FINAL REPORT

R104 Benefits achieved by major infrastructure projects in the study area of Bruce Highway (2019/20)

ARRB Project No.: 015334

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Final Report

AN INITIATIVE BY:

SUMMARY

R104 aims to better understand the past and current economic cost of traffic congestion on Bruce Highway, evaluate the effectiveness of smart motorway treatments that were implemented, and assess the potential impacts of a series of major infrastructure projects on the performance of the Bruce Highway southbound (citybound) and the broader road network. The results can also assist in determining the effectiveness of past investments, inform future investments, and benchmark performance.

Four major infrastructure projects or response strategies were identified for benefit evaluations as follows:

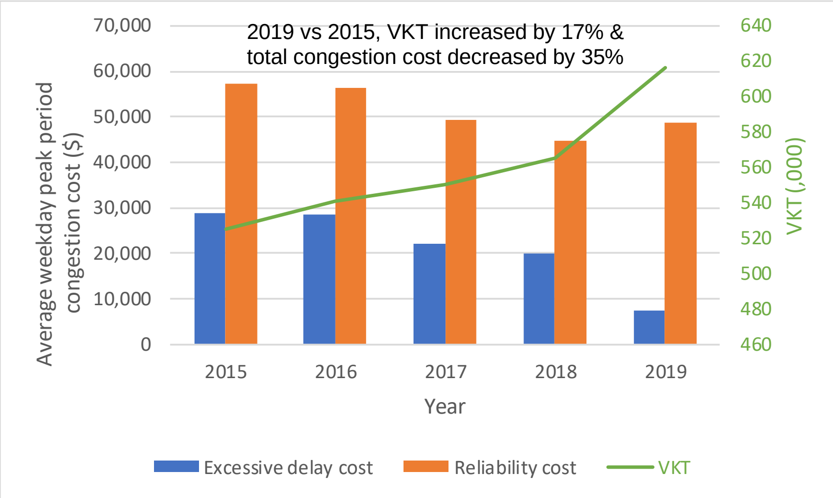
- ramp metering, variable speed limit (VSL) and automatic queue detection and queue protection (QPQD) systems
- Boundary Road interchange
- Gateway Upgrade North (GUN)
- Redcliffe Peninsula Rail Line (RPRL).

This study covered the following two parts:

- Part 1 Bruce Highway traffic performance evaluation: focus on the before-and-after comparison for Bruce Highway southbound to assess the impacts of the first three projects listed above individually.
- Part 2 Travel choice changes investigation: investigate how the infrastructure works influenced mode choice and impact on Bruce Highway and the broader road network, particularly focused on evaluation of RPRL and GUN projects.

Part 1 of the study focused on an analysis of average weekday peak period congestion cost between 5 and 10 am when the managed motorway was operating. The congestion cost reductions identified on the Bruce Highway southbound between 2015 and 2019 are as follows:

- Although the average daily vehicle-kilometre-travelled (VKT) increased by 17% from 2015 to 2019 (see figure below), the peak period congestion cost was reduced by 35% on a typical weekday. A bulk of these cost-savings originated from reduced excessive delay cost, which experienced a 74% reduction. The travel time reliability cost also reduced by 15%.
- When normalising by VKT to control for the effects of natural traffic growth over time, more significant cost savings were identified. Reductions of total congestion, excessive delay and reliability costs per VKT were found to be 45%, 78% and 28% respectively.



Part 2 combines two modes of travel – private road usage (passenger vehicle occupants) and public transport (rail and bus passengers). The focus was on overall trends between 2016 and 2019 and on the impact of two of the major infrastructure projects, namely the completion of the GUN in early 2019 and the opening of the RPRL in October 2016. Five screenlines (SLs) were defined in order to capture traveller numbers at different parts of the road and rail network. Similar to Part 1, average weekday peak period traveller numbers were analysed. The key findings are:

- Traveller numbers on the road and public transport networks in the study area increased over time. Between the first year of the study period (June 2016 to May 2017) and the last year of the study period (January 2019 to December 2019), traveller numbers across most SLs increased, with SL 3 showing the highest increase (17.6%).
- The public transport mode share gradually increased over time which is demonstrated by a higher percentage of travellers using public transport between 2016 and 2018. The increase of public transport ridership in the study area was also higher compared to the South East Queensland (SEQ) average. Again, the differences were particularly noticeable on SL 3 where rail passenger volumes on the new RPRL grew up to 30.3% more than the average SEQ (relative change in March 2019 based on February 2017 baseline).

The benefits and impact of the four major infrastructure projects are summarised as follows:

1. Ramp metering, VSL and QDQP systems

It was observed from the data that the ramp metering, VSL and QDQP systems were best utilised and performed best when all systems were activated, e.g. the before-and-after comparison (2015 versus 2017), where all ramp metering, VSL and QDQP systems were activated, revealed significant congestion reduction on Bruce Highway. While there was still ongoing traffic disruption from the GUN project, after-period data revealed a 21% reduction in normalised excessive delay cost and 23% reduction in both normalised reliability cost and total cost. QDQP added significant benefits to the Bruce Highway congestion reduction.

The implementation of ramp metering, VSL and QDQP systems were also able to increase the Bruce Highway operational capacity before the flow breakdown and maintain at higher operational capacity after the flow breakdown.

2. Boundary Road interchange upgrade

Significant reduction in motorway congestion cost was observed from a before-and-after comparison (2016 versus 2018) for the links directly impacted by the upgrade. While the average weekday peak period VKT increased by 3%, the normalised excessive delay cost, reliability cost and total cost were reduced by 55%, 45% and 47% respectively. However, due to over-lapping of project time frames, a portion of the reduction in congestion cost should be attributed to the benefits of ramp metering, VSL and QDQP systems.

3. GUN

The completion of the GUN project led to an operational capacity improvement, attracted a large increase in demand for the Bruce Highway southbound and at the same time eased the peak period congestion significantly. Comparing the selected periods between 2018 and 2019, while 2019 had an increase of 12% in average daily peak period VKT for the links directly impacted by the GUN, the normalised excessive delay cost and total costs were reduced by 67% and 17% respectively. However, the completion of the GUN also led to a stagnation of public transport usage in the study area despite consistent population growth.

4. RPRL

Following the opening of the RPRL in October 2016, an instant shift towards a higher public transport (rail) mode share can be observed. Comparing June to August 2016 (before-period) to June to August 2017 (after-period), the mode share at SL 3 increased from 0.1% to 5.7% (+5.6%). This trend of above-average values for the RPRL also continued into 2018. The mode share shifts at the other SLs were lower (+1.4% to +3.9%), but they increased as well indicating an uptake of public transport usage. It is concluded that the above-average figures for the RPRL are due to the particularly high population growth near the new RPRL (SL 3) as well as due to the availability of the new rail line with increased capacity, and truncation/rerouting of bus services.

As part of the project, ARRB also developed a beta version Bruce Highway cost of congestion analysis Excel spreadsheet tool that enables fast processing of the before-and-after analyses. This tool can be used directly to measure the excessive delay cost, reliability cost, average volumes, average speeds, vehicle delay and other key performance indicators on a link level or route level of the Bruce Highway study route.

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1 INTRODUCTION

Project R104: Benefits achieved by major infrastructure projects in the study area of Bruce Highway is funded under the National Asset Centre of Excellence (NACoE) research agreement. It aims to better understand the past and current economic cost of traffic congestion on Bruce Highway, evaluate the effectiveness of smart motorway treatments that were implemented in the past years, and assess the potential impacts of a series of major infrastructure projects on Bruce Highway southbound performance. The results can also assist to determine the effectiveness of past investments, inform future investments, and benchmark performance.

NACoE R22 (Measuring On-road Congestion Costs for Multi-modal Travel) Bruce Highway case study (Han & Byrne 2016) and R22 technical Note (Han, Kutadinata & Wu 2018) evaluated the benefits achieved in improving network performance in the study area of Bruce Highway with smart motorway treatments implemented.

Project R22 has produced a methodology for estimating congestion costs associated with multiple road users that includes passenger cars, heavy vehicles (HVs), buses, cyclists and pedestrians (Luk, Han & Byrne 2016). This project advances the methodology developed in the R22 project, and evaluates the impacts of a series of infrastructure projects or response strategies to further determine the benefits achieved in network performance in the study area, as shown in Figure 1.1.

The list of projects that have been identified to have potential impacts on the southbound (citybound) performance of the Bruce Highway, during peak period 5 am to 10 am on weekdays, are as follows:

- Managed motorway treatments, including ramp signalling at five locations, variable speed limit (VSL) signs and queue detection/queue protection (QDQP) systems
- Boundary Rd interchange
- Gateway Upgrade North (GUN)
- Redcliffe Peninsula Rail Line (RPRL) – joining the Caboolture line at Petrie, with six new stations between Kippa-Ring on the Redcliffe peninsula and Petrie station.

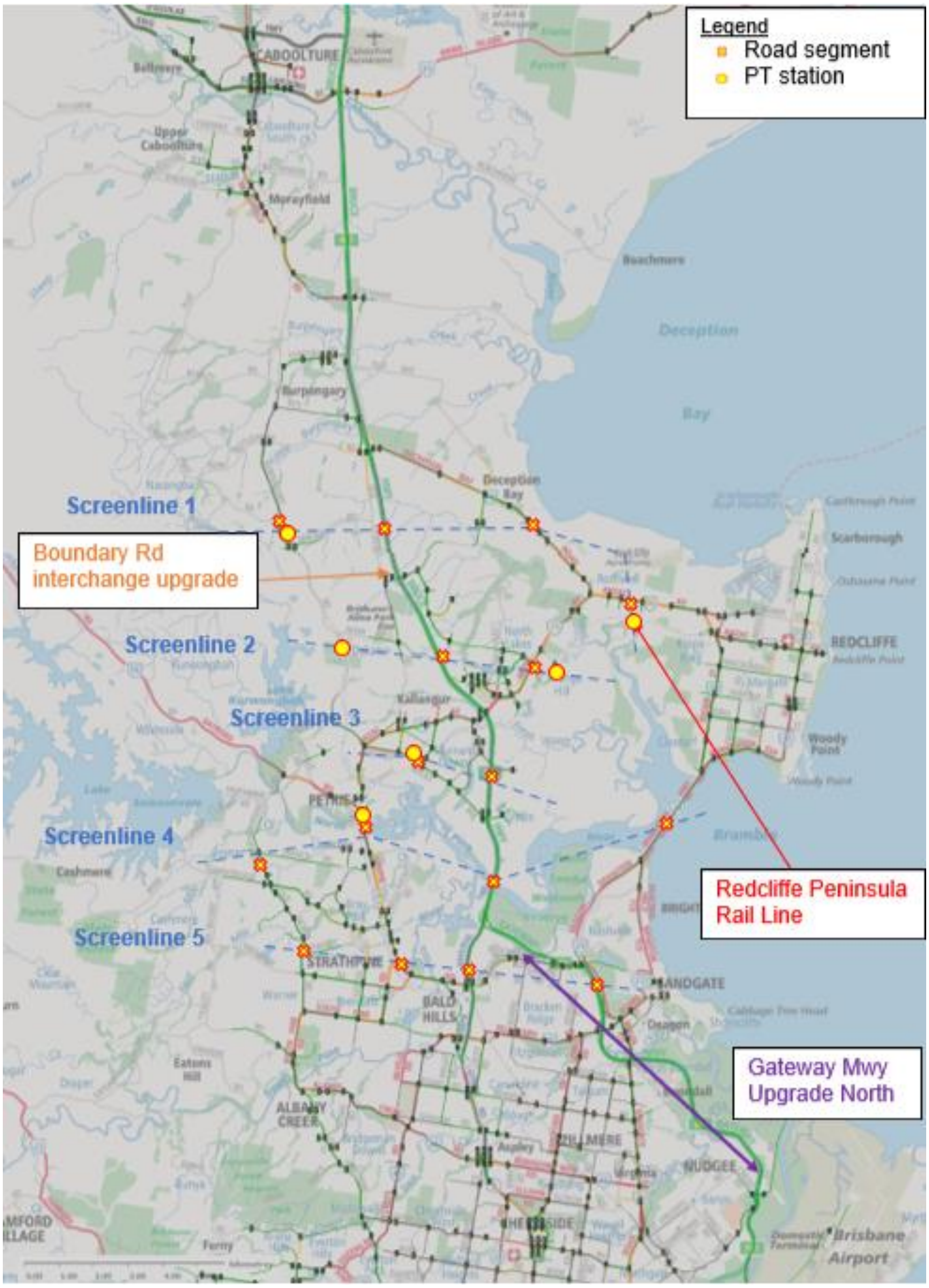
The study covers two parts:

- Part 1 – Bruce Highway traffic performance evaluation (Section 2 and Section 3): Focus on the before-and-after comparison for Bruce Highway southbound to assess the impacts of the first three projects listed above individually.
- Part 2 – Travel choice changes investigation (Section 4 and Section 5): Investigate how the infrastructure works influenced mode choice and the impact on Bruce Highway and the broader road network, particularly focused on evaluation of the RPRL and GUN projects.

This report discusses the methodology, study results and key findings of Part 1 and Part 2 respectively. The report concludes with a combined conclusion section, which summarises the findings from both Part 1 and Part 2 and provides a holistic overview of the results and benefits from those key infrastructure projects.

In this report, congestion cost is defined as the sum of excessive delay cost and travel time reliability cost. Other congestion cost components such as environmental costs and vehicle operating costs are not relevant to the travel time reliability measurement. They have been discussed in Austroads (2009) and implemented in TMR cost-of-congestion practices, but were out-of-scope of this case study.

Figure 1.1: Study area/corridors of concern



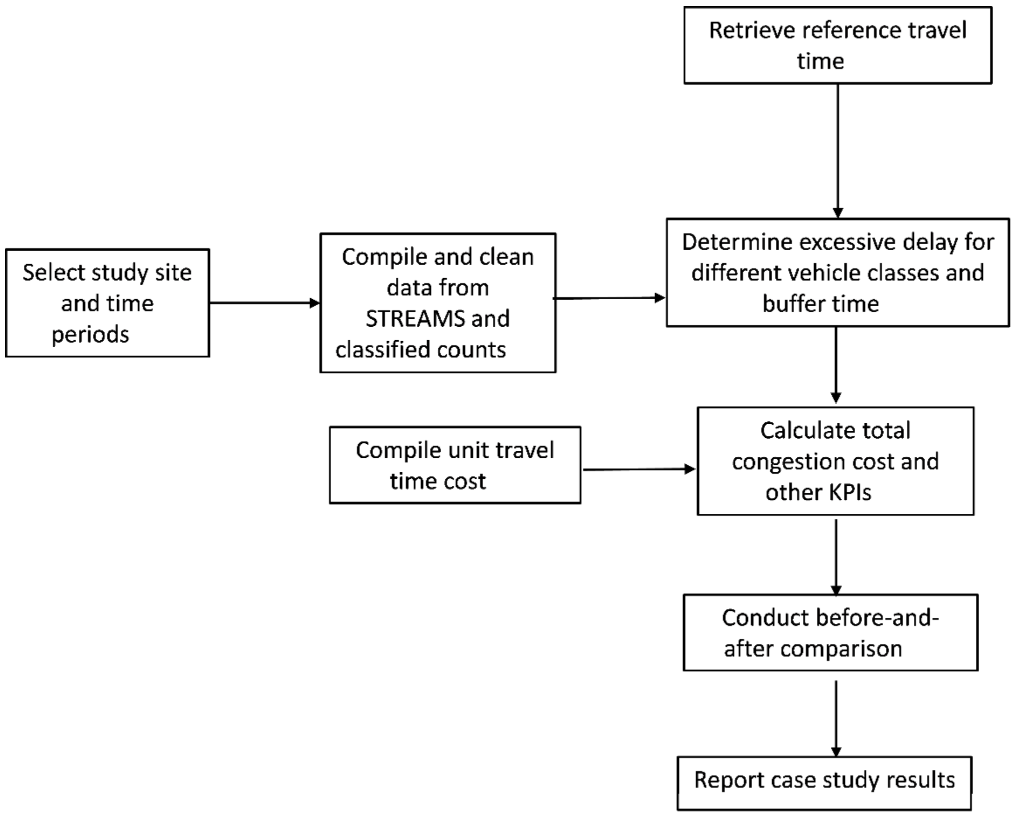
Source: STREAMS (2020), Map extracted from STREAMS Explorer.

2 METHODOLOGY OF BRUCE HIGHWAY PERFORMANCE EVALUATION (PART 1)

2.1 BEFORE-AND-AFTER COMPARISON METHODOLOGY IN R22

The R22 methodology report (Luk, Han & Byrne 2016) outlined the framework for estimating freeway congestion cost with multiple vehicle classes. This study followed the eight-step process in the R22 methodology report to evaluate the Bruce Highway southbound peak period (5 am to 10 am) performance over a five-year period, from 1 January 2015 to 31 December 2019. Figure 2.1 shows the procedure followed in the analysis.

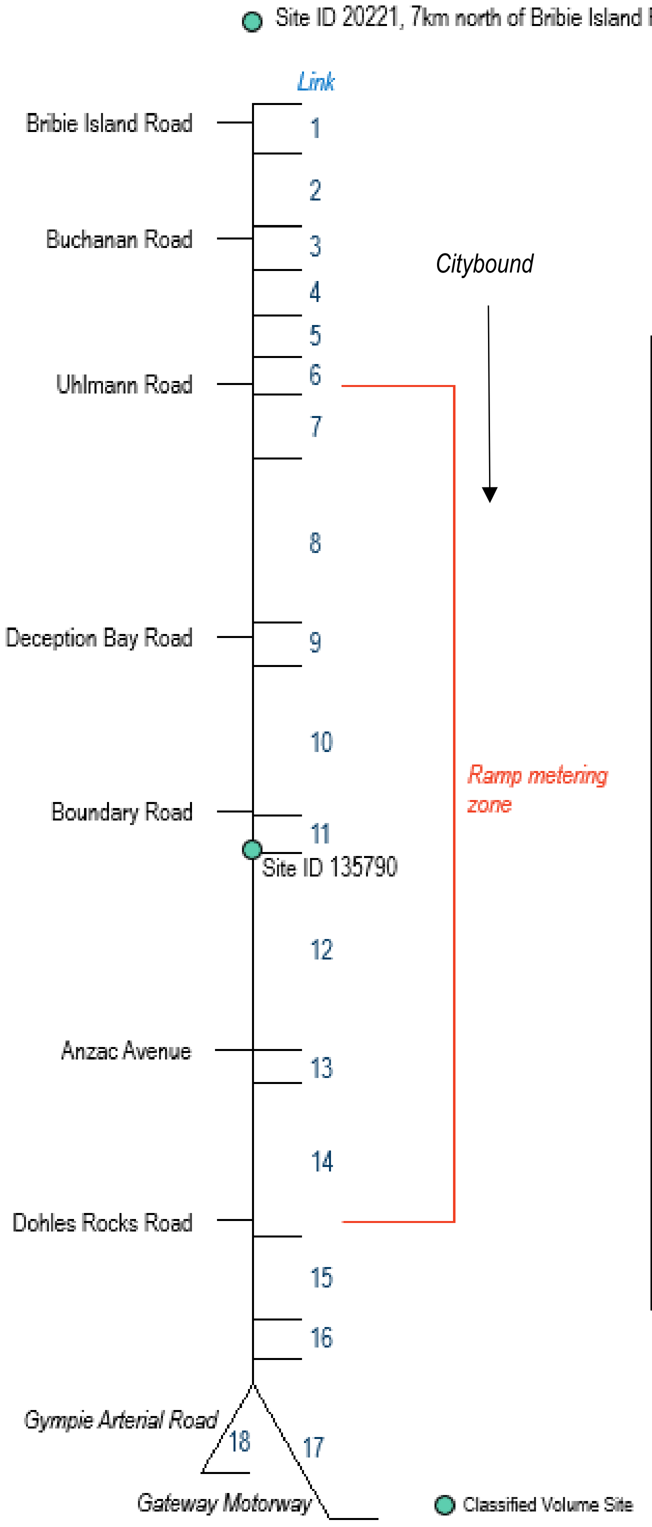
Figure 2.1: Methodology for Bruce Highway case study



2.2 DATA CLEANSING

Figure 2.2 shows a diagrammatic representation of the study site, along with the locations of the classified sites. Vehicle composition data between 2015 and 2019 from site ID 135790 was used as the main data source and data from site ID 20221 was used as supplementary data for gap filling purposes. Speed and flow data from 1 January 2015 to 31 December 2019 for the18 links were extracted from the STREAMS NPI system for the analysis of congestion cost. Data cleansing and gap filling were then conducted to ensure high quality of data.

