(2)
Head-on crashes	248	-(2)	-1.1%	-(2)
Same direction crashes	216	-(2)	-1.1%	-(2)
Intersection crashes	153	-(2)	-6.7%	-(2)
Single vehicle crashes	368	-86.2%	-0.9%	-(2)
Non-single vehicle crashes	330	-(2)	-1.1%	-(2)

1 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

2 Zero crashes in either before or after period; percentile not calculated.

Correlations between before-after analysis results and passing lane length, speed limit and AADT were evaluated. There were no apparent correlations between the analysis results and these parameters (Table 3.11).

**Table 3.11: Correlations between before-after analysis results and specific parameters for injury crashes downstream of passing lanes**

Crash type	Correlation (R <sup>2</sup> )		
	Passing lane length	Speed limit	AADT
All types (see note)	0.0%	0.1%	1.1%
Head-on crashes	1.3%	1.3%	0.4%
Same direction crashes	0.2%	0.0%	0.4%
Intersection crashes	0.1%	0.1%	2.6%
Single vehicle crashes	0.1%	0.1%	0.5%
Non-single vehicle crashes	0.1%	0.2%	1.0%

Note: 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

Comparison between the jurisdictions suggests that the results for downstream sections of road were also biased in favour of Jurisdiction 3, with 80% of the analysed crashes occurring in this jurisdiction. The results were not statistically significant (Table 3.12).

**Table 3.12: Before-and-after analysis of injury crashes downstream of passing lanes by jurisdiction**

Crash type	Jurisdiction 1		Jurisdiction 2		Jurisdiction 3	
	No. of crashes analysed	% change <sup>(2)</sup>	No. of crashes analysed	% change	No. of crashes analysed	% change
All types <sup>(1)</sup>	387	-8.9%	281	+0.3%	2566	-11.5%
Head-on crashes	51	+35.3%	39	+71.7%	557	-18.3%
Same direction crashes	81	-13.7%	62	+29.0%	385	-15.0%
Intersection crashes	39	+19.8%	43	-36.8%	273	+10.4%
Single vehicle crashes	183	-16.7%	125	-18.5%	1226	-14.1%
Non-single vehicle crashes	162	+5.2%	144	+12.8%	1178	-10.7%

<sup>1</sup> 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

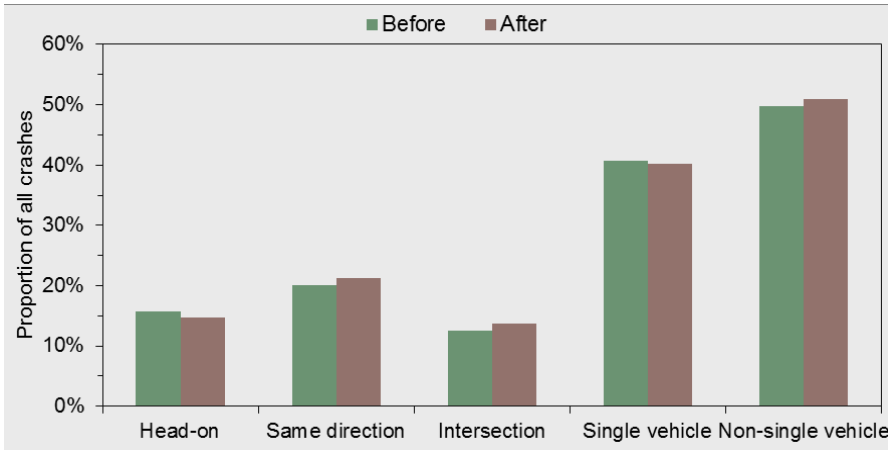
<sup>2</sup> None of the results were statistically significant.

## Routes

Crash data was provided by two jurisdictions for the analysis of injury crashes that occurred along routes where passing lanes were installed. Not all routes had reported crashes of specific types for the analysis period and where no crashes were recorded, the routes were excluded from the analysis.

Figure 3.7 profiles the crash types on routes. There was little change in the profile of crashes after the installation of passing lanes. Head-on and same direction crashes contributed to a combined 35.7% of all crashes before installation of passing lanes and 36.0% after installation.

Figure 3.7: Profile of crash type categories for injury crashes along routes where passing lanes were installed



A statistically significant reduction in all crash types was found in the before-and-after analysis summarised in Table 3.13. All analysed crash types showed a reduction in crashes after installation of passing lanes along the routes where they were installed. The Wilcoxon Signed-Rank test results were significant for all types, single vehicle and non-single vehicle types of crashes, as was the Student’s T-test result (Table 3.13). All results except that of intersection type crashes were statistically significant according to the Chi-squared test results.

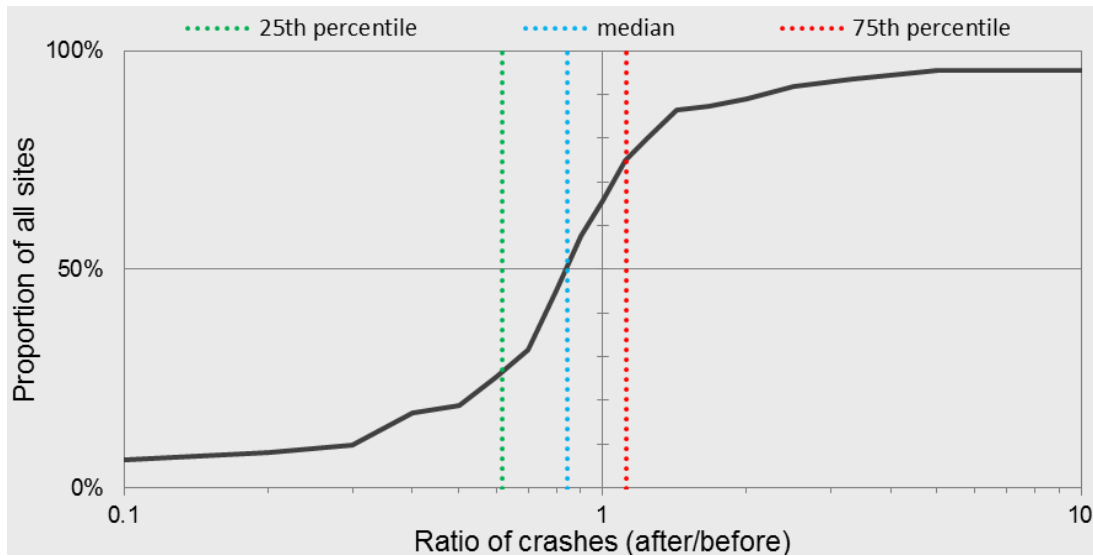
Table 3.13: Before-after analysis of injury crashes along routes where passing lanes were installed

Crash type	Number of sites	Number of injury crashes analysed	% change	Chi Squared p-value	Student’s T-test p-value <sup>(2)</sup> (Shapiro-Wilk p-value)	Wilcoxon p-value
All types <sup>(1)</sup>	111	13 287	–15.9%	0.000 (s <sup>(3)</sup> )	0.000 (0.171) (s)	0.000 (s)
Head-on crashes	89	2 019	–21.0%	0.000 (s)	N/A (0.033)	0.088
Same direction crashes	87	2 748	–10.8%	0.003 (s)	0.136 (0.265)	0.273
Intersection crashes	73	1 740	–7.8%	0.090	0.304 (0.295)	0.443
Single vehicle crashes	107	5 385	–16.8%	0.000 (s)	0.014 (0.891) (s)	0.013 (s)
Non-single vehicle crashes	105	6 676	–13.7%	0.000 (s)	0.019 (0.507) (s)	0.024 (s)

1 ‘All types’ contain crashes of any type, including crash types not considered in any of the specific crash type categories.  
 2 Student’s T-test statistic given only if Shapiro-Wilk test-of-normality p-value > 0.05 (i.e. rejecting assumption of non-normality).  
 3 ‘s’ means statistically significant.

The distribution of change in crashes is shown in Figure 3.8. Seventy-three (66%) of the analysed routes showed a reduction in crashes, with 38 (34%) showing an increase in crashes. Six (5%) sites had no crashes after installation of the passing lane, and 5 (5%) had no crashes before installation. The median change in crashes before-after treatment was a reduction of 15.6%. A variation was seen across the sites with a 25<sup>th</sup> percentile change of –38.5% (reduction) and a 75<sup>th</sup> percentile change of +12.3% (increase) (Table 3.14).

Figure 3.8: Cumulative distribution of after/before crash ratio for routes


 Table 3.14: Median, 25<sup>th</sup> percentile and 75<sup>th</sup> percentile change in crashes on routes

Crash type	Number of routes analysed	% change <sup>(2)</sup>		
		25 <sup>th</sup> percentile	Median	75 <sup>th</sup> percentile
All types <sup>(1)</sup>	111	-38.5%	-15.6% <sup>4</sup>	+12.3%
Head-on crashes	89	-48.4%	-18.6%	+86.8%
Same direction crashes	87	-51.9%	-10.3%	+42.6%
Intersection crashes	73	-45.3%	-6.1%	34.5%
Single vehicle crashes	107	-40.8%	-14.1%	+34.5%
Non-single vehicle crashes	105	-44.5%	-11.0%	+23.7%

1 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

2 Change in observed number of crashes after installation of passing lanes considering control for each jurisdiction.

Correlations between before-after analysis results and passing lane density, speed limit and average AADT were evaluated. There were no apparent correlations between the analysis results and these parameters as shown in Table 3.15.

Table 3.15: Correlations between before-after analysis results and specific parameters for injury crashes on routes

Crash type	Correlation (R <sup>2</sup> )		
	Speed limit	AADT	Passing lane density
All types (see note)	0.0%	1.6%	0.0%
Head-on crashes	0.3%	3.0%	0.2%
Same direction crashes	1.0%	4.3%	7.1%
Intersection crashes	1.5%	0.0%	0.7%
Single vehicle crashes	0.1%	0.9%	1.0%
Non-single vehicle crashes	0.3%	2.5%	2.1%

Note: 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

Assessment by jurisdiction found that there was a large amount of variation between the jurisdictions as shown in Table 3.16. The aggregated results (see Table 3.13) were largely influenced by Jurisdiction 3, which had a substantially greater number of crashes than the other two jurisdictions combined. While the results for Jurisdiction 3 showed a nearly uniform reduction for all types of crashes, the results for Jurisdictions 1 and 2 were more varied. It was noted that there was a significant increase in head-on crashes in Jurisdiction 2.

**Table 3.16: Before-and-after analysis of injury crashes on routes by jurisdiction**

Crash type	Jurisdiction 1		Jurisdiction 2		Jurisdiction 3	
	No. of crashes analysed	% change <sup>(2)</sup>	No. of crashes analysed	% change	No. of crashes analysed	% change
All types <sup>(1)</sup>	1 246	-26.4% (s <sup>(3)</sup> )	1 878	+6.8%	10 163	-18.2% (s)
Head-on crashes	129	+8.8%	169	+34.6% (s)	1 721	-26.9% (s)
Same direction crashes	192	-15.1%	410	+16.9%	2 146	-15.0%
Intersection crashes	111	+14.1%	400	-7.8%	1 229	-9.6%
Single vehicle crashes	591	-4.1%	779	+2.0%	4 015	-21.7% (s)
Non-single vehicle crashes	411	-3.7%	979	+8.7%	5 286	-18.1% (s)

1 'All types' contain crashes of any type, including crash types not considered in any of the specific crash type categories.

2 Change in observed number of crashes after installation of passing lanes considering control for each jurisdiction.

3 's' means statistically significant.

### 3.1.3 Limitations

Though care was undertaken to not introduce bias into the analyses, there were a number of limitations associated with the study that could lead to bias:

- There was bias towards jurisdictions that provided more sites/crashes in the crash data. This was somewhat offset by including individual analysis of each jurisdiction to better understand the differences between findings from each jurisdiction.
- No information was gathered about other works that were undertaken at the sites during the analysis periods that could have affected the outcome of the analyses. Bias from this limitation was somewhat reduced by analysing a large sample. Thus, any other treatments were likely to affect only a small proportion of sites (e.g. targeted treatments such as blackspot or blacklength treatments) or be implemented on a more widespread basis such that they would also affect the control sample (e.g. mass action programs and regular maintenance).
- Injury crashes on rural two-lane/two-way roads with a speed limit of 80 km/h or more were used for the control sample. While these roads are assumed to represent the types of roads that passing lanes are installed along, it is important to recognise that the observed effect at these sites may be different to what would be expected at each site where a passing lane was installed. Again, this limitation was somewhat offset by analysing a large sample.
- Applying a correction, or no correction at all, to crash data means that the analysis will be biased towards some sites in the sample when undertaking evaluations of ranking or correlation. For this project, a correction was applied to the before and after number of crashes for each site (discussed above). The relevance of findings can be bolstered by drawing the use of corrections from a well-developed theory. However, it should be understood by the reader that bias will always be present and that this bias will affect the findings of the study.
- Much of the analysis was hindered by low crash numbers. Many sites had no more than one or two crashes in the before and after periods. Where a sufficient number of sites are available, this issue can be overcome by evaluating data for a large sample size. This was not always possible and meant that results were often statistically non-significant.

## 3.2 Lane-use, Speed and Headway Analysis

This section presents an analysis of lane use, speed and headway around passing lanes. The data for the analysis was provided by DPTI.

### 3.2.1 Method

#### Survey location and period

DPTI commissioned data collection from six passing lanes along three rural highways in South Australia in April and May 2015. The period of data collection was seven days for each passing lane. An additional seven days of data was collected from traffic counters along each passing lane for validation purposes. Validation was conducted to ensure that motorist behaviour was not significantly affected by the survey equipment.

The speed limit along all three roads where the surveyed passing lanes were located was 110 km/h.

#### Survey layout

The traffic surveys were carried out using traffic counters, with pneumatic tubes laid across the roadway to detect vehicles. Two groupings of traffic counters were used:

- one group along the three-lane/two-way section of roadway containing the passing lane
- one group were used to survey the surrounding two-lane/two-way section of roadway.

At points along the three-lane/two-way sections, two traffic counters were used to collect data on the left lane (one traffic counter) and the right and opposing direction lanes (one traffic counter). Pneumatic tubing was laid over only the right half of the right lane to avoid double counting of vehicles straddling both the left and right lanes of the passing lane (see Figure 3.9 and Figure 3.10). For the two-lane/two-way sections of roadway, one traffic counter was used to collect data for both lanes which ran in opposing directions.

Figure 3.9: Traffic counter locations and nomenclature along the surveyed passing lane sites

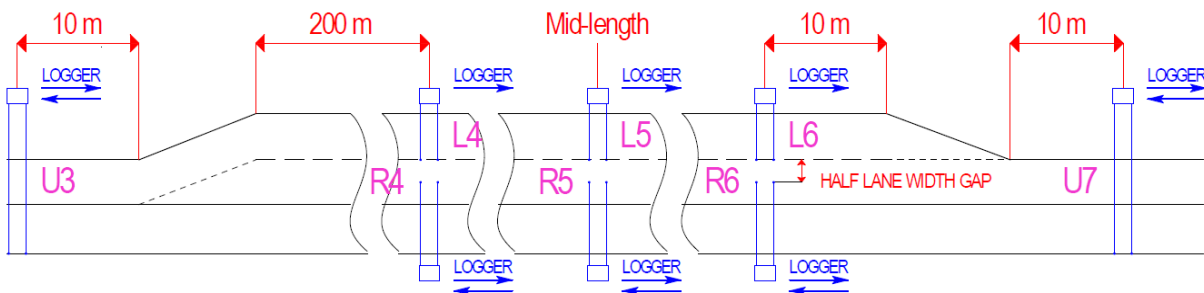


Figure 3.10: Traffic counter locations and nomenclature either side of the surveyed passing lane sites



The data collection points were as follows:

- 10 m from either side of the tapers were selected for data collection (i.e. U3, L6/R6 and U7). These points were used to collect data as close as practical to the tapers, where a high number of vehicle conflicts were thought to occur.
- 200 m after the diverge taper was selected for data collection to allow enough space for overtaking vehicles to change lanes and accelerate to a desired overtaking speed (i.e. L4/R4).
- Mid-way along the passing lane was selected for data collection wherein vehicles on both lanes of the passing lane settled to a comfortable travel speed (i.e. L5/R5).

- Traffic counters were placed symmetrically (where possible) along the two-lane/two-way section of roadway on both sides of the passing lane (i.e. U1, U2, D8 and D9). Preferable distances of 2 km and 5 km from the passing lane were used, however the actual distances were adjusted when it was practical to do so.
- Data was also collected from vehicles travelling along the opposing direction lane at the same locations above.

The locations of the surveyed passing lanes and the placement of the traffic counters were determined to ensure that traffic counters are placed away from potential sources of bias (such as intersections and townships) and where possible, adjacent to each other.

### Collected data

Data were collected using the traffic counters and extracted. While a wide range of data can be extracted from the traffic counters, the data of interest to this study were:

- time of vehicle count
- vehicle location (i.e. lane)
- vehicle direction
- vehicle speed
- vehicle to vehicle gap (based on headway and vehicle length measurements)
- vehicle classification.

### Validation of survey method

Due to the high number of traffic counters that were placed on comparatively short sections of roadway, there was a possibility that these may affect a driver’s speed behaviour and therefore skew the results of the surveys. In order to test the validity of the data collection method, a reduced number of traffic counters were placed at each passing lane one week before the beginning of the survey. These reduced numbers of traffic counters used during the validation stage were expected to have significantly less effect on drivers than the full number of traffic counters used in the surveys. The validation stage reduced the number of traffic counters along each passing lane from five in each lane to only one in each lane. Analysis of the validation data sets indicated no perceptible change in driver behaviour between the validation and survey periods.

## 3.2.2 Results

### Lane usage on the passing lane

Table 3.17 illustrate the proportion of traffic on the right lane. Only 13% to 28% of the traffic used the right lane, which means that the majority of the traffic used the left lane.

Table 3.17: Proportion of vehicles using the right lane

Site		Proportion in right lane on the passing lane		
Road	Passing lane	Start (L1/R1)	Midway (L2/R2)	End (L3/R3)
1	A	13.3%	14.1%	36.8%
	B	12.1%	15.7%	32.6%
2	C	12.7%	13.1%	22.3%
	D	13.0%	11.0%	31.6%
3	E	15.7%	10.6%	17.4%
	F	19.4%	13.5%	22.8%
Average		14.1%	13.2%	27.9%

### Speed

The speed profiles of each passing lane, showing the 85<sup>th</sup> percentile speeds at each traffic counter location, are shown in Figure 3.11 to Figure 3.16.

Figure 3.11: 85<sup>th</sup> percentile speeds for Road 1, Passing Lane A

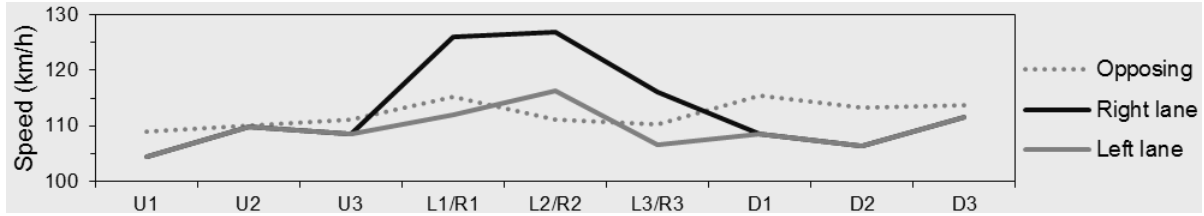


Figure 3.12: 85<sup>th</sup> percentile speeds for Road 1, Passing Lane B

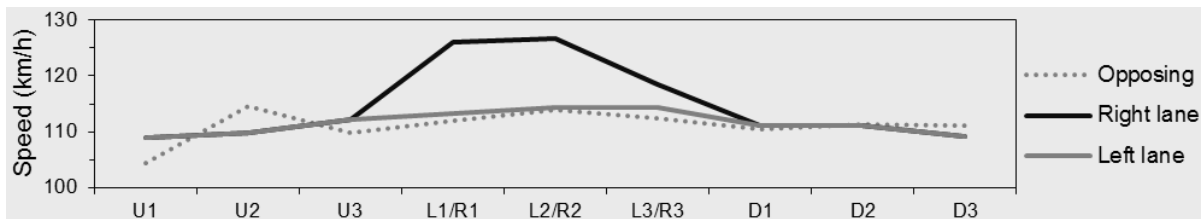


Figure 3.13: 85<sup>th</sup> percentile speeds for Road 2, Passing Lane C

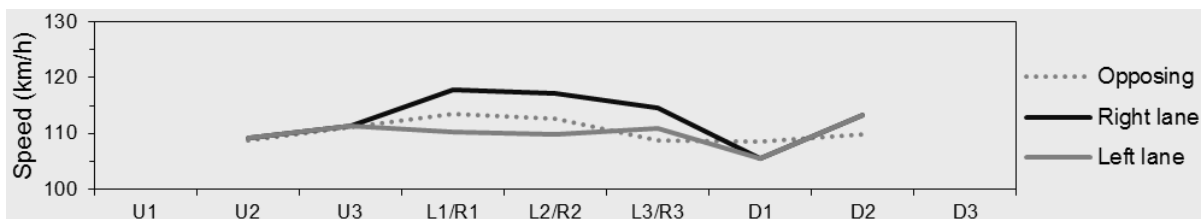


Figure 3.14: 85<sup>th</sup> percentile speeds for Road 2, Passing Lane D

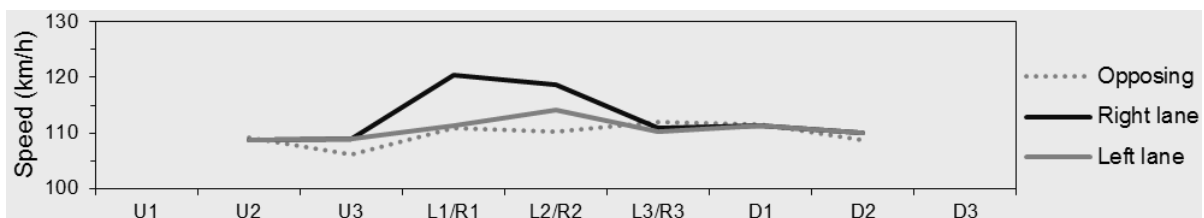


Figure 3.15: 85<sup>th</sup> percentile speeds for Road 3, Passing Lane E

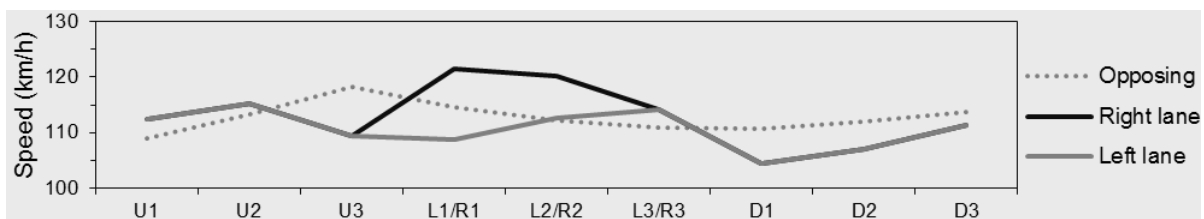
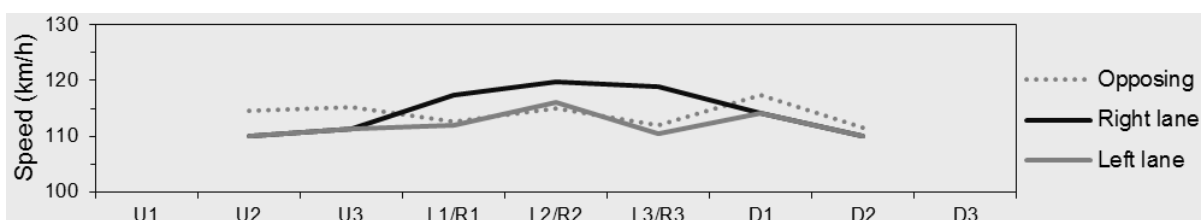


Figure 3.16: 85<sup>th</sup> percentile speeds for Road 3, Passing Lane F



Comparisons of the left and right lanes along the length of the passing lanes showed large and statistically significant differences in 85<sup>th</sup> percentile speeds (Table 3.18). The largest difference was observed at the start of the passing lanes, with an average difference in 85<sup>th</sup> percentile speeds of 10.3 km/h. As traffic progressed down the length of each passing lane, the average difference appeared to reduce, though right lane speeds only started to reduce at the last traffic counter position before the merge taper. Like the comparisons of the left and right lanes, comparisons of the opposing and right lanes showed large and statistically significant differences in 85<sup>th</sup> percentile speeds. Again, right lane traffic was on average nearly 10 km/h faster than traffic in the opposing lane.