Figure 2.2: Representation of the Bruce Highway study site and location of key features



Link #	Length (m)
1	997
2	1481
3	849
4	949
5	798
6	764
7	1307
8	3301
9	861
10	2995
11	751
12	3955
13	676
14	3066
15	1662
16	812
17	3123
18	2075

An incident search was conducted to identify any incidents that had significant impact on link mean travel speed and for a duration of two hours or more based on examination of speed data from 2015 to 2019. Table 2.1 lists all the incident days that fit in those criteria and only extreme weather conditions or major incidents (3 out of 9 incidents) were excluded from the analysis.

Extreme weather conditions and major incidents that involved multiple lane closures have a significant impact on traffic volume and speed, particularly travel time reliability. As this report is focused on facilitating a robust comparison between month to month cost of congestion to evaluate the impact of major infrastructure projects, days that experienced major incidents were excluded from the analysis. This was done to ensure that day-to-day variation in travel times did not adversely bias the results due to those rare events. Since the managed motorway treatments are likely mitigating the impact of incidents, the exclusion of the disastrous events in this study potentially causes the measured benefits to be conservative.

Table 2.1: Incident details, 2015 to 2019

Incident date	Speed impacted links	Impacted time period	Incident notes	Excluded from analysis?
1-May-15	1 to 9	2 pm to 7 pm	Incident type: Flood	Yes
4-Mar-16	8 to 14	5.45 am to 10 am	Incident type: crash south of Exit 30 at 05:38 – 3 lanes blocked	Yes
14-Mar-18	1 to 6	4 am to 7 am	Incident type: crash after Station Rd – 3 lanes blocked Incident type: crash at end of Deception Bay Road on ramp – 1 lane blocked	Yes
4-Oct-16	13 to 17	12 pm to 3 pm	Incident type: non-recurring congestion from Plantation Rd to Gateway Motorway	No
23-Oct-17	1 to 8	7 am to 11 am	Incident type: crash after Station Rd overpass at 06:41 – 1 lane blocked	No
7-Jun-18	1 and 2	10 am to 1.30 pm	Incident type: crash between Bribie Island Rd and Buchanan Rd Incident type: crash south of Uhlmann Rd – 1 lane blocked	No
15-Aug-18	1 to 8	3 pm to 6 pm	Incident type: crash south of Bribie Island overpass, Partial lane blocked	No
11-Oct-18	1 to 4	8.15 am to 10 am	Incident: Crash at 300 m north of Caboolture BP, 1 lane blocked	No
16-Oct-19	10 to 15	4.45 am to 9 am	Incident type: Congestion Classification: LUMS/VSL intervention	No

The data from STREAMS was cross-checked by TMR before being applied in the study. The data was of sufficiently good quality for the purpose of this study.

The percentage of missing flow or speed data for the peak period (5 am – 10 am) of each calendar year was as follows:

- for 2015, 1.8% of records (2,300 out of 127,800)
- for 2016, 0.5% of records (666 out of 128,160)
- for 2017, 1.8% of records (2,249 out of 124,920)
- for 2018, 1.3% of records (1,651 out of 128,880)
- for 2019, 0.6% of records (721 out of 128,880).

These missing entries were replaced using hot-deck imputation. A flow or speed value from the same 15-minute segment of the day, but from the closest same weekday, for instance both on Monday, was used in its place. Due to the use of the similar time period data and the small percentage of gaps which was filled, the impact on the calculation results is deemed to be minimal.

2.3 UPDATE OF UNIT COST

Data from classified traffic counts were used to update the percentages of vehicle classes used in R22. Traffic counts were classified into four vehicle classes according to vehicle length or Austroads 12 vehicle classes as shown in Table 2.2. Table 2.3 then outlines the unit travel time costs for the four vehicle classes.

Table 2.2: Vehicle classification

Classification by vehicle length	Threshold values (m)	Closest Austroads axle-based classes
1 (short)[1]	length < 6	1 – 2[1]
2 (medium)	6 ≤ length < 13	3 – 5
3 (long)	13 ≤ length < 21	6 – 9
4 (combination)	length ≥ 21	10 – 12

[1] This class is further classified into private trips and business trips in the cost estimation

Source: Austroads (2006).

Table 2.3: Unit cost of travel time (in 2019 Australian dollars)

Vehicle class	Road users (urban)	Travel time cost ($/person per hour)	Average vehicle occupancy (person/ vehicle)	Travel time cost ($/vehicle per hour)	Freight travel time cost[1] ($/vehicle per hour)	Applicability factor for reliability estimation
Short vehicles	Car private	$17.40	1.6	$27.84	n. a.	0.6
Short vehicles	Car business	$55.68	1.4	$77.95	n. a.	1.0
Medium vehicles	Medium HV	$31.74	1.3	$41.26	$4.15	1.0
Long vehicles	Articulated HV	$32.97	1.0	$32.97	$39.01	1.0
Combination vehicles	B-double HV	$33.92	1.0	$33.92	$64.91	1.0

1. Assume freight travel time cost remains constant between 2013 and 2019.

Sources: Vehicle class sourced from Austroads (2006). Travel time cost and vehicle occupancy rate supplied by TMR (2019), Freight travel cost sourced from Transport and Infrastructure Council (2015). Applicability factor sourced from Wang (2014).

For this study, TMR provided a more detailed private/business trip split matrix encompassing all 15-minute time intervals for typical weekdays and weekends. The trip split matrix was sourced from the *South East Queensland Household Travel Survey* (2009-12 combined survey) and weighted to 2011 values (TMR 2016). This allowed the private/business trip split to change according to time of day for typical weekdays, as shown in Table 2.4. Thus, although only four vehicle classes were measured by the classifying stations, five vehicle classes were used to estimate congestion cost.

Table 2.4: Weekday short vehicle private/business split ratio by time of day

Time of day	Private/business split ratio	
	Short vehicle private	Short vehicle business
0 am to 6 am	93%	7%
6 am to 10 am	92%	8%
10 am to 3 pm	86%	14%
3 pm to 7 pm	92%	8%
7 pm to 0 am	93%	7%

3 FINDINGS OF BRUCE HIGHWAY TRAFFIC PERFORMANCE

Using the analysis processes shown in Figure 2.1, the following results were obtained for the peak period (from 5 am to 10 am) when the managed motorways operate:

- comparison of vehicle-kilometres travelled (VKT) 2015 to 2019 (Section 3.1)
- comparison of average congestion cost for weekdays 2015 to 2019 (Section 3.2)
- comparison of average congestion cost per VKT for weekdays 2015 to 2019 (Section 3.3)
- major project impacts assessment (Section 3.4).

All cost values in this report are in 2019 Australian dollars ($2019) for consistency.

3.1 COMPARISON OF AVERAGE WEEKDAY PEAK PERIOD VKT

VKT provides a standard metric for determining the total amount of traffic that passed through the study site for the five-year period. This was calculated using the flow data from STREAMS and the link lengths provided by TMR for each 15-minute time slice. Table 3.1 shows the average weekday peak period VKT for each month and the annual average weekday peak period VKT for each year between 2015 and 2019 across the whole study site. It also shows the annual growth rate and the percentage difference from the base year of 2015.

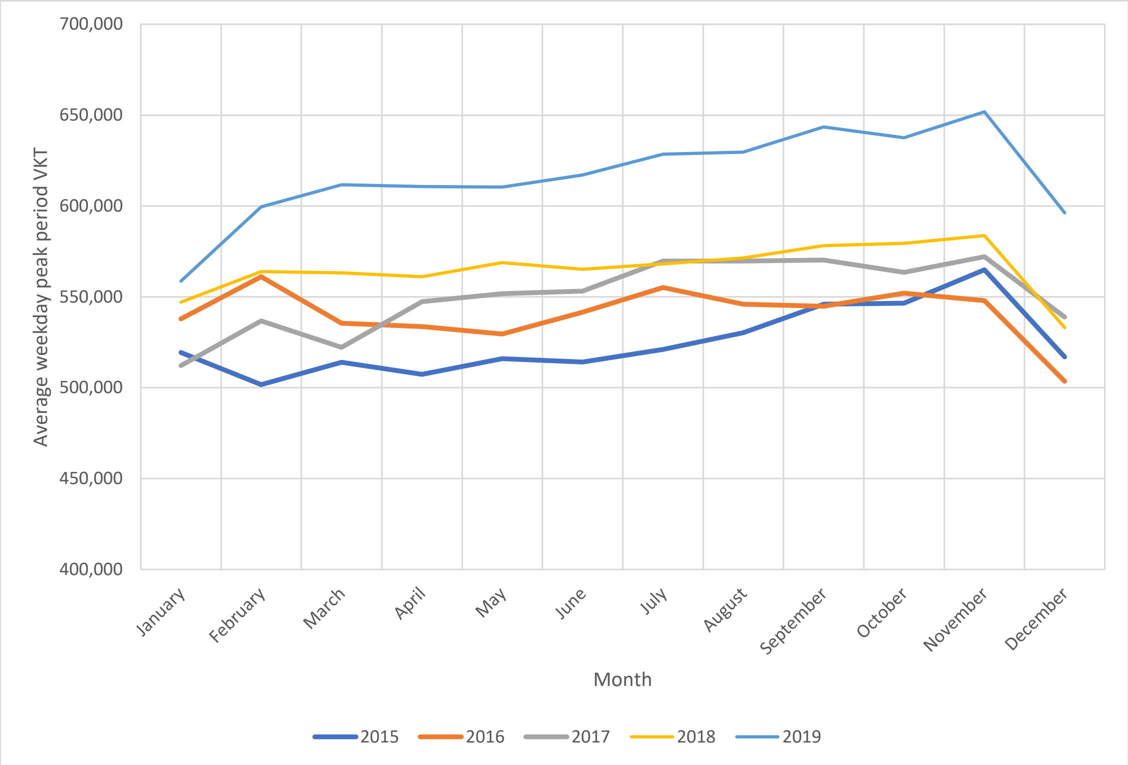
Table 3.1: Average weekday peak period VKT comparison

Month	Average VKT for weekday peak period (5 am – 10 am)				
	2015	2016	2017	2018	2019
January	519,373	537,909	512,177	547,028	558,624
February	501,727	561,111	536,746	563,885	599,585
March	513,920	535,463	522,233	563,188	611,641
April	507,333	533,655	547,333	561,144	610,652
May	515,941	529,494	551,735	568,922	610,415
June	514,094	541,516	553,168	565,241	617,071
July	521,045	555,207	569,691	568,214	628,461
August	530,231	545,876	569,670	571,435	629,715
September	545,897	544,819	570,262	578,191	643,577
October	546,533	551,986	563,459	579,518	637,565
November	564,900	547,994	572,042	583,660	651,871
December	516,965	503,511	538,878	533,012	596,295
Average weekdays	524,830	540,712	550,616	565,287	616,289
Average weekdays % difference to 2015	–	3%	5%	8%	17%
Average weekday annual growth rate	–	3%	2%	3%	9%

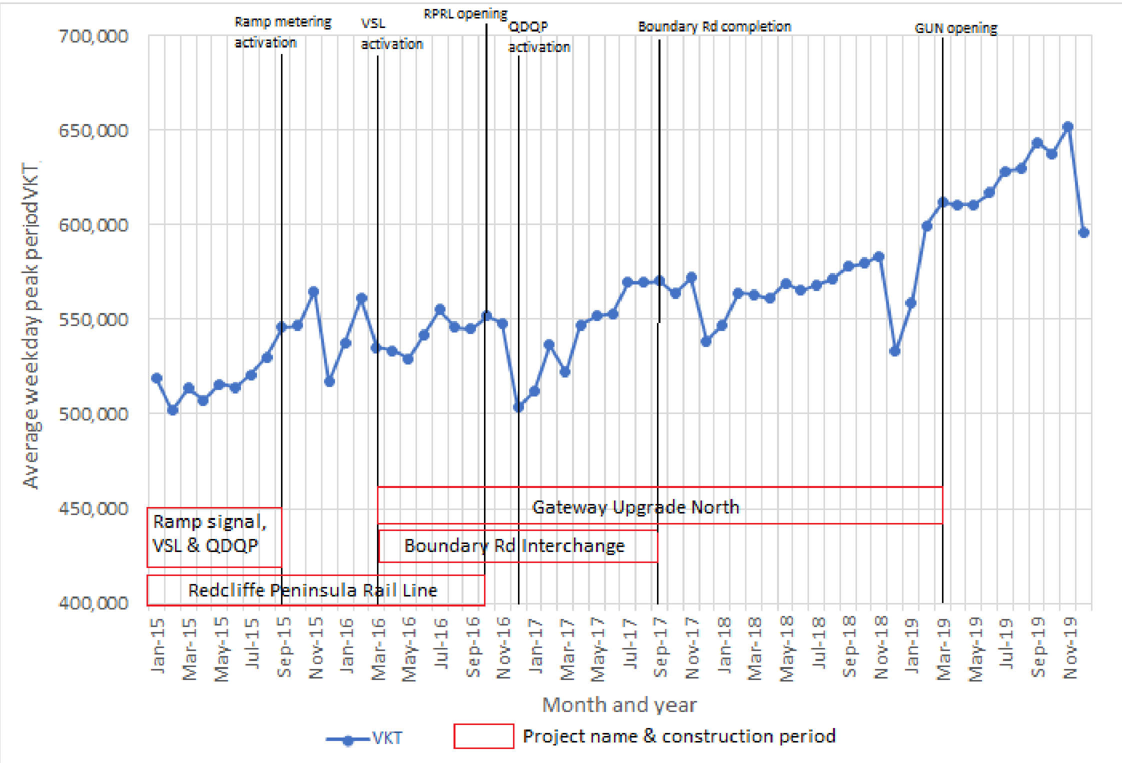
As major incident days and public holidays had been excluded from the analysis, the number of weekdays may not be the same for each month. To ensure that average VKT values were not biased, averages for each of the weekdays were used to ensure that fair comparison was made for each month.

Figure 3.1 shows the monthly variation in the average weekday peak period VKT over the five years between 2015 and 2019. Figure 3.1 a) allows the direct comparison of each month between different years, Figure 3.1 b) shows the month-on-month peak period VKT trend over five years.

Figure 3.1: Monthly average weekday peak period VKT comparison



(a) Monthly comparison for each year



(b) Month-on-month trend over 5 years

Table 3.1 and Figure 3.1 show that there is a clear trend that the average daily peak period VKT increased by 2–3% per annum from 2015 to 2018, until the completion of GUN in March 2019. Compared to other years, 2019 had the most significant annual increase in VKT (9% compared with 2018).

Table 3.1 and Figure 3.1 also show a seasonal reduction in VKT in December and January, and the average peak period VKT for Decembers were generally the lowest compared to other months of the year. This is due to the summer holiday season and school holiday period when local residents generate less trips in comparison to other periods. The consistent increases in VKT year-on-year can also be an indication of an improvement in operational capacity on Bruce Highway.

3.2 COMPARISON OF MONTHLY AVERAGE WEEKDAY PEAK PERIOD CONGESTION COST

Average peak period congestion cost per day was calculated through aggregation of total peak period congestion cost across all weekdays in the month. Weekends and public holidays were excluded from the comparison. Table 3.2 summarises the comparison results of average weekday peak period congestion cost on monthly and monthly average basis between 2015 and 2019, and its annual percentage changes and the percentage changes compared to the base year 2015.

Table 3.2: Average weekday peak period congestion cost comparison ($2019)

Month	Category	2015	2016	2017	2018	2019
January	Excessive delay cost	$14,061	$10,518	$9,901	$13,819	$3,352
	Reliability cost	$59,570	$32,033	$44,086	$59,038	$18,971
	Total cost	$73,631	$42,551	$53,987	$72,857	$22,323
February	Excessive delay cost	$50,430	$34,693	$28,743	$35,955	$10,804
	Reliability cost	$52,435	$39,671	$64,663	$38,555	$71,314
	Total cost	$102,865	$74,364	$93,407	$74,510	$82,118
March	Excessive delay cost	$59,467	$49,034	$27,423	$35,563	$2,080
	Reliability cost	$71,219	$59,042	$63,521	$43,448	$21,198
	Total cost	$130,686	$108,076	$90,944	$79,010	$23,278
April	Excessive delay cost	$24,063	$37,229	$21,672	$21,304	$6,742
	Reliability cost	$47,322	$78,146	$43,292	$70,586	$51,636
	Total cost	$71,386	$115,374	$64,964	$91,890	$58,378
May	Excessive delay cost	$26,273	$26,684	$22,626	$9,795	$6,374
	Reliability cost	$67,491	$72,916	$43,857	$32,343	$54,369
	Total cost	$93,764	$99,600	$66,483	$42,138	$60,743
June	Excessive delay cost	$18,739	$18,419	$7,620	$13,822	$6,056
	Reliability cost	$72,503	$43,456	$37,527	$59,643	$52,262
	Total cost	$91,243	$61,875	$45,147	$73,465	$58,318
July	Excessive delay cost	$8,245	$14,314	$12,943	$17,215	$1,242
	Reliability cost	$36,053	$47,635	$47,816	$45,155	$11,881
	Total cost	$44,298	$61,949	$60,760	$62,371	$13,123
August	Excessive delay cost	$14,803	$27,133	$15,250	$10,940	$10,387
	Reliability cost	$34,711	$54,468	$36,282	$21,583	$76,619

Month	Category	2015	2016	2017	2018	2019
	Total cost	$49,514	$81,601	$51,532	$32,523	$87,006
September	Excessive delay	$31,651	$40,134	$21,676	$17,495	$2,752
	Reliability cost	$70,140	$89,005	$42,862	$31,042	$19,439
	Total cost	$101,791	$129,139	$64,538	$48,537	$22,191
October	Excessive delay cost	$45,434	$33,290	$34,465	$19,411	$19,158
	Reliability cost	$72,136	$37,576	$76,044	$36,495	$95,935
	Total cost	$117,570	$70,865	$110,510	$55,906	$115,093
November	Excessive delay cost	$27,804	$27,615	$39,689	$25,882	$14,414
	Reliability cost	$40,919	$50,920	$49,356	$54,247	$65,097
	Total cost	$68,724	$78,535	$89,045	$80,129	$79,510
December	Excessive delay cost	$23,759	$22,744	$22,520	$17,479	$5,915
	Reliability cost	$62,526	$71,461	$43,231	$42,941	$44,696
	Total cost	$86,285	$94,205	$65,751	$60,419	50,611
Monthly average	Excessive delay cost	$28,727	$28,484	$22,044	$19,890	$7,440
	Reliability cost	$57,252	$56,361	$49,378	$44,590	$48,618
	Total cost	$85,980	$84,845	$71,422	$64,480	$56,058
Monthly average % difference to 2015	Excessive delay cost	–	–1%	–23%	–31%	–74%
	Reliability cost	–	–2%	–14%	–22%	–15%
	Total cost	–	–1%	–17%	–25%	–35%
Monthly average annual growth rate	Excessive delay cost	–	–1%	–23%	–10%	–63%
	Reliability cost	–	–2%	–12%	–10%	9%
	Total cost	–	–1%	–16%	–10%	–13%

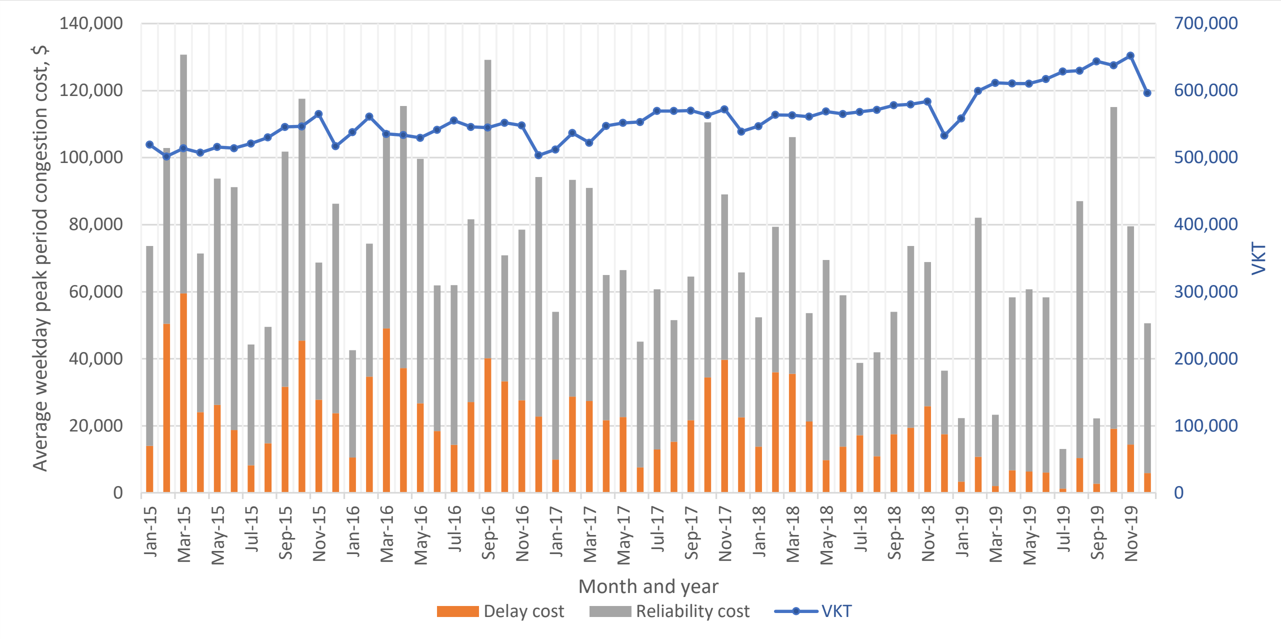
The main findings from Table 3.2 are:

- From 2015 to 2019, traffic responded positively to the treatments applied on Bruce Highway. Excessive delay cost reduced by 23% in 2017 as a result of successful implementation of managed motorway measures. The excessive delay cost further reduced by 63% in 2019 upon the completion of GUN. Both investments demonstrated a significant improvement in travel efficiency.
- The 2017 figures achieved the greatest annual percentage reduction in total congestion cost (16%), with 23% reduction in excessive delay cost and 12% reduction in reliability cost.
- The 2019 figures achieved the greatest annual percentage reduction in excessive delay cost by 63%. In terms of annual change in reliability cost, while other years (2016 to 2018) had consistent reduction in their cost, 2019 had an increase in reliability cost by 9% comparing to 2018. Overall, 2019 still achieved a high reduction in total congestion cost of 35% compared to 2015 and 13% compared to 2018.
  - The completion of GUN in 2019 noticeably eased congestion by removing a downstream bottleneck at Gateway Motorway, supplying more capacity to the network and increasing the speed limit to 100 km/h. That seemed to have an effect on journey time variability, as a greater speed range was observed between the free flow to saturation conditions, and hence the higher reliability cost in 2019. The average reliability cost per month in 2019 was $48,600, which was made up of 86% of the total cost, while in other years, the reliability cost made up 65–70% of the total cost.

- A monthly congestion cost comparison revealed that it may not be sufficient to compare a single month's data for before-and-after comparison of a project due to the high month to month variation. A minimum of three months average results should be considered in before-and-after analysis to mitigate the volatility of the results.

Figure 3.2 plots the monthly average weekday peak period congestion cost and VKT between 2015 and 2019, with congestion cost in the primary vertical axis, VKT in the secondary axis, and time in the horizontal axis.

Figure 3.2: Monthly average weekday peak period congestion cost and VKT comparison ($2019)



A clear seasonal trend was observed from Figure 3.2. January and July generally have the lowest congestion cost; March, September and October tend to have higher congestion cost with a few exceptions. Figure 3.2 also shows the high volatility in congestion cost between consecutive months or same month for different years. This further confirmed that a minimum of 3-months' data should be considered in before- and after-period project evaluation to mitigate seasonal or volatility impacts.

Despite the gradual increases in average weekday peak period traffic volumes, the cost of congestion reduced continuously from 2015 to 2019. Figure 3.2 shows clear evidence of how much the performance of Bruce Highway southbound has improved during the peak period from 2015 to 2019. It is also worth noting that the completion of GUN from March 2019 onwards led to a significant boost in highway demand, and both delay cost and reliability cost began trending upward.

3.3 COMPARISON OF MONTHLY CONGESTION COST PER 1000 VKT 2015 TO 2019, WEEKDAY MORNING PEAK

In addition to average congestion cost in weekday peak periods, the average congestion cost per 1000 VKT was also calculated. This indicator normalises congestion cost by VKT and it mitigates the effects of increased traffic volumes between different years. Table 3.3 summarises these results.

Table 3.3: Average congestion cost per 1000 VKT for weekdays ($2019)

Month	Category	2015	2016	2017	2018	2019
January	Excessive delay cost	$27	$20	$19	$25	6
	Reliability cost	$115	$60	$86	$108	$34
	Total cost	$142	$79	$105	$133	$40

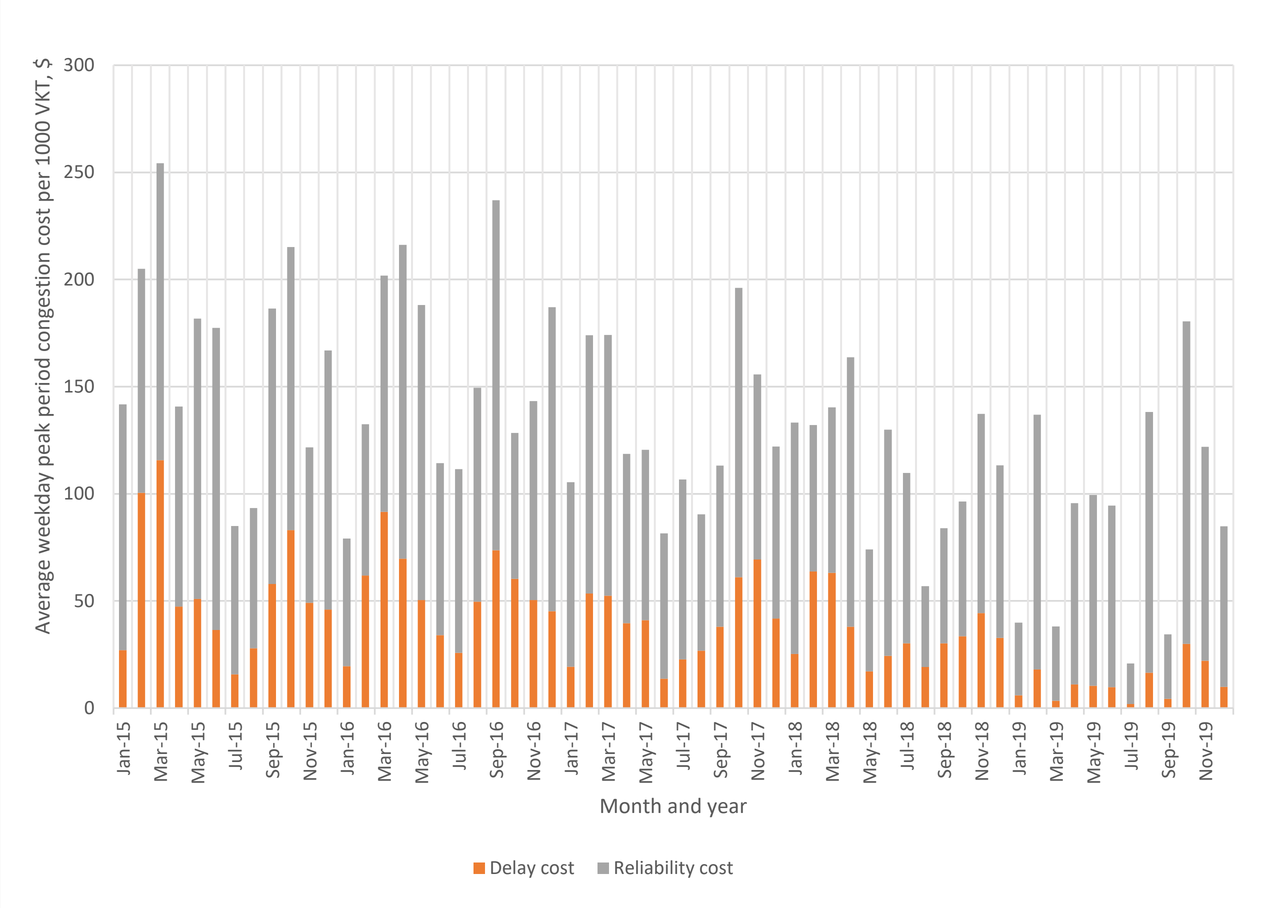
Month	Category	2015	2016	2017	2018	2019
February	Excessive delay cost	$101	$62	$54	$64	$18
	Reliability cost	$105	$71	$120	$68	$119
	Total cost	$205	$133	$174	$132	$137
March	Excessive delay cost	$116	$92	$53	$63	$3
	Reliability cost	$139	$110	$122	$77	$35
	Total cost	$254	$202	$174	$140	$38
April	Excessive delay cost	$47	$70	$40	$38	$11
	Reliability cost	$93	$146	$79	$126	$85
	Total cost	$141	$216	$119	$164	$96
May	Excessive delay cost	$51	$50	$41	$17	$10
	Reliability cost	$131	$138	$79	$57	$89
	Total cost	$182	$188	$120	$74	$100
June	Excessive delay cost	$36	$34	$14	$24	$10
	Reliability cost	$141	$80	$68	$106	$85
	Total cost	$177	$114	$82	$130	$95
July	Excessive delay cost	$16	$26	$23	$30	$2
	Reliability cost	$69	$86	$84	$79	$19
	Total cost	$85	$112	$107	$110	$21
August	Excessive delay cost	$28	$50	$27	$19	$16
	Reliability cost	$65	$100	$64	$38	$122
	Total cost	$93	$149	$90	$57	$138
September	Excessive delay cost	$58	$74	$38	$30	$4
	Reliability cost	$128	$163	$75	$54	$30
	Total cost	$186	$237	$113	$84	$34
October	Excessive delay cost	$83	$60	$61	$33	$30
	Reliability cost	$132	$68	$135	$63	$150
	Total cost	$215	$128	$196	$96	$181
November	Excessive delay cost	$49	$50	$69	$44	$22
	Reliability cost	$72	$93	$86	$93	$100
	Total cost	$122	$143	$156	$137	$122
December	Excessive delay cost	$46	$45	$42	$33	$10
	Reliability cost	$121	$142	$80	$81	$75
	Total cost	$167	$187	$122	$113	$85
Monthly average	Excessive delay cost	$55	$53	$40	$35	$12
	Reliability cost	$109	$105	$90	$79	$78
	Total cost	$164	$157	$130	$114	$90

Month	Category	2015	2016	2017	2018	2019
Monthly average % difference to 2015	Excessive delay cost	–	–4%	–27%	–36%	–78%
	Reliability cost	–	–4%	–17%	–28%	–28%
	Total cost	–	–4%	–21%	–30%	–45%
Monthly average annual growth rate	Excessive delay cost	–	–4%	–25%	–13%	–66%
	Reliability cost	–	–4%	–14%	–12%	–1%
	Total cost	–	–4%	–17%	–12%	–21%

Table 3.3 reveals the following observations:

- Key trends of normalised congestion costs are consistent with the findings from the congestion cost comparison in Section 3.2.
- From 2015 to 2019, gradual reductions in normalised excessive delay cost, reliability cost and total cost year on year were observed, with 4%, 17%, 12% and 21% annual percentage reduction in normalised total cost for 2016, 2017, 2018 and 2019 respectively.
- The 2017 figures achieved the greatest annual percentage reduction in normalised congestion cost compared to the year before, with 25% reduction in normalised excessive delay cost, 14% reduction in normalised reliability cost, and 17% reduction in normalised total cost.
- The 2019 figures achieved the greatest percentage reduction of normalised excessive delay cost by 78% comparing to 2015, 66% compared to 2018. In comparison to the annual increase of 9% in reliability cost for 2019 from Table 3.2 compared to 2018, normalising by VKT shows a minor reduction in reliability cost rounded to 1%. Overall, 2019 achieved a high reduction in normalised total cost of 45% compared to 2015 and 21% compared to 2018.
- Again, the monthly comparison revealed that it may not be sufficient to compare a single month's data for before-and-after evaluations. A minimum of three months average results should be considered in before-and-after analysis to mitigate the volatility of the results.

Figure 3.3: Average weekday peak period congestion cost per 1000 VKT comparison



A similar trend was observed from Figure 3.3 in comparison to the observations from Figure 3.2. The reduction of the normalised excessive delay cost, reliability cost and total cost trendlines became more significant. The month to month congestion cost variations were still high. The 2019 data showed the greatest reduction in excessive delay cost during the peak period when the GUN project was completed.

3.4 MAJOR PROJECT IMPACTS ON BRUCE HIGHWAY SOUTHBOUND PERFORMANCE

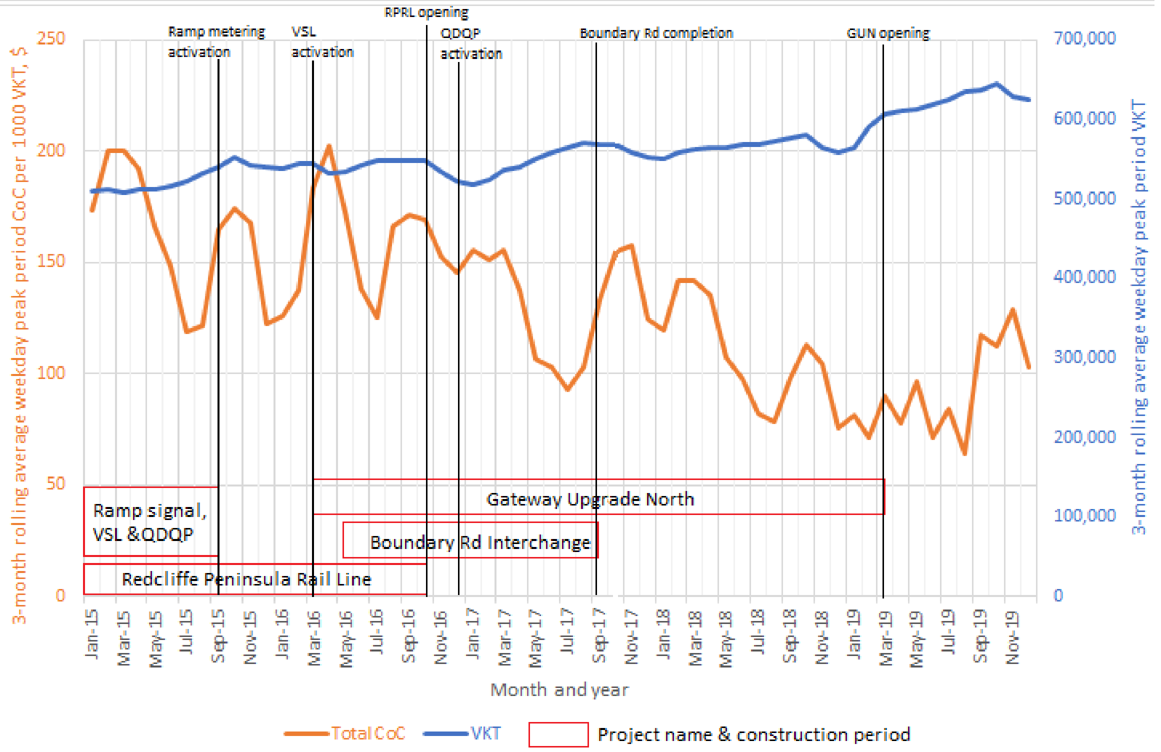
This section presents the analysis results of the major project impacts on Bruce Highway southbound performance between 2015 and 2019. The three major projects that had a direct influence are:

- ramp metering, VSL and QDQP systems (Section 3.4.1)
- Boundary Road interchange upgrade (Section 3.4.2)
- GUN project (Section 3.4.3).

There was a fourth project named the RPRL which is believed to have had a mode choice impact on travel preference and could potentially shift a portion of Bruce Highway southbound traffic volume to rail passenger volume. An initial investigation of potential impact for the RPRL by time of day is conducted in Section 3.4.1. A detailed RPRL evaluation is presented in Section 5.2.1.

Figure 3.4 shows a holistic picture of the change in the 3-month rolling average total congestion cost and VKT for the weekday peak period between 5 am to 10 am from years 2015 to 2019, with inclusion of the four major projects commissioning and construction time spans. The rolling averages were calculated based on the mean of 3 consecutive months' values from 1-month before to 1-month after. The rolling averages are effective in smoothing out short-term fluctuations and highlight longer-term trends.

Figure 3.4: Average weekday peak period congestion cost per 1000 VKT, VKT and projects construction time span



3.4.1 RAMP METERING, VSL AND QDQP SYSTEMS

The managed motorways project involved the installation of ramp metering, VSL signs and QDQP systems on Bruce Highway between Deception Bay Rd and the Gateway Motorway/Gympie Arterial Rd. The construction periods for those systems began in May 2014 and were completed by September 2015. Three systems were not activated at the same time. Ramp signals were first activated on Monday 21 September 2015, VSL was operated in static capacity from March 2016 until QDQP was activated in December 2016. The managed motorway treatments were expected to improve travel time reliability, reduce level of congestion, crash rates and severity. Table 3.4 shows the project related information for ramp metering, VSL and QDQP system installations and Table 3.5 presents the results of the congestion cost evaluation for different periods.

Table 3.4: Project evaluation information – Ramp metering, VSL & QDQP

Project	Ramp metering, VSL and QDQP systems	Notes
Construction period	May 2014 to Sep 2015	
Commissioning date	Ramp metering was activated in Sep 2015, VSL was activated in Mar 2016, QDQP was activated in Dec 2016	
Before-period	Jun 2015 to Aug 2015	None of those three systems were activated during this period.
After-period 1	Jun 2016 to Aug 2016	Ramp metering was activated and VSL was operated manually during this period.
After-period 2	Jun 2017 to Aug 2017	First year all three system were fully activated.
After-period 3	Jun 2018 to Aug 2018	Second year all three system were activated.
Time period of analysis	AM peak 5 am to 10 am	
Immediate impacted links	Link 1 to link 18	

Table 3.5: Analysis results average daily peak period – Ramp metering, VSL & QDQP

	Before-period 2015	After-period 1 2016	After-period 2 2017	After-period 3 2018	Percentage difference to before-period		
					After-period 1	After-period 2	After-period 3
VKT	521,644	547,415	563,415	568,344	5%	8%	9%
Excessive delay cost	$13,825	$20,042	$11,799	$13,995	45%	–15%	1%
Reliability cost	$47,777	$48,533	$39,539	$41,858	2%	–17%	–12%
Total cost	$61,602	$68,575	$51,337	$55,852	11%	–17%	–9%
Excessive delay cost per 1000 VKT	$27	$37	$21	$25	38%	–21%	–7%
Reliability cost per 1000 VKT	$92	$89	$70	$74	–3%	–23%	–20%
Total cost per 1000 VKT	$118	$125	$91	$98	6%	–23%	–17%

Table 3.5 reveals the following observations:

- The before-period and after-period 1 comparison did not show an improvement, i.e. a reduction of congestion cost for ramp metering and VSL systems, e.g. the normalised excessive delay cost increased by 38%, the normalised reliability cost reduced by 3%, and the normalised total cost increased by 6%. It is worth noting that due to GUN major construction beginning on February 2016, the after-period 1 results were impacted by the disruption in travel conditions and significant delay was observed from link 17 Gateway Motorway up to link 11 Boundary Road interchange. Therefore, this result could not reflect the actual benefits of ramp metering and VSL.
- Since the QDQP was activated in December 2016, the comparison of after-period 2 with the before-period indicated the actual benefits of ramp metering, VSL and QDQP systems. Even though there were still ongoing construction impacts from the GUN project, significant congestion cost reduction was observed - a 21% reduction in normalised excessive delay cost, 23% reduction in both normalised reliability cost and total cost were observed for after-period 2 in comparison to the before-period. QDQP added significant benefits to Bruce Highway southbound operating performance. The finding confirmed that ramp metering, VSL and QDQP performance was at their best when all systems were activated and coordinated.
- In addition, taking into account that major traffic delays were caused by work on the GUN project in both 2016 (after-period 1) and 2017 (after-period 2), the actual benefits of those systems could be greater than the benefits estimated in this report. By comparing after-period 2 with after-period 1, the observed improvements are 43%, 21% and 27% reduction in normalised excessive delay cost, reliability cost and total cost respectively, which is an alternative option for measuring the benefits gained from activating ramp metering, VSL and QDQP together.