**Table 3.18: 85<sup>th</sup> percentile speed on the right and left lane on passing lanes**

Location on the passing lane	Average of 85 <sup>th</sup> percentile speeds, km/h		Difference, km/h	Student's T-test p-value	Wilcoxon p-value
	Right	Left			
Start (L1/R1)	121.5	111.2	+10.3	0.001 (s), see note	0.028 (s)
Midway (L2/R2)	121.6	113.9	+7.6	0.005 (s)	0.028 (s)
End (L3/R3)	115.5	111.1	+4.4	0.027 (s)	0.043 (s)

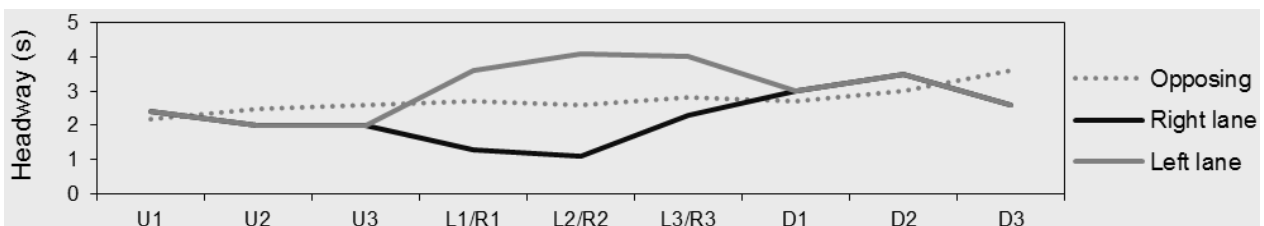
Note: 's' means statistically significant.

Comparisons were also undertaken between traffic counter locations upstream, along and downstream of the passing lanes. Not surprisingly, there were large and statistically significant differences in 85<sup>th</sup> percentile speeds when the right lane of the passing lanes was compared to the upstream and downstream sections of road. On average, the right lane was more than 11 km/h faster than these other sections of road. Comparison between upstream of the passing lanes and along the left lane of the passing lanes also showed a statistically significant difference, with the left lane traffic being moderately faster. This faster speed was however not carried through to the downstream sections, with a statistically significant reduction in 85<sup>th</sup> percentile speed between the left lane of the passing lanes and downstream of the passing lanes. Additionally, there was no evidence of a statistically significant difference in 85<sup>th</sup> percentile speeds between the upstream and downstream sections of road.

### Headway

The headway profiles of each passing lane, showing the 15<sup>th</sup> percentile headways at each traffic counter location, are shown in Figure 3.17 to Figure 3.22.

**Figure 3.17: 15<sup>th</sup> percentile headways for Road 1, Passing Lane A**



**Figure 3.18: 15<sup>th</sup> percentile headways for Road 1, Passing Lane B**

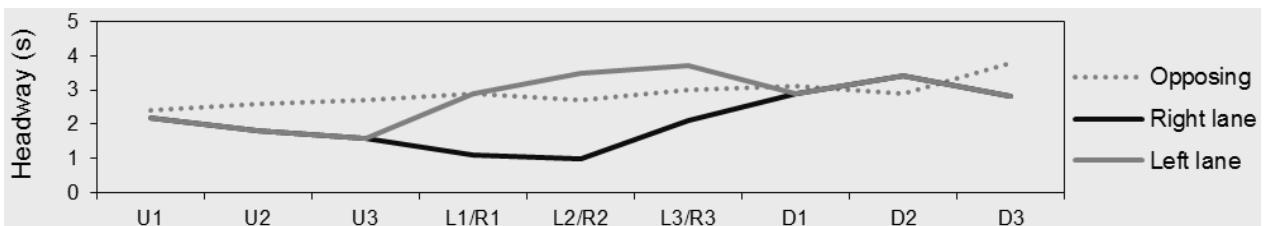


Figure 3.19: 15<sup>th</sup> percentile headways for Road 2, Passing Lane C

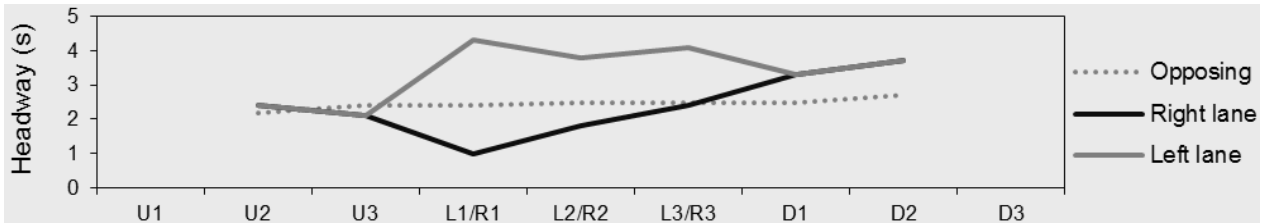


Figure 3.20: 15<sup>th</sup> percentile headways for Road 2, Passing Lane D

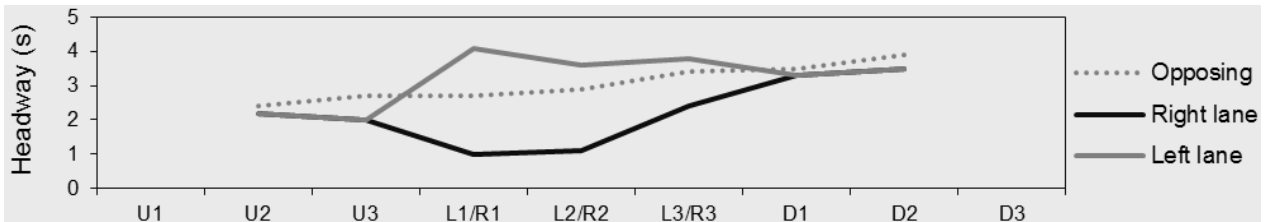


Figure 3.21: 15<sup>th</sup> percentile headways for Road 3, Passing Lane E

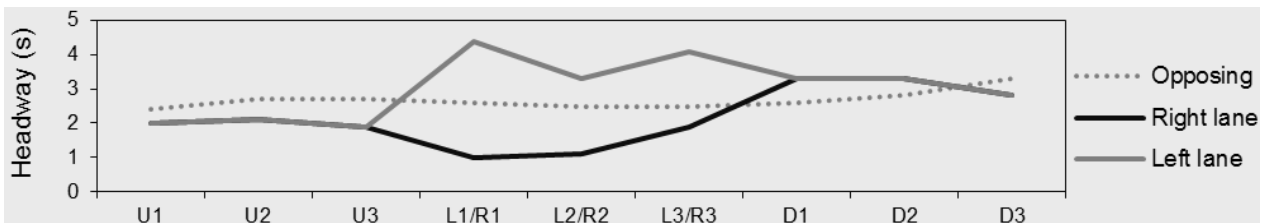
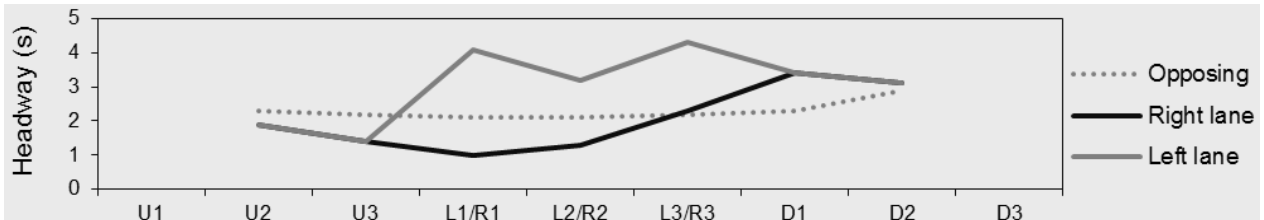


Figure 3.22: 15<sup>th</sup> percentile headways for Road 3, Passing Lane F



Comparisons of the left and right lanes along the length of the passing lanes showed large and statistically significant differences in 15<sup>th</sup> percentile headways (Table 3.19). Left lane headways are higher than the right lane headways. Small headways on the right lane suggests tailgating on the right lane as drivers begin to overtake slower traffic.

Comparisons were also then undertaken between traffic counter locations upstream and downstream of the passing lanes. As expected, 15<sup>th</sup> percentile headways downstream of the passing lanes are higher than upstream of the passing lanes. The mean difference of +1.4 s is statistically significant.

Table 3.19: 15<sup>th</sup> percentile headway on the right and left lane along passing lanes

Location	Avg. of 15 <sup>th</sup> percentile headways, s		Difference, s	Student's T-test p-value	Wilcoxon p-value
	Right	Left			
Start (L1/R1)	1.1	3.9	-2.8	0.000 (s)	0.027 (s)
Midway (L2/R2)	1.2	3.6	-2.4	0.000 (s)	0.027 (s)
End (L3/R3)	2.2	4.0	-1.8	0.000 (s)	0.027 (s)

Note: 's' means statistically significant.

### 3.3 Overtaking, Speed and Gap Analysis

This section examines motorist overtaking behaviour through the analysis of the following:

- proportion of overtaking undertaken on a passing lane
- overtaking speed
- space gap between vehicles when overtaking.

The data for the analysis was collected through an instrumented vehicle survey. The instrumented vehicle data was provided by DPTI.

#### 3.3.1 Method

The surveys were conducted using an instrumented vehicle equipped with video cameras and Lidar sensors. The instrumented vehicle surveys were undertaken by the Centre for Automotive Safety Research (CASR) for the DPTI in South Australia.

#### Survey location and period

Three sections of rural highway were surveyed including one section on the Augusta Highway and two sections on the Dukes Highway. The selected sections had the following attributes:

- straight and flat
- passing lanes with a minimum length of 1.5 km (including tapers)
- passing lanes located at least 1 km from the nearest point of traffic flow interruption, such as changes of speed limit, townships and major intersections
- speed limit of 110 km/h.

The surveys were conducted during the period April and May 2015.

#### Data collection technology

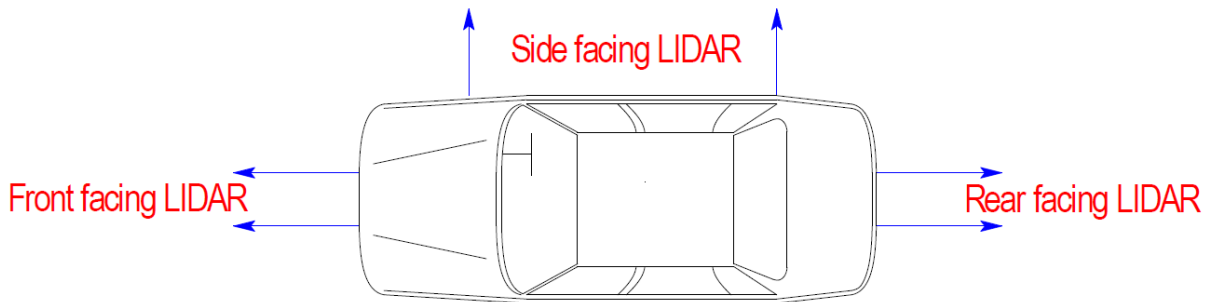
Data were collected using six Light Detection and Ranging (LIDAR) sensors placed at the front (two units), rear (two units) and to the right side of the instrumented vehicle (two units) (see Figure 3.23). This data was used to calculate the distance between the instrumented vehicle and other vehicles behind (rear mounted LIDAR) and in front (front mounted LIDAR). The side mounted LIDAR was used to calculate the differential speed between the instrumented vehicle and another vehicle passing to the right.

There are certain limitations with the setup of LIDAR sensors used on the instrumented vehicle. These limitations affected both the data that could be recorded and the proportion of collected data that could be used. These limitations are as follows:

- The LIDAR sensors had a maximum range of approximately 40 m.
- The direction of each front/rear facing LIDAR was calibrated to detect only vehicles directly in front/behind the instrumented vehicle (e.g. data issues arose where there were horizontal curves).
- The angle of each front/rear facing LIDAR was calibrated for level sight (e.g. data issues where there were vertical curves, which resulted in the detection of the road surface instead of another vehicle).
- The side facing LIDAR were prone to detecting traffic passing in the opposing direction to that of the instrumented vehicle and roadside objects.
- The LIDAR units suffered from noise detection.

Due to the above limitations, video data was also collected and analysed with the LIDAR data. This was done to collect data that were not possible using only the LIDAR units (e.g. types of vehicles) and to check the validity of data (e.g. to check for the possibility of errors due to the limitations of the LIDAR arrangements). Filters were developed and applied to minimise the effect of the above limitations of the LIDAR sensors.

Figure 3.23: Layout of the LIDAR units mounted to the instrumented vehicle



### Data collection method

Each survey route was driven multiple times in both directions. Two speeds were selected for the instrumented vehicle to travel at, with each run along a survey route being driven at one of these two speeds. The pre-determined speeds were 80 km/h and 90 km/h. These speeds were measured using Global Positioning System (GPS). The instrumented vehicle speedometer readings at these speeds were 88 km/h and 99 km/h, respectively. The speed of the instrumented vehicle was set using the vehicle's cruise control. The following protocol was used during each run along the survey route:

- The instrumented vehicle would sit at a pre-determined starting location before beginning the survey.
- The instrumented vehicle would begin at the start of the survey route when another vehicle was sighted upstream.
- Once the survey began, the instrumented vehicle would be maintained at the pre-determined speed while another vehicle was in sight upstream (behind) the instrumented vehicle. This speed was maintained unless unsafe to do so.
- If no other vehicle was in sight upstream, the instrumented vehicle would be slowed to about 60 km/h to allow another vehicle to catch up.
- If a slower vehicle was encountered in front of the instrumented vehicle, it was slowed to match the slower vehicle's speed. Overtaking was only undertaken along an overtaking lane if no other vehicles were behind the instrumented vehicle.
- Each run along the survey route was ended at a pre-defined location.

## 3.3.2 Results

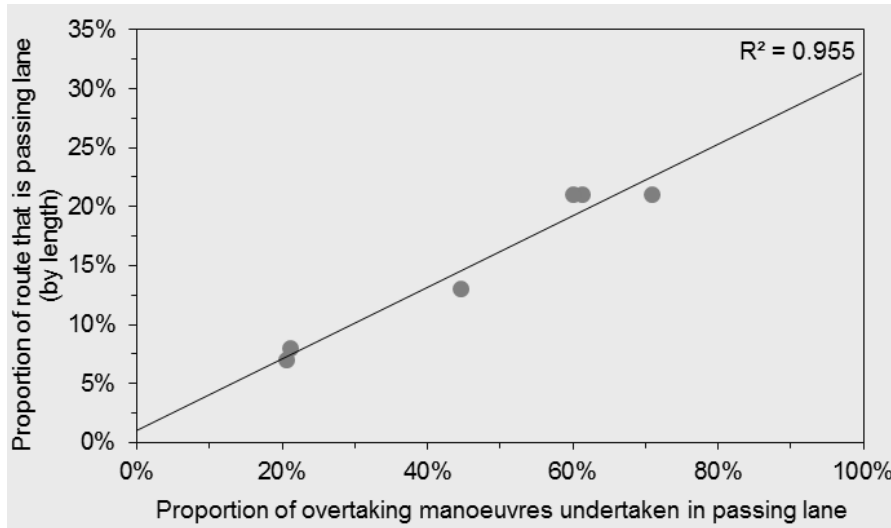
### Overtaking on the passing lane

A total of 379 overtaking manoeuvres were observed from 34 runs along the six survey routes (i.e. 2 directions x 3 sections). The proportion of overtaking manoeuvres undertaken within the passing lane and the proportion of the route length that is a passing lane (in length) is plotted in Figure 3.24. The figure suggests a strong correlation between the density of passing lanes along a route and the proportion of overtaking manoeuvres that were undertaken on passing lanes.

Correlation between passing lane density (measured as the proportion of a route by length that is a passing lane) and the proportion of overtaking manoeuvres that were undertaken inside of a passing lane confirm that the greater the density of passing lanes, the more overtaking that will be undertaken along them. The linear correlation between these two measures was statistically evaluated using the Pearson product-moment correlation coefficient. The  $R^2$  value was 95.5%, with a corresponding p-value of 0.000.

The installation of passing lanes thereby encourages motorists to execute overtaking manoeuvres in passing lanes, where it is considered safer.

Figure 3.24: Density of passing lanes versus the proportion of overtaking manoeuvres in passing lanes



### Overtaking speed

The speed differential between the survey vehicle and an overtaking vehicle was measured and classified by whether the manoeuvre was executed inside or outside the passing lane. The average speed differentials are shown in Table 3.20. On average, the speed differential on the passing lane was 2.6 km/h (or 12%) less than outside the passing lane. A lower speed differential is considered safer.

Table 3.20: Speed differentials between instrumented survey vehicle and overtaking vehicles

Highway section	Average overtaking speed differential (km/h) by survey route						Average of all survey routes (see note)
	Augusta		Dukes (section 1)		Dukes (section 2)		
	To	From	To	From	To	From	
Direction (to or from Adelaide)							
Inside passing lane	19.0	21.0	18.8	20.2	19.2	20.8	19.8
Outside passing lane	22.1	23.2	21.6	20.9	24.2	22.6	22.4

Note: Difference between overtaking speed differential inside and outside the passing lane are statistically significantly different (Student's T-test p-value = 0.002; Wilcoxon p-value = 0.028).

### Overtaking gap

The minimum gap between the survey vehicle and an overtaking vehicle was measured. The minimum gaps recorded during each overtaking manoeuvre were averaged over each survey route and are shown in Table 3.21. The results suggest longer gaps before overtaking inside of passing lanes compared to outside passing lanes. This suggests safer overtaking manoeuvres inside of the passing lane. However, the results are statistically insignificant at a confidence level of 95%.

Table 3.21: Minimum gap between survey (leading) and overtaking vehicle (following) before overtaking

Overtaking location	Average minimum gap before overtaking, m						Average of all survey routes (see note)
	Augusta		Dukes (section 1)		Dukes (section 2)		
	To	From	To	From	To	From	
Direction (to or from Adelaide)							
Inside passing lane	27.81	20.39	13.79	20.58	17.13	19.36	19.80
Outside passing lane	17.82	17.34	15.58	12.01	18.12	13.94	15.80

Note: Difference between overtaking speed differential inside and outside the passing lane are not statistically significantly different (Student's T-test p-value = 0.098; Wilcoxon p-value = 0.116).

### 3.4 Discussion

The lane use, speed and headway data analysis showed the following:

- The majority of vehicles on the passing lane use the left lane, while a minority (13% to 28%) use the right lane.
- The differential of the 85<sup>th</sup> percentile speed between the right lane and the left lane of a passing lane was 10.3, 7.6 and 4.4 km/h (with the right lane faster) at start, midway and end of the passing lane respectively.
- The 15<sup>th</sup> percentile headways on the left lane is 0.5 to 1.5 s more than on the right lane.

Speeds and headways on the right lane therefore create potentially higher risk conditions that could lead to severe crashes. The left lane is operating under safer operating conditions, with respect to speed and headways. There appears to be a trade-off in terms of the safe operating conditions between the left lane and the right lane of a passing lane. The majority of vehicles use the relatively safer left lane, which in a limited sense, can be considered a positive safety outcome.

The overtaking, speed and gap analysis findings were as follows:

- The availability of passing lanes increases the tendency for overtaking manoeuvres to be executed inside the passing lanes, e.g. nearly 80% of overtaking is inside the passing lane, when 20% of the route length is a passing lane.
- Overtaking inside the passing lane is executed with lower speed differential (i.e. 2.6 km/h) and longer gap prior to overtaking (i.e. 4 m, albeit not statistically significant) than when overtaking is executed outside the passing lane.

With respect to speed and gap, overtaking manoeuvres inside the passing lane are considered safer than when done outside the passing lane. The availability of passing lanes also encourages motorists to overtake inside them which means that overtaking manoeuvres are conducted on sections of the route that have been purposely designed for such manoeuvres.

The traffic data analysis above demonstrated aspects of passing lanes that could affect a positive safety outcome. However, before-and-after crash data showed significant variation in crash outcome, although there was a reduction in crashes on average. The average and range (i.e. 25<sup>th</sup> percentile to 75<sup>th</sup> percentile) of change in number of crashes were as follows:

- on the passing lane section: reduction of 18.9% of injury crashes (–71.8% to +217.1%)
- 2 km upstream of the passing lane: reduction of 17.6% of injury crashes (–72.7% to +97.7%)
- 5 km downstream of the passing lane: reduction of 10.2% of injury crashes (–78.3% to undefined)
- for the entire route: reduction of 15.6% of injury crashes (–38.5% to +12.3%).

Injury crashes decreased at half of the analysed passing lane sites and increased at the other half. Other factors and/or natural randomness of crashes could influence the before-and-after analysis results. It was attempted to examine the correlation of selected factors to before-and-after outcomes to identify external factors that may explain the variation in outcomes. However, relationships of crash impacts with design and operational factors, such as gradient, passing lane length, speed limit and traffic volume, could not be identified. There was too much variance in the data that the impact of the specific factors that were assessed were found to be not correlated with crash impacts. Further research is needed to identify the design and operational factors that affect an increase or decrease in safety performance along individual passing lanes; such factors were not able to be identified in this study. A better understanding of factors that influence the effectiveness of passing lanes in reducing crashes would assist in determining where passing lanes would be more effective and where they may be potentially counterproductive.

Therefore, due to the variability of the crash analysis results, the assumption of average safety benefit for assessment of passing lane impacts should be applied with caution. The calculated average reduction in injury crashes is best applied to assessing a project involving installation of several passing lanes. The calculated average reduction in injury crashes should not be applied to the safety performance of an individual passing lane. Application to a passing lane needs to be supported by site-specific evidence.

## 4. Journey Time Assessment

This section covers journey time assessment of passing lanes. Section 2.2.3 reviewed modelling of journey experience, and it was suggested that two viable methods, i.e. the HCM method (analytical model) and TRARR (simulation model), be considered. The aim of this section is to prepare guidance in the application of these two modelling approaches. In particular, the contents of this section are as follows:

- Examination of the inputs and outputs of HCM and TRARR (Section 4.1).
- Review and refinement of default TRARR parameters based on field measurements (Section 4.1.3).
- A numerical experiment using TRARR is presented in Section 4.3. The numerical experiment illustrates the impact of passing lane density and passing lane length on journey time.

### 4.1 Modelling Techniques

This section examines the HCM and TRARR models. The aim of this section is to outline the sensitivity of these two models to passing lane analysis and their impact on journey experience.

#### 4.1.1 HCM Method

HCM (TRB 2016) is a deterministic method for analysing two-lane two-way roads. The method is applied to a uniform directional segment of a two-lane two-way road. Although traffic flows in the two directions interact due to overtaking movements, the analysis for each direction is undertaken separately. A summary of inputs and performance measures of the HCM method is presented in Table 4.1. HCM recommends using the percentage of vehicles travelling at headways of smaller than 3 s as a surrogate measure for per cent time spent following (PTSF).

Table 4.1: HCM method’s inputs and performance measures

Input	Performance measure
<ul style="list-style-type: none"> <li>• Highway class</li> <li>• Lane width, shoulder width, access point density</li> <li>• Terrain type (level, rolling, specific grade)</li> <li>• Per cent no-passing zone</li> <li>• Free-flow speed</li> <li>• Passing lane length</li> <li>• Traffic volume</li> <li>• Directional volume split</li> <li>• Analysis period</li> <li>• Peak hour factor</li> <li>• Heavy vehicle percentage, recreational vehicle percentage</li> </ul>	<ul style="list-style-type: none"> <li>• Average travel speed (ATS)</li> <li>• Ratio of ATS to free-flow speed (FFS)</li> <li>• Per cent time spent following (PTSF)</li> <li>• Level of service (LOS)</li> <li>• Average travel time</li> <li>• Volume-to-capacity ratio</li> </ul>

Source: TRB (2016).

### 4.1.2 TRARR Method

TRARR is a traffic simulation model for two-lane, two-way rural roads. The name TRARR is an abbreviation for TRAffic on Rural Roads. TRARR is a time-step model in which the movement of each vehicle during each interval (e.g. one second) is determined by a combination of factors that include the vehicle and driver characteristics, the road geometry, sight distance, speed limit and the proximity of other vehicles (Troutbeck 1981).

The TRARR package includes two programs:

- T17 – an interface program that prepares input files for TRARR.
- TRARR – a microsimulation software that analyses passing lanes (i.e. primary program).

The structure of the TRARR package is shown in Figure 4.1. The scope of TRARR inputs are listed in Table 4.2, which includes data on the carriageway, passing lane, demand, vehicle attributes and driver attributes.