Figure 3.5: Average flow per hour by time of day for links 12, 13 and 14 for months of July and August

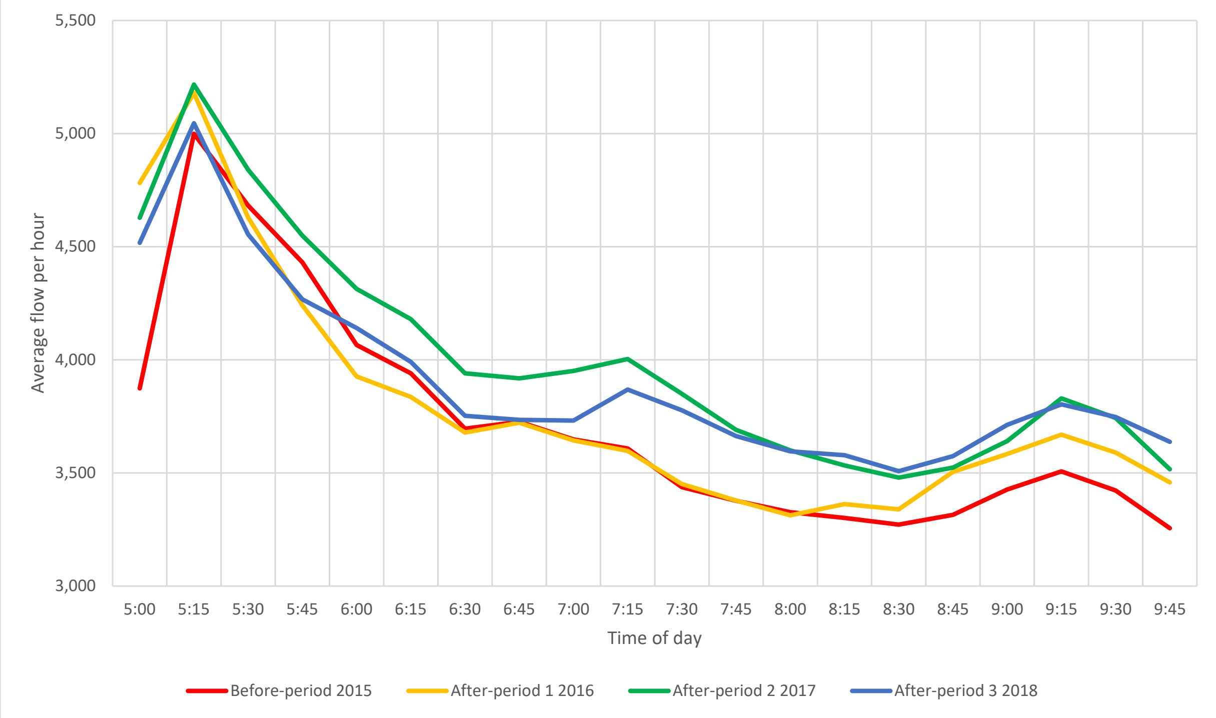


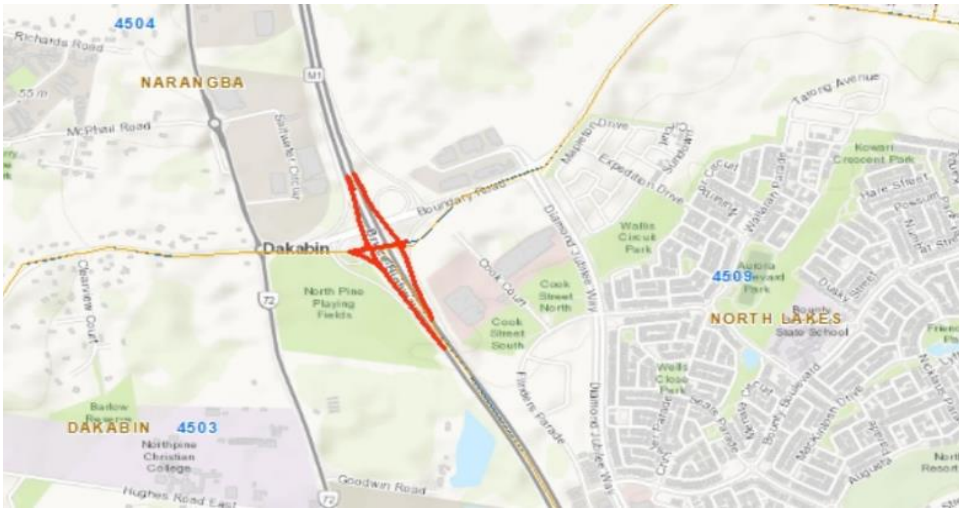
Figure 3.5 shows the time of day comparison between average link flow on weekdays for links 12, 13 and 14 near Anzac Ave on Bruce Highway for the month of June and July between different periods. The figure focuses only on link 12, 13 and 14 with the aim of identifying any potential impacts on travel behaviour change or mode shift due to the completion of RPRL on 3 October 2016, which was between after-period 1 and after-period 2. As the graph shows, other than there was slight reduction by up to 3% for after-period 2 in comparison to after-period 1 between 5 am to 5.15 am, all other times in after-period 2 had a higher flow. Based on these results, there was insufficient evidence to conclude that the RPRL caused a significant mode shift from vehicle trips on Bruce Highway southbound to rail trips citybound. Neither did it provide evidence that the completion of RPRL had improved the congestion on Bruce Highway southbound.

Figure 3.5 also revealed that for the before-period 2015, Bruce Highway links 12, 13 and 14 had an average maximum traffic flow of 5000 vehicles per hour at 5.15 am before flow breakdown. The implementation of ramp metering, VSL and QDQP systems was able to increase this maximum flow by up to 4% to 5216 vehicles per hour before flow breakdown. After flow breakdown at 5.15 am, after-periods were generally able to maintain higher operational capacity than the before-period. This was an indication of operational capacity improvement on Bruce Highway due to the implementation of ramp metering, VSL and QDQP smart motorway treatments.

3.4.2 BOUNDARY RD INTERCHANGE UPGRADE

The project involved the upgrade of the Boundary Road interchange approximately 30 km north of the Brisbane CBD and included a new six lane, four span concrete bridge over the Bruce Highway. Construction began in May 2016 and opened to service on 8 September 2017. The project was expected to improve peak period operations and reduce delays and queuing for the road users who accessed Bruce Highway from this interchange. The improvements would provide a reduction in travel time, improving road user safety by reducing congestion-related accidents. Figure 3.6 shows the Boundary Road interchange upgrade sections highlighted in red.

Figure 3.6: Boundary Road interchange upgrade



Source: The Department of Infrastructure, Transport, Regional Development and Communications (2020), 'Bruce Highway – Boundary Road Interchange'.

Table 3.6 shows the project related information for the Boundary Road interchange upgrade and Table 3.7 presents the results of the congestion cost evaluation.

Table 3.6: Project evaluation information – Boundary Road interchange upgrade

Project	Boundary Road interchange upgrade
Construction period	May 2016 to September 2017
Commissioning date	8 September 2017
Before-period	Feb 2016 to Apr 2016
After-period	Feb 2018 to Apr 2018
Time period of analysis	AM peak 5 am to 10 am
Immediate impacted links	Link 10 and link 11

Table 3.7: Congestion cost analysis - average daily peak period – Boundary Road interchange upgrade

	Before-period 2016	After-period 2018	Percentage difference
VKT	68,749	70,653	3%
Excessive delay cost	$1,246	$574	–54%
Reliability cost	$4,897	$2,778	–43%
Total cost	$6,142	$3,352	–45%
Excessive delay cost per 1000 VKT	$18	$8	–55%
Reliability cost per 1000 VKT	$71	$39	–45%
Total cost per 1000 VKT	$89	$47	–47%

Table 3.7 reveals the following observations:

- A significant reduction in congestion cost was achieved for the after-period compared to the before-period. The average weekday daily peak period VKT increased by 3%, however the normalised excessive delay cost, reliability cost and total cost were reduced by 55%, 45% and 47% respectively.
- Since VSL and QDQP were activated between the before- and after-periods, a portion of the reduction in congestion cost should be attributed to the benefits of ramp metering, VSL and QDQP systems rather than attributing the benefits solely to the Boundary Road interchange upgrade. Therefore by comparing the after-period 3 to after-period 1 in Table 3.5 of Section 3.4.1, ramp metering, VSL and QDQP systems achieved 32%, 17% and 23% reduction in excessive delay cost, reliability cost and total cost

respectively. By assuming these percentages for the benefits of ramp metering, VSL and QDQP systems are applied uniformly across all links in the route, then the Boundary Road interchange upgrade potentially accounted for 23% (out of 55%), 28% (out of 45%) and 24% (out of 47%) for the normalised excessive delay cost, reliability cost and total cost reductions respectively.

3.4.3 GATEWAY UPGRADE NORTH

The project involved upgrade of the Gateway Motorway between Nudgee and Deagon, with additional pavement and safety works through to Bracken Ridge. Preliminary works to prepare the site started in September 2014. Major construction started in February 2016. At the end of November 2018, widened motorway lanes were made available to motorists southbound between the Sandgate Road bridges and Nudgee. The project was completed in March 2019 and was commissioned on 15 March 2019. The project is expected to reduce congestion, improve travel time reliability, accommodate future growth and improve motorists' safety on the Gateway Motorway.

Table 3.8 shows the project related information for the GUN, Table 3.9 and Table 3.10 present the results of the congestion cost evaluation.

Table 3.8: Project evaluation information – GUN

Project	GUN
Construction period	Feb 2016 to Mar 2019
Commissioning date	15 March 2019
Before-period	Jun 2015 to Aug 2015
Inter-period 1	Jun 2016 to Aug 2016
Inter-period 2	Jun 2017 to Aug 2017
Inter-period 3	Jun 2018 to Aug 2018
After-period	Jun 2019 to Aug 2019
Time period of analysis	AM peak 5 am to 10 am
Immediate impacted links	Link 9 to link 17
Alternative before-period	Inter-period 3: Jun 2018 to Aug 2018

Table 3.9: Analysis results average daily peak period on Bruce Highway – before and after GUN completion

	Before-period 2015	Inter-period 1 2016	Inter-period 2 2017	Inter-period 3 2018	After-period 2019	% difference 2019 to 2018
VKT	322,558	348,422	356,641	362,482	406,632	12%
Excessive delay cost	$13,615	$19,506	$11,413	$13,065	$5,062	–61%
Reliability cost	$45,365	$45,514	$36,627	$37,887	$42,693	13%
Total cost	$58,980	$65,020	$48,041	$50,953	$47,755	–6%
Excessive delay cost per 1000 VKT	$42	$56	$32	$36	$12	–67%
Reliability cost per 1000 VKT	$141	$131	$103	$105	$105	0%
Total cost per 1000 VKT	$183	$187	$135	$141	$117	–17%

Table 3.10: Percentage difference to before-period 2015 of average daily peak period – before and after GUN completion

	Inter-period 1, 2016	Inter-period 2, 2017	Inter-period 3, 2018	After-period, 2019
VKT	8%	11%	12%	26%

	Inter-period 1, 2016	Inter-period 2, 2017	Inter-period 3, 2018	After-period, 2019
Excessive delay cost	43%	–16%	–4%	–63%
Reliability cost	0%	–19%	–16%	–6%
Total cost	10%	–19%	–14%	–19%
Excessive delay cost per 1000 VKT	33%	–24%	–15%	–71%
Reliability cost per 1000 VKT	–7%	–27%	–26%	–25%
Total cost per 1000 VKT	2%	–26%	–23%	–36%

Comparison of results in Table 3.9 and Table 3.10 reveals the following observations:

- For the before-period and inter-period 1 comparison, ramp metering and VSL were activated between those periods. However, other than a 7% reduction in reliability cost per 1000 VKT, the excessive delay cost per VKT significantly increased by 33%, and the total cost per VKT increased marginally by 2%. Possibly all of the increase in excessive delay cost was due to the major construction of the GUN project which began in February 2016.
- For the before-period and inter-period 2 comparison, the full benefits of ramp metering, VSL and QDQP can be revealed. It was anticipated that those systems can only be best utilised when all systems were activated. As QDQP was activated in December 2016, the congestion cost data in 2017 showed a significant improvement. The normalised excessive delay cost, reliability cost and total cost were reduced by 24%, 27% and 26% respectively.
- The inter-period 3 total congestion cost per VKT was marginally higher than inter-period 2 by 4%. Considering the average VKT was 1% higher than inter-period 2, the results are within the expected range. No other major project happened in between those periods except the completion of RPRL, which was expected to cause travel mode shift from vehicles to rail and reduce a small portion of VKT on Bruce Highway southbound. However, no reduction in VKT was observed in the Bruce Highway southbound volume data potentially due to the huge population boom in the North Lakes SA3 region where the population growth rates were consistently higher than 5% annually between 2015 to 2019 (Australian Bureau of Statistics 2017, 2019, 2020a, 2020b).
- Since the completion of the GUN project in March 2019, additional trips were generated on Bruce Highway southbound due to congestion easing, operational capacity improvement and better driving experience. Compared to inter-period 3 2018, after-period 2019 had an increase of 12% in average daily peak period VKT. At the same time, the normalised excessive delay cost and total cost were reduced by 67% and 17% respectively, no change was observed in normalised reliability cost.
- The normalised excessive delay cost, reliability cost and total cost were reduced by 71%, 25% and 36% respectively by comparing after-period to the before-period. Again, a portion of those benefits should be attributed to other projects which occurred on Bruce Highway between 2016 and 2018.

3.5 LIMITATION OF THE STUDY

The limitation of the study is as follows:

- There were only two classified vehicle counters available with significant data gaps in each of the datasets. Therefore, the two datasets were combined to obtain a more complete dataset. Vehicle composition data from classified vehicle counters site 135790 was used as the main source of data and data from the other classified vehicle counter site 20221 was used for gap filling. Also, due to lack of vehicle composition data from 2015, it was assumed the 2015 data was identical to 2016 data. This assumption was deemed appropriate as the split did not change significantly between 2015 and 2016. This combined dataset was then applied to cover the 18 links across the study site. If more classified counting stations were available, the resolution of traffic composition data used to calculate congestion costs would have been improved, thus providing more accurate results.

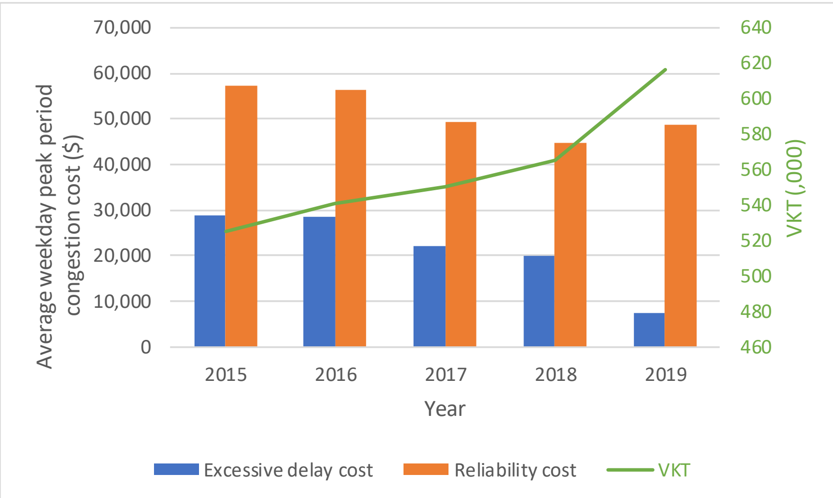
3.6 SUMMARY

Part 1 of the study focuses on the evaluation of the effects of three major motorway treatments on motorway performance on Bruce Highway southbound. Those projects were ramp metering, VSL and QDQP systems project, Boundary Road interchange upgrade, and the GUN project. The findings from this study confirmed the benefits of these treatments between 2015 and 2019, with significant reductions in congestion costs and improvement of road user experience and highway operating capacity during the morning peak commute time (5 am to 10 am). From 2015 to 2019, the VKT were observed to have increased consistently year on year, indicating the treatments have potentially increased the operational capacity of Bruce Highway. Using 2015 as the base year, the average peak period VKT for weekdays in 2016 was 3% higher, in 2017 it was 5% higher, in 2018 it was 8% higher and in 2019 it was 17% higher. It was observed that when the GUN project was completed in March 2019, 2019 had the most significant increase in VKT, with an additional 9% of 2018 VKT added to the southbound route. Considering the average background annual VKT growth of 2% to 3% on Bruce Highway southbound prior to 2019, the GUN project significantly improved the operational capacity and added an additional 6% of traffic approximately for Bruce Highway southbound in 2019.

Significant month-to-month variation was found in the average weekday cost of congestion for the peak period. Traffic conditions were heavily dependent on seasonality, the number of minor incidents which occurred on Bruce Highway, and the stage of road works that impacted on the surrounding network. If only a single month of data is compared, results may potentially be biased depending on the selection of month. Therefore, it was agreed that for selection of before- and after-periods, a minimum period of 3 months for same months of the year is recommended in order to mitigate the seasonal or volatility impacts on the results.

Over the five years, the Bruce Highway has demonstrated significant performance improvement and congestion cost reductions. Figure 3.7 shows the annual average weekday peak period congestion cost and VKT between 2015 and 2019. Although the average daily VKT increased by 17% from 2015 to 2019, the peak period congestion cost was reduced by 35% on a typical weekday. The bulk of these cost-savings originated from reduced excessive delay cost, which experienced a 74% reduction. The travel time reliability cost also reduced by 15%. When normalising by 1000 VKT to control for the effects of natural traffic growth over time, more significant cost savings were identified. Reductions in total congestion, excessive delay and reliability costs per VKT were 45%, 78% and 28% respectively. These are the combined benefits of the three major motorway treatment projects listed above. All costs are in 2019-dollar values.

Figure 3.7: Annual average weekday peak period congestion cost and VKT comparison ($2019)



Key findings from before-and-after comparison of each project are also summarised as follows:

- ramp metering, VSL and QDQP systems
  - The before-and-after comparison (2015 versus 2016), when only ramp metering and VSL were activated, revealed that ramp metering and VSL did not lead to a reduction in Bruce Highway

southbound congestion cost. Instead, the after-period had a 38% increase in normalised excessive delay cost, 3% reduction in normalised reliability cost, and 6% increase in normalised total cost. It was concluded that those observations were the result of traffic disruption caused by the GUN project.

  - The before-and-after comparison (2015 versus 2017), when ramp metering, VSL and QDQP systems were all activated, revealed significant congestion improvement on Bruce Highway. While there was still ongoing traffic disruption from the GUN construction project, after-period data revealed a 21% reduction in normalised excessive delay cost, 23% reduction in both normalised reliability cost and total cost. QDQP added significant benefits to Bruce Highway congestion improvement. It was also observed that the ramp metering, VSL and QDQP systems were best utilised and performed when all systems were activated.
  - The time of day flow capacity comparison between different periods confirmed that the implementation of ramp metering, VSL and QDQP systems was able to increase the flow before the flow breakdown at 5.15 am by up to 4% for the selected comparison links; and after the flow breakdown, after-periods were generally able to maintain higher operational capacity than in the before-period.
  - It was also concluded that due to the traffic disruption caused by the GUN project construction, the actual benefits of the ramp metering, VSL and QDQP systems would be greater than the benefits estimated in this study.
- Boundary Road interchange upgrade
  - A significant reduction in congestion cost was observed from the before-and-after comparison (2016 versus 2018). While the average weekday daily peak period VKT increased by 3% for the links impacted directly by the upgrade, the normalised excessive delay cost, reliability cost and total cost reduced by 55%, 45% and 47% respectively.
  - It was also concluded that, due to over-lapping of projects, a portion of the reduction in congestion cost should be attributed to the benefits of ramp metering, VSL and QDQP systems rather than all attributed to the benefits of the Boundary Road interchange upgrade.
- GUN
  - The construction of the GUN caused a major disruption to usual traffic on Bruce Highway southbound between Deception Bay Road and Gateway Motorway between February 2016 and March 2019. By comparing the before-period and the year when major construction began (2015 versus 2016), the excessive delay cost per VKT was significantly increased by 33%.
  - The completion of the GUN project led to significant operational capacity improvement, attracted a large surplus of demand for Bruce Highway southbound and at the same time eased the peak period congestion significantly. Comparing the selected periods between 2018 and 2019, while 2019 had an increase of 12% in average daily peak period VKT for the links impacted directly by the GUN, the normalised excessive delay cost and total cost reduced by 67% and 17% respectively. There was no improvement in reliability cost due to the removal of the downstream bottleneck, allowing a wider speed range between the free flow and saturation conditions.
  - For the before-and-after comparison (2015 versus 2019), significant reduction in congestion cost was observed in 2019. The normalised excessive delay cost, reliability cost and total cost were reduced by 71%, 25% and 36% respectively for the section between Deception Bay Road and Gateway Motorway. A portion of those benefits should be attributed to the other projects on Bruce Highway between 2016 and 2018.

Note that due to the over-lapping of construction projects over an extensive period of time, each had an impact on the Bruce Highway performance. Breaking down and quantifying the exact or exclusive benefits of each project was not feasible.

4 TRAVEL CHOICE CHANGES INVESTIGATION (PART 2)

Part 2 of this project focussed on investigating how some of the infrastructure works described in Part 1 influenced mode choice in the study area (i.e. choice between public transport and use of private vehicles), in order to provide additional supporting evidence for the changes identified in Bruce Highway traffic performance. In addition, overall long-term trends have been investigated. The analysis is based on a combination of traffic volume data from the road network including Bruce Highway and surrounding major arterial roads, and public transport ridership data (bus and rail).

4.1 OBJECTIVES AND KEY PERFORMANCE INDICATORS

The first main objective of this part of the project was to analyse overall long-term trends and changes that could potentially be observed during the study period. Both public transport and road travel patterns were analysed. For example, a steady increase in public transport ridership was expected because of the rail network upgrade (opening of the RPRL) and increased adoption by travellers and commuters over time if it proved successful. Population growth has also been taken into consideration as it can affect the trends.