Figure 4.1: TRARR package

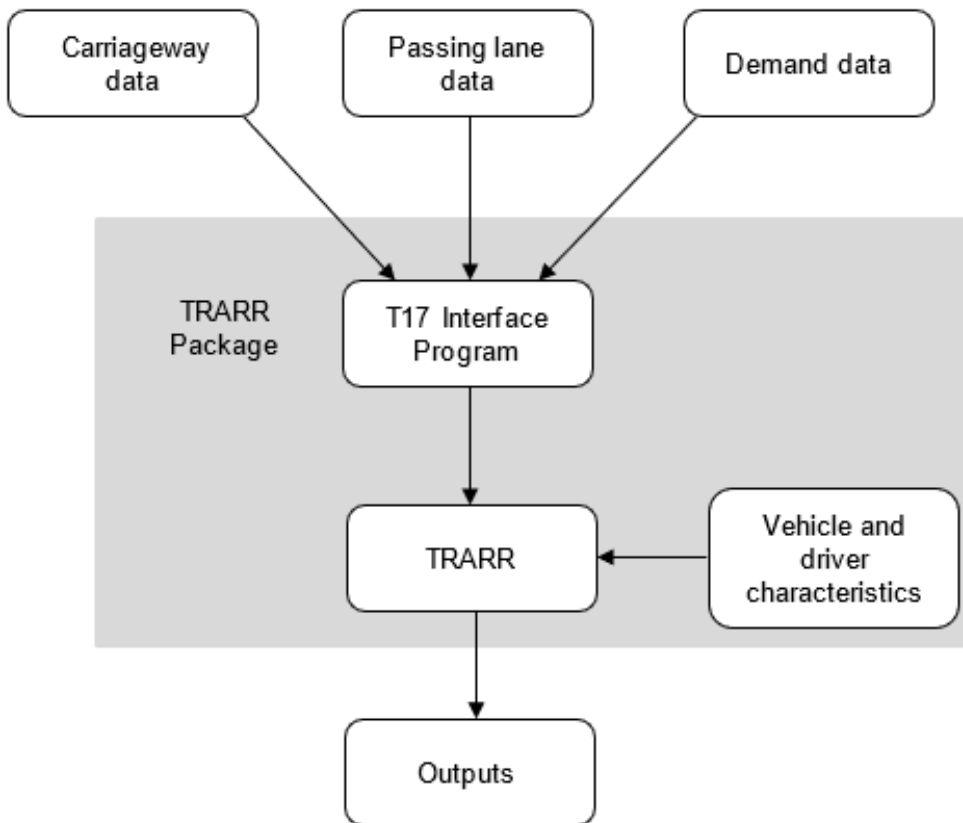


Table 4.2: TRARR inputs

Type	Attributes
Carriageway data at 100 m intervals	<ul style="list-style-type: none"> <li>Chainage, latitude, longitude, altitude, land bearing</li> <li>Barrier lines, speed limit</li> <li>Horizontal and vertical curvature, grade, cross-fall</li> </ul>
Passing lanes	<ul style="list-style-type: none"> <li>Location</li> <li>Length</li> </ul>
Demand data (one period of constant demand only)	<ul style="list-style-type: none"> <li>Settling down period for simulation and duration for simulation</li> <li>Demand by vehicle type in each direction</li> <li>Arrival pattern (per cent following on arrival), note that adjustment of arrival parameters may be required to be edited manually to ensure accurate representation of arrival patterns</li> </ul>
Vehicle data	<ul style="list-style-type: none"> <li>Vehicle types</li> <li>Maximum acceleration and deceleration</li> <li>Maximum power-to-weight ratio</li> <li>Wind and rolling resistance characteristics</li> <li>Length of vehicle</li> <li>Mass of vehicle</li> <li>Fuel consumption</li> </ul>
Driver data (specified by vehicle type)	<ul style="list-style-type: none"> <li>Driver speed compliance</li> <li>Mean and standard deviation of desired speeds</li> <li>Speed type distribution</li> <li>Overtaking speed multipliers</li> <li>Driver aggression factors for overtaking manoeuvres</li> <li>Overtaking behaviour parameters</li> </ul>

Source: Troutbeck (1981).

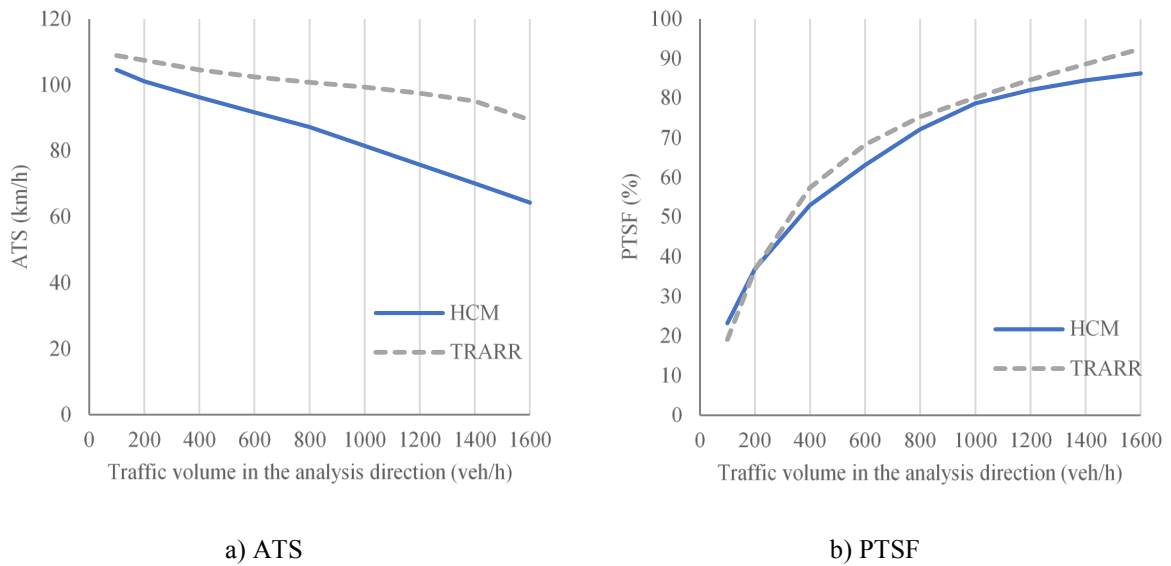
TRARR provides two types of outputs, i.e. point observations and interval observations. Outputs are measured for each vehicle category at each 'point observation' along the road and at 'interval observations' between specified start and end points. Point observations include numbers of overtaking commenced, mean speeds and percentages following. Interval observations reported include travel times (mean and standard deviation), per cent time spent following, overtaken vehicles and fuel consumption. Both point and interval observations are provided for each direction of travel. Interval observations are also provided for both directions combined.

### 4.1.3 Comparison of TRARR and HCM

Figure 4.2 illustrates estimated average travel speed (ATS) and PTSF (using a 3 s headway threshold) from TRARR and HCM for the Augusta Highway southbound section (described in Section 4.2). The TRARR model parameters were calibrated as discussed in Section 4.2.

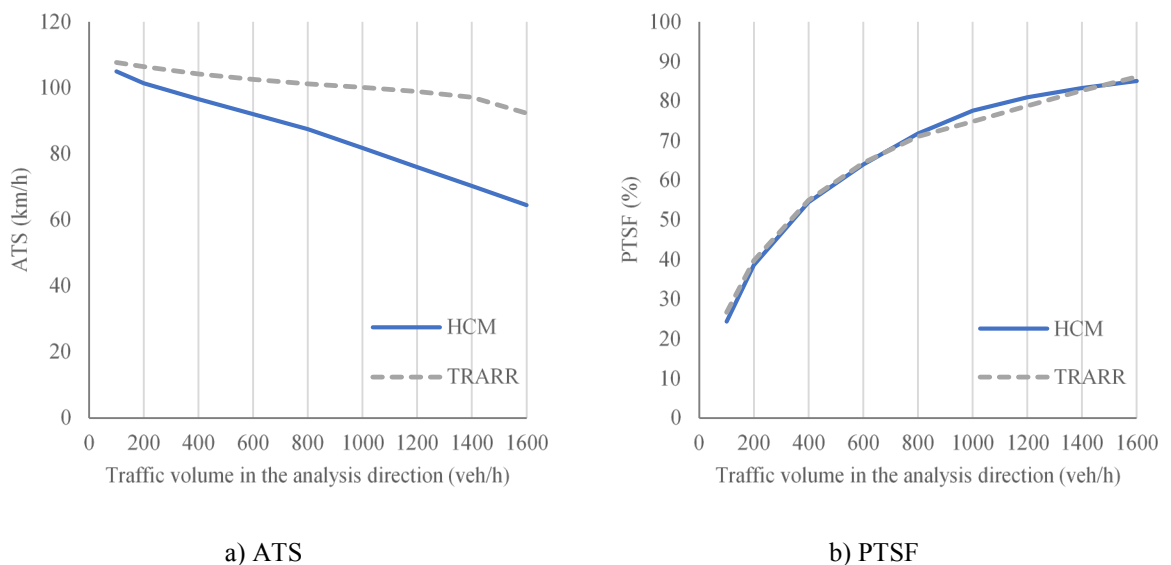
The results showed that while ATS from both TRARR and HCM decreased with increasing traffic volume, ATS from TRARR were higher than those from HCM. Results also indicated that PTSF from both TRARR and HCM increased with increasing traffic volume. PTSF from TRARR was slightly lower compared to those from HCM, particularly with higher traffic volume. However, the difference in PTSF estimates were not significant.

Figure 4.2: Comparison of TRARR and HCM for Augusta Highway section (southbound)



Comparative results of TRARR and HCM using the Dukes Highway southbound section (described in Section 4.2) are shown in Figure 4.3. It was also evident that ATS estimates were lower using HCM than TRARR. However, PTSF estimates by TRARR and HCM were nearly the same. This observation was consistent with the results for the Augusta Highway section.

Figure 4.3: Comparison of TRARR and HCM for Dukes Highway section (southbound)



Overall, results indicate similar patterns from HCM and TRARR, i.e. ATS decreases while PTSF increases with increasing traffic volume. PTSF estimates by TRARR and HCM are comparable. However, compared to TRARR, HCM estimates lower ATS. Without field data at higher volumes, it is not possible to ascertain which method produces more accurate ATS results.

## 4.2 TRARR Review and Calibration

This section is a review and refinement of TRARR's default parameters. The current default parameters were mainly developed by Hoban et al. (1991).

### 4.2.1 Method

TRARR was calibrated and validated using field data collected in 2015. The data was provided for this project by DPTI. A 17 km section of Augusta Highway (chainages from 47 km to 63 km) with a passing lane in the southbound direction was selected for calibration and designated as Site A. In addition, a 14 km section of Dukes Highway (chainages from 99 km to 113 km) with one passing lane in each direction were selected for validation and designated as Sites B and C. Augusta Highway and Dukes Highway are in South Australia. The speed limit on both road sections was 110 km/h.

Traffic demand (flow rate and vehicle composition) and speed and PTSF (i.e. headway less than 3 s) at various locations upstream of the passing lane, within the passing lane, and downstream of the passing lane were collected from field data. Observed traffic demand data were used as an input for the TRARR models. Data on road geometry, speed limits, barrier lines and passing lanes were compiled and encoded in the TRARR models of the two road sections. Measured speed and PTSF were compared against TRARR outputs for calibration and validation. Ten simulation runs were performed to obtain reliable outputs from the TRARR model.

TRARR’s vehicle and traffic parameters were adjusted so that simulated speed and per cent following were similar to field data. The calibrated parameter set was then validated using the Dukes Highway section model. To compare TRARR outputs and field data, GEH statistic and root mean squared error (RMSE) were calculated (Equation 1):

$$GEH = \sqrt{\frac{2(x_i - y_i)^2}{x_i + y_i}} \tag{1}$$

$$RMSE = \sqrt{\frac{1}{N} \sum_1^N (x_i - y_i)^2}$$

where

- $x_i$  = model measurement
- $y_i$  = field measurement
- $N$  = number of measurements

GEH of less than 5 indicates a good fit.

### 4.2.2 Field Data

The data was collected in April and May of 2015, on Augusta Highway and Dukes Highway in South Australia. These sites are listed in Table 4.3.

**Table 4.3: Traffic data collection sites in 2015**

Site	Highway	Location	Position of passing lane	Use of the data	Survey dates
A	Augusta Hwy	~ 55 km south of Port Augusta	Southbound	Calibration	02/05/15–16/05/15
B	Dukes Hwy	~ 22 km north-west of Keith	Northwest bound	Validation	25/04/15–09/05/15
C	Dukes Hwy	~ 21 km south-east of Tintinara	Southeast bound	Validation	25/04/15–09/05/15

The traffic data were collected using pneumatic tubes. Site A on the Augusta Hwy was used for calibration while sites B and C on Dukes Hwy were used for validation. Traffic data were collected upstream, downstream and within the passing lanes, as detailed in Table 4.4.

**Table 4.4: Data collection points of calibration and validation sites**

Site	Data collection points
A	<ul style="list-style-type: none"> <li>• 2 km and 5 km downstream of the passing lane</li> <li>• 2 km and 5 km upstream of the passing lane</li> <li>• 3 points within the passing lane</li> <li>• Data was collected from the southbound lane, northbound lane and the passing lane</li> </ul>
B and C	<ul style="list-style-type: none"> <li>• 2 km downstream of the passing lane</li> <li>• 1.6 km, 3.2 km, 4.5 km and 6.5 km upstream of the passing lane</li> <li>• 3 points within the passing lane</li> <li>• Data was collected from the northwest bound lane, southeast bound lane and the passing lanes</li> </ul>

Data collected included the following:

- number of axle hits
- date and time of the first axle hit
- direction of travel
- speed of the vehicle
- headway, time since the first axle of the last vehicle travelling in the same direction
- number of axles of the vehicle
- number of axle groups of the vehicle.

The traffic data was reviewed to determine a peak period of homogeneous flow (i.e. constant demand and uniform vehicle type mix profile). The selected periods for the sites were as follows:

- Augusta Highway: 9 am to 1 pm on weekdays (applicable to site A)
- Dukes Highway: 10 am to 2 pm on weekdays (applicable to both sites B and C).

These periods were utilised for the calibration and validation of TRARR. The traffic demand during the peak periods are shown in Table 4.5. In addition, per cent following at the entry point of the section in TRARR was adjusted to match the field measurements.

**Table 4.5: Traffic volume and vehicle composition on Augusta Highway and Dukes Highway**

Vehicle composition	Augusta Highway (9:00–13:00 weekday)		Dukes Highway (10:00–14:00 weekday)	
	Southbound	Northbound	Southbound	Northbound
% Road train	5%	3%	1%	0%
% Double articulated	3%	2%	10%	6%
% Single articulated	8%	8%	11%	6%
% Rigid	9%	12%	5%	6%
% Car tow	10%	12%	7%	11%
% Cars	65%	62%	66%	71%
Total volume (veh/h)	123	137	146	126

*Note: Percentage sums may not add up to 100% due to rounding.*

### 4.2.3 Calibration and Validation

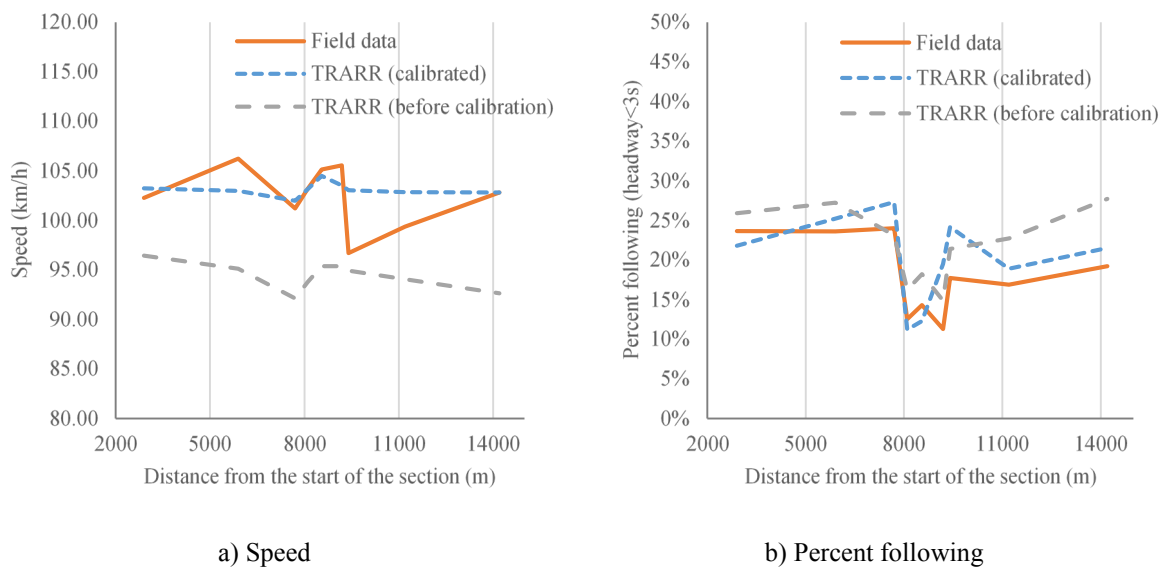
#### Calibration

Analysis identified parameters related to vehicle maximum power to weight ratio, wind resistance coefficients, and mean desired speeds required re-calibration. Figure 4.4 depicts outputs from the calibrated TRARR model and TRARR model before calibration in comparison with field data for the southbound direction. Before calibration, TRARR generated significantly lower speed and higher per cent following compared to field data in both travel directions. The re-calibrated TRARR model can be seen to output speed and PTSF similar to field data. The GEH statistic at all locations was less than 1. RMSE were also relatively small with 2.8 km/h for speed and 3.9% for per cent following.

It was noted that the field data depicted a dip in speed just after the passing lane, which could be a result of the merging of vehicles at this point. TRARR was not able to model this phenomenon.

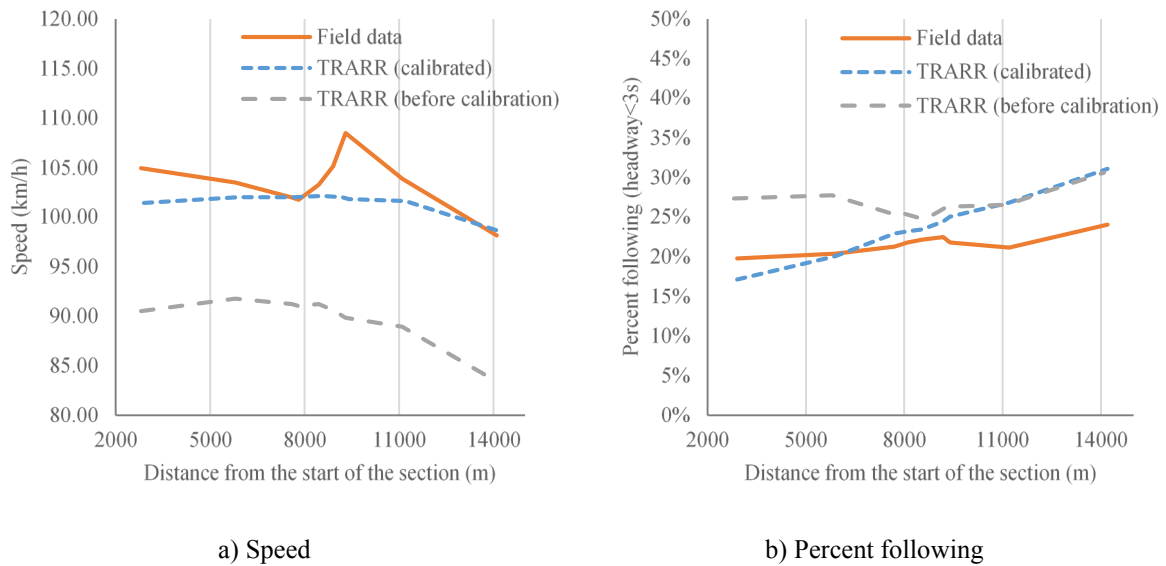
Figure 4.5 shows the results for the northbound direction, which has no passing lane. Before calibration, TRARR output much lower speed but higher PTSF than field data. The calibrated TRARR model speed outputs were lower than field data, but the difference was relatively small with GEH of less than 1 and RMSE of 2.9 km/h. Differences in PTSF between field data and the calibrated TRARR model were also small with GEH of less than 1 and RMSE of 3.5%.

**Figure 4.4: Speed and per cent following for the Augusta Highway – southbound direction**



*Note: Passing lane between 7700 m and 9400 m; per cent following based on headway < 3 s.*

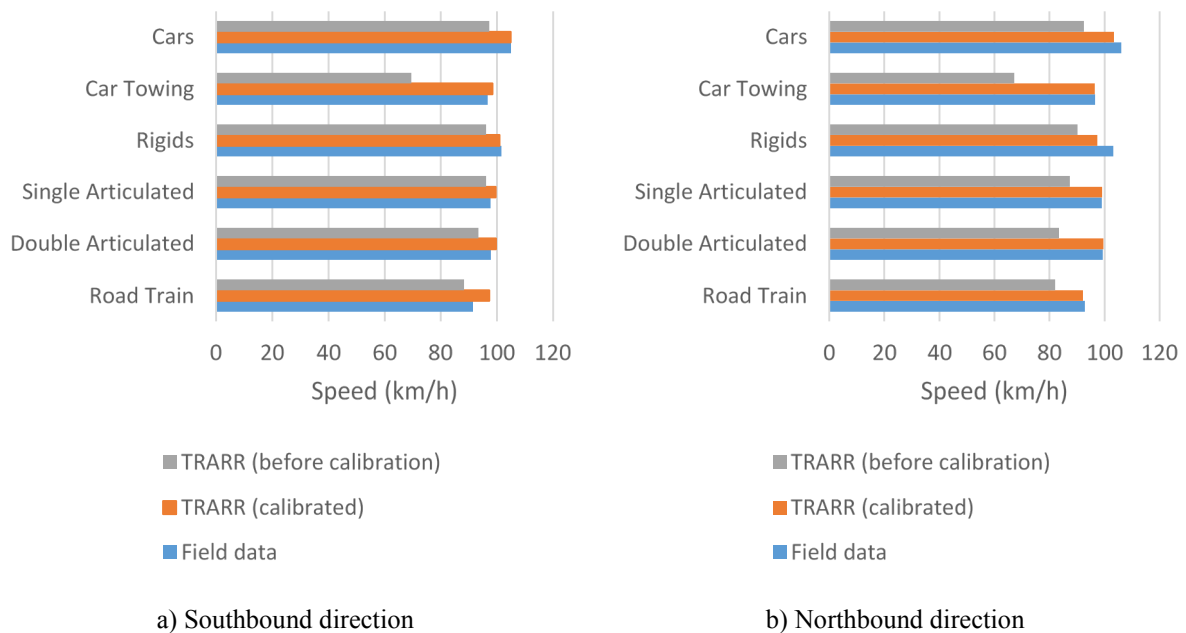
Figure 4.5: Speed and per cent following for the Augusta Highway – northbound direction



Note: Per cent following based on headway < 3s.

Figure 4.6 compares average speeds by vehicle category by TRARR (before and after calibration) and field data. Before calibration, speeds of car-towing class vehicles were significantly underestimated by TRARR. After calibration, the estimated speeds by vehicle class were similar to field data.

Figure 4.6: Average speed by vehicle category in each direction



#### 4.2.4 Recommended Parameters

Table 4.6 presents the list of calibrated parameters. The complete lists of recommended parameters, including unchanged parameters, are presented in Appendix B (traffic parameters) and Appendix C (vehicle parameters).

Calibrated mean desired speeds for all vehicle categories in TRARR were scaled up compared to the default values. Note that these parameters are based on a speed limit of 110 km/h. The maximum power-to-weight ratios were increased, which may be indicative of higher powered vehicles now than in 1991. Moreover, the wind resistance factor of car-towing vehicles was decreased as the default values resulted in car-towing speeds that were significantly slower than field data.