The second main objective was to investigate the potential relationships that can be established between changes in traffic patterns on the road network and changes in public transport usage in the context of the infrastructure works in the area during the study period (2015 to 2019). The main infrastructure works to be considered are:

- Opening of the RPRL in October 2016:
  The new RPRL is a 12.6 kilometre dual track passenger rail line connecting Kippa-Ring on the Redcliffe peninsula and Petrie north of Brisbane. The rail line has six new stations servicing growing suburbs in the southern Moreton Bay region including Rothwell, Deception Bay, Mango Hill, North Lakes, Murrumba Downs and Kallangur which were not serviced by a rail line prior to October 2016. Bus services only were available until then. The RPRL project also included upgrades to Petrie station where the RPRL connects to the Caboolture rail line which connects the northern suburbs of Brisbane to the southern Moreton Bay region. A total of 2850 park-and-ride car spaces are provided at all six new stations. The RPRL should reduce travel time between the Redcliffe peninsula area and Brisbane CBD, offering a consistent 55 minute journey time between Kippa-Ring and Brisbane Central (TransLink 2020a). At the same time as the RPRL opening, the number of bus services was reduced, and routes shortened to provide feeder services only to the new railway stations.
  The completion of the RPRL was expected to have a positive impact on the road network in the area by encouraging some road users to use public transport more and drive less, which could result in lower observed traffic volumes.

  However the opening of RPRL sparked a train driver shortage issue and a reduced timetable was rolled out with numerous service cancellations. The timetable was gradually ramped up over the years and in July 2019, the full train timetable was restored (Caldwell 2019). The “return to full service” plan added one additional service per day from Mondays to Thursdays, and three additional services on Fridays on the RPRL (TransLink, personal communication). The increased number of services has the potential to encourage more people to use public transport, because trains run more frequently which increases travel convenience.
- Gateway Upgrade North (GUN) completion in March 2019:
  As described in Section 3.4.3, the GUN project was designed to improve traffic flow, reduce congestion and accommodate future growth of traffic volumes. The completion of the upgrade could potentially have an opposite effect to the opening of the RPRL by encouraging people to drive instead of using public transport because congestion was eased, and journey times reduced on the upgraded sections of Bruce Highway and Gateway Motorway.

The above-mentioned RPRL and GUN infrastructure projects, their potential impacts on mode share and overall trends, and the corresponding methodologies and key performance indicators (KPIs) to assess the impacts are summarised in Table 4.1. More detailed information about the GUN project can be found in Section 3.4.3.

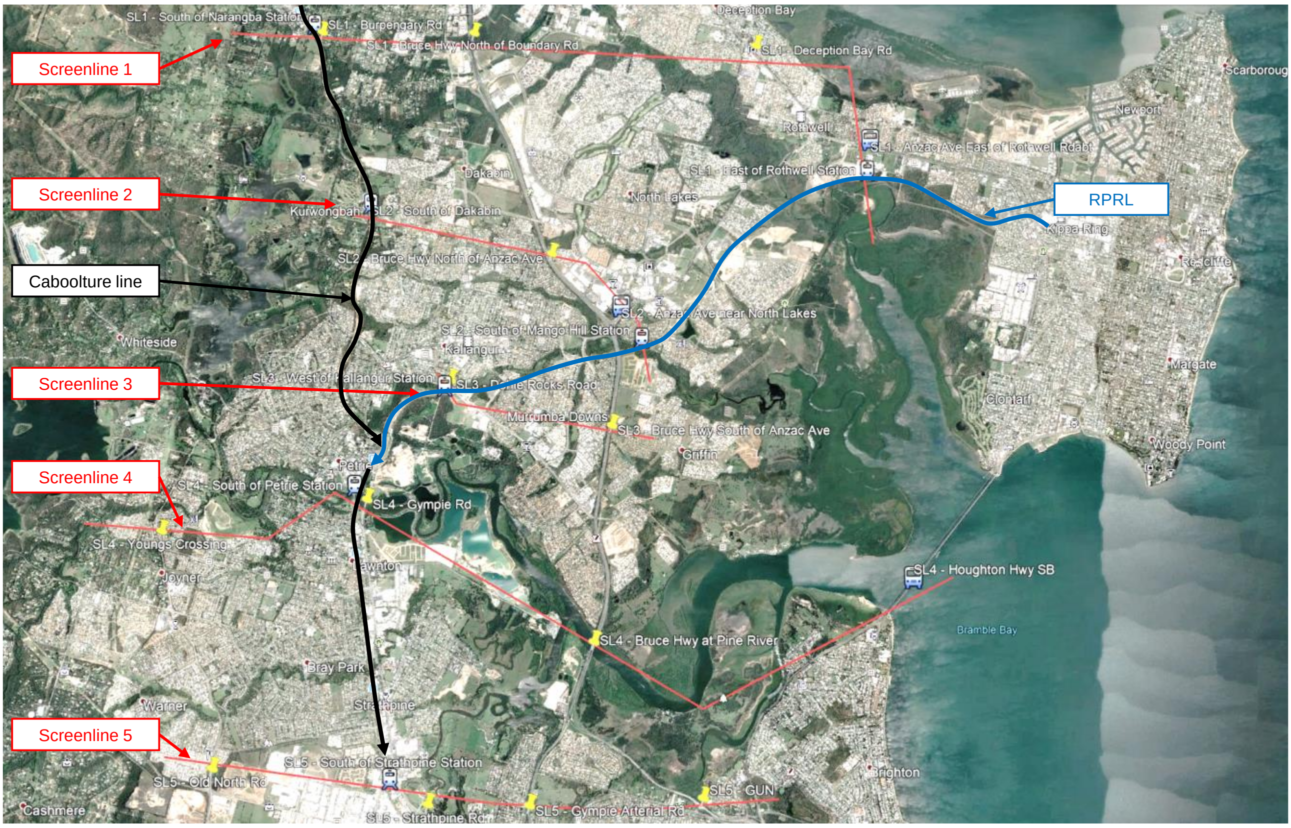
Table 4.1: Major infrastructure works relevant to Part 2 of the study

Project	Effective from	Potential impacts and trends	Methodology	KPIs
RPRL opening	October 2016	Trend: increased usage of the RPRL and connecting inbound rail services, and reduction of bus trips over time Impact: mode share expected to shift towards higher public transport usage in the study area, reducing traffic volumes on the local road network	Before-and-after comparison of mode shares Before-period: Jun to Sep 2016 After-periods: 1. Jun to Sep 2017, 2. Jun to Sep 2018, 3. Jun to Sep 2019	Change of mode share (% of passengers/travellers) based on – public transport ridership data – traffic volume data for Bruce Highway and major arterial roads, converted to vehicle occupant numbers
Completion of the GUN	March 2019	Impact: Mode share expected to shift towards higher road usage compared to public transport	Before-and-after comparison of mode shares Before-periods: 1. Jun to Aug 2016, 2. Jun to Aug 2017, 3. Jun to Aug 2018 After-period: Jun to Aug 2019	Total number of travellers on the road/rail network

4.2 STUDY AREA, PERIOD AND TIME OF DAY

The study area is depicted in Figure 4.1 which shows the southern Moreton Bay region including the Redcliffe Peninsula. Five screenlines (SLs) were defined in order to structure the analysis and capture traffic and public transport users from the different suburbs in the area on their way to Brisbane (inbound).

Figure 4.1: Southern Moreton Bay study area with screenlines



Source: Google Earth 2020, 'southern Moreton Bay region', map data, Google, California, USA.

Table 4.2 lists the details of all crossings in the study area between the five SLs and the rail lines, bus routes, major arterial roads and motorways in an inbound direction. This set of crossings was determined by TMR to be a representative set which captures most travellers and commuters. Similar to Part 1, only inbound trips (from the study area to Brisbane city) during the weekday morning peak period between 5 am and 10 am were analysed, as this is the key period of the day for commuters and the busiest time of the day. Weekends and public holidays were excluded from the analysis.

Table 4.2: Inbound screenline crossings for public transport routes and major roads

Screenlines	Public transport route crossings (inbound)		Road network crossings (inbound)	
	Bus routes	Rail lines	Arterial road links	Motorway links
SL 1	Anzac Ave (west bound)	RPRL (inbound)	Anzac Ave (west bound)	Bruce Highway (south bound)
	Deception Bay Road (south-east bound)	Caboolture Line (inbound)	Deception Bay Road (south-east bound)	
SL 2	Anzac Ave (south-west bound)	RPRL (inbound)	Anzac Ave (south-west bound)	Bruce Highway (south bound)
		Caboolture Line (inbound)	Anzac Ave (south-east bound ramp to Bruce Highway)	
SL 3	Dohles Rocks Rd (inbound)	RPRL (inbound)	Dohles Rocks Rd (south-east bound)	Bruce Highway (south bound)
SL 4	Gympie Rd (south bound)	Caboolture Line/RPRL (inbound)	Gympie Rd (south bound)	Bruce Highway (south bound)
	Youngs Crossing Rd (south bound)		Youngs Crossing Rd/Old North Rd (south bound)	Ted Smout Bridge (south-west bound)
	Houghton Highway (south-west bound)			
SL 5	Strathpine Rd (south bound)	Caboolture Line/RPRL (inbound)	Gympie Rd (south-east bound)	Gympie Arterial Rd (south bound)
			Old North Rd (south bound)	Gateway Motorway (south-east bound)

The study period was defined as June 2016 to December 2019. This study period is shorter than for Part 1, as sufficiently reliable data was only available for this period. The study encountered several challenges in accessing the required data: rail patronage data prior to June 2016 was not readily available, loop detectors from several road links on the SLs were disrupted due to the road works associated with the new RPRL stations. This resulted in large data gaps prior to June 2016, therefore it was decided to exclude this data from the analysis in order to avoid skewed results and incorrect conclusions.

4.3 DATA SOURCES AND DATA CLEANSING

Three main data sets were used as an assessment basis:

- Public transport data:
  TransLink provided weekday 5 am to 10 am monthly average public transport ridership data for the bus routes and rail lines in the study area listed in Table 4.2. In addition, a reference data set was made available for the same time period, containing public transport ridership data in South-East Queensland (SEQ), excluding the study area.
- STREAMS traffic data:
  TMR provided daily 5 am to 10 am traffic volume (flow) data in 15-minute intervals for all arterial road and motorway links listed in Table 4.2.

- Population data:
  Annual population statistics for the suburbs in the study area were sourced from the Australian Bureau of Statistics.

These data sets were cleaned as outlined in the following sections.

4.3.1 PUBLIC TRANSPORT DATA

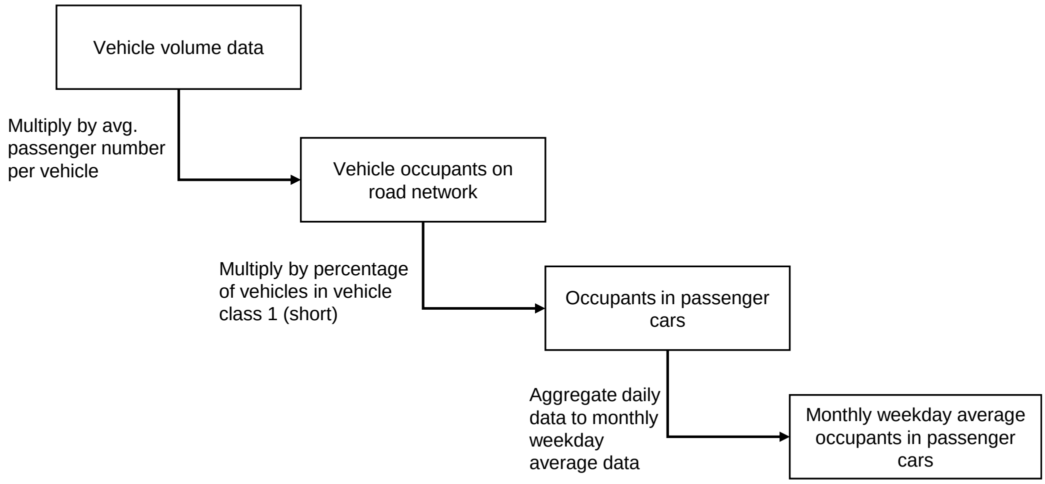
The weekday monthly average public transport ridership data was structured in order to be able to identify changes along each SL and mode of transport. Passenger volumes across each SL for the 5 am to 10 am period were attributed to each bus route and rail line to obtain the total passenger numbers. Further data aggregation was not required.

The SEQ reference public transport data set contained weekday monthly average bus and rail ridership data for the same period. It was structured in the same way as the public transport data from the study area (separation of bus and rail) in order to offset seasonality effects.

4.3.2 MOTORWAY AND ARTERIAL ROAD DATA

Motorway and arterial road volume data was available for all days during the study period. In order to be able to compare the data to the public transport ridership data (see Section 4.3.1), the volume data was converted to vehicle occupant numbers which are directly comparable to passenger numbers on the public transport network. The approach of converting flow data to vehicle occupant numbers is shown in Figure 4.2. This approach was followed for all motorway and arterial road links. In total, seven inbound motorway links and nine inbound arterial road links were used (see Table 4.2).

Figure 4.2: Data transformation and aggregation methodology for motorway and arterial road data



Notes:

- *Average passengers per vehicle as per Table 2.3 was used.*
- *The same class 1 vehicle composition data (passenger vehicles) as in Part 1 was used (Table 2.4).*
- *Prior to the steps shown in the figure, vehicle volumes were derived from 15-minute flow data.*

It is important to note that the motorway and arterial road data is only a representative selection of roads in the study area which does not cover all road crossings of each of the SLs. Hence, the number of vehicle occupants calculated based on the vehicle volume data is likely to be lower than the total number of people crossing the SLs using private passenger vehicles. Therefore, when compared to the public transport ridership data, relative changes were analysed.

Similar to the Part 1 data, the Part 2 motorway and arterial road data also contained data gaps. These gaps were filled by using the same hot-deck imputation method as described in Section 2.2. The percentage of missing data for the 5 am to 10 am period of each calendar year is summarised in Table 4.3. However, it is important to note that not all gaps were filled because filling gaps with data from weeks before or after the actual week could potentially skew trends in the data set when aggregating data points to average monthly data. Considering that a trend analysis is an important part of the study, it was preferred to calculate the average of the original data only, ignoring smaller gaps. Only large gaps of more than 14 days were filled with data from the closest adjacent week or month in order to limit the effect of outliers on the calculated averages.

Table 4.3: Percentage of missing data (data gaps) for each calendar year of the study period

Year	Motorways	Arterial roads
2016 (from June onwards)	0.63% of records (122 out of 19,460)	4.97% of records (1244 out of 25,020)
2017	4.86% of records (1668 out of 34,300)	4.56% of records (2013 out of 44,100)
2018	0.97% of records (334 out of 34,580)	2.07% of records (922 out of 44,460)
2019	0.10% of records (36 out of 34,720)	2.98% of records (1332 out of 44,640)

Note: The above figures are based on the total number of data points for inbound links during the selected hours of 5 am to 10 am, weekdays only, excluding public holidays.

4.3.3 POPULATION DATA

Annual population data from 2016 to 2019 for the suburbs in the study area was available (Australian Bureau of Statistics 2017, 2019, 2020a, 2020b). This data was used as an indicator of demand growth in the area. Direct relationships, e.g. on a SL level, between the population statistics and public transport ridership or traffic volumes could not be established without access to a multimodal transport model.

5 MULTIMODAL TRAVEL ANALYSIS RESULTS

This section provides an overview of the results from the data in the study area described in Section 4. General trends over the study period as well as the impact of the infrastructure works on the mode share outlined in Table 4.1 are analysed.

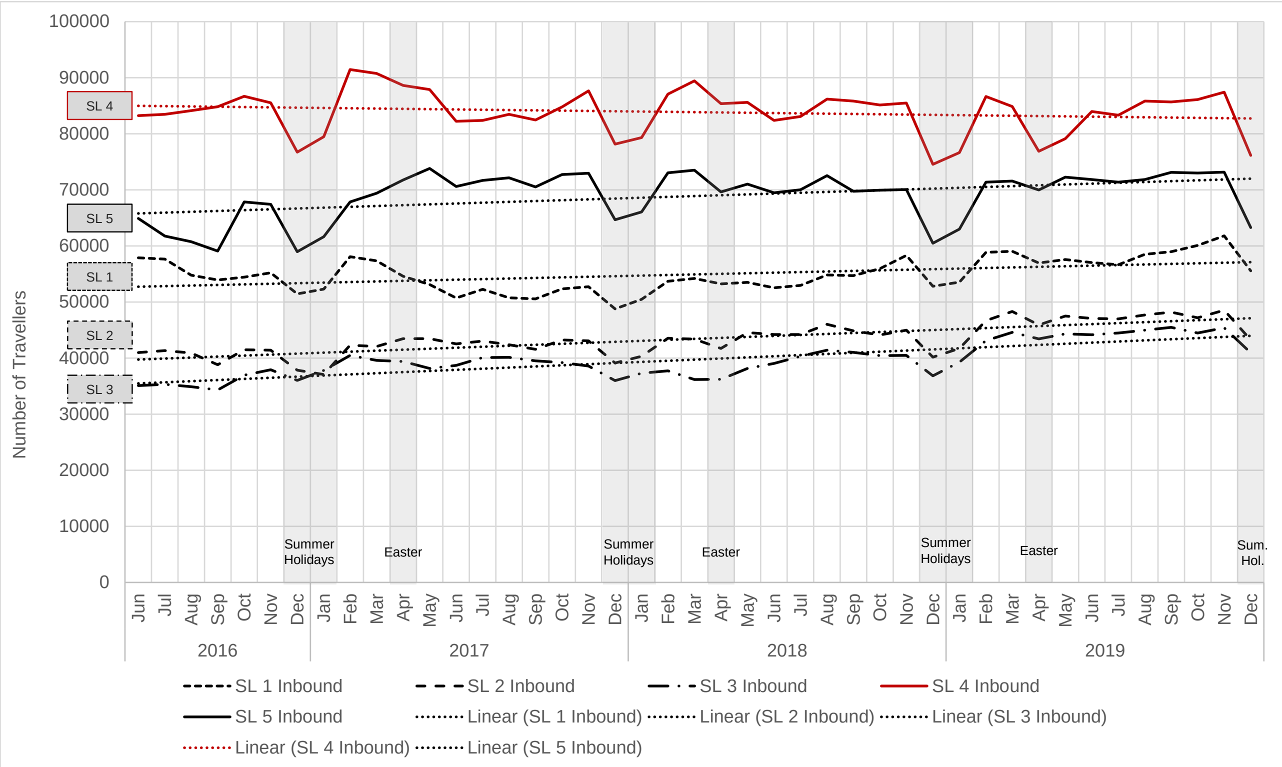
5.1 TREND ANALYSIS

5.1.1 OVERALL TREND OF TRAVELLER NUMBERS

Figure 5.1 shows the combined number of travellers in all transport modes (bus, rail and private passenger vehicles) crossing each SL inbound (towards Brisbane city) between 5 am and 10 am on weekdays. The number of travellers in private passenger vehicles crossing each SL were estimated as outlined in Figure 4.1.

Overall, a positive trend can be observed for most SLs, i.e. the passenger numbers increase over time. Only the trend for SL4 is flat.

Figure 5.1: Monthly total number of travellers (combined road and public transport) across each SL (5 am to 10 am)



The numbers in Table 5.2 support the figure above. Over the duration of the study period, traveller numbers on the network generally increased. SL 4 is an exception where a slight decline can be observed. It is suspected that infrastructure upgrade works that affected traveller numbers on Gympie Road were the cause. Travellers might have used alternative routes that were not captured by the SL.

Table 5.1: Change of total number of travellers across each SL during study period

Screenlines	Beginning of study period: Average June 2016 to May 2017	End of study period: Average Jan 2019 to Dec 2019	Change
SL 1	55,062	57,878	+5.1%
SL 2	40,925	46,584	+13.8%
SL 3	37,159	43,714	+17.6%
SL 4	85,228	82,711	–3.0% *
SL 5	65,431	70,482	+7.7%

Note: Upgrade (signalisation) works at the Dohles Rocks Road interchange with Bruce Highway may have attracted travellers to use the interchange at Dohles Rocks Road to get onto Bruce Highway earlier, rather than continuing their inbound journey on Gympie Road.

Only the overall trends are relevant, but the total passenger volumes of the individual graphs should not be directly compared with each other. The total numbers in this graph do not fully represent the total number of travellers on the network. While most public transport passengers have been captured in the data, the road travel data analysed is only a representative selection of the vehicles crossing each SL on the Bruce Highway and major arterial roads.

The general positive trends are in line with the population increase in the Moreton Bay region. The average annual and total population increases are listed in Table 5.2. Some suburbs such as North Lakes/Mango Hill and Murrumba Downs/Griffin showed above-average annual growth of about 5–8% (Australian Bureau of Statistics 2017, 2019, 2020a, 2020b). This is reflected in the growth figures for SL 2 and SL 3 in Table 5.2.

Table 5.2: Population increase

Key suburbs with high population increase	Population growth rate based on previous year (per annum)		
	2017	2018	2019
Murrumba Downs – Griffin	+7.48%	+8.31%	+6.27%
North Lakes – Mango Hill	+7.42%	+7.10%	+5.35%
Dakabin – Kallangur	+4.12%	+2.81%	+3.87%
Narangba	+2.04%	+3.33%	+1.98%
Burpengary	+1.44%	+1.52%	+2.77%
Whole study area	**2017**	**2018**	**2019**
Average annual increase	+2.87%	+2.53%	+2.47%
Average total increase based on baseline year 2016	+2.87%	+5.48%	+8.09%

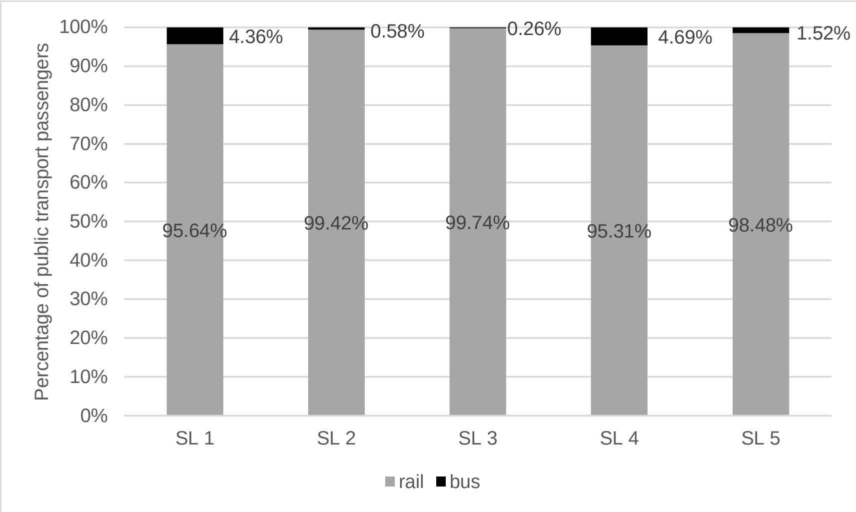
Note: The figures are based on population growth figures for the Moreton Bay region, selecting only suburbs from where people potentially travel through any of the SLs inbound towards Brisbane. Population data from suburbs situated south of SL 5 are excluded.

Source: Australian Bureau of Statistics (2017, 2019, 2020a, 2020b).

5.1.2 PUBLIC TRANSPORT PASSENGER TRENDS IN STUDY AREA

Rail makes up 95% to 99% of all public transport inbound trips depending on the SL as shown in Figure 5.2. Hence, rail can be regarded as representative of the public transport usage in the area when compared to traveller numbers (vehicle occupants) on the road network (arterial roads and Bruce Highway). Consequently, the subsequent analyses are based on rail passenger data only.

Figure 5.2: Public transport passengers: average rail and bus share for all SLs (Jun 2016 to Dec 2019)

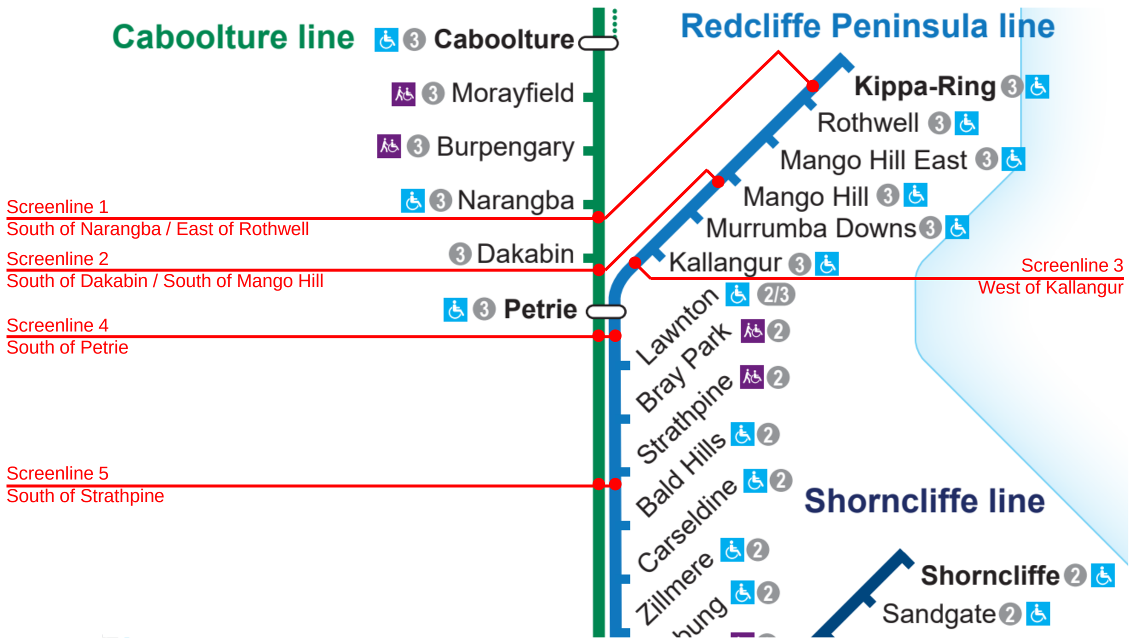


Note: For SL3, the bus share is 100% prior to October 2016. The graphs above show the shares for October 2016 onwards only.

Figure 5.3 shows a map of the southern Moreton Bay rail network including the SLs. For the analysis that is visualised in Figure 5.4 to Figure 5.6, the inbound rail passenger numbers across the SLs were grouped as follows:

- Caboolture line north of Petrie station: crossing SL1 and 2 (blue curves, Figure 5.4)
- RPRL north of Petrie station: crossing SL 1, 2 and 3 (red and orange curves, Figure 5.5)
- Caboolture line south of Petrie station (equivalent to RPRL in terms of passenger numbers): crossing SL 4 and 5 (green curves, Figure 5.6).

Figure 5.3: Rail network and SLs in study area



Source: Modified from TransLink (2020b).

Travelling inbound from the study area to Brisbane city, the Caboolture line picks up passengers from the RPRL. As a result, the number of passengers crossing SL 4 (Figure 5.6) is the combination of the number of passengers crossing SL 2 on the Caboolture line (Figure 5.4), SL 3 on RPRL (Figure 5.5) and passengers boarding at Petrie Station. However, the shapes of the graphs remain similar. There is an overall increasing trend with clear drops in passenger volumes on the rail lines during the main holiday periods in December/January (summer holidays) and in April (Easter).

Figure 5.4: Caboolture line – average weekday passenger numbers crossing SL 1 and 2 (5 am to 10 am)

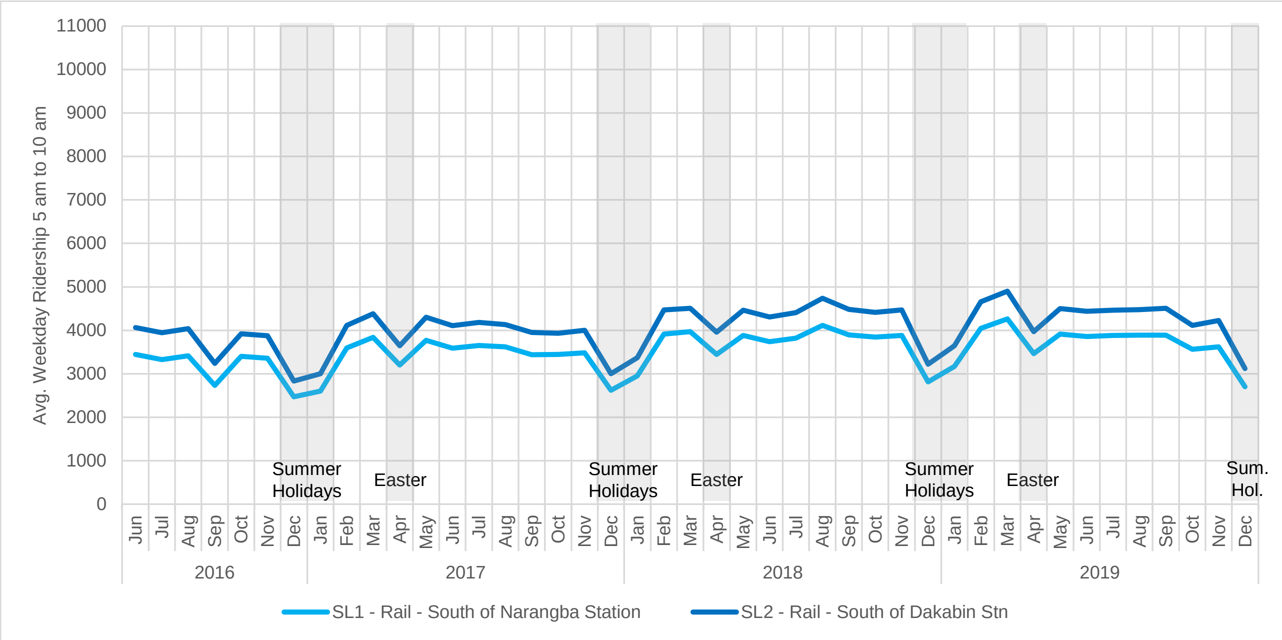


Figure 5.5: RPRL – average weekday passenger numbers crossing SL 1, 2 and 3 (5 am to 10 am)

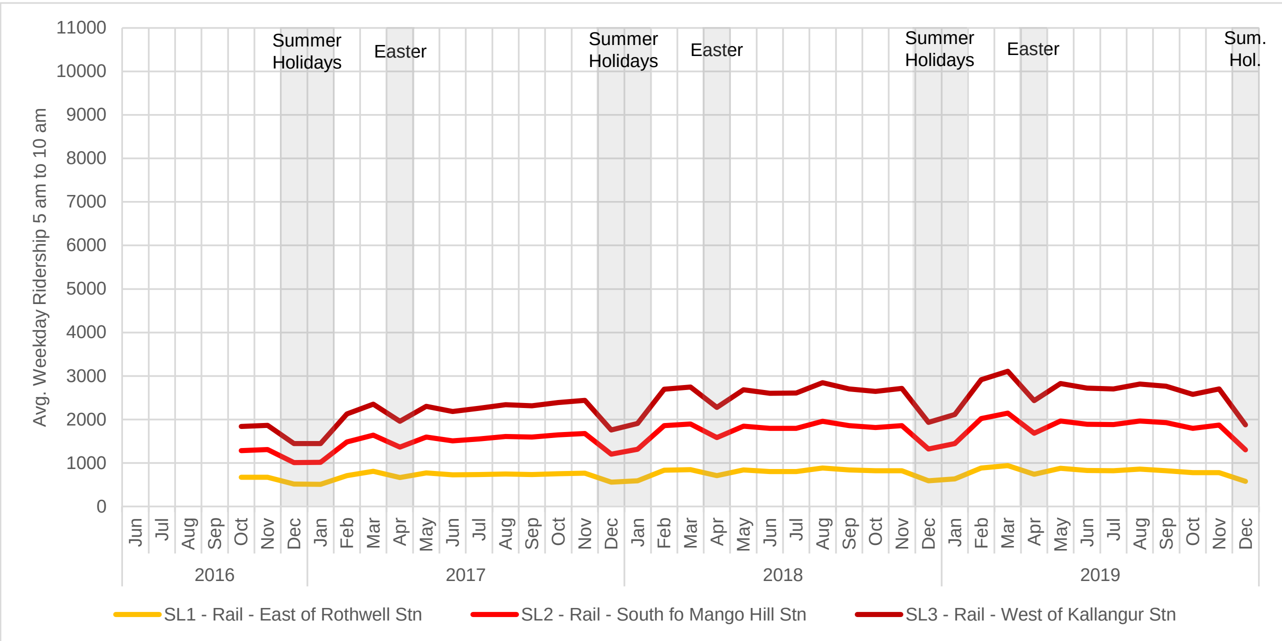
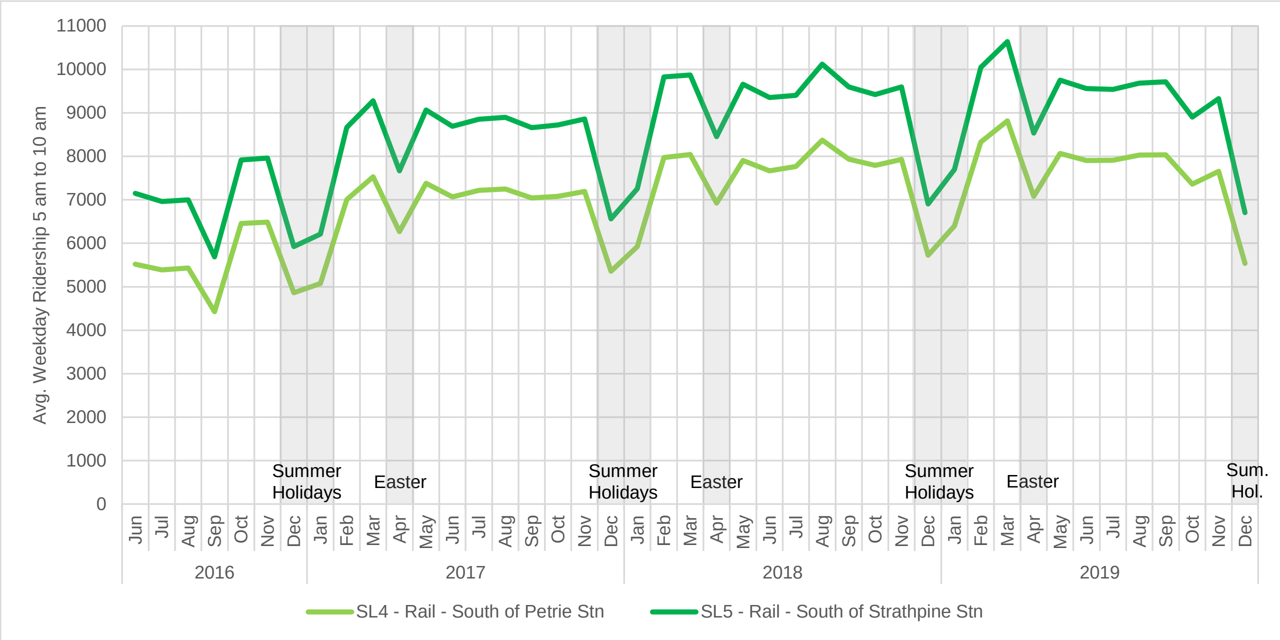


Figure 5.6: Caboolture line – average weekday passenger numbers crossing SL 4 and 5 (5 am to 10 am)



The increase in passenger numbers is seen in Table 5.6, again showing particularly large increases for SL 2 and SL 3 (36–37%), which can be attributed to the above-average population growth in those areas. An increased adoption of the new RPRL over time is likely to have a contributing effect.

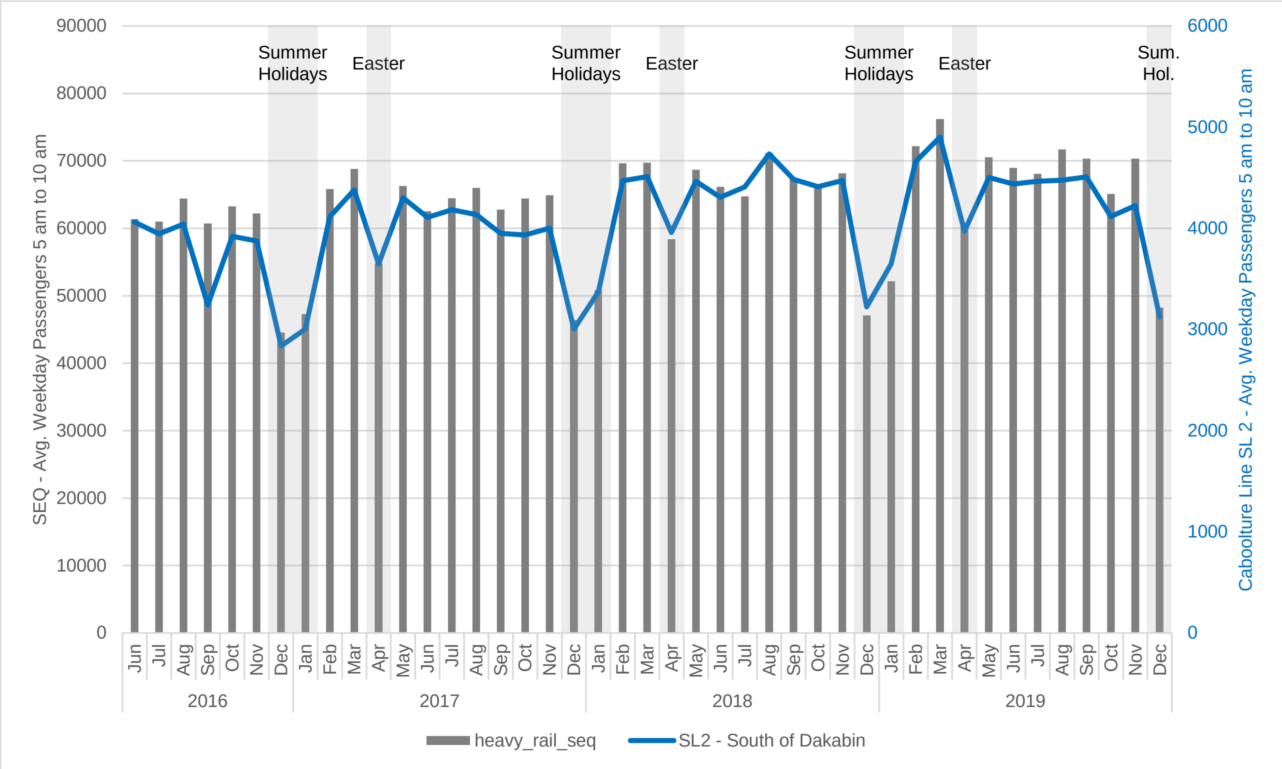
Table 5.3: Change of total number of rail passengers across each SL during study period

Screenlines	Group	Average weekday morning rail passengers (5 am to 10 am) Beginning of study period: June 2016 to May 2017	Average weekday morning rail passengers (5 am to 10 am) End of study period: Jan 2019 to Dec 2019	Increase beginning to end
SL1 – Rail – East of Rothwell station	RPRL only	668	798	+19.6%
SL2 – Rail – South of Mango Hill station		1341	1826	+36.2%
SL3 – Rail – West of Kallangur station		1919	2632	+37.1%
SL1 – Rail – South of Narangba station	Caboolture line only	3265	3689	+13.0%
SL2 – Rail – South of Dakabin station		3781	4252	+12.5%
SL4 – Rail – South of Petrie station	Caboolture line & RPRL	5986	7594	+26.9%
SL5 – Rail – South of Strathpine station		7458	9176	+23.0%

5.1.3 PUBLIC TRANSPORT PASSENGER TRENDS COMPARED TO SEQ AVERAGE

As shown in Figure 5.7, the data set representing the average SEQ rail usage, excluding the study area (grey bars), shows a very similar pattern to the rail data in the study area (blue line, representing the Caboolture line at SL 2), with clear reductions in passenger numbers on the network during the holiday seasons and higher ridership for the other months of the year.

Figure 5.7: Comparison of data pattern between SEQ and Caboolture line SL 2



Also, a long-term increase in total passenger numbers is noticeable throughout the study period. In order to highlight this long-term change of ridership and identify a clearer trend, the SEQ data was used as a reference data set in order to eliminate short-term seasonal changes from the rail data in the study area. As the total ridership in SEQ was significantly higher than in the study area, the values had to be normalised to comparable %-change values. The following steps were taken:

1. Calculate the %-change of ridership between a base month and the other months during the study period, for both the study area (Moreton Bay) data and the SEQ reference data.
   February 2017 was selected as the base month as it represented the first month after the summer school holiday period, which is when the travel patterns should have settled after the opening of RPRL in October 2016.
   For every month m and weekday average 5 am to 10 am ridership R during that month, the %-change is calculated as follows:

$$\%change = \frac{R_m}{R_{Feb\ 2017}} - 1$$

   %-change values are predominantly positive for both the study area and SEQ. **Positive** (negative) values indicate an **increase** (decrease) in rail usage since February 2017.