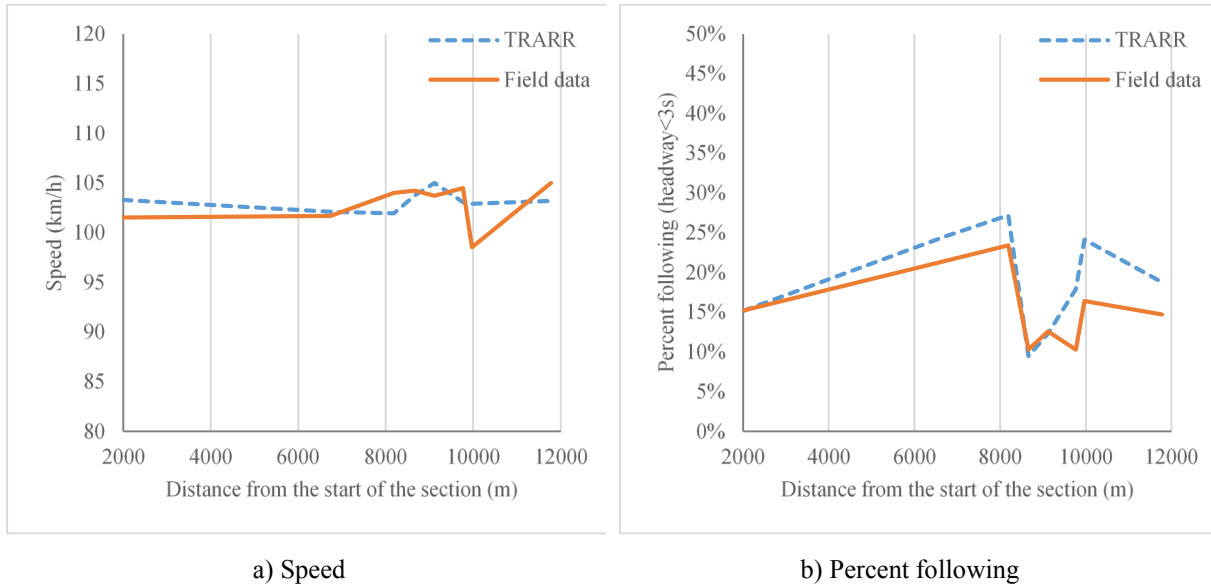
**Table 4.6: Calibrated parameters (110 km/h speed limit conditions)**

Parameters	Before calibration (default)	Calibrated
<b>Mean desired speed (km/h) – VMF</b>		
Car	106	110
Car-towing	101	105
Rigid	102	106
Single articulated	99	103
Double articulated	99	103
Road train	93	97
<b>Maximum Power/Weight (kW/ton) – VNP, VXP</b>		
Car-towing	11	22
Unaggressive ccar	30	45
Low powered car	30	45
Typical SUV/Sedan	33	49.5
Small hatchback	32	48
<b>Wind resistance coefficient – VWRC</b>		
Car-towing	7	5
<b>Time component of following distance – VFDB2</b>		
Car-towing	1.0	0.7
Low powered car	1.0	0.5
Typical SUV/Sedan	1.0	0.5
Small hatchback	1.0	0.5

## Validation

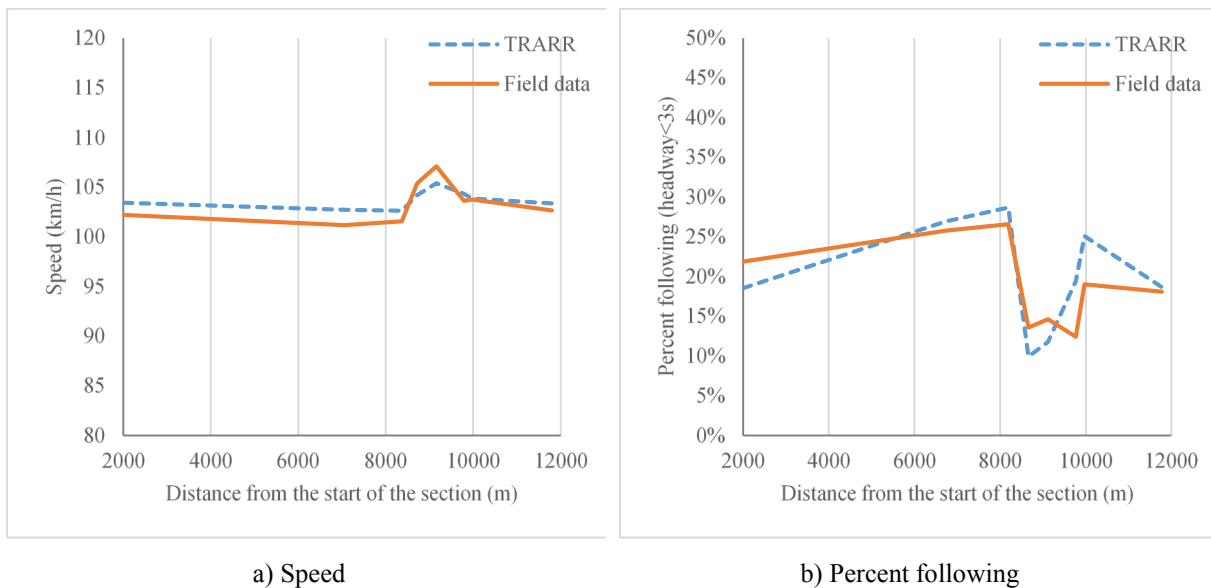
The recommended TRARR parameters were validated using the Dukes Highway section that has one passing lane in each direction. Traffic volumes in the southbound and northbound directions are 146 veh/h and 127 veh/h respectively. Figure 4.7 and Figure 4.8 demonstrate similarity between TRARR outputs and field data. GEH statistics at all locations were less than one. RMSE for speed and per cent following are small (1.1–2.1 km/h for speed and 4.0% – 4.5% for per cent following). The validation results confirm that the recommended parameters are reasonable.

Figure 4.7: Speed and per cent following for the Dukes Highway – southbound direction



Note: Passing lane between 8 200 m and 10 000 m; per cent following based on headway < 3 s.

Figure 4.8: Speed and per cent following for the Dukes Highway – northbound direction



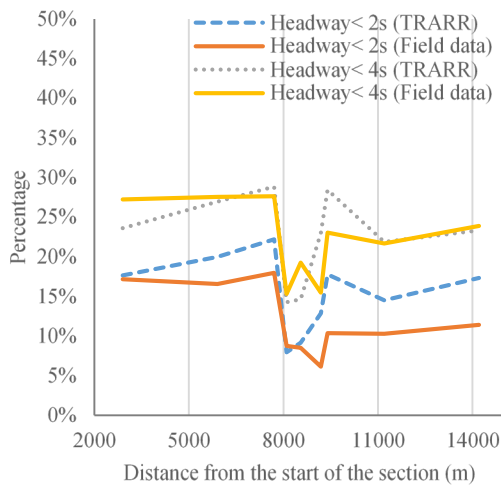
Note: Passing lane between 8 400 m and 10 000 m; per cent following based on headway < 3 s.

#### 4.2.5 Sensitivity Analysis of Headway Thresholds for PTSF

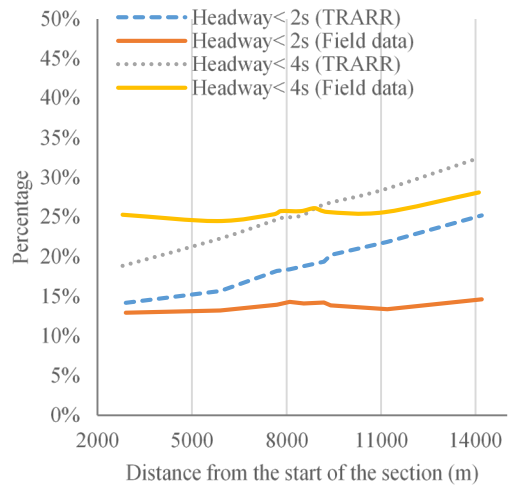
A 3 s headway threshold was adopted for calculating per cent following (i.e. headway < 3 s) for calibration and validation. This section tests the performance of the calibrated parameters with other headway thresholds.

Figure 4.9 and Figure 4.10 show percentages of headways less than 2 s and 4 s for the Augusta Highway and Dukes Highway sections, respectively. The calibrated parameter set performed well with the 2 s and 4 s headway thresholds for calculating per cent following, except for the northbound direction on Augusta Highway. In this case, TRARR overestimated percentages of headways smaller than 2 s, particularly at the end of the Augusta Highway section in the northbound direction. Attempts to further refine the TRARR parameters were not able to further enhance TRARR outputs to match field data in all cases. A more detailed review with more data points would be necessary to further improve TRARR.

Figure 4.9: Percentage of headways smaller than 2 s and 4 s along Augusta Highway

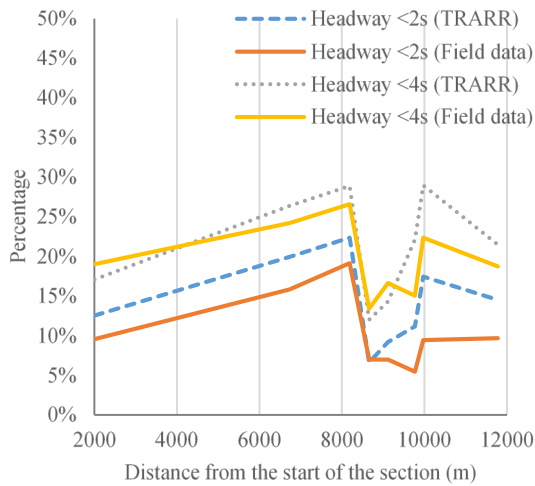


a) Southbound direction

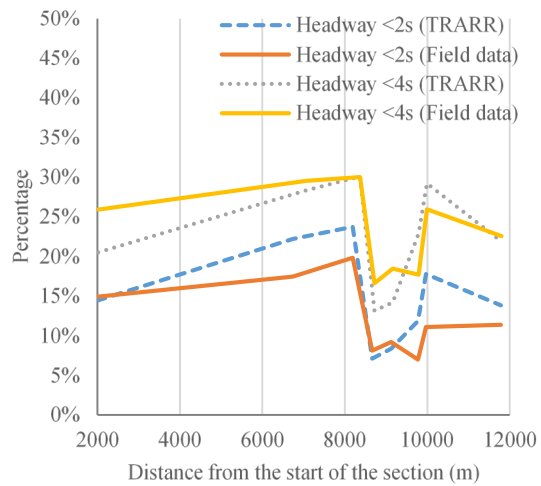


b) Northbound direction

Figure 4.10: Percentage of headways smaller than 2 s and 4 s along Dukes Highway



a) Southbound direction



b) Northbound direction

### 4.3 Numerical Analysis

This section is an analysis of an example two-lane two-way rural highway. The analysis aims to illustrate how passing lanes impact journey time, including average travel speed and PTSF. The analysis examined the impact of passing lane density (Section 4.3.2) and passing lane length (Section 4.3.3).

### 4.3.1 Highway and Demand Attributes

The highway configuration of a 64 km section of Dukes Hwy between Coonalpyn and Keith (Figure 4.11) was utilised as the basis of the numerical analysis. This section is relatively straight and flat as shown in Figure 4.12 and the percentage of the route with no passing is 29% in both directions, excluding passing lanes. The speed limit for the entire section was assumed to be 110 km/h. The actual Dukes Hwy section has some short sections with a lower speed limit (e.g. 60 km/h and 80 km/h) but this was modified for the purpose of isolating the impact of the passing lane so that the results are not due to these sections.

The section was modelled in TRARR with varying levels of overtaking opportunity and hourly traffic volumes to assess changes in average travel speeds and PTSF. With each configuration of passing lanes, incrementally larger hourly flows from 200 veh/h to 1900 veh/h in each direction were modelled. For each of the hourly flows, two compositions were modelled, the first containing 30% slow vehicles and the second containing 15% slow vehicles. The slow vehicles comprise of road trains, double and single articulated trucks, rigid trucks and cars towing. The relative number of vehicles in each of these categories were based on the 2015 field data for Dukes Highway (refer to Section 4.2.2). The assumed vehicle composition is in Table 4.7.

Figure 4.11: Dukes Highway section between Coonalpyn and Keith (South Australia)

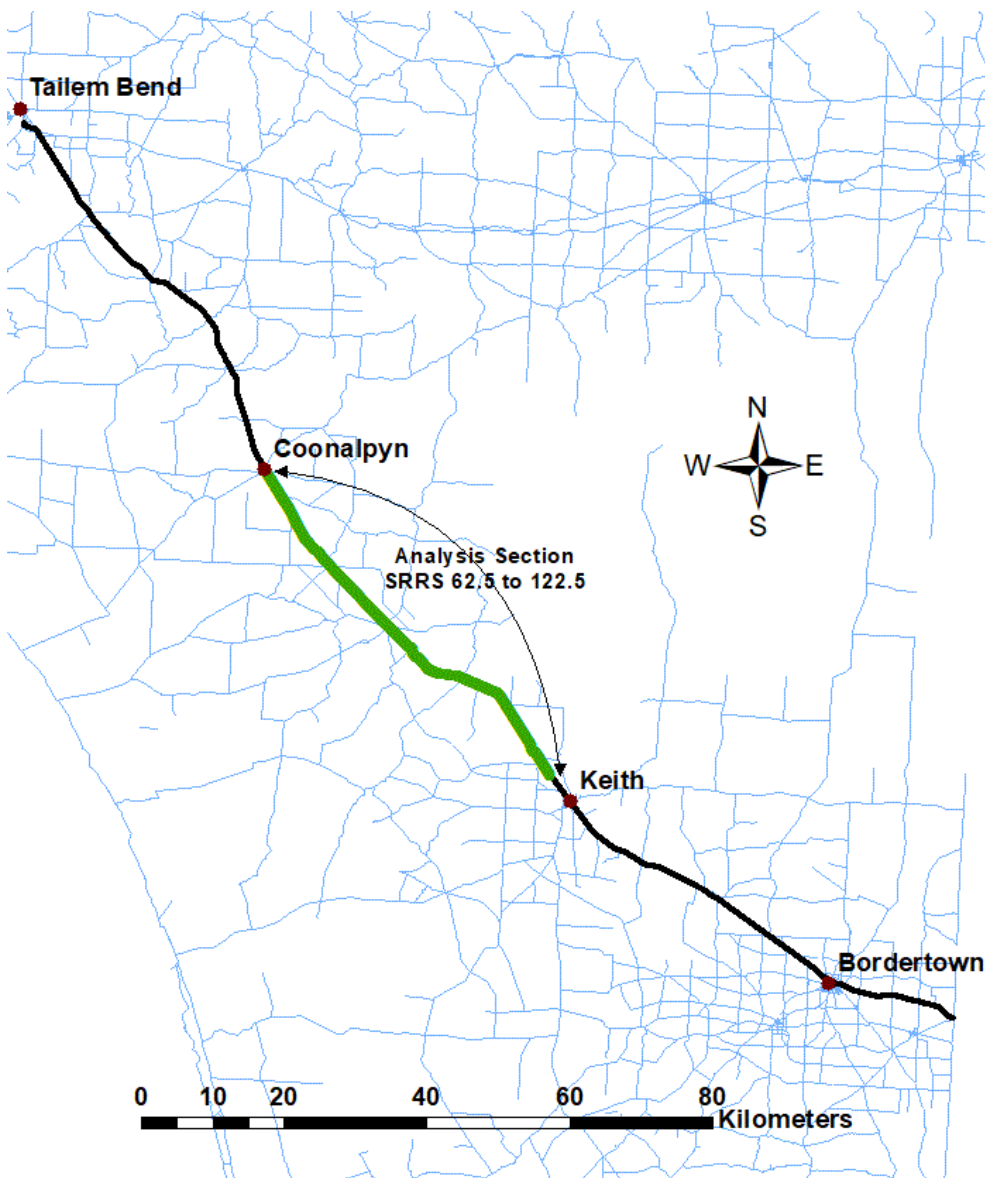


Figure 4.12: Dukes Hwy profile from Coonalpyn to Keith (southbound)

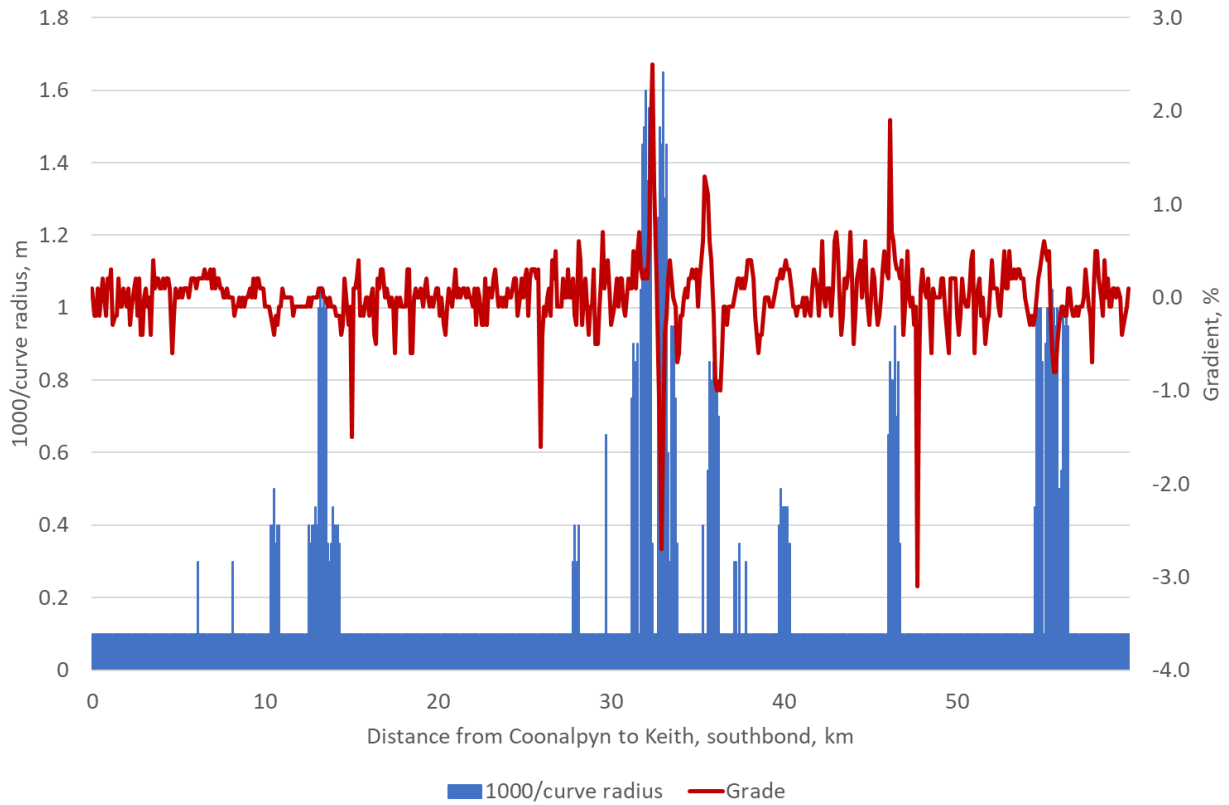


Table 4.7: Vehicle composition of assumed demand

Vehicle type	30% slow vehicles	15% slow vehicles
Cars	70%	85%
Car towing	11%	5%
Rigid trucks	6%	3%
Single articulated	6%	3%
Double articulated	6%	3%
Total	100%	100%

### 4.3.2 Passing Lane Density

This section shows the results of the numerical analysis on passing lane density, ranging from no passing lanes to one passing lane every 5 km. All passing lanes were set to 1.3 km in length (i.e. same as in the field). Passing lane density scenarios are described in Table 4.8.

Table 4.8: Passing lane density scenarios

Lane	Location as measured in the southbound direction, km		Passing lane density scenario			
	Start	End	Every 5 km	Every 10 km	Every 20 km	No passing lanes
Southbound	3.1	4.3	✓	✓	✓	–
	8.1	9.3	✓	–	–	–
	10.5	11.7	✓	✓	–	–
	15.1	16.3	✓	–	–	–
	21.7	22.9	✓	✓	✓	–
	26.3	27.5	✓	–	–	–
	32.8	34	✓	–	–	–
	35.3	36.5	✓	✓	–	–
	44	45.2	✓	–	–	–
	47.2	48.4	✓	✓	✓	–
	53.4	54.6	✓	–	–	–
	55.2	56.4	✓	✓	–	–
Northbound	3	1.8	✓	–	–	–
	8	6.8	✓	✓	–	–
	10.4	9.2	✓	–	–	–
	15	13.7	✓	✓	✓	–
	21.6	20.4	✓	–	–	–
	26.2	24.9	✓	✓	–	–
	32.7	31.5	✓	✓	✓	–
	35.2	34	✓	–	–	–
	43.9	42.7	✓	✓	–	–
	47.1	45.9	✓	–	–	–
	53.3	52.1	✓	✓	✓	–
	55.1	53.9	✓	–	–	–

### Average travel speed

Figure 4.13 and Figure 4.14 show the average travel speeds with 30% and 15% slow vehicles, respectively. The following were observed:

- Travel speeds gradually declined with volume up to around 1600 veh/h in one direction. At traffic volumes greater than 1600 veh/h there was a sharp decline in travel speed, which indicates flow breakdown and that traffic volumes were beyond capacity.
- When traffic volume was 1900 veh/h, travel speeds were 5 to 13 km/h faster without passing than with passing lanes. It appears that the presence of passing lanes led to slower speeds, probably because of diverging and merging of traffic at the passing lane resulting in conflicts and lowering of operational capacity.
- Generally, higher density of passing lanes improved average travel speed by up to 4 km/h. Changes in travel speeds due to passing lanes are shown in Table 4.9.

Figure 4.13: Average travel speeds with 30% slow vehicles and variable passing lane (PL) spacing

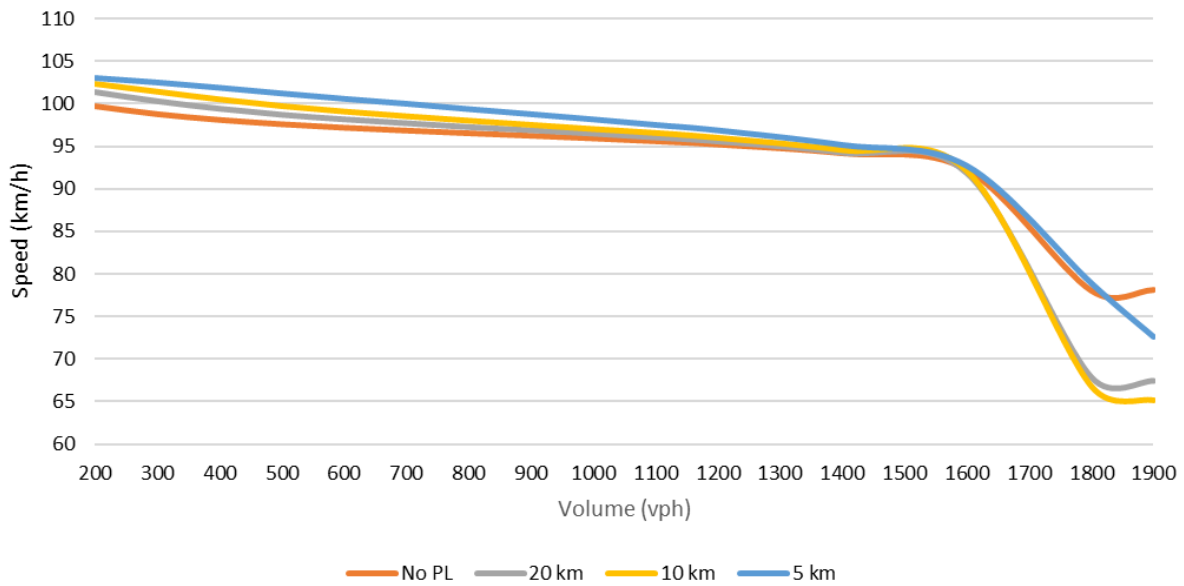


Figure 4.14: Average travel speeds with 15% slow vehicles and variable passing lane (PL) spacing

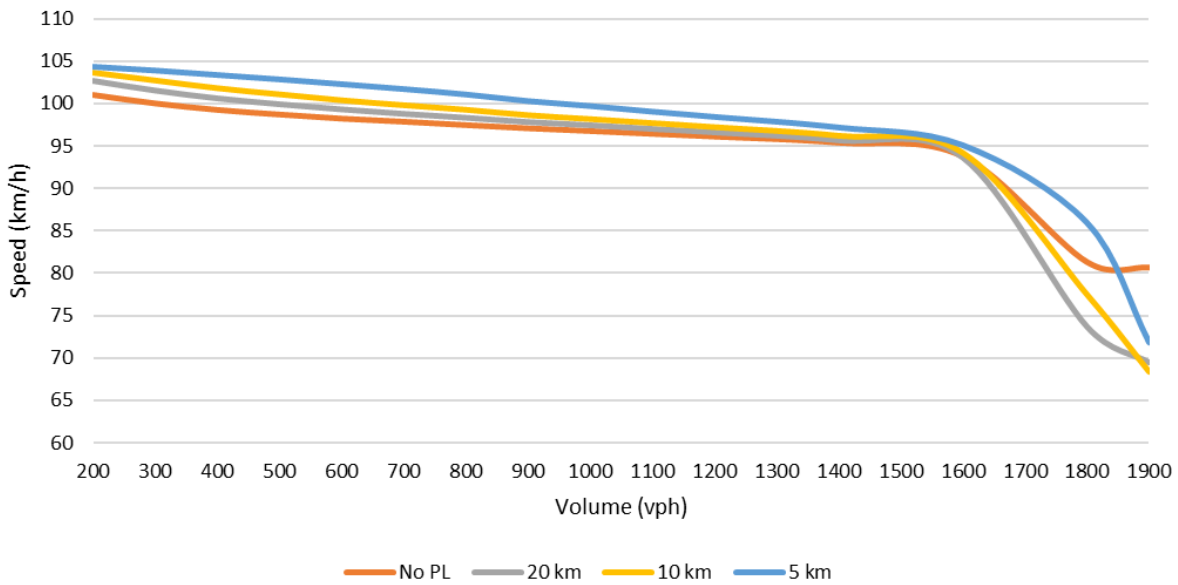


Table 4.9: Change in average travel speed due to passing lanes

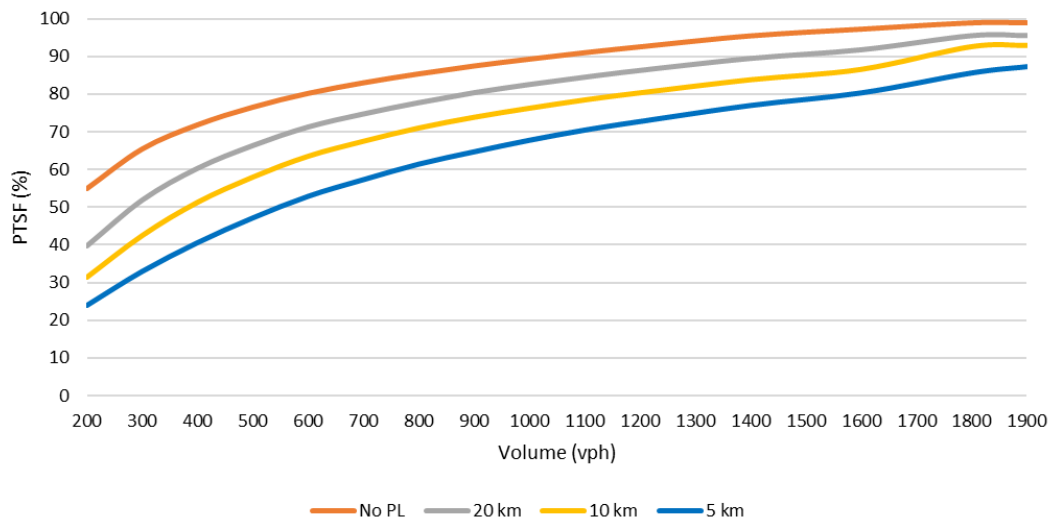
Traffic volume in each direction, veh/h	Change in average travel speed by passing lane density and percentage of slow vehicles, km/h ('with' minus 'without')					
	15% slow vehicles			30% slow vehicles		
	Every 20 km	Every 10 km	Every 5 km	Every 20 km	Every 10 km	Every 5 km
200 to 600	+1.4	+2.5	+4.0	+1.3	+2.2	+3.6
700 to 1000	+0.8	+1.7	+3.5	+0.7	+1.3	+2.7
1100 to 1400	+0.5	+1.0	+2.3	+0.3	+0.6	+1.5
1600 to 1900	-6.3	-5.3	-0.9	-7.0	-8.1	-1.3

### Per cent time spent following

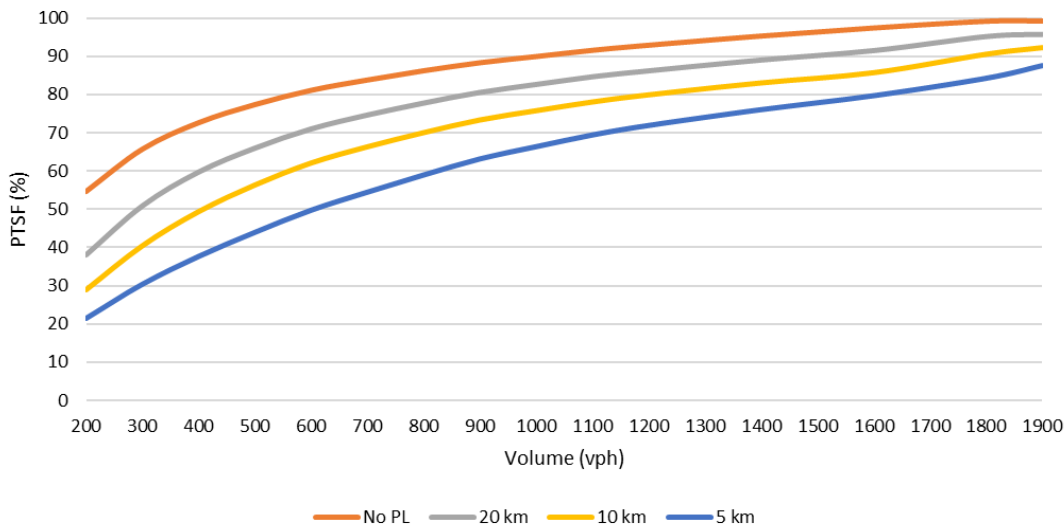
Figure 4.15 and Figure 4.16 show the PTSF with 30% and 15% slow vehicles, respectively. The following were observed:

- PTSF increases relatively linearly as traffic volumes increase.
- PTSF is notably reduced with increasing passing lane density. Change in per cent time spent following due to passing lanes is shown in Table 4.10.