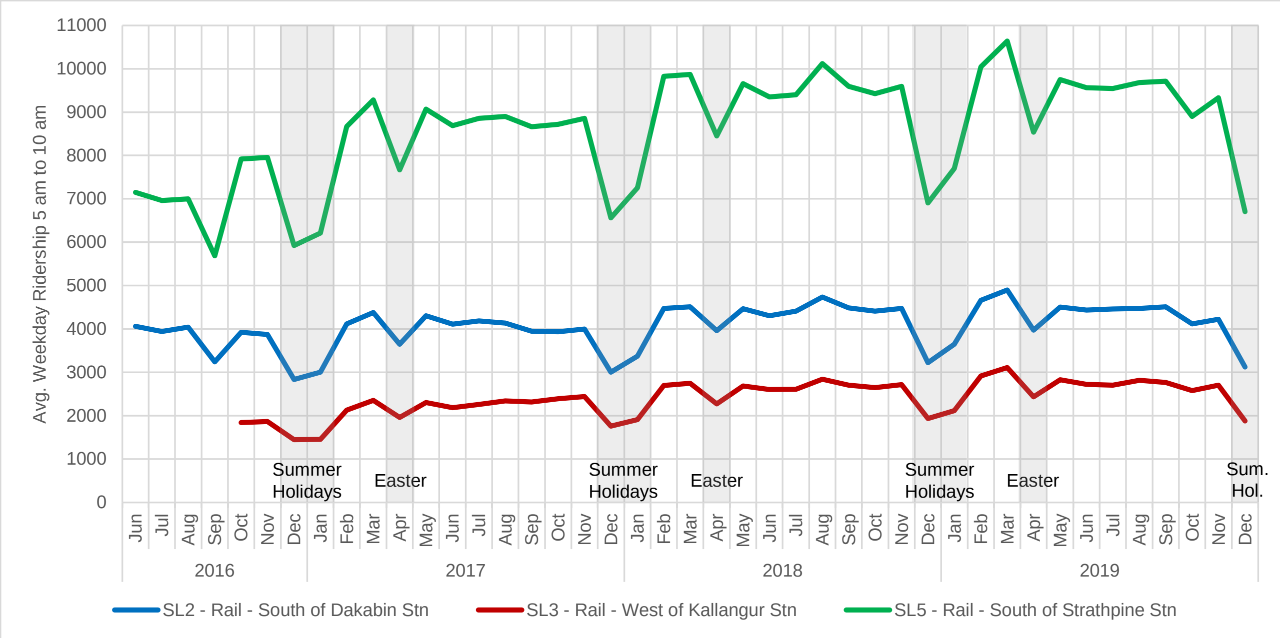
2. For every month m and every SL, compare the %-change values from the study area data set to the %-change value from the SEQ data set.
   The resulting values represent the relative change between the ridership in the study area and the average of SEQ (excluding the study area).
   An **increasing** (decreasing) **trend** indicates that rail usage in the study area grew **faster** (slower) compared to the average of SEQ.

$$relative\ change = \%change_{study\ area} - \%change_{SEQ}$$

In order to visualise the relative change, only one representative SL crossing was chosen for each of the three groups of SLs shown in Figure 5.4 to Figure 5.6 (see Section 5.1.2 and Table 5.3). The total passenger numbers for the three chosen SLs are shown in Figure 5.8 below:

- SL 2 – South of Dakabin station represents the relative change on the Caboolture line north of Petrie station (blue curve).
- SL 3 – West of Kallangur station represents the relative change on the RPRL (red curve).
- SL 5 – South of Strathpine station represents the relative change on the Caboolture line south of Petrie station after taking on passengers from the RPRL (green curve).

Figure 5.8: Average weekday passenger numbers crossing SL 2 (South of Dakabin), SL 3 (West of Kallangur) and SL 5 (South of Strathpine) (5 am to 10 am)



For the chosen SLs, Figure 5.9 shows the relative change values in percent for the Caboolture line (blue) north of Petrie station, and for the RPRL (red). Figure 5.10 shows the relative change values in percent for the Caboolture line south of Petrie station, after taking on passengers from the RPRL.

Figure 5.9: North of Petrie station: SL 2 on the Caboolture line and SL 3 on the RPRL – relative change of ridership compared to SEQ average

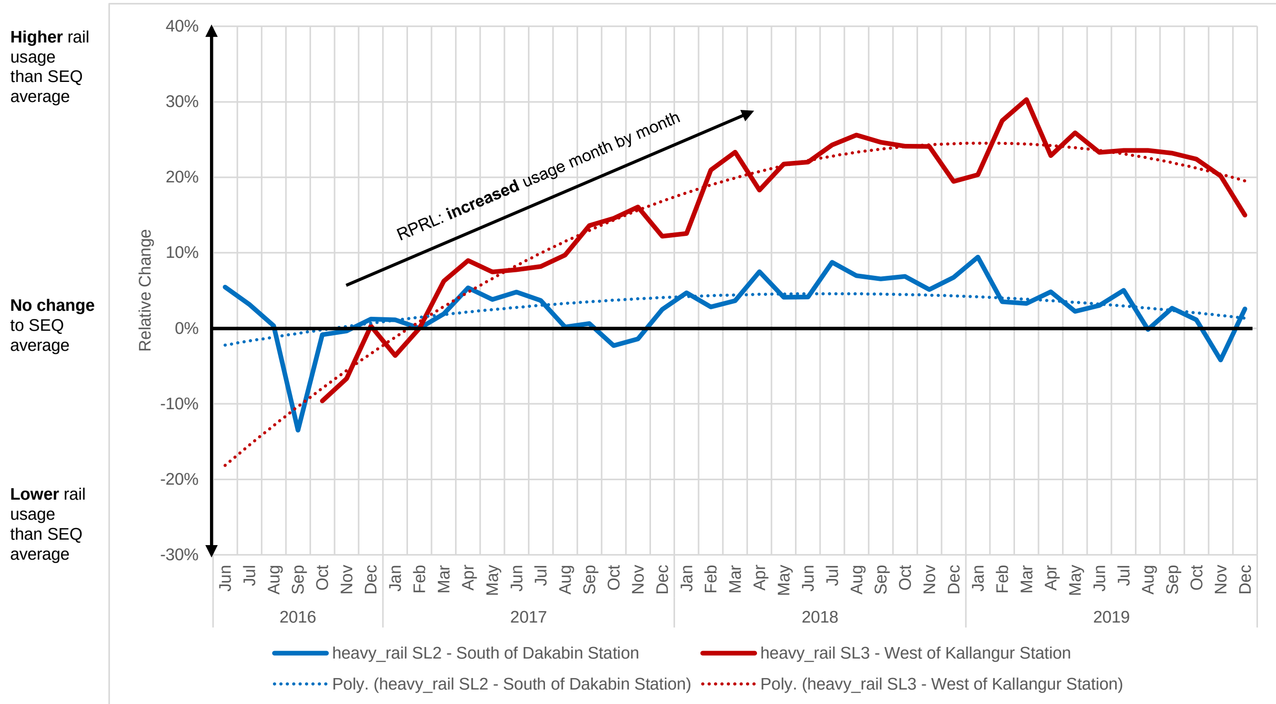
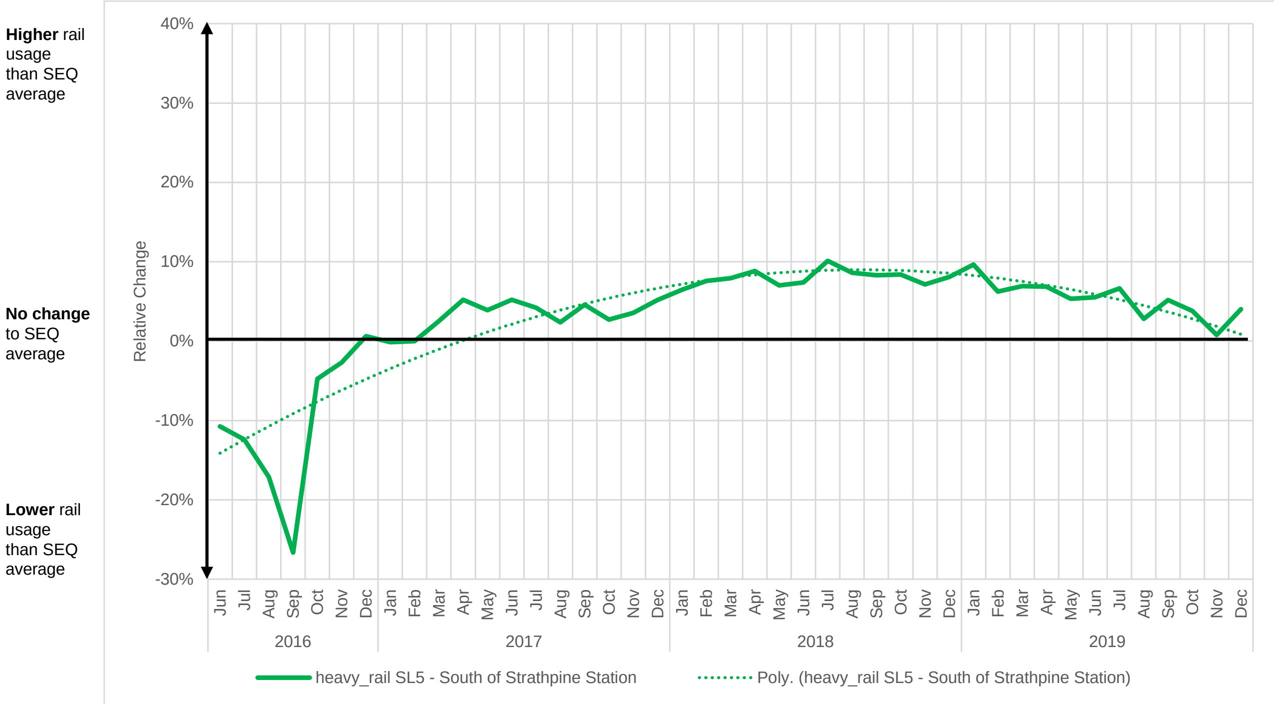


Figure 5.10: South of Petrie station: SL 5 on the Caboolture line – relative change of ridership compared to SEQ average



The long-term trends of mode share during the study period between June 2016 and December 2019 show different trends for each section of the railway lines:

- There is a steep increase of ridership on the RPRL after the commuters settled in their new travel choice despite the reduced timetable (SL 3, red curve, Figure 5.9). The values increase over time suggesting a faster growth compared to the average SEQ ridership. By March 2019, ridership on the RPRL had grown 30.3% more than the SEQ average (46.1% growth on RPRL vs. 15.8% growth in SEQ).
- In contrast, the values for the Caboolture line north of Petrie station (SL 2, blue curve, Figure 5.9) are closer to the line of no change, although they are still positive. Relative increases are highest in 2018 and early 2019 (e.g. +8.8% in July 2018 and +9.4% in January 2019), although the average over the study period is only 2.7%. This indicates that only slightly more people are using the Caboolture rail line compared to the SEQ average.
- The trend on the Caboolture line changes after the RPRL joins the Caboolture line Petrie (SL5, green curve, Figure 5.10). The trend turns more positive due to the positive trend on the RPRL, reaching a peak of +10.1% in July 2018 with an average of +2.9% for the entire study period. The green curve can be regarded as a mix between the strongly positive trend on the RPRL and the almost neutral trend on the Caboolture line.

The peak and average relative change values for all rail SL crossings are listed in Table 5.4.

Table 5.4: Relative change values study area vs SEQ

Screenlines	Group	Peak relative change	Average relative change Jun 2016 to Dec 2019
SL1 – East of Rothwell station	RPRL only	+16.7% (March 2019)	+9.6%
SL2 – South of Mango Hill station		+28.5% (March 2019)	+14.8%
SL3 – West of Kallangur station		+30.3% (March 2019)	+16.0%
SL1 – South of Narangba station	Caboolture line only	+9.0% (January 2019)	+2.2%
SL2 – South of Dakabin station		+9.4% (January 2019)	+2.7%

Screenlines	Group	Peak relative change	Average relative change Jun 2016 to Dec 2019
SL4 – South of Petrie station	Caboolture line & RPRL	+12.4% (July 2018)	+4.0%
SL5 – South of Strathpine station		+10.1% (July 2018)	+2.9%

The overall positive trends can be explained as follows:

- The new RPRL can considered to be a success for the region, offering faster travel times and higher passenger capacities. More and more people take the RPRL or are diverted towards it by truncated feeder bus routes (opposed to direct bus routes to Brisbane city).
- The population growth in the area is above-average, which leads to a naturally higher usage of the rail network in the study area compared to the SEQ average. The average growth in the study area is about 2.5% year-on-year between 2016 and 2019 (see Table 5.2), with some suburbs including Murrumba-Downs, Griffin, North Lakes and Mango Hill growing by 7–8% per year. Those suburbs are close to the new RPRL which can explain the above-average ridership increase.

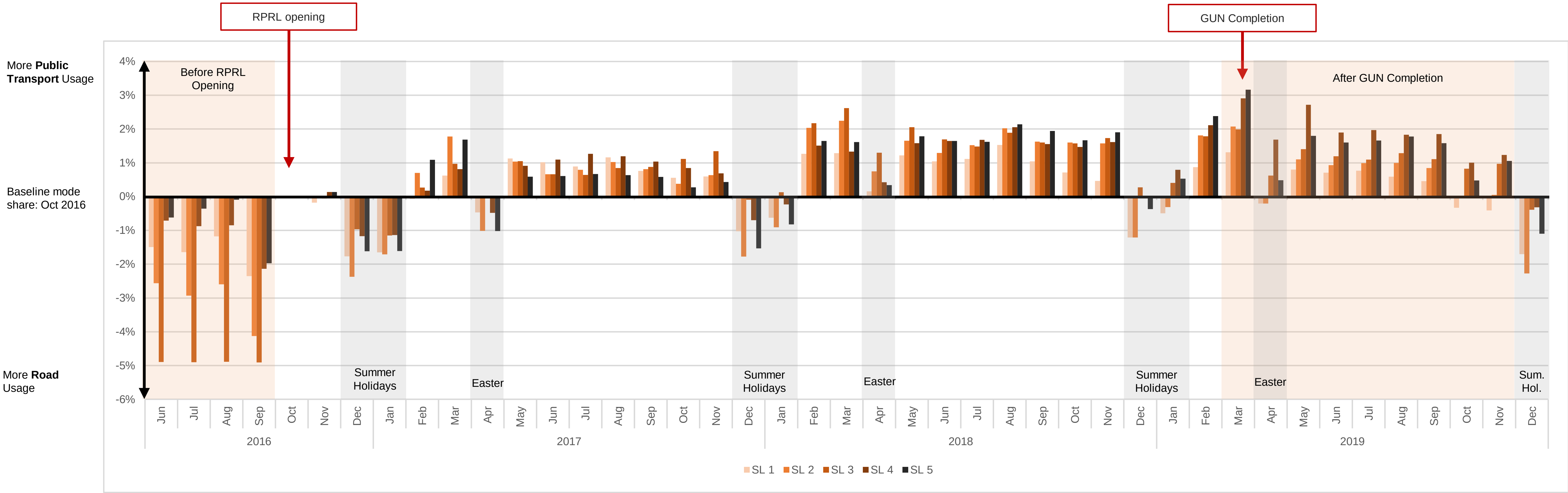
Figure 5.9 and Figure 5.10 also reveal that the positive trends (based on the February 2017) are flattened or show downward trends from early 2019 onwards. This can be explained by the completion of the GUN in 2019 (see Section 5.2).

5.2 IMPACTS OF MAJOR INFRASTRUCTURE PROJECTS AND PUBLIC TRANSPORT NETWORK CHANGES

The mode share, i.e. the number of public transport passengers compared to the number of travellers on the road network in private vehicles, is used to provide insights on how the major infrastructure works impact on Bruce Highway traffic performance.

Figure 5.11 shows the change of mode share at every SL throughout the study period relative to the mode share in October 2016 which is represented by the zero-line.

Figure 5.11: Mode share change during study period for all screenlines



After the opening of the RPRL, the mode shares at all SLs shift by about 1% towards higher public transport usage in 2017, and even further in 2018 and early 2019. The only exceptions are the holiday periods which still show high road usage.

However, the trend reverses from about mid-2019 which coincides with the completion of the GUN. In addition, a strong shift of mode share towards more public transport usage can be observed directly after the opening of the RPRL from late 2016 onwards. These two events are discussed in the following sections.

The actual public transport mode shares during the study period varied between about 4% and 14% depending on the SL and month. Table 5.5 explains the general picture of Figure 5.11, showing the average annual public transport mode shares for all SLs during the study period and corresponding changes compared to 2016.

Table 5.5: Average annual public transport mode share by SL and relative change to 2016

Screenlines	Average 2016 **	Average 2017		Average 2018		Average 2019	
	Mode share	Mode share	Change relative to 2016	Mode share	Change relative to 2016	Mode share	Change relative to 2016
SL 1	6.7%	8.2%	+1.5%	8.5%	+1.9%	8.1%	+1.4%
SL 2	10.5%	12.9%	+2.4%	13.8%	+3.3%	13.1%	+2.6%
SL 3	2.1% *	5.5%	+3.5% *	6.5%	+4.5%	6.0%	+4.0%
SL 4	7.1%	8.4%	+1.3%	9.2%	+2.0%	9.6%	+2.4%
SL 5	11.3%	12.1%	+0.8%	13.2%	+1.9%	13.2%	+1.9%

** Strong shift towards road usage in 2016 for SL 3 as the RPRL only opened in October 2016. Only a small number of bus trips crossed SL 3 prior to October 2016.*

*** Based on June to December 2016 data only.*

Note: The mode share is calculated based on the available data only which is likely to underrepresent the number of travellers (vehicle occupants) in private vehicles on the road network. Hence, the actual public transport mode share is likely to be lower.

5.2.1 OPENING OF THE RPRL

Mode shares in one before-period and three after-periods are shown in Table 5.6 and Figure 5.12. A clear and instant shift towards a higher share of public transport after the opening of the RPRL in October 2016 can be observed. The following can be noted:

- For all SLs, the values are positive which indicates increased public transport usage compared to before the opening of the RPRL.
- There is a sharp increase in public transport usage after the opening of the RPRL. The increase is noticeable on all SLs, but particularly on SL 3 (+5.6%) which was only crossed by 34 (bus) passengers on an average weekday between 5 am and 10 am prior to October 2016. This figure increased to 2265 passengers during after-period 1, including 2261 on the new RPRL (see Table 5.7), which equates to 5.7% mode share up from 0.1%.
  It is likely that some of those additional trips were diverted trips that previously crossed SL 4 only via Houghton Highway from Redcliffe to Brighton. After the opening of the RPRL, some bus frequencies were reduced or rerouted, or bus routes truncated to provide feeder services only to the new railway stations, replacing longer routes which connected to different railway stations closer to Brisbane city (e.g. Sandgate).
- The trend towards higher public transport usage continued in 2018, but it mostly reversed in 2019, which can be explained by the completion of the GUN (see Figure 5.11 and Section 5.2.2).