**Figure 4.15:** Per cent time spent following with 30% slow vehicles and passing lane (PL) spacing



**Figure 4.16:** Per cent time spent following with 15% slow vehicles and passing lane (PL) spacing



**Table 4.10:** Change in PTSF due to passing lanes

Traffic volume on each direction, veh/h	Change in PTSF by passing lane density and percentage of slow vehicles, % points ('with' minus 'without')					
	15% slow vehicles			30% slow vehicles		
	Every 20 km	Every 10 km	Every 5 km	Every 20 km	Every 10 km	Every 5 km
200 to 600	-13.2	-22.8	-33.6	-11.8	-20.5	-30.1
700 to 1000	-8.1	-15.6	-26.3	-7.4	-14.1	-23.4
1100 to 1400	-6.5	-12.8	-20.7	-6.2	-12.1	-19.5
1600 to 1900	-4.3	-9.0	-14.7	-4.0	-7.7	-13.8

### 4.3.3 Passing Lane Length

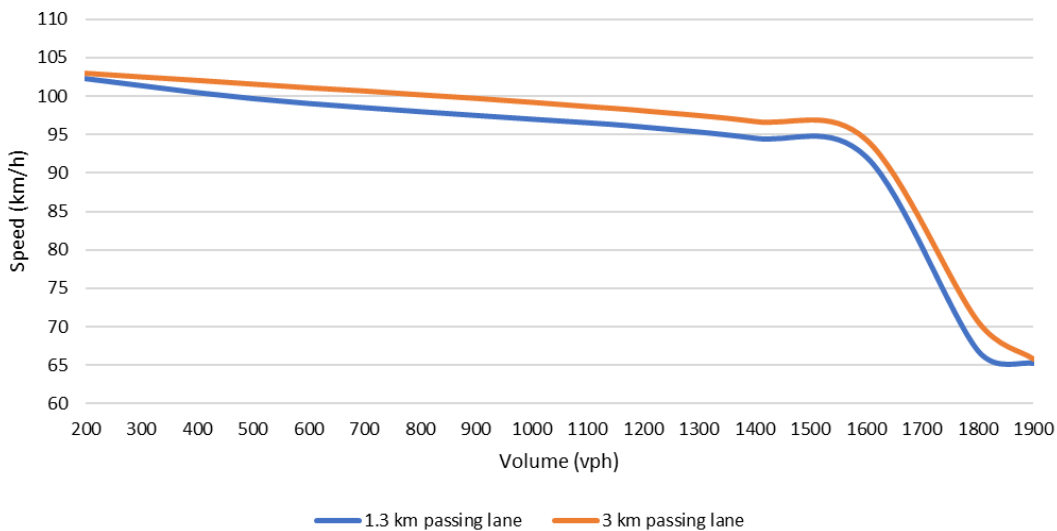
This section examines the effect of passing lane length on travel speed and PTSF. Two passing lane lengths were examined, 1.3 km and 3 km. The analysis was conducted with passing lane density of one every 10 km (described in Table 4.8).

#### Average travel speed

Figure 4.17 and Figure 4.18 show the average travel speeds with 30% and 15% slow vehicles, respectively. The following were observed:

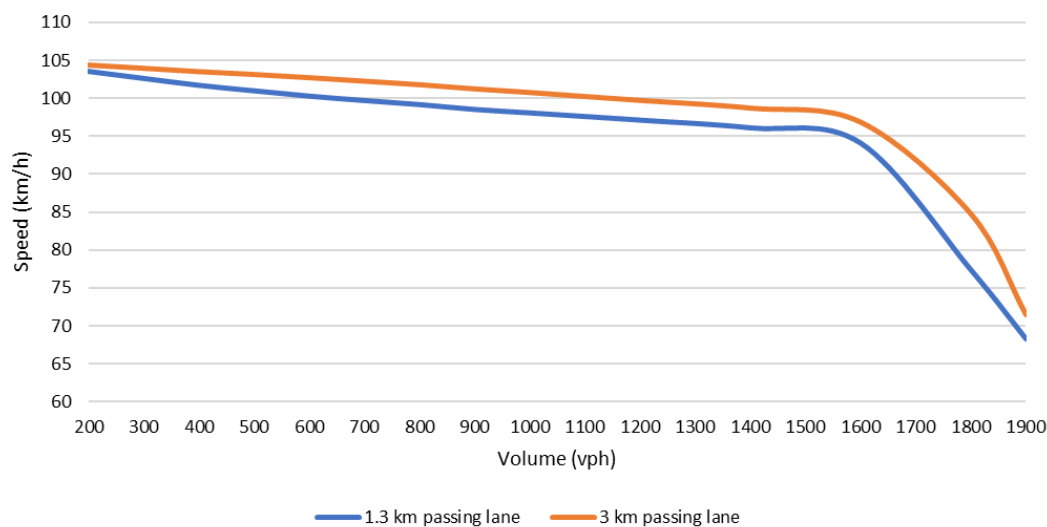
- Travel speed was higher in the 3 km passing lane case than in the 1.3 km passing lane case.
- Average improvement in speed was +2.0 and +2.6 km/h for 30% and 15% slow vehicle share, respectively.
- The improvement in speed was less when traffic volume was less than 500 veh/h, i.e. +1.2 km/h for both 30% and 15% slow vehicle share.

Figure 4.17: Average travel speeds with 30% slow vehicles and passing lane length



Note: Passing lane density of one every 10 km.

Figure 4.18: Average travel speeds with 15% slow vehicles and passing lane length



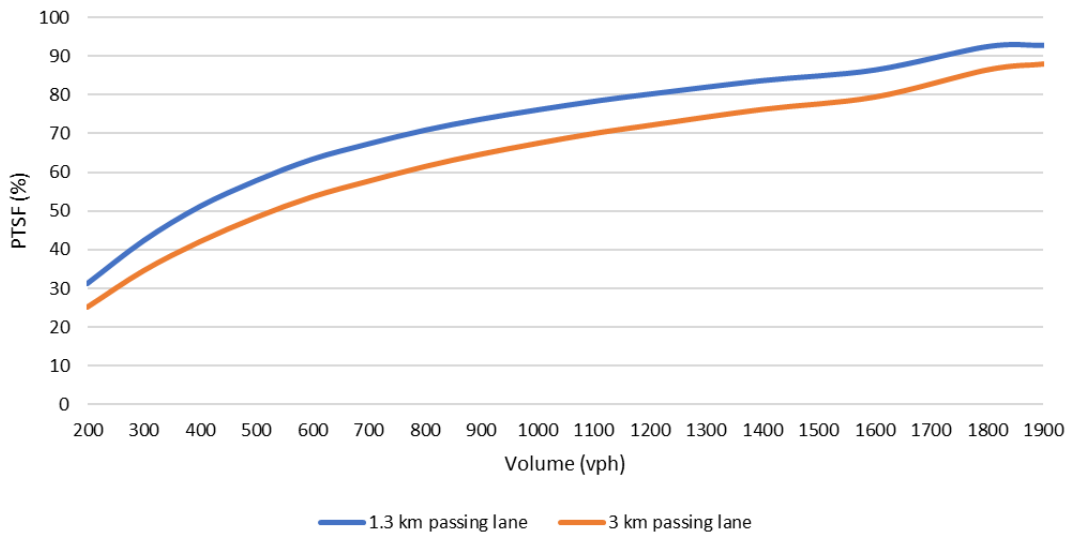
Note: Passing lane density of one every 10 km.

### Per cent time spent following

Figure 4.19 and Figure 4.20 show the PTSF with 30% and 15% slow vehicles, respectively. The following were observed:

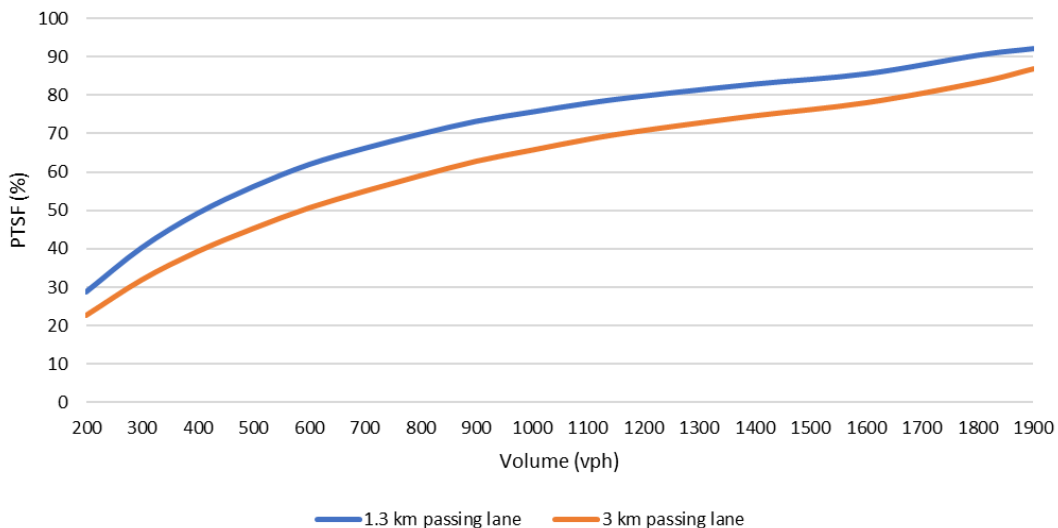
- PTSF was lower in the 3 km passing lane case than in the 1.3 km passing lane case.
- Average improvement in speed was –8.1% and –9.2% for 30% and 15% slow vehicle share, respectively.
- The improvement in speed was less when traffic volume was less than 400 veh/h, i.e. –7% and 7.4% for 30% and 15% slow vehicle share, respectively.

**Figure 4.19: PTSF with 30% slow vehicles and passing lane length**



Note: Passing lane density of one every 10 km.

**Figure 4.20: PTSF with 15% slow vehicles and passing lane length**



Note: Passing lane density of one every 10 km.

## 4.4 Discussion

This section examined how passing lanes impact journey time and how passing lane impacts could be estimated. Two methods that could be used to assess journey time impacts are TRARR and HCM. HCM is an analytical approach that can be applied relatively easily, without the need for specialist software and analyst. TRARR is a simulation model which can model site specific conditions. TRARR requires access to the TRARR software and trained personnel. Analysis using TRARR is not as accessible as HCM. TRARR however offers better representation of the highway being assessed, in particular, consideration of sight distance and gradients, as well as more detailed representation of vehicle type and capabilities. If a detailed assessment of passing lanes is required, it is recommended that TRARR be applied especially for an assessment of a route. The HCM method may also be applied if resources to perform a TRARR analysis are unavailable and a simple assessment is all that is required.

TRARR's accuracy is dependent on how well calibrated its parameters are. TRARR utilises several parameters and many of these parameters have not been reviewed since 1991. South Australian data provided by DPTI was used to review and refine TRARR parameters. The review indicated that the default TRARR parameters could be improved, if recalibrated, as speed estimates and per cent time spent following estimates did not match field data. A re-calibrated parameter set for TRARR was developed such that TRARR estimates closely matched field data. The re-calibrated parameters developed for TRARR may be considered as default parameters for TRARR. The parameters were developed using conditions wherein traffic volume was relatively low (i.e. 3 000 AADT, two-way). These parameters may require review if traffic volumes being assessed are high (i.e. >10 000 AADT, two-way).

TRARR (with the re-calibrated parameters) was compared with HCM. It was shown that per cent time spent following estimates of the two methods were equivalent. However, TRARR estimated higher average travel speeds than HCM. A significant difference in average travel speed estimates was noted (approximately 30% difference) when traffic volume was 1600 veh/h in one direction. The discrepancy in average travel speeds could not be examined in detail due to lack of field data at high traffic volumes. It is suggested that average travel speed estimates of TRARR and HCM be treated cautiously until such time that field data is available to review the accuracy of TRARR and HCM estimates. However, the relative difference of speed with-and-without passing lane by TRARR and HCM may be used for analysis.

A numerical analysis was conducted to provide an example of how passing lanes impact average travel speed and per cent time spent following. The analysis was performed on a 64-km stretch of highway that is relatively straight and flat. Passing lane density and passing lane length were examined. Higher passing lane density up to one every 5 km and passing lane length up to 3 km (with one passing lane every 10 km) improved travel speed and PTSF. The benefits of passing lanes to journey time was clear from the analysis.

At high traffic volumes of around 1900 veh/h in one direction, it appeared that the presence of passing lanes was counterproductive, as a highway with no passing lanes performed better than one with passing lanes. Travel speeds were higher without passing lanes than with passing lanes. It is likely that the merge at the end of the passing lanes resulted in a capacity bottleneck. It has been considered by jurisdictions to temporarily close the passing lane during high peak traffic flows. Such practice is supported by the numerical analysis.

The numerical analysis showed that performance of two-lane two-way highways, regardless of whether they have passing lanes or not, significantly degrade when traffic volumes reach around 1600 veh/h in one direction. This may be considered as the practical capacity of a two-lane two-way highway. If traffic volumes are projected to regularly reach 1600 veh/h within the economic life of the pavement, the duplication of the highway to four lanes may be considered as a potentially viable option.

## 5. User Experience

This section examines the road user experience on two-lane, two-way highways. A survey was conducted to better understand how road users perceive performance in terms of safety, travel time and PTSF.

### 5.1 Surveys

Road user surveys were conducted on road user perception of highway performance. One survey was conducted in the field, surveying road users travelling on a specific route. At the same time, a traffic count survey was conducted on these routes. The traffic count data was used to model highway performance using TRARR. Another survey was conducted online to general road users to expand the number of samples collected.

#### 5.1.1 Route-specific Travel Experience Survey

The route specific survey intercepted road users in the field. This survey was designed to capture road user experience as close as possible to the time of travel. It included a user perception survey and a traffic count survey.

##### User perception survey

An online questionnaire survey was administered using SurveyMonkey to explore user experience on three routes in South Australia, including:

- Augusta Highway between Port Augusta and Port Pirie
- Dukes Highway between Taillem Bend and Bordertown
- Princes Highway between Taillem Bend and Meningie.

Locations of survey routes and service stations are presented in Figure 5.1 and Figure 5.2. These three routes were selected due to their typical characteristics of two-lane, two-way rural roads in Australia, readily available highway data, and presence of a suitable and safe survey site. A survey card (see Appendix D.1), which included information about the survey as well as the link and Quick Response (QR) code to the survey, were distributed to drivers at two service stations in Port Augusta and two service stations in Taillem Bend between 9 March and 12 March 2018. The survey period was during a weekend and holiday, when traffic demand was higher than normal. The online questionnaire survey was opened between 9 March and 29 March 2018 to collect responses from drivers who travelled on these three routes during the survey period. A \$10 voucher was offered for completion of the survey.

In the survey, participants were first asked where they picked up the survey card and which trip they made. They were then asked to provide the time and date of the trip, vehicle type and travel experience, such as extra travel time, per cent time spent following (PTSF) and level of acceptability for the trip. This was followed by a series of safety-related questions. Participants were then asked to indicate their perceived level of acceptability of the trip if PTSF was increased. The survey also included hypothetical questions where participants were presented with alternative routes which were longer, but not congested. Overall, the survey included more than 20 key questions (see Appendix D.2).

Approximately 800 survey cards were distributed, and the total number of valid responses was 48. The valid response rate was 6%. The number of valid responses was less than expected, which suggests that for this type of survey a longer survey period was needed to increase sample size. Table 5.1 shows that 73% of respondents drove a car. This is consistent with the percentage of cars on these routes, which indicate that there is no bias in vehicle type. More than half of respondents travelled on Augusta Highway between Port Augusta and Port Pirie.

Figure 5.1: Augusta Highway (Port Augusta – Port Pirie), service stations and traffic survey location

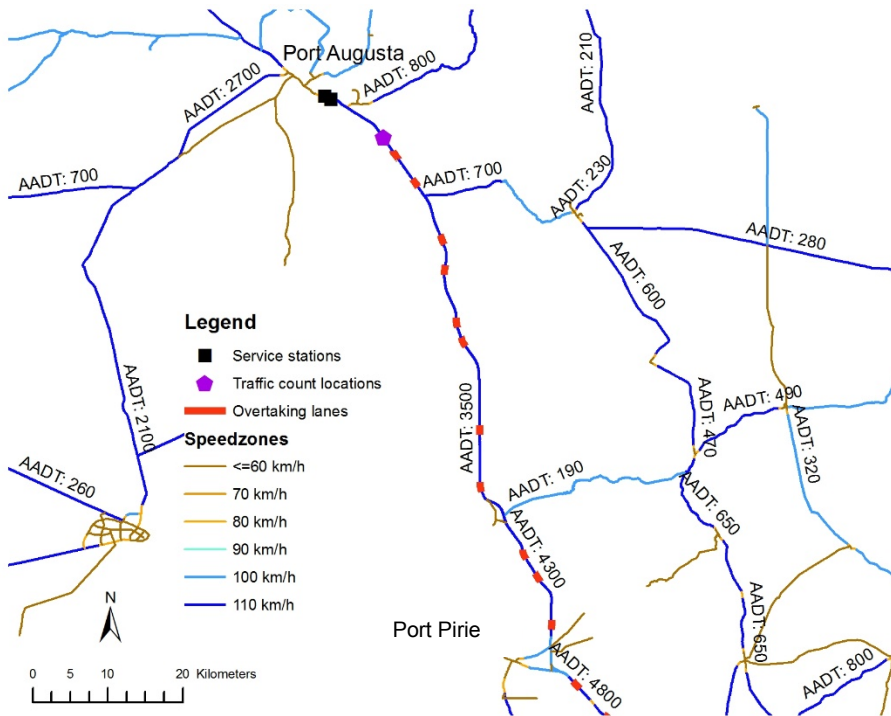
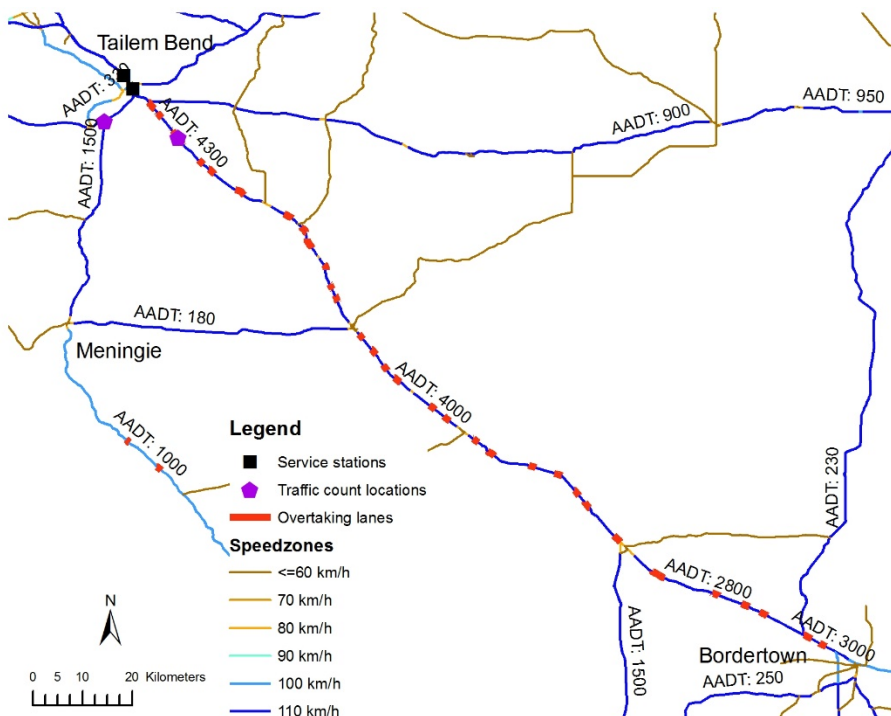


Figure 5.2: Dukes Highway (Taillem Bend – Bordertown), Princes Highway (Taillem Bend – Meningie), service stations, and traffic survey locations



**Table 5.1: Number of respondents by vehicle type and survey route**

Vehicle type	Route			Total
	Port Augusta – Port Pirie	Tallem Bend – Bordertown	Tallem Bend – Meningie	
Articulated truck	3	1	0	4
Car (incl. van, SUV, etc.)	19	13	3	35
Car-towing	6	0	1	7
Motorcycle	1	1	0	2
Total	29	15	4	48

### Traffic count survey

At the same time as the road user perception survey was being conducted (9 to 12 March 2018), a traffic count survey was also conducted with counters on each of the three routes. Locations of the traffic surveys are shown in Figure 5.1 and Figure 5.2. Based on historical AADT along each of the three routes, traffic volumes at other locations along each route were scaled up or down accordingly. The vehicle composition was assumed to be the same on each route, which was obtained from the traffic survey. The purpose of the traffic survey was to compare travel times and per cent time spent following reported by respondents and those estimated using TRARR for the same period.

### 5.1.2 General Travel Experience Survey

An online questionnaire survey was also administered through SurveyMonkey in March 2018 to explore user experience on two-lane two-way rural roads in Australia and New Zealand. Most of the survey questions were similar to those of the route-specific survey; however, the questions were modified to be generic rather than route specific (refer to Appendix D.3 for the survey questions). Several recruitment methods were applied for this general survey, including email lists and social networks. In total, there were 261 valid responses, including 171 from Australia and 90 from New Zealand. Profiles of the respondents are shown in Table 5.2. Similar to the results of the route-specific survey, most respondents reported driving a car for their trip on a two-lane two-way rural road.

**Table 5.2: The number of respondents by vehicle type and survey location**

Vehicle type	Australia	New Zealand	Total
Articulated truck	1	0	1
Car (incl. van, SUV, etc.)	153	87	240
Car towing	10	2	12
Motorcycle	5	1	6
Rigid truck, camper van or bus	2	0	2
Total	171	90	261

## 5.2 Reported Journey Experience and TRARR Estimates

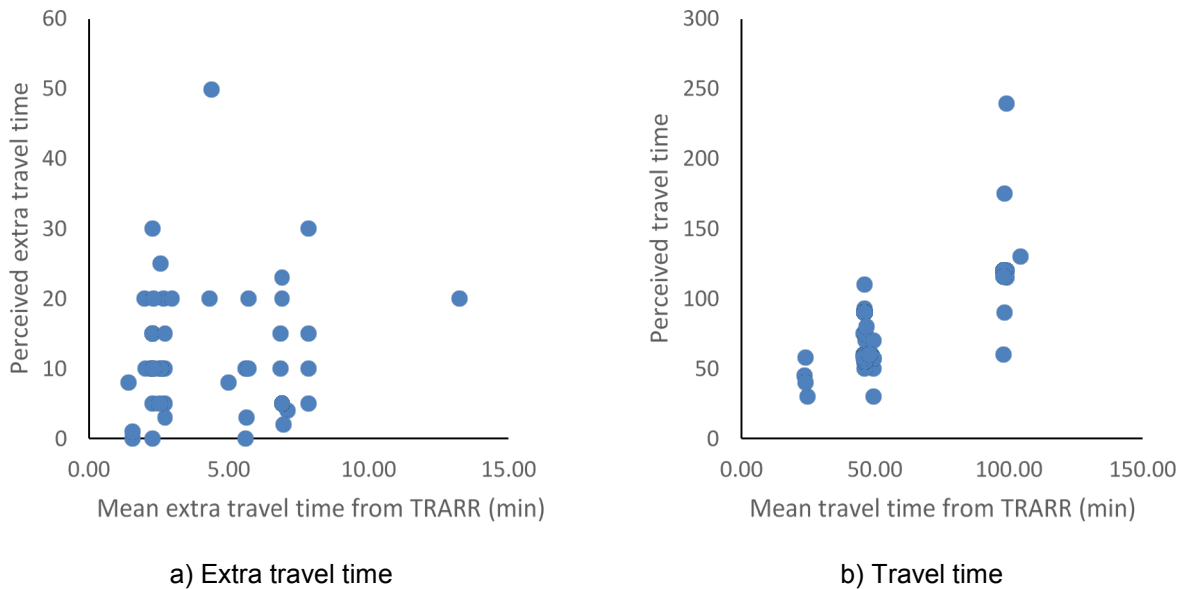
This section compares reported extra travel time and PTSF with TRARR estimates to gauge how representative TRARR estimates are of actual road user experience.

Based on the timing of each trip reported by survey respondents, traffic volume and vehicle compositions for the same time period were identified from the traffic survey. TRARR was then used to estimate the mean travel time, mean extra travel time due to following slower vehicles, and mean PTSF for this period.

Figure 5.3 presents travel time and extra travel time due to following slower vehicles reported by respondents and the mean values from TRARR. Apparently, respondents tend to report higher travel time and extra travel time due to following slower vehicles than TRARR estimates. However, positive correlation between perceived and TRARR travel times were evident (statistically significant at  $p < 0.001$ ).

Similarity between perceived and simulated PTSF was also identified, as shown in Table 5.3. Approximately 61% of perceived PTSF was within 10% of the mean PTSF estimated using TRARR. When respondents reported PTSF of less than 10%, they seemed to report lower PTSF than TRARR. When the perceived PTSF was greater than 10%, the correlation between perceived PTSF and the mean PTSF from TRARR was more evident. For example, 74% of perceived PTSF, which was greater than 10%, was within 10% of the mean PTSF estimated using TRARR. Overall, results suggest the mean PTSF from TRARR can be used as a proxy for perceived PTSF.

Figure 5.3: Perceived travel times versus TRARR travel times



Note: For the travel time comparison, Pearson’s correlation coefficient was 0.748, significant at  $p < 0.001$ .

Table 5.3: Number of respondents by perceived PTSF and mean PTSF from TRARR

Perceived PTSF	Mean PTSF from TRARR					
	Less than 10%	10% to 19%	20% to 29%	30% to 39%	40% to 49%	50% or above
Less than 10%		2	8	2		
10% to 19%		3	5	3		
20% to 29%		1	1	6		
30% to 39%		1	4	5		1
40% to 49%			1	1		
50% or above		1	1			

### 5.3 Perception of PTSF

In both route-specific and general surveys, survey participants were asked if the time they spent following a slower vehicle was acceptable. Table 5.4 shows the number of respondents indicating trip acceptability by perceived PTSF. Figure 5.4 illustrates the acceptability rate by PTSF. It is noted that due to small sample sizes, two categories of PTSF, (40 to 49% and 50% and above), were combined into one category. There was an overall trend where the acceptability rate declined with higher PTSF, which was expected. In the route-specific survey, a threshold of 30% PTSF was identified such that 50% of respondents would consider the journey as acceptable. From the generic survey, 40% PTSF was the threshold such that 50% of respondents would consider the journey acceptable.

**Table 5.4: Trip acceptability by perceived per cent time spent following (route-specific survey)**

PTSF	Route-specific survey		Generic survey	
	Acceptable	Unacceptable	Acceptable	Unacceptable
Less than 10%	10	2	82	12
10% to 19%	8	4	42	21
20% to 29%	4	5	20	20
30% to 39%	4	7	16	16
40% to 49%	1	1	9	5
50% or above	0	2	8	10
Total	27	21	177	84

*Note: Due to small sample sizes, 'acceptable' and 'just acceptable' were both considered as acceptable. Similarly, 'unacceptable' and 'definitely unacceptable' were considered as unacceptable.*

The survey examined road user perceptions when perceived PTSF levels were increased further. Road users rated acceptability of the journey experience if their perceived PTSF was increased by 1.5 times and 2 times and the results are illustrated for both surveys in Figure 5.5. The survey results show that the acceptability rate of PTSF significantly decreases (e.g. 0% in many cases), when PTSF is increased 1.5 and 2.0 times, particularly when the perceived PTSF is greater than 20%. This is indicative that if PTSF increases beyond 40%, road users would likely rate the journey experience as highly unacceptable.

Figure 5.4: Percentage of respondents indicating acceptability by PTSF (general survey)

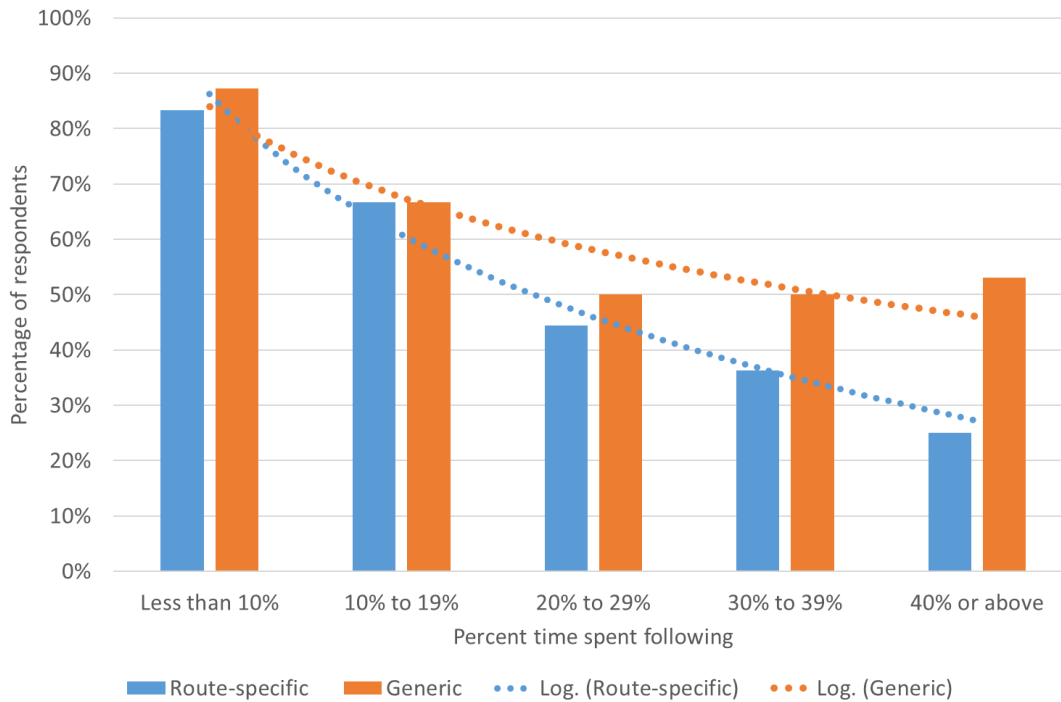
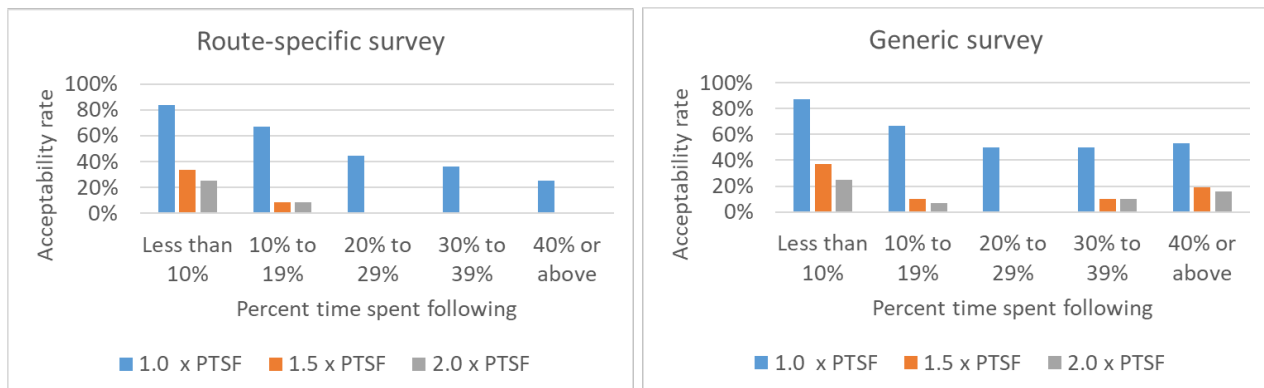


Figure 5.5: Acceptability rate of perceived PTSF



A 30% to 40% PTSF (as suggested by the survey results) is considered as LOS B according to HCM guidelines (see Table 2.2), wherein LOS B has a PTSF range of 30% to 50%. The HCM LOS C definition has a PTSF range of 50% to 65%, and Austroads (2016) guidelines recommend maintaining at least LOS C. The survey results suggest that to be acceptable for 50% of road users, a lower PTSF threshold is required than what is suggested in the Austroads guidelines.

If a threshold of PTSF ≤ 40% is to be maintained for a relatively straight and flat highway the following passing lane density would be needed (based on Figure 4.15 and Figure 4.16):

- one passing lane every 20 km when peak hourly traffic volume frequently reaches 200 veh/h in one direction
- one passing lane every 10 km when peak hourly traffic frequently reaches 300 veh/h in one direction
- one passing lane every 5 km when peak hourly traffic frequently reaches 500 veh/h in one direction.

## 5.4 Valuation of PTSF

This section examines how road users value PTSF. In both route-specific and generic questionnaire surveys, participants were asked whether they would use an alternative route which was 5% or 10% longer, but uncongested (i.e. no delay due to slower vehicles). If participants indicated they would use the alternative route, the value of PTSF can be estimated through the extra distance they would be willing to travel and associated operating costs. In addition, survey participants were asked to provide the maximum extra distance that they would be willing to travel to compensate for travelling with no congestion. This information can also be used to examine how participants value PTSF.

### 5.4.1 Route-specific Survey Results

Table 5.5 summarises the survey results in the route-specific survey, which shows the number of respondents indicating that they will switch to a longer but uncongested route.

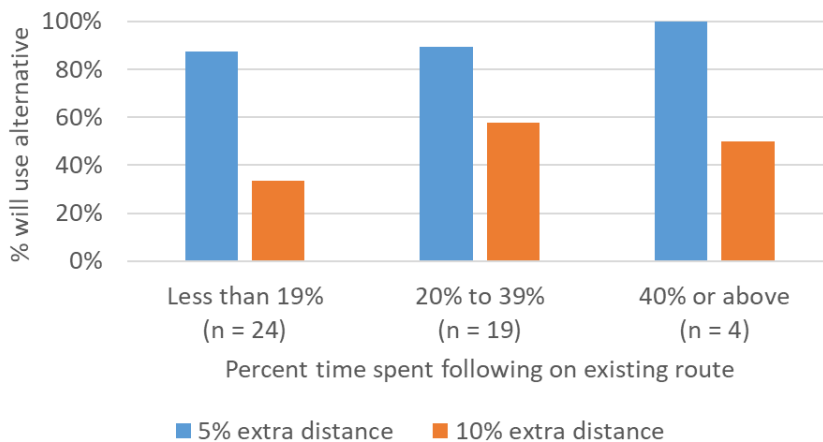
Figure 5.6 presents the survey results in percentages. When presented with an uncongested alternative route which is 5% longer, more than 80% of the road users reported that they would use the alternative route. If the alternative route is 10% longer, the percentage of road users indicating that they will switch routes declined to 33% and 58% when the PTSF on the existing route is less than 19% and 20% to 39%, respectively. There was limited data when PTSF was greater than 40% (i.e. n = 4).

The results demonstrated that road users value PTSF and there is trade-off between PTSF and extra distance of the route. Road users therefore intrinsically attach an economic value to PTSF. Unfortunately, the number of samples from the route-specific survey was limited to quantitatively model the trade-off. Broadly, it appears that 20% to 39% PTSF is worth at the minimum an extra 5% extra distance and possibly 10% extra distance. However, if the PTSF is less than 19%, its value is at least 5% extra distance but less than 10% extra distance.

**Table 5.5: Acceptability of an uncongested but longer alternative route (route-specific survey)**

PTSF on existing route	Use alternative (5% extra distance)		Use alternative (10% extra distance)	
	No	Yes	No	Yes
Less than 19%	3	21	16	8
20% to 39%	2	17	8	11
40% of above	0	4	2	2

**Figure 5.6: Percentage of respondents who would use a longer but uncongested route (route-specific survey)**



Using data from the route-specific survey, Table 5.6 illustrates the maximum extra distance of an uncongested alternative route that respondents would be willing to use instead of their existing route. As expected, if respondents considered the trip as unacceptable, they were more willing to travel a longer distance on the alternative route. This was particularly evident for Dukes Highway (Tailem Bend and Bordertown) and Augusta Highway (Port Augusta and Port Pirie). For Princes Highway (Tailem Bend and Meningie), the difference in the maximum extra distances of the alternative route when the reported trip was acceptable and unacceptable was not significant, which may be attributed to the limited samples for this route. The maximum extra distance for an uncongested route to be a viable alternative range from +8% to +23%, with a median value of +13%.

**Table 5.6: Maximum extra distance of the uncongested alternative route (route-specific survey)**

Route	Road user assessment of current PTSF	Average PTSF	Approximate route distance, km	Maximum extra distance for alternative uncongested route to be still viable	
				Extra km	% increase
Tailem Bend – Meningie	Unacceptable	30% to 39%	50	+8	+16%
	Acceptable	20% to 29%		+7.5	+15%
Tailem Bend – Bordertown	Unacceptable	20% to 29%	180	+19.5	+11%
	Acceptable	10% to 19%		+15.4	+9%
Port Augusta to Port Pirie	Unacceptable	30% to 39%	80	+18.2	+23%
	Acceptable	20% to 29%		+6.5	+8%

## 5.4.2 Generic Survey Results

Table 5.7 presents the generic survey results on the maximum extra distance such that a route with no congestion would be considered a viable alternative route. Overall, the mean maximum extra distance ranges between 9% and 12%. It is apparent that PTSF has an economic trade-off to extra route distance. It was expected that the maximum acceptable extra distance is directly proportional to PTSF on the existing route, however this was not evident from the data.

**Table 5.7: Maximum extra distance of the alternative route (general survey)**

PTSF on existing route	Maximum extra distance of uncongested route to be a viable alternative	
	Mean, %	Standard deviation, %
Less than 10%	+10.3	5.0
10% to 19%	+10.4	5.6
20% to 29%	+8.7	3.3
30% to 39%	+10.7	5.6
40% to 49%	+10.8	4.5
50% or above	+11.5	5.2

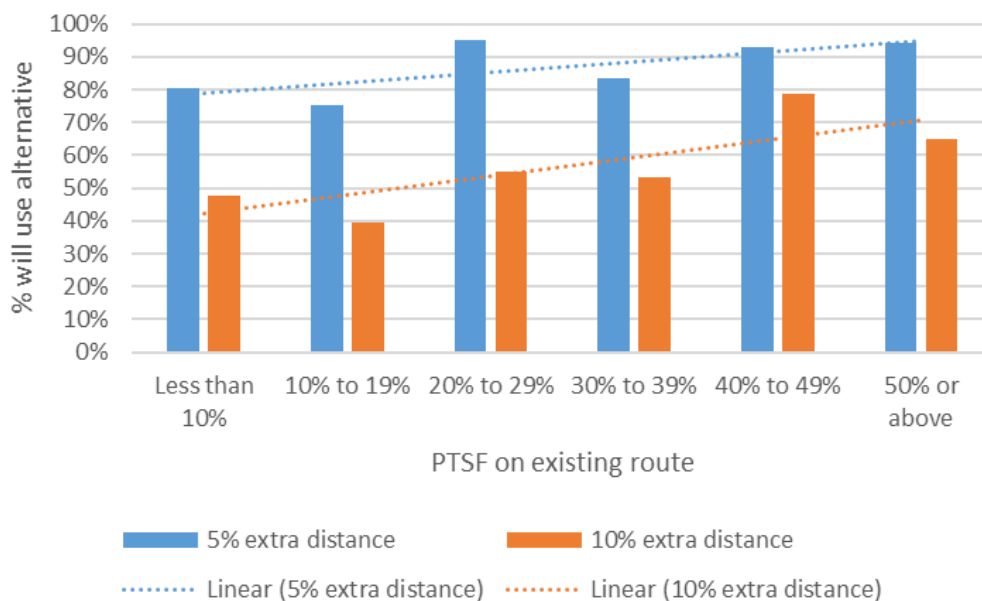
Respondents were asked if they would use an uncongested alternative route with 5% and 10% extra distances and the results are summarised in Table 5.8 and Figure 5.7. The results showed that for both cases of the extra distance, the likelihood to use the alternative route increased with increasing PTSF. This relationship was statistically significant according to the Chi-square test. In other words, if survey respondents experienced a higher level of PTSF, they would be more likely to use the alternative route which is longer but not congested. Moreover, the likelihood to use the uncongested alternative route seemed to decline if the alternative route was longer. For example, if PTSF is between 30% to 39%, the rates of using the alternative route with a 5% extra distance and with a 10% extra distance are 83% and 53% respectively.

Table 5.8: Acceptability of an uncongested but longer alternative route (generic survey)

PTSF on existing route	Use alternative (5% extra distance)		Use alternative (10% extra distance)	
	No	Yes	No	Yes
Less than 10%	17	69	45	41
10% to 19%	15	46	37	24
20% to 29%	2	38	18	22
30% to 39%	5	25	14	16
40% to 49%	1	13	3	11
50% or above	1	16	6	11

Note: Chi-square test for the use of the alternative (5% extra distance) was significant at  $p < 0.05$ ; Chi-square test for the use of the alternative (10% extra distance) was significant at  $p < 0.1$ .

Figure 5.7: Percentage of road users who indicate they would use a longer but uncongested route (generic survey)



The effects of the perceived PTSF and extra distance on the use of the alternative route was further investigated using binary logistic regression. The model was specified and calibrated as follows (Equation 2):

$$prob(alt) = \frac{\exp(V_{alternative})}{\exp(V_{alternative}) + \exp(V_{existing})} \tag{2}$$

$$V = -0.51ptsf - 0.1dist$$

where

$$ptsf = \begin{cases} 1 & \text{if PTSF less 10\%} \\ 2 & \text{if PTSF is 10\% to 19\%} \\ 3 & \text{if PTSF is 20\% to 29\%} \\ 4 & \text{if PTSF is 30\% to 39\%} \\ 5 & \text{if PTSF is 40\% to 49\%} \\ 6 & \text{if PTSF is 50\% or above} \end{cases}$$

$$dist = \text{percentage extra distance} \times 100$$

The model was calibrated using regression analysis. The *ptsf* coefficient was highly significant at *p-value* of 0.4% and its negative sign was logical, i.e. increasing *ptsf* decreases the probability of selecting the route. The *dist* coefficient was moderately significant at *p-value* of 14.3%, i.e. significant with 85% confidence. The *dist* coefficient negative sign was logical, i.e. increasing *ptsf* decreases the probability of selecting the route. Figure 5.8 illustrates how the model estimates compare to data when estimating the probability that a road user would use an uncongested but longer route. The model estimates were generally in line with data; however, the model has a correlation coefficient ( $R^2$ ) of 0.31 (i.e. between estimated and data), thereby the model can account for 30% of the variance in the data. While the correlation coefficient was relatively low, the model estimates generally fall on the 45-degree line (i.e. the linear trendline has a slope of 1.01).

Figure 5.9 illustrates the model estimates of probability of using the alternative route given extra distance and PTSF of the route. The trade-off is that improvement by one PTSF category (e.g. 30% – 39% to 20% – 29%) is equivalent to a saving of 4.7% distance.

Figure 5.8: Probability of selecting alternative route given PTSF and extra distance, model estimates versus data

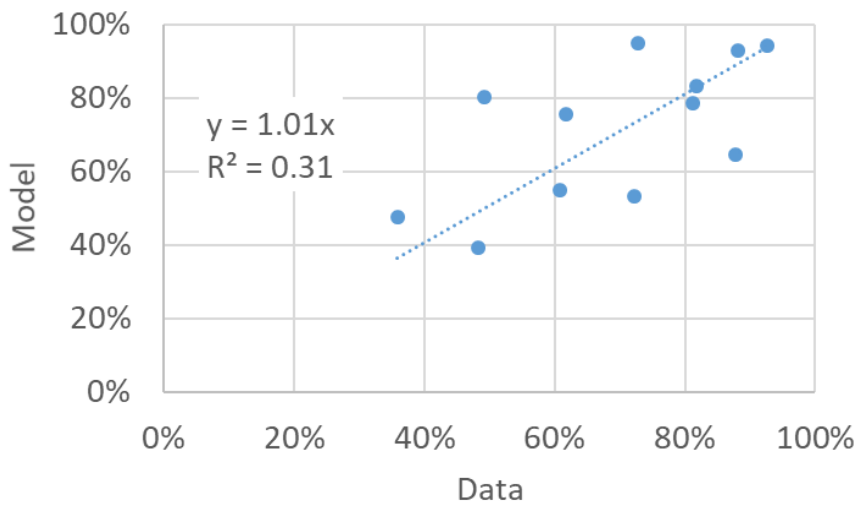
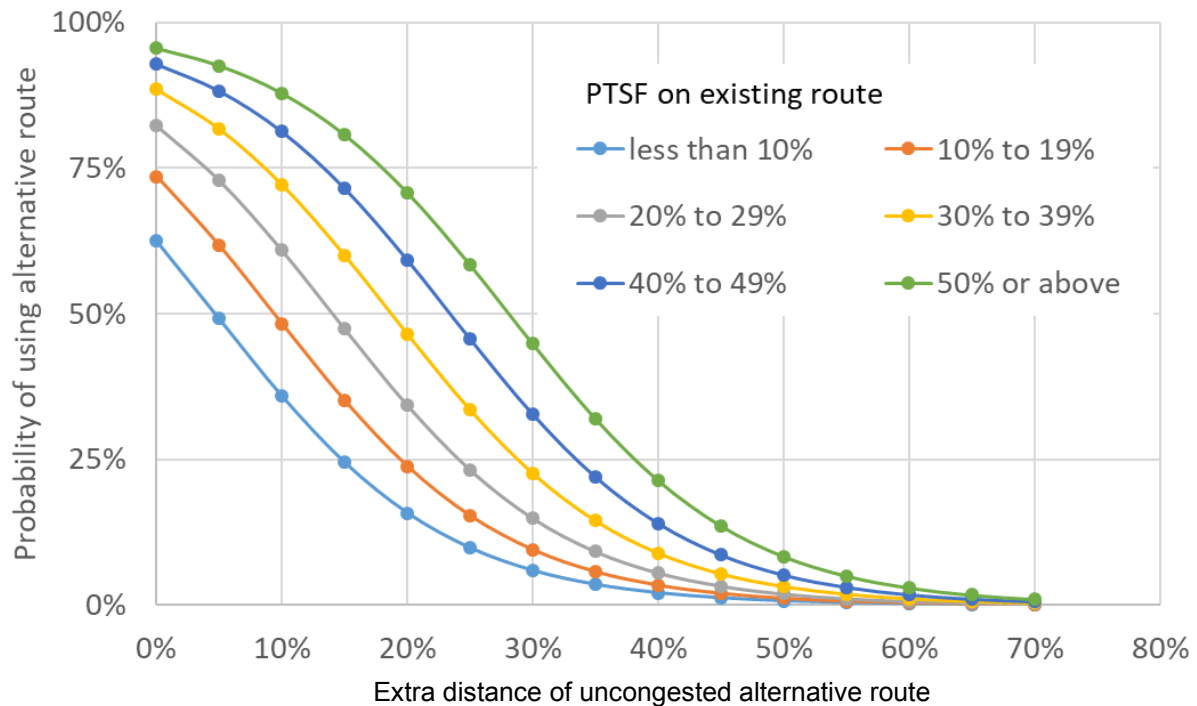


Figure 5.9: Probability of using uncongested but longer alternative route given PTSF on the existing route



The model was also calibrated using maximum likelihood estimation (i.e. instead of regression analysis). The model coefficients were similar to the coefficients determined using regression analysis, as follows (Equation 3):

$$V = -0.43ptsf - 0.06dist \quad 3$$

The model prediction performance was 67.7% (i.e. percentage that the model correctly predicted if the alternative route will be used). The model was significant at  $p\text{-value} < 0.001$  with a pseudo- $R^2$  of 0.2, indicating a relatively good fit. From the model coefficients it was determined improvement by one PTSF category (e.g. 30% – 39% to 20% – 29%) is equivalent to a saving of 6.6% extra distance (note: 4.7% when using regression analysis).