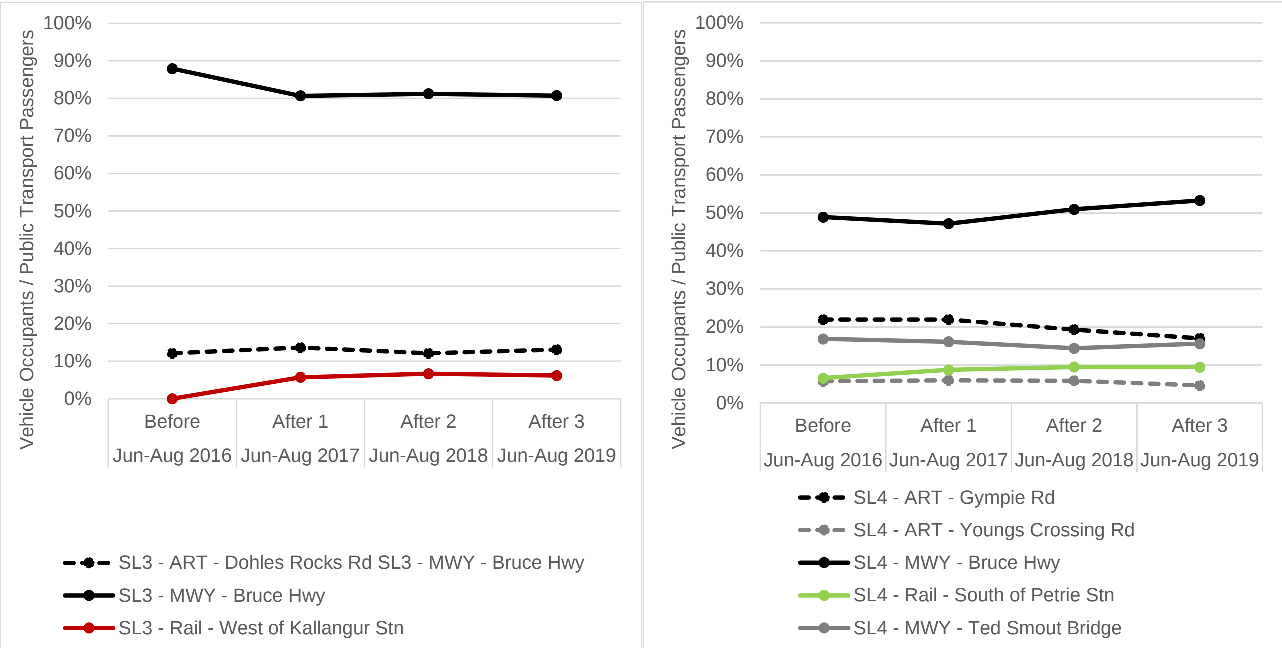
Table 5.6: Increase in public transport mode share following RPRL opening in October 2016

Screenlines	Before-period 1: Jun to Aug 2016	After-period 1: Jun to Aug 2017		After-period 2: Jun to Aug 2018		After-period 3: Jun to Aug 2019	
	Mode share	Mode share	Change relative to before-period	Mode share	Change relative to before-period	Mode share	Change relative to before-period
SL 1	6.4%	8.9%	+2.7%	9.1%	+2.9%	8.6%	+2.4%
SL 2	9.9%	13.4%	+3.9%	14.2%	+4.7%	13.6%	+4.0%
SL 3	0.1%	5.7%	+5.6%	6.7%	+6.6%	6.2%	+6.1%
SL 4	7.1%	9.1%	+2.3%	9.7%	+2.9%	9.8%	+3.0%
SL 5	11.5%	12.5%	+1.4%	13.7%	+2.6%	13.6%	+2.4%

Table 5.7: Details of traveller numbers at SL 3 and SL 4 over time

Screen-lines	Road/rail name	Before-period 1: Jun to Aug 2016	After-period 1: Jun to Aug 2017	After-period 2: Jun to Aug 2018	After-period 3: Jun to Aug 2019
SL 3	ART – Dohles Rocks Rd	4244	5401	4875	5825
	MWY – Bruce Highway	30821	31974	32701	35943
	Rail – West of Kallangur Station	–	2261	2687	2748
SL 4	ART – Gympie Rd	18235	18094	16145	14302
	ART – Youngs Crossing Rd	4750	4919	4896	3879
	MWY – Bruce Highway	40637	38860	42620	44772
	MWY – Ted Smout Bridge	14030	13274	12052	13110
	Rail – South of Petrie Station	5445	7178	7934	7947

Figure 5.12: Details of mode share change for SL 3 and SL 4 over time



5.2.2 COMPLETION OF THE GUN

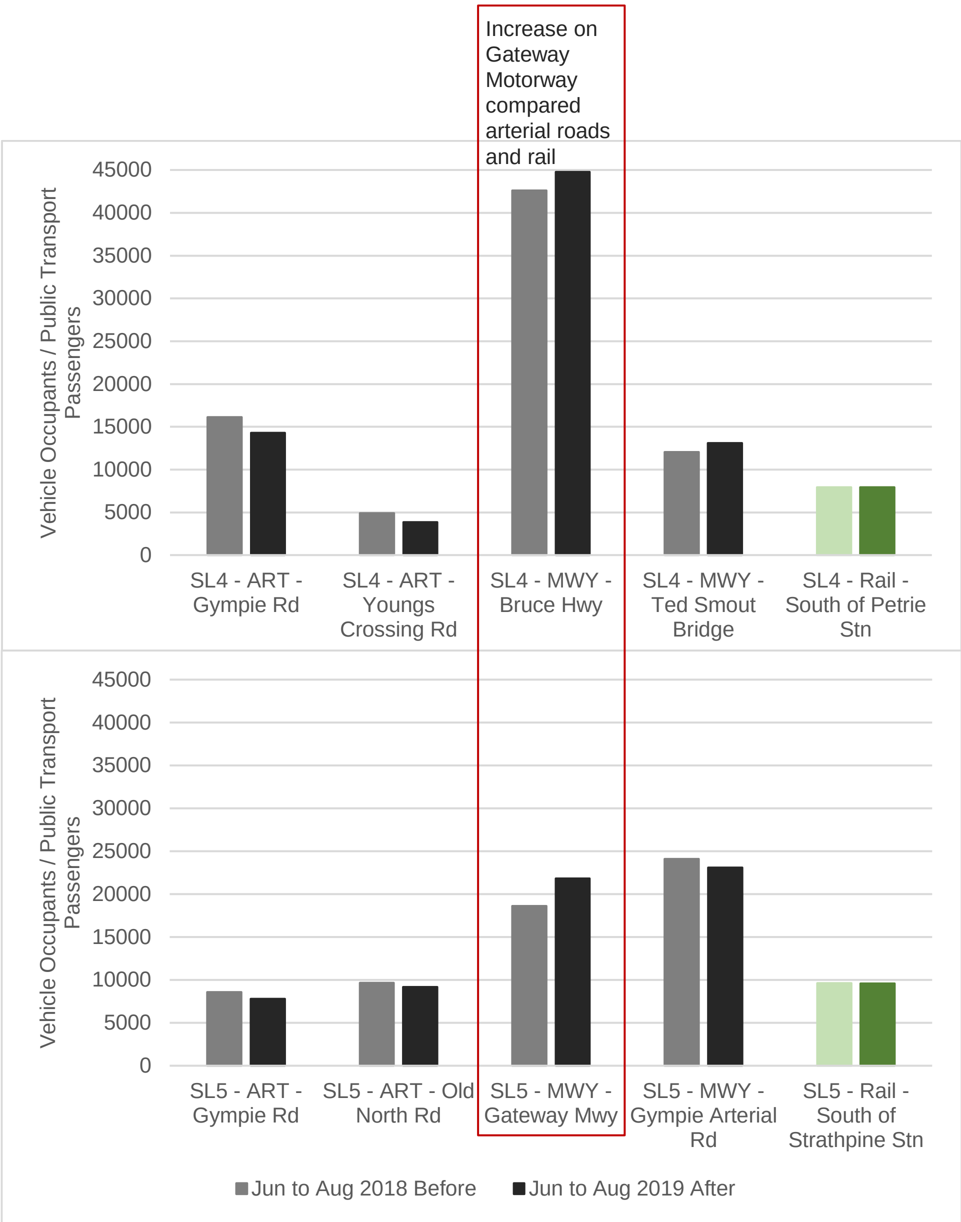
The schedule for the GUN project is outlined in Table 3.8. The after-period is defined as June to August 2019, and the before-period as June to August 2018.

The impact of the GUN is visualised in Figure 5.13 (showing changes at SL 4 and SL 5) and Figure 5.14 (showing trends at SL 5) by an increase in the number of travellers crossing SL 5 on the Gateway Motorway (middle columns). An increase of 17.3% can be observed for SL 5 from the before-period in 2018 to the after-period in 2019 (see Table 5.8). In contrast, the number of people crossing SL 5 on the other major roads and on the Caboolture rail line decreased from 2018 to 2019. This indicates a diversion of traffic and people towards the upgraded Gateway Motorway. Some people may also have shifted from using the rail line to travelling in private vehicles as congestion eased on the upgraded Gateway Motorway and Bruce Highway (see lower congestion costs in Table 3.9). SL 4 shows a similar pattern (see Figure 5.14). However, the change on the Bruce Highway traveller volume percentage is less significant.

Table 5.8: Before-and-after traveller volume analysis of the GUN project for SL 4 and SL 5

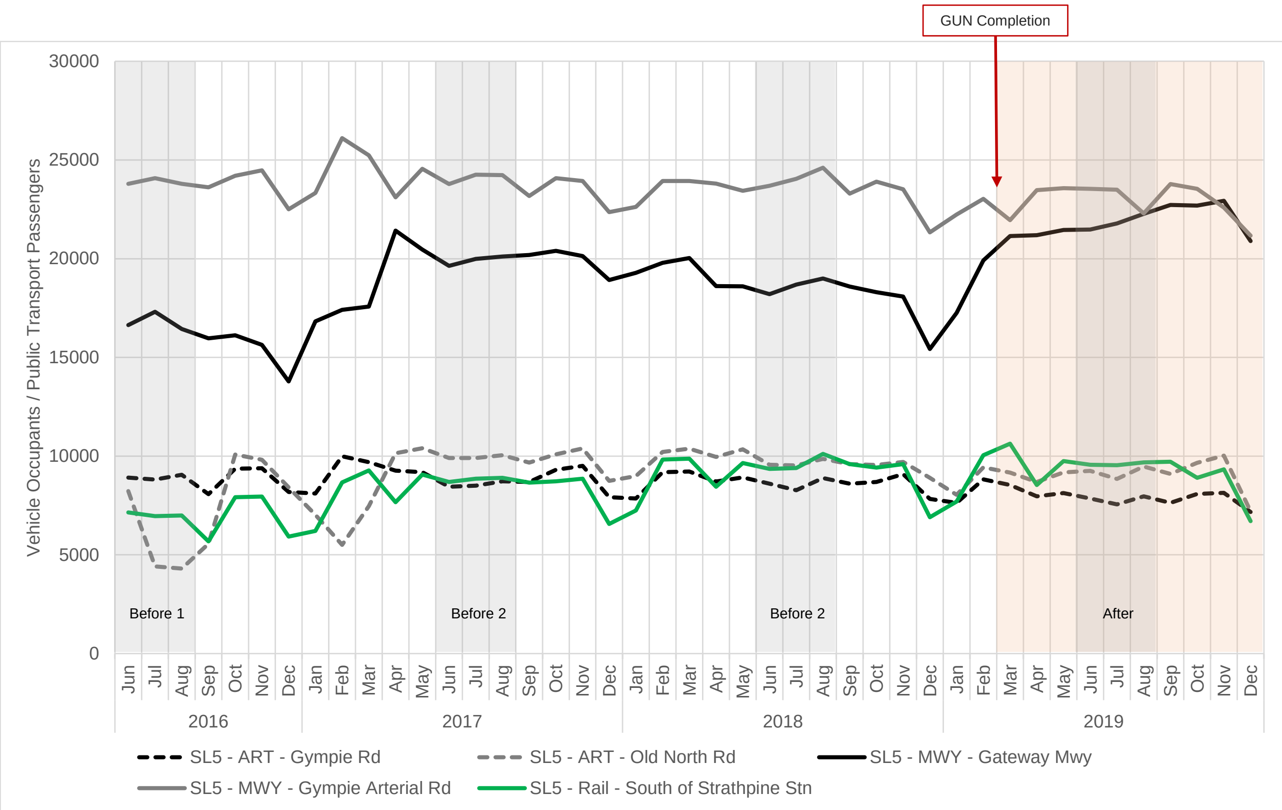
Screen-lines	Road/rail name	Before-period: Jun to Aug 2018	After-period: Jun to Aug 2019	Change (%) 2018 to 2019
SL 4	ART – Gympie Rd	16145	14302	–11.4%
	ART – Youngs Crossing Rd	4896	3879	–20.8%
	MWY – Bruce Highway	42620	44772	+5.1%
	MWY – Ted Smout Bridge	12052	13110	+8.9%
	Rail – South of Petrie Station	7934	7947	+0.2%
SL 5	ART – Gympie Rd	8590	7792	–9.3%
	ART – Old North Rd	9650	9190	–4.8%
	MWY – Gateway Mwy	18631	21846	17.3%
	MWY – Gympie Arterial Rd	24117	23109	–4.2%
	Rail – South of Strathpine Station	9624	9595	–0.3%

Figure 5.13: Before-and-after analysis of the GUN project for SL 4 and SL 5



A clear increase in traffic volumes on the Gateway Motorway can already be noticed from early 2019 onwards (see Figure 5.14) following the 2018/2019 summer holiday period.

Figure 5.14: Number of travellers crossing SL 5 (excluding bus trips)



5.3 LIMITATIONS OF THE STUDY

The study revealed a few limitations which could be addressed in future projects:

- **Travel demand**

  Knowing the travel demand in the area or for individual services, directions or routes could add value to the analysis. For example, knowing the demand would help to judge trends and changes in traffic volumes or public transport ridership, and provide explanations about why changes in the data can be observed. Demand can change over time or with population growth. Consumer surveys among residents in the study area could help with an insight into the demand side.

- **Population growth**

  No direct relationship between population growth in specific suburbs and the mode shares or people on the road network could be established. However, the overall positive trend of the population in the area aligns with data which suggests increasing traffic and ridership over time. Future studies could look at population trends of specific suburbs or areas in order to investigate the impact on the local road network, nearby railway stations or bus lines. This could also provide an insight into the demand side and help to answer the point above.

- **Bus data**

  Bus passengers only accounted for a small fraction of less than 5% of the total public transport ridership (see Figure 5.2). In addition, bus data was excluded from the analysis due to some anomalies that could have skewed the results or led to invalid conclusions.

- **Overlapping impacts**

  Impacts of different projects may overlap each other. This includes projects that were out of the scope of this study. For example, the drop of passengers on the rail network in September 2016 prior to the opening of the RPRL and a decline of the number of travellers on Youngs Crossing Road and Gympie Road across SL 4 in 2019 remains unexplained, but could be the result of other road improvement projects in the area. Further investigations into the data sets and background information about other influencing events may be required to clarify those incidents.

5.4 SUMMARY

Part 2 of the study focussed on the comparison of road usage and public transport (rail) usage in the southern Moreton Bay region. The two major infrastructure projects considered for the study period of June 2016 to December 2019 were:

- Public transport infrastructure: opening of the new RPRL connecting the Redcliffe peninsula (Kippa-Ring station) to Petrie station on the Caboolture line
- Road infrastructure: completion of the GUN project.

The following trends and impacts of the infrastructure projects were observed.

Trends

- Traveller numbers on the road and public transport networks in the study area generally increased over time. Between the first year of the study period (June 2016 to May 2017) and the last year of the study period (January 2019 to December 2019), traveller numbers across most SLs increased, with SL 3 showing an increase of 17.6%. Looking at public transport (rail) passengers only, SL 3 shows an increase of 37.1% for the same period.
- These increases reflect the population growth in the area. The average annual growth is about 2.5% with some suburbs (e.g. North Lakes, Mango Hill, Griffin, Murrumba Downs) showing a population growth of 5–8% per year. Those suburbs are close to SL 3, which can contribute to the above-average increase of travellers across this SL. In addition, an increased uptake of the RPRL may have contributed to these figures (see below).
- The increase of public transport ridership in the study area is generally higher than the SEQ average. Again, the differences are particularly noticeable on the new RPRL (SL 3) where rail passenger volumes grew up to 30.3% more than the average SEQ (relative change). However, passenger volumes on the existing Caboolture line were also higher where the average relative change throughout the study period was 2.2% to 2.7% (SL 1 and 2).
- The mode share gradually increased over time with a higher percentage of travellers using public transport between 2016 and 2018. The shift is particularly high on SL 3 (+4.5% in public transport share) and lowest on SL 1 and SL 5 (+1.9%).
  Also, the mode share clearly shifts towards higher road usage during the peak holiday periods of December and January (summer) and April (Easter) in all years.

Impact of infrastructure works

- Following the opening of the RPRL in October 2016, an instant shift towards a higher public transport (rail) mode share can be observed (see Figure 5.11). Comparing June to August 2016 (before-period) to June to August 2017 (after-period), the mode share at SL 3 increased from 0.1% to 5.7% (+5.6%). The mode share shifts at the other SLs were lower (+1.4% to +3.9%). This trend of above-average values for the RPRL also continued into 2018.
  It is concluded that the above-average figures for the RPRL are due to the particularly high population growth near the new RPRL (SL 3), as well as due to the actual availability of the new rail line compared to pre-October 2016, offering higher capacities than bus services and shorter travel times.
- In contrast, the completion of the GUN project has had an opposite effect. A significantly higher number of travellers were observed on Gateway Motorway and Bruce Highway following the GUN completion. Between June to August 2018 (before-period) and June to August 2019 (after-period), the number of travellers crossing SL 5 on the Gateway Motorway increased by 17.3%, whereas a decrease of 4.2% to 9.3% could be observed for SL 5 on all the other roads. Rail passenger numbers also dropped by 0.3%. A similar pattern can be observed for SL 4. Hence, the GUN has had a negative effect on the public

transport mode share in 2019, despite the increased rail mode share in the previous years following the RPRL opening.

6 CONCLUSIONS

Part 1 of the study focused on the evaluation of three major motorway treatment projects using STREAMS NPI data from January 2015 to December 2019. Before-and-after period analyses were conducted to analyse motorway performance on Bruce Highway southbound and to determine the projects' individual impacts on Bruce Highway operation performance. The projects were the ramp metering VSL and QDQP systems project, Boundary Road interchange upgrade project, and the GUN project.

Part 2 of the study focused on the comparison of road usage and public transport (rail) usage in the southern Moreton Bay region between June 2016 and December 2019. It investigated how the infrastructure works influenced mode choice and impacted on Bruce Highway and the broader road network. Two infrastructure projects were evaluated, including the RPRL project and the GUN project.

The benefits and impact of the four major infrastructure projects are summarised as follows:

1. Ramp metering, VSL and QDQP systems

   Ramp metering, VSL and QDQP systems were best utilised and performed best when all systems were activated. For example, the before-and-after comparison (2015 versus 2017), when the ramp metering, VSL and QDQP systems were all activated, revealed significant congestion reduction on the Bruce Highway. While there was still ongoing traffic disruption from the GUN project, after-period data revealed a 21% reduction in normalised excessive delay cost, 23% reduction in both normalised reliability cost and total cost. QDQP added significant benefits to the Bruce Highway congestion reduction.

   The implementation of ramp metering, VSL and QDQP systems were also able to increase the Bruce Highway operational capacity before flow breakdown and maintain a higher operational capacity after flow breakdown.

2. Boundary Road interchange upgrade

   A significant reduction in motorway congestion cost was observed from the before-and-after comparison (2016 versus 2018) for the links impacted directly by the upgrade. While the average weekday daily peak period VKT increased by 3%, the normalised excessive delay cost, reliability cost and total cost were reduced by 55%, 45% and 47% respectively. However, due to over-lapping of projects' time frames, a portion of the reduction in congestion cost should be attributed to the benefits of ramp metering, VSL and QDQP systems.

3. GUN

   The completion of the GUN project led to an operational capacity improvement, attracted a large increase in traffic on the Bruce Highway southbound and at the same time eased the peak period congestion significantly. Comparing the selected periods between 2018 and 2019, while 2019 had an increase of 12% in average daily peak period VKT for the links impacted directly by the GUN completion, the normalised excessive delay cost and total costs were reduced by 67% and 17% respectively. However, the completion of GUN also led to a stagnation of public transport usage in the study area despite consistent population growth.

4. RPRL

   Following the opening of the RPRL in October 2016, an instant shift towards a higher public transport (rail) mode share can be observed. Comparing June to August 2016 (before-period) to June to August 2017 (after-period), the mode share at SL 3 increased from 0.1% to 5.7% (+5.6%). This trend of above-average values for the RPRL also continued into 2018. The mode share shifts at the other SLs were lower (+1.4% to +3.9%), but they increased as well indicating an uptake of public transport usage. It is concluded that the above-average figures for the RPRL are due to the particularly high population growth near the new RPRL (SL 3) as well as due to the availability of the new rail line and truncation/rerouting of bus services.

In general, findings from Part 1 and Part 2 are consistent, in particular the findings about the impact of the GUN project which was investigated in both Part 1 and Part 2. The following can be noted:

- VKT and traveller numbers following the completion of the GUN:
  There is a considerable increase of VKT on the Bruce Highway in June to August 2019 compared to the same period in 2018 (+12%, see Table 3.9). This is in line with the increase of traveller numbers on the upgraded Gateway Motorway (+17.3%, see Table 5.7), and the corresponding drop-off on the arterial roads and rail line (–0.3% to –9.3%).
- Seasonal changes:
  Comparable seasonal change patterns were observed for VKT on the Bruce Highway (Part 1) and traveller numbers at all SLs (Part 2) during the holiday seasons each year. The average weekday peak period VKT reduced for each December and January summer holiday season (see Figure 3.1). A corresponding reduction of traveller numbers across each SL was observed (see Figure 5.1). At the same time, of those travelling during this time, a greater proportion of travellers were driving during the holiday summer season compared to using public transport (see Figure 5.11).

This confirms the positive impacts as a result of these major motorway treatment projects and the RPRL project on Bruce Highway and the broader road network. The amount of congestion has been remarkably reduced, with improvements seen in operational capacity, travel time and travel time reliability along the Bruce Highway during the peak period when the managed motorway system is operating. The opening of RPRL had a positive impact with a sharp increase in public transport usage for all SLs in the study region. The completion of the GUN project significantly eased the congestion and attracted some generated traffic on Bruce Highway. However, it also had a negative effect on rail usage.

As part of the project, ARRB also developed a beta version Bruce Highway cost of congestion analysis Excel spreadsheet tool that enables fast processing of the before-and-after analyses described in Part 1 of this report, and significantly reduces the amount of human inputs that were originally required. This tool can be used directly to measure the excessive delay cost, reliability cost, average volumes, average speeds, vehicle delay and other key performance indications at the link or route levels of the Bruce Highway study route. With some modifications, the congestion analysis tool can be potentially used for other arterial or motorway routes.

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