From the analysis it was determined that a 10% improvement in PTSF is equivalent to 4.7% to 6.6% distance savings. According to the *Australian Transport Assessment and Planning Guidelines* (Transport and Infrastructure Council (TIC) 2016), the weighted average unit costs (adjusted to 2017 prices) with 30% slow vehicles are vehicle operating cost of \$0.42/vehicle-km and travel time cost of \$31.8/vehicle-hour. Assuming 2 000 vehicles during the peak period per day, a 100 km route and speed of 100 km/h, the estimated benefit of an improvement in PTSF of 10% is \$3.5~\$4.9 per vehicle or \$6 900~\$9 700 per day. If there are 100 days in a year that experience congestion, then the annual benefit is approximately \$690 000~\$970 000. Note that the example assumes a highly congested route and a less congested route would have less benefits.

## 5.5 Perceptions of Safety

Results of safety-related questions from the route-specific survey and general survey are presented in Table 5.9. Key observations are as follows:

- The majority of respondents tend to use passing lanes to overtake.
- The majority of respondents felt safe when overtaking on a passing lane, while the majority felt unsafe when overtaking using the opposing lane.
- While overtaking on two-lane two-way highways, less than half of respondents reported pulling back mid-manoeuvre.
- More than half of respondents noted unsafe tailgating at the start of the passing lane and unsafe merging at the end of the passing lane.
- More than half of respondents noted unsafe overtaking manoeuvres outside of the passing lane.

The survey indicates that respondents perceive safety benefits in using the passing lane. They would tend to use passing lanes to overtake and generally feel safer on passing lanes. The value of passing lanes to road users as a location to be able to safely overtake is evident. This benefit was not quantified by this study, but it appears to be an important aspect of passing lanes and should be noted in investment decisions on passing lanes.

While passing lanes was perceived to offer safety benefits, tailgating at the start of the passing lane and the unsafe merging at the end of the passing lane was reported by road users albeit not broadly. It is recommended that these issues be investigated further if there are any further solutions to reduce the reported unsafe tailgating and merging around passing lanes.

**Table 5.9: Perception of safety related to overtaking**

Question	Option	Route-specific survey	General survey
When you were trying to pass slower vehicles, what did you do?	Mainly used overtaking lanes	67%	52%
	Mainly used the opposing lane	26%	41%
	Generally, not able to pass	6%	7%
If you passed one or more slower vehicles using passing lanes, how safe did it feel?	Very safe	54%	56%
	Slightly safe	22%	31%
	Slightly unsafe	17%	9%
	Very unsafe	7%	4%
If you passed one or more slower vehicles using the opposing lane, how safe did it feel?	Very safe	18%	16%
	Slightly safe	23%	20%
	Slightly unsafe	36%	52%
	Very unsafe	23%	12%
Were there any occasions in the course of the trip when you started to overtake another vehicle but then pulled back because you realised you didn't have time to overtake safely?	Yes, more than one occasions	25%	17%
	Yes, one occasion	25%	21%
	No	50%	62%
Did you observe or experience any unsafe tailgating approaching the start of the overtaking lanes?	No	43%	46%
	Yes	57%	54%
Did you observe or experience any unsafe merging at the end of the overtaking lanes?	No	50%	47%
	Yes	50%	53%
Did you observe or experience any unsafe overtaking manoeuvre outside of the overtaking lanes?	No	48%	40%
	Yes	52%	60%

## 5.6 Effect of Travel Information

In Australia, signs informing motorists of an overtaking lane ahead are placed 3 km upstream of the overtaking lane, while in New Zealand they are placed 2 km ahead. The closest of these signs to the overtaking lane are typically posted 300 m ahead. Respondents were asked if an advisory sign of a passing lane would influence their decision to wait for the passing lane to overtake.

Table 5.10 summarises the results of the survey. More than 80% of the respondents reported that the advisory sign would influence their decision to overtake on the passing lane. The results indicate the effectiveness of advisory signs. Advisory signs are an important component of passing lane operation.

**Table 5.10: Advisory sign (passing lane in the next 2 or 3 km) and decision to overtake on a passing lane**

Survey	Did the advisory sign influence you to wait for the passing lane to overtake?	
	Yes	No
Route-specific (South Australia)	84.1%	15.9%
Generic – Australia	88.3%	11.7%
Generic – New Zealand	82.8%	17.2%

## 6. Conclusions

This project examined the impacts of passing lanes on safety, journey time and user experience and developed guidance to assist in the development of passing lane installation projects.

### 6.1 Safety Impacts

Review of literature on the safety impacts of passing indicated that there appears to be a degree of consensus that passing lanes contribute to the improvement of safety. Injury crash reduction as a result of passing lane installation ranged from 20% to 40% across the various documents reviewed.

The user perception survey identified that motorists recognise the safety benefits of passing lanes. Motorists feel safer overtaking on the passing lane rather than using the opposing lane outside of the passing lane. Thereby, the majority of motorists would use passing lanes when overtaking. Signs informing of availability of passing lanes 2 to 3 km in advance encouraged motorists to forego overtaking using the opposing lane and wait to overtake using the passing lane instead. Analysis of traffic data also showed that passing lanes impact choice of location of overtaking, differential speed, headway, and gap such that overtaking is executed in a manner that can be considered safer than overtaking on the opposing lane.

Before-and-after crash analysis identified that passing lanes resulted in a 16% average reduction of crash injury over the route. The observed crash reduction however varies significantly with an interquartile range from a reduction of 38% to an increase of 12%. The median is a reduction of 16%, and 66% of the analysed routes showed a reduction of crashes, while 34% showed an increase in crashes.

The analysis examined crashes at specific segments of routes before-and-after installation of passing lanes. The analysis examined crashes within the passing lane, 2 km upstream of a passing lane and 5 km downstream separately. The before-and-after analysis provided inconclusive results. Gradient, passing lane length, passing lane density, speed limit and traffic volume were also examined but a clear correlation with before-and-after crash impacts was also not identified.

Due to the variability of the crash analysis results, assumption of average crash reduction should be made with caution. It is best applied over several passing lane sites (e.g. over a route), rather than a specific passing lane. Assessment of crash benefits of a specific passing lane needs to be supported by site-specific evidence.

### 6.2 Journey Time Impacts

Past research on the impact of passing lanes on journey time indicated a +2 to +3 km/h improvement in travel speed and reduction of per cent time spent following of 10%.

Numerical experiments on a relatively straight and flat highway showed that passing lanes could increase travel speed by 0.3 km/h to 4 km/h depending on percentage of slow vehicles, traffic volume and density of passing lanes. At the same time, per cent time spent following is also improved by 6% to 34%. Increasing passing lane density from one every 20 km to one every 5 km improved travel speed by 1.2 km/h to 2.6 km/h; and, per cent time spent following was reduced by 13% to 20%.

The numerical experiments also identified benefits in increasing passing lane length. For example, increasing from 1.3 km to 3 km improved travel speed by approximately 2 km/h and per cent time spent following by around 9%.

The analysis identified that at high traffic volumes of around 1900 veh/h, passing lanes were counterproductive as they resulted in traffic flow breakdown. Travel speed with passing lanes was 1 km/h to 8 km/h slower than without passing lanes. It was conjectured that the merge at the end of the passing lane resulted in a bottleneck. It may be beneficial to temporarily close passing lanes, during periods of high demand to maintain travel speed.

The analysis also showed that regardless of whether the highway has passing lanes or not travel speeds reduce sharply when traffic volumes reach 1600 veh/h, which may be considered as the practical capacity of a two-lane two-way highway. If traffic volumes are expected to reach this level within the life of the pavement, then duplication of the highway may be considered as an option.

As part of the numerical experiments the TRARR model was reviewed and its parameters were re-calibrated to match current vehicle fleet and recent field data. The new parameters are provided in this report as guidance for modellers to apply TRARR to assess passing lane impacts on journey time. Moreover, it was demonstrated using field survey data that TRARR model outputs are representative of actual motorist journey experience. Hence, TRARR can be reliably used for passing lane analysis.

## 6.3 User Experience

A review of past research indicated that motorists recognise the benefits of passing lanes. Platooning behind slow vehicles was identified by motorists as a major source of delays and frustration.

Surveys (on-site and online) were conducted to better understand motorists' perceptions of highway performance and passing lanes. The survey data suggested that 50% of motorists consider 30% to 40% time spent following as a maximum acceptable level, which is rated as LOS B. This means that for a relatively straight and flat highway, passing lane density of 1 every 10 km/h will be required when peak traffic volume frequently reaches 300 veh/h in one direction to maintain peak period per cent time spent following at 40%.

The surveys also examined the valuation of motorists of per cent time spent following. It was determined that a 10% reduction in per cent time spent following is equivalent to 4.7% to 6.6% savings in route distance, or, an improvement of 10% in per cent time spent following is approximately equivalent to a benefit of \$3.5 to \$4.9 per 100 vehicle-km.

## 6.4 Recommendations for Future Research

### 6.4.1 Variance in Passing Lane Crash Impacts

The safety analysis showed a broad spectrum of crash change results. While the average crash reduction across all sites indicated a reduction in crashes, variation in results was significant such that around half of the sites experienced a reduction in crashes while the other half experienced an increase in crashes. It is not possible to reliably predict if a specific passing lane site would lead to a reduction in crashes or may even potentially lead to an increase in crashes. It was attempted in this project to examine potential factors that may explain the variation in crash impacts across the sites, but it was not successful. It is likely that the method of analysis (including data) needs to be more refined to have a better understanding of crash impacts of passing lanes. Future research should focus on determining common attributes of sites that may lead to a lesser or greater risk of crashes occurring. It is suggested that such a study may be achieved through detailed case studies of different sites that have shown different crash changes after installation of the passing lane(s).

## 6.4.2 TRARR Calibration for High Traffic Volume Conditions

This project was able to calibrate the TRARR model with the available data from DPTI with a calibration range of 150 veh/h. The journey time analysis was extrapolated based on the calibrated parameters. To enhance the reliability of TRARR model parameters and to validate the findings from the numerical experiments, it is recommended to conduct a more extensive calibration of TRARR parameters covering highways with high traffic volumes and a higher percentage of heavy vehicles.

## 6.4.3 Extended User Experience Survey and Analysis

The on-field road user survey response rate was only 6% which resulted in a limited number of samples for analysis. While the online survey responses were able to supplement the relatively low number of samples from the on-field surveys, it is beneficial to gather more on-field survey responses to improve the reliability of the findings in this project. In particular, it is recommended to survey routes that carry higher traffic volumes to examine road user perceptions after they experience significant congestion on the highways.

## 6.4.4 Updates to the Guides

The findings in this project have implications for the Austroads guides, including the following:

- Guide to Road Safety
- Guide to Road Design.
- Guide to Traffic Management.

These implications are examined in Appendix E which can be used to update the Guides mentioned above.

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# Appendix A Crash Data Analysis

## A.1 Data Request Sent to Austroads Jurisdictions

The following data and information was requested:

### A.1.1 Mass/police crash data

For recorded crashes that have occurred along passing lanes (i.e. between start of diverge and end of merge) and for recorded crashes that have occurred along roads where passing lanes have been implemented (i.e. for sections containing passing lanes bounded by townships/major intersections):

- crash type
- RUM/DCA code
- crash location
- crash date/time
- crash severity
- vehicles involved (type, direction)
- lighting
- weather
- speed limit
- police narrative (if available).

For crashes occurring along passing lanes, data is requested for five years before and five years after installation of the passing lane.

For crashes occurring along roads where passing lanes have been implemented, data is requested for five years before the installation of the earliest passing lane and for and five years after the installation of the last passing lane for that road.

### A.1.2 Passing lane information/data

Passing lane installation/modification data and locations, including:

- road name
- length of passing lane
- gradient of passing lane
- direction of passing lane
- road running distance/GPS location/mapped location
- date of installation/modification.

Location data will need to be compatible with mass/police crash data location information.

General data for roads containing passing lanes, including:

- road name
- road class
- traffic flow
- modal distribution.

## A.2 Crash Categories

**Table A1: Categorisation of head-on crashes**

RUM code	Vehicle movement code	Crash type description
20-23, 27, 51, 54	AB, AE, BA-BF, BO, LA-LB, LO, MB	Head-on

**Table A2 : Categorisation of same direction crashes**

RUM code	Vehicle movement code	Crash type description
30-33, 35-39, 52-53, 55-56	AA, AC-AD, AF-AG, FA-FF, FO, GA-GC, GD, GF, GO	Rear End, Side Swipe

**Table A3: Categorisation of intersection crashes**

RUM code	Vehicle movement code	Crash type description
10-19	JA-JC, JO, KA-KC, KO	Right Angle, Right Turn

**Table A4 : Categorisation of single vehicle crashes**

RUM code	Vehicle movement code	Crash type description
70-77, 80-85	CA-CC, CO, DA-DC, DO	Hit Fixed Object, Left Road – Out of Control, Roll Over

**Table A5 : Categorisation of non-single vehicle crashes**

RUM code	Vehicle movement code	Crash type description
10-19, 20-23, 30-39, 50-56,	AA-AG, AO, BA-BF, BO, FA-FF, FO, GA-GD, GF, GO, JA-JC, JO, KA-KC, KO, LA-LB, LO, MB-MC	Head-on, Rear End, Right Angle, Right Turn, Side Swipe

**Table A6: Crashes included in 'All types' but not included in any specific crash type categories**

RUM code	Vehicle movement code	Crash type description
1-9, 24-26, 40, 42-49, 60-67, 69, 90-98	MA, MD-MG, MO, NA-NG, NO, PA-PG, PO, QA-QG, QO	Hit Animal, Hit Object on Road, Hit Parked Vehicle, Hit Pedestrian, Other

### A.3 Control Data

Figure A1: Control data for Jurisdiction 1. Solid line represents linear regression line used to equate expected change in injury crashes

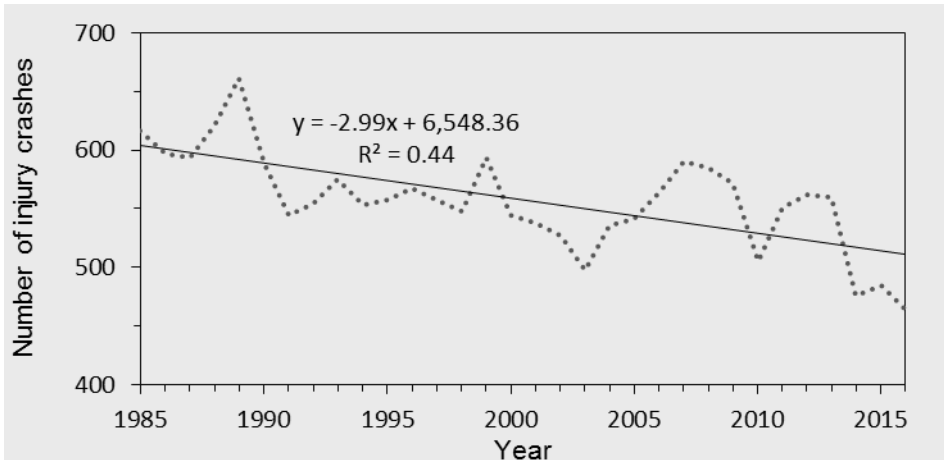


Figure A2: Control data for Jurisdiction 2. Solid line represents linear regression line used to equate expected change in injury crashes

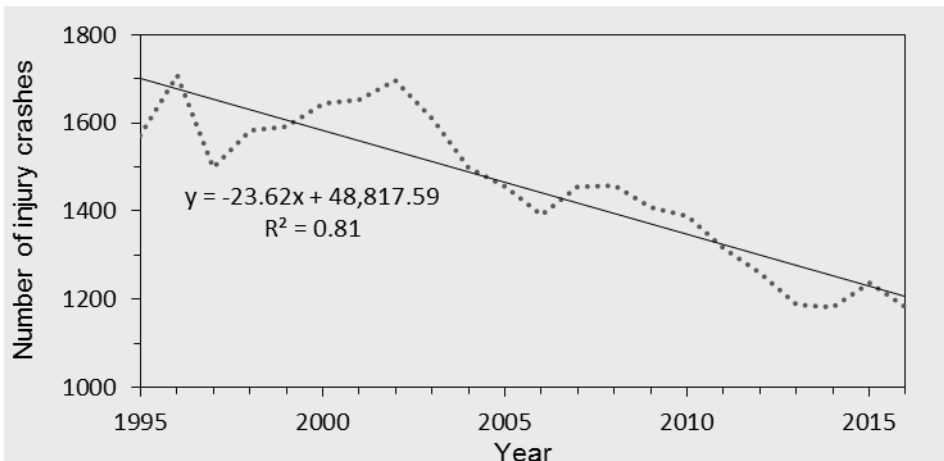
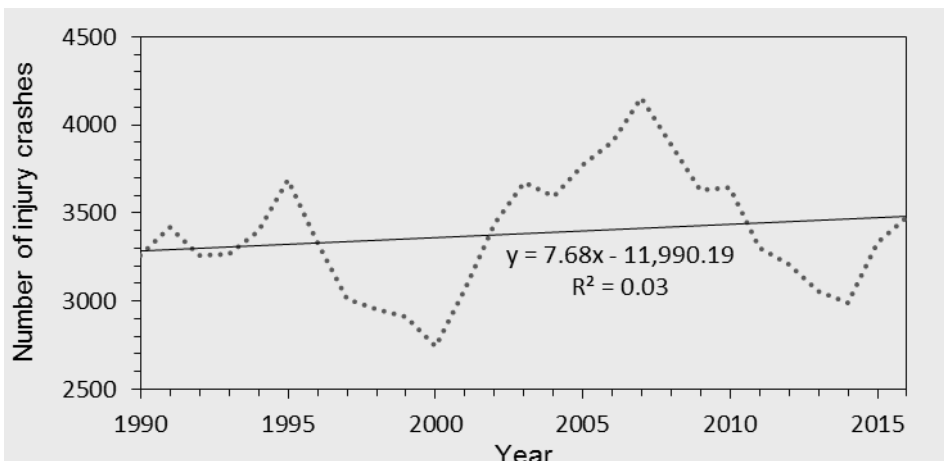


Figure A3: Control data for Jurisdiction 3. Solid line represents linear regression line used to equate expected change in injury crashes



## Appendix B Calibrated Traffic Parameters (Template for TRF File)

TEMPLATE

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WHERE NOT SPECIFIED UNITS ARE IN SECONDS, METRES AND KM/H.

BASIC TIME UNIT FOR THE SIMULATION (TUN)

SETTLING DOWN TIME FOR THE SIMULATION (TSE)

DURATION OF THE SIMULATION (TSI); NOTE THAT THE PROGRAM KEEPS RUNNING UNTIL ALL VEHICLES WHICH ARRIVED IN THIS TIME HAVE DEPARTED.

0 OPTION: 0=TRARR4; 1=STANDARD; 2=USE ITRAF; 3=USE PBAYS;  
5=GRAFIC DISPLAY; 6=TIME DISPLAY;

LENGTH OF NO OVERTAKING TO CREATE BUNCHING IN DIRECTION 1 (DTS1)

LENGTH OF NO OVERTAKING TO CREATE BUNCHING IN DIRECTION 2 (DTS2)

PERCENT FOLLOWING IN PLATOONS ON ARRIVAL IN DIRECTION 1 (PFOL1)

PERCENT FOLLOWING IN PLATOONS ON ARRIVAL IN DIRECTION 2 (PFOL2)

NOTE ZERO %FOLL GIVES RANDOM ARRIVALS; NEG %FOLL USES DEFAULTS.

NUMBER OF VEHICLE GENERATION CATEGORIES (NSTR); CHECK FORMATS IN THIS FILE IF NSTR IS CHANGED. ONLY NSTR OF THE COLUMNS BELOW ARE READ.

RANDOM SEED NUMBER (NSEED0); RANGE IS 0. TO 999999.

0 ICHECK: 1=PRINT INPUT DATA TO FILE CHKOUT FOR CHECKING; 0=NO CHECK

THE REMAINING PARAMETERS DESCRIBE THE SIMULATED TRAFFIC STREAM

ADTV: PROPORTIONS OF VEHICLE TYPES IN VARIOUS CATEGORIES

\*\*\*\*\*

\* TRAFFIC GENERATION CATEGORIES \* TYPE \*

\*\*\*\*\*

CARS CAR TOW RIGIDS SGLARTC DBLARTC RDTRAIN EXTRA1 EXTRA2 \* \*

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 \* 1 \*

0.0 0.0 0.0 0.0 0.0 0.03 0.0 0.0 \* 2 \*

0.0 0.0 0.0 0.0 0.0 0.04 0.0 0.0 \* 3 \*

0.0 0.0 0.0 0.0 0.0 0.93 0.0 0.0 \* 4 \*  
 0.0 0.0 0.0 0.0 0.0 0.01 0.0 0.0 0.0 \* 5 \*  
 0.0 0.0 0.0 0.0 0.0 0.08 0.0 0.0 0.0 \* 6 \*  
 0.0 0.0 0.0 0.0 0.0 0.77 0.0 0.0 0.0 \* 7 \*  
 0.0 0.0 0.0 0.0 0.0 0.14 0.0 0.0 0.0 \* 8 \*  
 0.0 0.0 0.0 0.74 0.0 0.0 0.0 0.0 \* 9 \*  
 0.0 0.0 0.0 0.26 0.0 0.0 0.0 0.0 \* 10 \*  
 0.0 0.0 0.01 0.0 0.0 0.0 0.0 0.0 \* 11 \*  
 0.0 0.0 0.24 0.0 0.0 0.0 0.0 0.0 \* 12 \*  
 0.0 0.0 0.75 0.0 0.0 0.0 0.0 0.0 \* 13 \*  
 0.0 1.00 0.0 0.0 0.0 0.0 0.0 0.0 \* 14 \*  
 0.15 0.0 0.0 0.0 0.0 0.0 0.0 0.0 \* 15 \*  
 0.10 0.0 0.0 0.0 0.0 0.0 0.0 0.0 \* 16 \*  
 0.60 0.0 0.0 0.0 0.0 0.0 0.0 0.0 \* 17 \*  
 0.15 0.0 0.0 0.0 0.0 0.0 0.0 0.0 \* 18 \*

ADVGC: PROPORTION OF FLOW IN EACH LANE AND DIRECTION

0.50 0.50 DIR1 BASIC LANE  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 AUX. LANE  
 0.50 0.50 DIR2 BASIC LANE  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 AUX. LANE

VMIT: TWO-DIRECTIONAL TRAFFIC VOLUME(VEH/H) FOR EACH CATEGORY

0.0 0.0

VMF: MEAN DESIRED SPEED(KM/H)

110.0 105.0 106.0 103.0 103.0 97.0 75.0 75.0

VSDF: STANDARD DEVIATION OF DESIRED SPEEDS(KM/H)

4.0 4.0 4.0 4.0 3.0 5.0 10.0 10.0

LFSD: INDICES INDICATING TYPE OF SPEED DISTRIBUTION

1 1 1 1 1 1 1 1

PFQ1: DEFAULT PLATOONING-FLOW DISTRIBUTION USED WHEN PFOL IS INPUT AS -1

0.0 200.0 400.0 800.0 1200.0 1600.0 2000.0 2800.0  
 0.0 15.0 30.0 50.0 65.0 75.0 90.0 100.0

## Appendix C Calibrated Vehicle Parameters (VEHS File)

FILE VEHS - TO BE USED ONLY WITH TRARR VERSIONS 17.1 ONWARDS

----- - PBS VEHS

VEHICLE AND DRIVER CHARACTERISTICS ARE SPECIFIED FOR 18 VEHICLE TYPES:

ROW 1: ROW 2:

- 1 PBS 4B Vehicles 10 (single) Artic light load
- 2 Triple Road Train (Type II) 11 3/4 axle Rigid heavy load (or Bus)
- 3 Triple Road Train 12 3/4 axle Rigid light load (or Bus)
- 4 Double Road Train (Type I) 13 2 axle Rigid
- 5 PBS 2B A-Double 14 Car Towing
- 6 B-double heavy load 15 Unaggressive Car
- 7 B-double heavy load (low power) 16 Low powered Car
- 8 B-double light load 17 Typical SUV / Sedan
- 9 (single) Artic heavy load 18 Small Hatchback

LIF: DESIRED SPEED GROUP

3 3 3 3 2 2 2 2 2  
2 1 1 1 1 4 4 4 4

VOSFN: OVERTAKING SPEED FACTOR WHEN THERE IS NO AUXILIARY LANE

1.02 1.06 1.06 1.06 1.10 1.07 1.06 1.08 1.10  
1.10 1.10 1.06 1.05 1.05 1.10 1.10 1.10 1.08

VOSFA: OVERTAKING SPEED FACTOR WHERE THERE IS AN AUXILIARY LANE

1.02 1.03 1.03 1.03 1.04 1.05 1.04 1.06 1.05  
1.05 1.06 1.05 1.05 1.05 1.05 1.05 1.08 1.08

VHSFN: HAPPY SPEED FACTOR WHERE THERE IS NO AUXILIARY LANE

1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
1.00 1.00 1.00 1.00 .94 .96 .98 .98 .98

VHSFA: HAPPY SPEED FACTOR WHERE THERE IS AN AUXILIARY LANE

1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
1.00 1.00 1.00 1.00 .97 .98 .99 .99 .99

VDE: MAXIMUM DECELERATION (AS AN ACCELERATION)

-3.00 -3.00 -3.00 -3.00 -3.00 -3.00 -3.00 -3.00 -3.00  
 -5.00 -4.00 -4.00 -6.00 -4.00 -6.00 -6.00 -6.00 -6.00

VXA: MAXIMUM ACCELERATION

2.05 1.01 1.10 1.30 1.40 1.50 1.40 1.60 1.80  
 2.20 2.30 2.00 3.50 4.20 5.60 4.90 6.50 5.50

VNP: MAXIMUM POWER/WT TO BE USED WHILE NOT OVERTAKING 85% POWER

3.50 3.60 4.80 4.05 5.12 6.40 5.12 7.75 7.80  
 10.00 10.50 10.70 11.00 22.00 45.00 45.00 49.50 48.00

VXP: MAX POWER/WT TO BE USED WHILE OVERTAKING

3.50 3.60 4.80 4.05 5.12 6.40 5.12 7.75 7.80  
 10.00 10.50 10.70 11.00 22.00 45.00 45.00 49.50 48.00

VWRC: RESISTANCE COEFF. OF SPEED\*\*2 DUE TO WIND ETC.

12.00 12.00 10.00 10.00 10.00 10.00 10.00 9.50 10.00  
 9.50 9.50 9.00 8.50 5.00 3.00 3.00 4.00 3.00

VLN: LENGTH OF VEHICLE

60.00 53.50 42.00 36.50 30.00 26.00 26.00 26.00 19.00  
 19.00 8.00 8.00 8.00 12.00 4.80 4.80 4.60 4.50

VFA: ACCELERATION TO BE USED FOR SMOOTH FOLLOWING BEHAVIOUR

.50 .50 .50 .50 .50 .50 .50 .50 .50  
 .50 .50 .50 .50 .50 .50 .50 .50 .50

VFB: (REL. SPEED)/(DIST. TO BE MADE UP) FOR SMALL FOLL. DEVIATIONS

.10 .10 .10 .10 .10 .11 .10 .12 .10  
 .12 .10 .10 .15 .12 .10 .12 .15 .15

VFDA1: DISTANCE SPACING FOR BASIC LANE WHEN NOT THINKING OF OVERTAKING

2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00  
 2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00

VFDB1 TIME SPACING

2.00 1.50 1.50 1.50 1.00 2.00 2.00 2.00 1.00  
 1.00 1.00 1.00 1.00 2.00 2.00 1.80 1.80 1.80

VFDA2: DISTANCE SPACING WHEN IN BASIC LANE, CONSIDERING OVERTAKING

2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00  
 2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00

VFDB2 TIME SPACING

1.50 1.50 1.50 1.50 1.00 1.00 1.00 1.00 1.00  
 1.00 1.00 1.00 1.00 .70 1.00 .50 .50 .50

VFDA3: DISTANCE SPACING FOR OVERTAKING LANE WHERE THERE IS NO AUX. LANE

5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00  
 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00

VFDB3: TIME SPACING IN SAME SITUATION

2.00 2.00 2.00 2.00 1.70 1.70 1.70 1.70 1.00  
 1.00 .70 .70 .70 1.00 1.30 .70 .70 .70

VFDA4: DIST. SPACING WHEN IN OVERTAKING LANE WHERE THERE IS AN AUX. LANE

3.50 3.50 3.50 3.50 3.50 3.50 3.50 3.50 3.50  
 3.50 3.50 3.50 3.50 3.50 3.50 3.50 3.50 3.50

VFDB4: TIME SPACING

2.50 2.50 2.50 2.50 2.00 1.30 1.30 1.30 1.30  
 1.30 1.00 1.00 1.00 2.00 1.00 1.00 1.00 1.00

VSHA: FIXED DISTANCE COMPONENT OF MINIMUM DESIRED FOLLOWING DISTANCE

.80 .80 .80 .80 .80 .80 .80 .80 .80  
 .80 .80 .80 .80 .80 .80 .80 .80 .80

VSHB: TIME COMPONENT OF FOLLOWING SPACE WHEN HASSLED

1.00 .50 .50 .50 .30 .20 .20 .20 .20  
 .20 .20 .20 .20 .50 .50 .20 .20 .20

VDFD: FOLLOWING DISTANCE FACTOR (PER SECOND)

.01 .00 .00 .00 .00 .00 .00 .00 .00  
 .01 .00 .01 .01 .01 .01 .01 .01 .01

VDFDC: FOLLOWING DISTANCE FACTOR CUTOFF VALUE (MAXIMUM FACTOR)

1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
 1.00 1.00 1.00 1.00 1.60 2.00 3.00 3.00 3.00

LAG: AGGRESSION NUMBER (0 = ONLY OVERTAKES WHERE THERE IS AN AUX. LANE)

3 3 3 3 3 3 3 3

4 3 3 3 2 2 3 3 3

LAGB: WAIT FOR VEHICLE BEHIND IF ITS AGGRESSION NUMBER EXCEEDS THIS

7 7 7 7 7 7 7 7

7 7 7 7 5 4 7 7 7

LAGF: WAIT FOR VEHICLE IN FRONT IF ITS AGGRESSION NUMBER EXCEEDS THIS

4 4 4 4 4 4 4 4 4

4 4 4 4 4 4 4 4 4

LBS: WHETHER OVERTAKE WHEN BEYOND SECOND IN A PLATOON

T T T T T T T T T T

T T T T F F T T T T

LLA: WHETHER OBEYS OPTIONAL OVERTAKING RESTRICTIONS (T = YES, F = NO)

T T T T T T T T T T

T T T T T T T T T T

LRO: WHETHER DO RISKY OVERTAKINGS

F F F F F F F F F F

F F F F F F F F F F

LUO: WHETHER USE OPPOSING AUXILIARY LANE TO ADVANTAGE

F T T T T T T T T T

T T T T F F T T T T

VTO: CONSIDER YOURSELF BEING O'TAKEN IF VEH WILL REACH YOUR REAR IN VTO

5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00

5.00 4.00 4.00 4.00 5.00 5.00 4.00 4.00 4.00

VSFSA: SAFETY FACTOR: SIGHT-RESTRICTED OVERTAKING, AUXILIARY LANE STARTS

2.00 2.00 2.00 2.00 2.00 1.80 2.00 1.90 1.80

1.80 1.60 1.60 1.60 1.80 2.50 1.50 1.70 1.70

VSFSN: SAFETY FACTOR FOR OTHER SIGHT-RESTRICTED OVERTAKINGS

2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00 1.80

1.80 1.60 1.60 1.60 1.80 2.50 1.50 1.70 1.70

VSFVA: SAFETY FACTOR: OPPOSING VEHICLE VISIBLE, AUXILIARY LANE STARTS

2.20 2.20 2.20 2.20 2.00 2.00 2.20 2.00 2.00  
 1.80 1.80 1.80 1.80 2.00 2.70 1.70 1.90 1.90

VSFVN: SAFETY FACTOR: OPPOSING VEHICLE VISIBLE, NO AUXILIARY LANE

2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00 1.80  
 1.80 1.60 1.60 1.60 1.80 2.50 1.50 1.70 1.70

VSOA: DIST. COMPONENT OF SPACE TO BE LEFT AFTER O'TAKING (INCL. LENGTH)

70.00 60.00 60.00 60.00 45.00 45.00 45.00 45.00 35.00  
 35.00 20.00 20.00 20.00 22.00 13.00 10.00 10.00 10.00

VSOB: TIME COMPONENT OF SPACE TO BE LEFT AFTER OVERTAKING

.20 .20 .20 .20 .20 .20 .20 .20 .20  
 .20 .20 .20 .20 .20 .30 .30 .30

VEXA: LEAST SPACING SUCH THAT NO EXTRA OVERTAKING TIME IS ALLOWED

100.00 80.00 80.00 80.00 65.00 60.00 65.00 55.00 45.00  
 46.00 30.00 30.00 30.00 40.00 35.00 25.00 25.00 25.00

VEXB: EXTRA OVERTAKING TIME PER METRE OF INSUFFICIENT SPACING

.10 .10 .10 .10 .10 .10 .10 .10 .10  
 .10 .10 .10 .10 .10 .10 .10 .10 .10

VCLB: CHANGE LANE TIME WHEN SOMEONE BEHIND

15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00  
 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00 15.00

VCLN: CHANGE LANE TIME WHEN NO ONE BEHIND

30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00  
 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00

VAM: TIME ALLOWED FOR MERGING AFTER OVERTAKING

5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00  
 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00

VMGA: DISTANCE COMPONENT OF END-OF-AUX.-LANE MERGING DISTANCE ALLOWED

60.00 50.00 50.00 50.00 40.00 40.00 40.00 40.00 30.00  
 30.00 20.00 20.00 20.00 50.00 20.00 30.00 20.00 20.00

VMGB: TIME COMPONENT OF SAME

10.00 10.00 10.00 10.00 10.00 10.00 10.00 10.00 8.00  
 8.00 7.00 6.00 7.00 7.00 5.00 6.00 4.00 4.00

VTS: TIME UNTIL SETTLE AFTER MERGING

30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00 30.00  
 30.00 30.00 30.00 30.00 30.00 10.00 30.00 30.00 30.00

VSS: SPEEDS FOR WHICH END-OF-AUXILIARY-LANE MERGING IS STOP-START

5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00  
 10.00 10.00 10.00 10.00 14.00 14.00 10.00 10.00 10.00

VFE: IF ACCELERATION FOR SMOOTH MERGING EXCEEDS THIS, DO NOT DECELERATE

-1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00  
 -1.00 -1.00 -1.00 -1.00 -1.00 -1.20 -1.00 -1.00 -1.00

VFCA: FUEL CONSUMPTION PER SECOND WHEN IDLING (ML/S)

1.10 0.90 0.90 0.90 0.72 0.72 0.72 0.72 0.70  
 0.70 0.45 0.70 0.45 0.47 0.35 0.30 0.45 0.45

VFCB:FUEL CONSUMPTION EFFICIENCY FACTOR BETA1 (ML/KJ)

.06 .06 .06 .06 .06 .06 .06 .06 .06  
 .06 .06 .06 .06 .08 .08 .09 .08 .08

VFCC:FUEL CONSUMPTION EFFICIENCY FACTOR BETA2 (ML/(KJ.M/S)))

.018 .018 .018 .018 .018 .018 .018 .018 .018  
 .018 .018 .018 .018 .036 .036 .040 .036 .036

VFCD:DRAG FORCE PARAMETER (KN), MAINLY RELATED TO ROLLING RESISTANCE

12.77 12.50 12.20 10.00 7.20 7.00 7.20 6.90 3.60  
 3.50 1.90 1.80 1.30 0.24 0.22 0.19 0.22 0.19

VFCE:DRAG FORCE PARAMETER (KN/(M/S))), MAINLY RELATED TO AEROD. RESIST.

6.50 6.00 6.00 5.50 5.30 5.30 5.30 5.30 4.50  
 4.50 3.40 3.55 3.40 1.20 0.63 0.60 0.70 0.70

VFCF:VEHICLE MASS (KG\*1000) = 80% GCM

110.00 105.00 85.00 68.00 65.00 55.00 55.00 45.00 36.00  
 30.00 20.00 17.00 12.00 3.00 1.55 1.55 1.60 1.50

VFCG: MULT. FACTOR FOR ROLLING RESISTANCE ACCORDING TO ROAD SPEED INDEX

1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00  
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00

SMX CIOV RTUHN SMN XMFH XMIPH MPS  
30.00 .80 10.00 2.50 2.5 3.8 35

VFCH: VEHICLE USES (P)ETROL) OR (D)IESEL  
D D D D D D D D  
D D D D P P P P

#EOF

## Appendix D Survey

### D.1 Survey Card for the Route-specific Survey



### We want to hear about your travel experience

The Australian Road Research Board (ARRB) is the leading provider of research services to road agencies (such as DPTI / VicRoads / RMS / MRWA / TMR). We are conducting a survey for Austroads, the peak organisation for the road agencies, to investigate the quality of travel experience on three routes (Tailem Bend - Bordertown, Tailem Bend - Meningie, and Port Augusta - Port Pirie).

It should take about five minutes and we are offering a **\$10 voucher** to each of the first 100 people who complete the survey.

To go to the survey, please simply scan the QR code or visit:  
<https://www.surveymonkey.com/r/NZ6GLRW>

If you have any questions, please contact  
Long Truong on 03 9881 1557 or  
[long.truong@arb.com.au](mailto:long.truong@arb.com.au)

To protect the integrity of data, only one  
survey can be completed per computer,  
tablet, or smart phone device.



### D.2 Route-specific Survey

Australian Road Research Board (ARRB) is the leading provider of research services to road agencies (such as VicRoads/RMS/MRWA/TMR/DPTI). We are working on a project for Austroads, the peak organisation for the road agencies, to investigate the quality of travel experience on three routes (Tailem Bend – Bordertown, Tailem Bend – Meningie, and Port Augusta – Port Pirie).

It would help us greatly if you would be prepared to answer a few questions about that trip. It should take about five minutes. We are offering a \$10 voucher to each of the first 100 people who complete the survey. The voucher (or an acknowledgement if you are not in the first 100) will be delivered via your email within five working days of completion. We will not use your contact details for any purpose other than to send you this reply, will not pass these details on to any other party, and will erase your contact details from our response database as soon as practicable.

1. On what day did you make the trip?
2. What time did you leave (A or B)?
3. What time did you arrive at (B or A)?
4. What sort of vehicle were you driving?

<b>Motorcycle</b>	<b>Car (incl. van, SUV, etc.)</b>	<b>Car Towing</b>	<b>Rigid truck, camper van or bus</b>	<b>Articulated truck</b>
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5. How many times during the trip were you following a slower vehicle?

<b>0–1</b>	<b>2–3</b>	<b>4–5</b>	<b>6–7</b>	<b>8+</b>
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6. What percent of the trip was spent following a slower vehicle?

<b>Less than 10%</b>	<b>10% to 19%</b>	<b>20% to 29%</b>	<b>30% to 39%</b>	<b>40% to 49%</b>	<b>50% or above</b>
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7. How much extra travel time do you feel was added to the trip by following slower vehicles?  
\_\_\_\_\_minutes.

8. How would you rate the travel delays due to slower vehicles you experienced on this trip?

<b>Definitely unacceptable</b>	<b>Somewhat unacceptable</b>	<b>Just acceptable</b>	<b>Acceptable</b>
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9. Did you pass any slower vehicle? Yes/No

10. When you were trying to pass slower vehicles, what did you do?

Mainly used overtaking lanes/ Mainly used the opposing lane/ Generally was not able to pass

11. If you passed one or more slower vehicles using overtaking lanes, how safe did it feel?

<b>Very unsafe</b>	<b>Slightly unsafe</b>	<b>Slightly safe</b>	<b>Very safe</b>
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12. If you passed one or more slower vehicles using the opposing lane, how safe did it feel?

<b>Very unsafe</b>	<b>Slightly unsafe</b>	<b>Slightly safe</b>	<b>Very safe</b>
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13. Were there any occasions in the course of the trip when you started to overtake another vehicle but then pulled back because you realised you didn't have time to overtake safely?

Yes, one occasion/ Yes, more than one occasions/ No

14. Did you observe or experience any unsafe tailgating approaching the start of the overtaking lanes?  
Yes/No

15. Did you observe or experience any unsafe merging at the end of the overtaking lanes? Yes/No

16. Did you observe or experience any unsafe overtaking manoeuvre outside of the overtaking lanes?  
Yes/No

17. When you saw a road sign telling about an overtaking lane coming up in the next 3 km, did it influence you to wait for the overtaking lane to pass a slower vehicle? Yes/No

18. Imagine that there is an alternative route (with same speed limit) to the one you just travelled (x km from A to B). This alternative route is uncongested, and you would not be delayed by any slow vehicle; however, this alternative route is longer.

If this alternative route is y km longer (approx. 5%), would you use it? Yes/No

If this alternative route is z km longer (approx. 10%), would you use it? Yes/No

What is the maximum extra distance that you would be prepared to travel to use the alternative route? \_\_\_\_ km

19. In your answer to question 6, you said the percent of time spent following another vehicle was:

<b>Less than 10%</b>	<b>10% to 19%</b>	<b>20% to 29%</b>	<b>30% to 39%</b>	<b>40% to 49%</b>	<b>50% or above</b>
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and indicated in Question 8 that this was:

<b>Definitely unacceptable</b>	<b>Somewhat unacceptable</b>	<b>Just acceptable</b>	<b>Acceptable</b>
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20. If the percent of time spent following another vehicle increased by half, how acceptable would that be?

<b>Definitely unacceptable</b>	<b>Somewhat unacceptable</b>	<b>Just acceptable</b>	<b>Acceptable</b>
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21. If the percent of time following another vehicle doubled, how acceptable would that be?

<b>Definitely unacceptable</b>	<b>Somewhat unacceptable</b>	<b>Just acceptable</b>	<b>Acceptable</b>
--------------------------------	------------------------------	------------------------	-------------------

22. If you wish to claim the voucher for completing this survey, please provide an email address to which we can send it. Remember that only the first 100 respondents are eligible. We will not make your contact email available to other persons or organisations and will delete it after we have responded to you.

23. If you have any other comments regarding the survey, please specify

### D.3 General Survey

Australian Road Research Board (ARRB) is the leading provider of research services to road agencies (such as VicRoads/RMS/MRWA/TMR/DPTI). We are working on a project for Austroads, the peak organisation for the road agencies, to investigate the quality of travel experience on two-lane two-way rural roads.

It would help us greatly if you would be prepared to answer a few questions about your travel experience on rural roads. It should take about five minutes.

1. Did you drive on a two-lane two-way rural road within the last month? Yes/No

Think back about your last trip on a two-lane two-way rural road and please answer the following questions

2. Where did the trip start and where did it end? (Nearest major centres or junctions)

3. What sort of vehicle were you driving?

<b>Motorcycle</b>	<b>Car (incl. van, SUV, etc.)</b>	<b>Car Towing</b>	<b>Rigid truck, camper van or bus</b>	<b>Articulated truck</b>
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4. What percent of the trip was spent following a slower vehicle?

<b>Less than 10%</b>	<b>10% to 19%</b>	<b>20% to 29%</b>	<b>30% to 39%</b>	<b>40% to 49%</b>	<b>50% or above</b>
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5. What percentage of extra travel time was added to the trip by following slower vehicles?

<b>Less than 10%</b>	<b>10% to 19%</b>	<b>20% to 29%</b>	<b>30% to 39%</b>	<b>More than 40%</b>
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6. How would you rate the travel delays due to slower vehicles you experienced on this trip?

<b>Definitely unacceptable</b>	<b>Somewhat unacceptable</b>	<b>Just acceptable</b>	<b>Acceptable</b>
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7. Was there any overtaking lane anywhere along this route? Yes/No

8. Did you pass any slower vehicle? Yes/No

9. When you were trying to pass slower vehicles, what did you do?

Mainly used overtaking lanes/ Mainly used the opposing lane/ Generally was not able to pass

10.If you passed one or more slower vehicles using overtaking lanes, how safe did it feel?

<b>Very unsafe</b>	<b>Slightly unsafe</b>	<b>Slightly safe</b>	<b>Very safe</b>
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11.If you passed one or more slower vehicles using the opposing lane, how safe did it feel?

<b>Very unsafe</b>	<b>Slightly unsafe</b>	<b>Slightly safe</b>	<b>Very safe</b>
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12.Were there any occasions in the course of the trip when you started to overtake another vehicle but then pulled back because you realised you didn't have time to overtake safely?

Yes, one occasion/ Yes, more than one occasions/ No

13.Did you observe or experience any unsafe tailgating approaching the start of the overtaking lanes?

Yes/No

14.Did you observe or experience any unsafe merging at the end of the overtaking lanes? Yes/No

15.Did you observe or experience any unsafe overtaking manoeuvre outside of the overtaking lanes?

Yes/No

16.When you saw a road sign telling about an overtaking lane coming up in the 3 km (or 2 km in New Zealand), did it influence you to wait for the overtaking lane to pass a slower vehicle? Yes/No

17.Imagine that there is an alternative route (with same speed limit) for your last trip. This alternative route is uncongested, and you would not be delayed by any slow vehicle; however, this alternative route is longer.

If this alternative route is 5% longer, would you use it? Yes/No

If this alternative route is 10% longer, would you use it? Yes/No

What is the maximum percentage of extra distance that you would be prepared to travel to use the alternative route?

<b>5%</b>	<b>10%</b>	<b>15%</b>	<b>20%</b>	<b>More than 20%</b>	<b>Other (please specify)</b>
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18.In your answer to question 6, you said the percent of time spent following another vehicle was:

<b>Less than 10%</b>	<b>10% to 19%</b>	<b>20% to 29%</b>	<b>30% to 39%</b>	<b>40% to 49%</b>	<b>50% or above</b>
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and indicated in Question 8 that this was:

<b>Definitely unacceptable</b>	<b>Somewhat unacceptable</b>	<b>Just acceptable</b>	<b>Acceptable</b>
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19.If the percent of time spent following another vehicle increased by 50% more, how acceptable would that be?

<b>Definitely unacceptable</b>	<b>Somewhat unacceptable</b>	<b>Just acceptable</b>	<b>Acceptable</b>
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20.If the percent of time following another vehicle doubled, how acceptable would that be?

<b>Definitely unacceptable</b>	<b>Somewhat unacceptable</b>	<b>Just acceptable</b>	<b>Acceptable</b>
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21.If you have any other comments regarding the survey, please specify

# Appendix E Review of the Impacts to Austroads Guides

## E.1 Review of Guide to Road Safety

Parts 5, 8 and 9 of the Guide to Road Safety (GRS) were identified as relevant parts for review. The results of the review are in Table E 1.

**Table E 1: Review of the Guide to Road Safety**

Part	Review results
<i>GRS Part 5: Road Safety for Rural and Remote Areas</i> (Austroads 2006)	Overtaking lane is listed as one of the measures to improve safety (Table 4.4). The current report (i.e. NTM6025) confirmed that passing lanes are an effective measure. There does not appear to be a need to revise Part 5.
<i>GRS Part 8: Treatment of Crash Locations</i> (Austroads 2015a)	Crash modification factors for climbing/passing lane of 0.7 for head-on crashes and 1.1 for lane changing crashes was noted (Table F2). It is suggested to add a note on Table F2, reporting the crash reductions found in the current report, as follows. <i>'Before-and-after crash analysis of routes where passing lanes were installed showed an average reduction of injury crashes by 16%. There was significant variation in the impacts across analysed routes with 66% of the routes showing a reduction in crashes while 34% showed an increase in crashes. The variation in before-and-after crash impacts was even larger when the analysis was focussed on specific segments, such as the passing lane segment, 2 km upstream segment, and 5 km downstream segment, wherein half of the segments showed a decrease in crashes and half showed an increase in crashes. The assumption of average crash reduction therefore applies to an analysis of several passing lanes and would not necessarily apply to a specific passing lane, unless it is supported by site-specific evidence.'</i>
<i>GRS Part 9: Roadside Hazard Management</i> (Austroads 2008)	The term 'overtaking' was mentioned only once and it was in relation to centreline markings. There does not appear to be a need to revise Part 9 contents.

## E.2 Review of Guide to Road Design

Parts 3 and 6 of the Guide to Road Design (GRD) were identified as relevant parts for review. The results of the review are in Table E 2.

**Table E 2: Review of the Guide to Road Design**

Part	Review results
<i>GRD Part 3: Geometric Design</i> (Austroads 2016)	Overtaking lanes are covered in Section 9.4. The findings could be applied to extend the section on warrants. The tools to enhance the warrants are discussed in the current report. Significant effort is required to develop the warrants further, which would include modelling various scenarios of traffic and terrain conditions, as well as updated information on cost of construction. It suggested that discussions on further development of warrants in the Guide to Road Design be firstly coordinated with the Road Design Taskforce, which would cover the need for further content on warrants, and if needed what scope and format.
<i>GRD Part 6: Roadside Design, Safety and Barriers</i> (Austroads 2010)	Overtaking lanes were included as one type of treatment to address crashes (Table 5.1). The current report confirms that passing lanes are an effective measure. There does not appear to be a need to revise Part 8.

### E.3 Review of Guide to Traffic Management

Parts 2, 3 and 5 of the Guide to Traffic Management (GTM) were identified as relevant parts for review. The results of the review are in Table E 3.

**Table E 3: Review of Guide to Traffic Management**

Part	Review results
<i>GTM Part 2: Traffic Theory</i> (Austroads 2015b)	Theory and analytical models of overtaking traffic behaviour are in Part 2 and they are still current. There does not appear to be a need to revise Part 2.
<i>GTM Part 3: Traffic Studies and Analysis</i> (Austroads 2017a)	Section 4.2 covers two-lane two-way roads. It is suggested to introduce TRARR in Part 3, through the following: <ul style="list-style-type: none"> <li>• On page 40, insert heading 4.2.1 HCM Method to introduce the section sourced from HCM.</li> <li>• On page 43, after the HCM method, insert Section 4.1.2 TRARR Method of the current report as Section 4.2.2 TRARR Method; and, add a reference to this report for further details.</li> </ul>
<i>GTM Part 5: Road Management</i> (Austroads 2017b)	Section 3.3 Road Space Requirements for Auxiliary Lanes describes overtaking lanes and their function and applicability. There does not appear to be a need to revise Part 5.



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